North Carolina State University is a land-grant university and a constituent institution of The University of North Carolina

Nuclear Reactor Program

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27 August 2002

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

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

Dear Sir or Madam:

In compliance with Section 6.7.4 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 2001 through 30 June 2002. Please feel free to contact me at (919) 515-4601 if you have any questions or comments.

Sincerely,

Gerald D. Wicks

Gerald D. Wicks
Acting Associate Director
Nuclear Reactor Program

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A001

PULSTAR REACTOR ANNUAL REPORT TO

UNITED STATES NUCLEAR REGULATORY COMMISSION

for

01 July 2001 - 30 June 2002

NCSU NUCLEAR REACTOR PROGRAM

27 August 2002

Reference: PULSTAR Technical Specifications
Section 6.7.4

Docket No. 50-297

Department of Nuclear Engineering
North Carolina State University
Raleigh, North Carolina 27695

U. S. Nuclear Regulatory Commission
Document Control Desk
27 August 2002

Ref: NCSU PULSTAR Annual Report
Docket No. 50-297

copy w/attachments:

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Dr. Jim E. Riviere, Chairman
Radiation Safety Committee

Dr. Ayman I. Hawari, Chairman
Reactor Safety and Audit Committee

Dr. Paul J. Turinsky, Head
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DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

DOCKET NUMBER 50-297

For the Period: 01 July 2001 - 30 June 2002

The following report is submitted in accordance with Section 6.7.4 of the PULSTAR Technical Specifications:

6.7.4.a Brief Summary:

Reactor operations have been routine during this reporting period. Due to the events of 11 September, public access to the facility has been greatly restricted. The position of the Director of the Nuclear Reactor Program was filled in January 2002. The Reactor Health Physicist is still serving as the interim Associate Director. A personnel search is currently under way for the replacement for the Associate Director position. A staff member received his senior operator license in June 2002. One part-time reactor operator also received her license at the same time.

(i) (1) Reactor Operating Experience:

The NCSU PULSTAR Reactor has been utilized for the following:

• Teaching and Short Courses	80.6 hours
• Faculty and Graduate Student Research	372.7
• Isotope Production	30.8
• Neutron Activation Analysis	788.8
• Beam Tube and Irradiation Facilities	26.7
• Nuclear Training (Utilities)	0.0
• PULSTAR Reactor Training	105.5
• Reactor Cal/Measurements & Surveillance	76.3
• Reactor Health Physics Surveillance	24.8
• Reactor Sharing	10.8
TOTAL	1,517.0 hours
Last reporting period:	1,428.5 hours

(2) A Summary of Experiments Performed in the Reactor:

- Teaching laboratories, short courses, and research
  - reactor thermal power measurements
  - dynamic reactivity measurements
  - axial power and peaking factor measurements (flux mapping)
  - photoneutron effects on power decay after dropped rod

reactor power determination using photodiode arrays
neutron diffusion length in graphite by foil activation
neutron fluence and spectral measurements
neutron transmutation doping of diamond
neutron transmutation doping of silicon
in-core detector certification
radiation damage determination to fiber optic material

- Neutron Activation Analysis
  cereal/grain
  animal feed
  food samples
  fish and laboratory animal tissue
  human hair and nails
  (support for forensic work of Medical Examiner's office in a nearby city)
  urine and excrement
  sediment/soil
  water
  dyes
  polymers and plastics
  textiles
  fly ash
  crude oil
  fertilizers
  silicon crystals
  dust from World Trade Center

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

None

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

The reactor surveillance program has revealed no significant or unexpected trends in reactor systems performance during this reporting period. The Reactor Safety and Audit Committee (RSAC) performed its annual audit for the facility and determined that all phases of operation and supporting documents were satisfactory.

Health physics surveillance of reactor primary coolant water showed no fission products and that activity is below 10 CFR 20, App. B, Table 3 limits.

6.7.4.b <u>Total Energy Output</u>:

19.4 Megawatt·days

Reactor was Critical:

762.2 hours

Cumulative Total Energy Output Since Initial Criticality:

923.0 Megawatt·days

6.7.4.c <u>Number of Emergency and Unscheduled Shutdowns</u>:

1. Emergency Shutdowns - none

2. Unscheduled Shutdowns - 6
   a. July - Shutdown due to dropped rod
   b. December - Shutdown due to dropped rod
   c. January - SCRAM in response to fire alarm
   d. April - SCRAM due to range switching error
   e. June - Shutdown due to incorrect compensating voltage
   f. June - SCRAM in response to fire alarm

Explanation of 2a. above:
A control rod dropped into the core during routine operations. The reactor operator initiated a reactor shutdown to drive the magnets to the down position. All magnet faces and their respective armatures were cleaned and inspected. The control rod extension was lubricated with a silicone spray. The reactor was returned to routine operation.

Explanation of 2b. above:
A control rod dropped into the core during routine operations. The reactor operator initiated a reactor shutdown to drive the magnets to the down position. Guide bearings were adjusted on the Regulating Rod and all magnet faces and their respective armatures were cleaned and inspected. The reactor was returned to routine operation.

Explanation of 2c. above:
The reactor operator initiated a Manual SCRAM in response to a building fire alarm. The alarm originated in a machine shop in an area external to the Reactor Building. Fumes from hot cutting oil triggered a smoke sensor.

Explanation of 2d. above:
While performing a routine startup with the Linear Channel on a milliwatt range, a reactor operator trainee started shimming out too close to the autoranging setpoint causing the power indication to exceed 120% of range before the autoranging circuit could change ranges. An automatic SCRAM occurs at 120% of any range on this channel. When performing a reactor startup and power level is near the range change setpoint, trainees as well as reactor operators have been advised to allow the autoranging circuit to change ranges prior to shimming out the control rods.

Explanation of 2e. above:
While performing the second startup of the day two hours after the reactor had been at 90% power for several hours, the second reactor operator set the

compensating voltage incorrectly (under compensated) for the Intermediate Range (Log N Channel). The value displayed on the readout was approximately 1.1E1 watts. It should be 1.1E-1 to 1.3E-1 watts when the compensating voltage is properly set. The reactor operator failed to notice that the minus sign was not present in the display. After several minutes into the startup and while still in the source range, the reactor operator noticed the error and shut down the reactor by Ganged Insert. The compensating voltage was increased until the display read the proper value. A startup was performed and the reactor was returned to routine operation. All reactor operators have been advised to compare the instrument indication with the Log N chart recorder to confirm that proper compensating voltage is set.

Explanation of 2f. above:
The reactor operator initiated a Manual SCRAM in response to a building fire alarm. The alarm originated at a pull station damaged by a contract worker in an area external to the Reactor Building.

6.7.4.d <u>Corrective and Preventative Maintenance</u>:

Preventative maintenance, tests and calibrations are scheduled, performed and tracked utilizing the PULSTAR Surveillance File System. Each major component of the Reactor Safety System defined in Section 3.3, and all surveillance required by Section 4 of the Technical Specifications are monitored by this file system to ensure that maintenance and calibrations are performed in a timely manner. All historical data relating to those components, in addition to many other minor components, are maintained in these files.

6.7.4.e <u>Changes in Facility, Procedures, Tests, and Experiments</u>:

1. Design Changes (DC)

   a. DC 01-1 modifies an existing design of four 2.5 inch diameter rotating vertical irradiation facilities. Two of the four will be replaced with a rectangular sleeve which will allow 4 inch diameter samples to be irradiated.

   b. DC 02-1 replaces a nine year old recorder for reactor building radiation monitors with a new paperless recorder by the same manufacturer.

   c. DC 02-2 replaces a 30 year old conductivity/resistivity measuring system required for the primary coolant. It also adds a new pH measuring equipment. Installation is pending.

2. Procedure Changes
   (NP = New Procedure, PC = Procedure Change, MC = Minor Change)

   a. NP 02-1 is a new Special Procedure 2.7 "Unplanned Event Notification and Reporting" providing guidance and references for determination if an unplanned event requires an immediate or special notification and/or report to ensure technical specification reporting requirements are met.

b. NP 02-2 is a new Surveillance Procedure PS-1-12 "Operation and Calibration of Installed Primary Coolant pH and Resistivity Monitoring Channels" providing instruction for the operation and calibration of the pH and resistivity monitoring channels to be installed by DC 02-2 described in 1.c above.

c. NP 02-3 is a new Security Procedure 6 "Heightened Security Levels" which offers guidance for management when security levels are put into effect by the Nuclear Regulatory Commission.

d. PC 10-01 was Revision 4 to Special Procedure 9.2 for the "Installation and Removal of Experimental Facilities, Vertical Exposure Ports (VEPs)" implementing changes required by DC 01-1 described in 1.a above.

e. PC 1-02 was Revision 1 to Special Procedure 5.10 "Primary Water Inventory" implementing trending measurements, dose assessment, and notification and actions associated with detectable net unaccounted primary coolant water losses.

f. MC 02-1 updated the implementing Emergency Procedure 1 " Emergency Plan Activation, Response, and Actions" for the PULSTAR Emergency Plan with current names and telephone numbers for callout list as well as organizational names. Also, typographical errors were corrected.

g. MC 02-2 was Revision 31 the PULSTAR Operations Manual providing updated checklist steps for the new Radiation Monitoring recorder installed by DC 02-1 described in 1.b above.

h. MC 02-3 was Revision 2 to Special Procedure 5.10 "Primary Water Inventory" making data entry more intuitive on the approved spreadsheet.

i. MC 02-4 was Revision 4 for Surveillance Procedure PS-17-6-1:A1 "Area Radiation Monitoring Channel Calibration" providing updated calibration steps required for the new Radiation Monitoring recorder installed by DC 02-1 described in 1.b above.

j. MC 02-5 was Revision 4 for Surveillance Procedure PS-17-6-2:A1 "Process Radiation Monitoring Channel Calibration" providing updated calibration steps required for the new Radiation Monitoring recorder installed by DC 02-1 described in 1.b above.

Summary:
Procedures were written or revised covering the calibration of installed equipment, reactor operations, surveillance, and Health Physics. These procedures have been

reviewed and/or approved by the Reactor Safety and Audit Committee (RSAC) and where required, approved by the Radiation Safety Committee (RSC).

6.7.4.f <u>Radioactive Effluent</u>:

1. Liquid Waste (summarized by quarters)

i. Radioactivity Released During the Reporting Period:

Period	(1) No. of Batches	(2) Total μCi	(3) Tot. Vol. Liters	(4)[1] Diluent Liters	(5) Tritium μCi
01 Jul - 30 Sep 01	1	13	3,420	3.0E4	9
01 Oct - 31 Dec 01	0	0	0	0	0
01 Jan - 31 Mar 02	0	0	0	0	0
01 Apr - 30 Jun 02	2	61	6,200	6.0E4	55

(6) 64 μCi of tritium was released during this reporting period.

(7) 74 μCi total activity was released during this reporting period.

ii. Identification of Fission and Activation Products:

The gross beta-gamma activity of the batches in (1) above were less than 2×10^{-5} μCi/ml. Isotopic analyses of these batches indicated low levels of typical corrosion and activation products. No fission products were detected.

iii. Disposition of Liquid Effluent not Releasable to Sanitary Sewer System:

All liquid effluent met the requirements of 10 CFR 20 for release to the sanitary sewer.

2. Gaseous Waste (summarized monthly)

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

(1) Gases:

Year	Period	Total Time In Hours	Curies
2001	01 Jul - 31 Jul	744	0.281
	01 Aug - 31 Aug	744	0.092
	01 Sep - 30 Sep	720	0.202

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

	01 Oct - 31 Oct	744	0.153
	01 Nov - 30 Nov	720	0.129
	01 Dec - 31 Dec	744	0.165
2002	01 Jan - 31 Jan	744	0.099
	01 Feb - 28 Feb	672	0.407
	01 Mar - 31 Mar	744	0.294
	01 Apr - 30 Apr	720	0.064
	01 May - 31 May	744	0.281
	01 Jun - 30 Jun	720	0.588
	Totals	8,760 hours	2.755 curies

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

Particulate filters from the Stack Particulate Monitoring Channel were analyzed upon removal. There was no particulate activity with $t_{1/2}$ >8 days indicated on any filter during this reporting period.

ii. Gases and Particulates Discharged During the Reporting Period:

(1) Gases:
Total activity of argon-41 release was 2.755 curies.

The yearly average concentration of argon-41 released from the PULSTAR reactor facility exhaust stack during this period was 8.2×10^{-9} µCi/cc . This is below the regulatory limit of 1×10^{-8} µCi/cc given in 10 CFR 20 Appendix B. Dose calculations were performed using the "COMPLY" code for the fiscal year. "COMPLY" code results were less than the 10 mrem constraint level given in 10 CFR 20.

(2) Particulates:
See gaseous waste i.(2) above.

3. Solid Waste from Reactor[2]

- Total volume of solid waste - 10 ft^3 (0.28 m^3)
- Total activity of solid waste - 0.06 mCi
- Dates of shipments and disposal - All waste is transferred to the NCSU Environmental Health and Safety Center for temporary storage and disposal under the NCSU state license. Transfers were made on 09 Mar 02.

[2] *Solid waste generated by the PULSTAR Reactor is transferred to the NCSU Radiation Safety Division for storage or disposal.*

6.7.4.g Personnel Radiation Exposure Report:

Twenty individuals were monitored for external radiation dose during the reporting period. Collective dose for this reporting period was 0.950 person-rem. Individual doses ranged from 0.001 to 0.080 rem with an average of 0.048 rem. No visitors required official monitoring during this reporting period.

6.7.4.h Summary of Radiation and Contamination Surveys Within the Facility:

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

- external radiation levels in the majority of areas were 2 mrem/h or less
- external radiation levels in the remaining areas were higher due to reactor operations
- contamination in most areas was not detectable
- when contamination was detected, the area or item was confined or decontaminated

6.7.4.i Description of Environmental Surveys Outside of the Facility:

See Attachment A prepared by the Radiation Safety Division of the Environmental Health and Safety Center at the end of this document.

Perimeter surveys were performed adjacent to the Reactor Building by the PULSTAR staff and indicated that:

- external radiation levels were at background levels for most areas (10 μrem/h)
- contamination was not detectable
- Net external radiation levels ranged up to 40 μrem/h in some areas when the reactor was operating at power. However, external radiation levels were at background levels in routinely occupied spaces.

ATTACHMENT A

PULSTAR REACTOR

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT

FOR THE PERIOD
JULY 1, 2001 - JUNE 30, 2002

NORTH CAROLINA STATE UNIVERSITY

ENVIRONMENTAL HEALTH AND SAFETY CENTER

RADIATION SAFETY DIVISION

by

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.

In November 2000 a member of the Radiation Safety Committee, Professor David DeMaster, performed an audit of the environmental sampling program and provided comments/suggestions regarding this program and the annual report. In response, the following actions have been taken and are reflected in this report:

1) A revised value for the "Average NC Gross Beta Activity Background Level" has been obtained from the State of North Carolina Division of Radiation Protection and included in this report in Table 2.3.

2) Specific activity data for I-131 in milk from the alternate year analysis will be included in each annual report for comparison with current year data.

3) Specific activity data for vegetation from the alternate year analysis will be included in each annual report for comparison with current year data.

4) The anomaly of higher TLD exposures at D.H. Hill Library was investigated for the possibility that it may be the result of radon daughter products. A passive radon detector was placed at this site and integrated for a seven-month exposure.

5) A wind rose has been included in Appendix 2 to show the wind field distribution expected in the vicinity of the reactor facility. Historical wind data for the RDU Airport Station # 13722 is provided since the NCSU campus meteorological data was not available at the time of this report.

Table 1:
Environmental Monitoring Programs for the PULSTAR Reactor at North Carolina State University

Sample	Activity Measured	Conducted By	Previous Frequency	Current Frequency	Basis For Measurement
Stack Gases	Gross Gamma	N.E.	Continuous	Continuous	10 CFR 20 T.S. 6.7.4
Stack Particles	Gross Beta Indiv. Gamma Emitters	N.E. N.E.	Monthly	Monthly	10 CFR 20 T.S. 6.7.4
Water from Reactor Facility	Gross Beta Gross Gamma Tritium	N.E. N.E. N.E.	Prior to Discharge (~ Monthly)	Prior to Discharge ~ Monthly	10 CFR 20 T.S. 6.7.4 City of Raleigh Ordinance
Air/Particles at 5 Campus Stations*	Gross Beta Indiv. Gamma Emitters	RSD/EHSC RSD/EHSC	Weekly Weekly	Quarterly	10 CFR 20 10 CFR 20
Air/Dosage at 8 Campus Stations+	TLD Dosimeter	RSD/EHSC	Quarterly	Quarterly	10 CFR 20
Surface Water Rocky Branch Creek	Gross Beta Indiv. Gamma Emitters	RSD/EHSC RSD/EHSC	Quarterly Quarterly	Quarterly Quarterly	NCSU NCSU
Vegetation NCSU Campus	Gross Beta Gamma	RSD/EHSC RSD/EHSC	Semi-annually	Alternate years Alternate years	NCSU NCSU
Milk Local Dairy	I-131	RSD/EHSC	Monthly	Alternate years	NCSU

Abbreviations Used in Table:

N.E. = Nuclear Engineering/Reactor Facility; RSD/EHSC = Radiation Safety Division.

*These 5 stations include:
Withers, Riddick, Broughton, Hill Library and Environmental Health & Safety Center.

+These 8 stations include: the PULSTAR stack, a control station (EHSC) and the 5 air sampling stations, and North Hall.

2. <u>AIR MONITORING</u> (TABLES 2.1, 2.2, AND 2.3; FIGURES 2a THROUGH 2e)

Air monitoring is performed continually for one week during each of four (4) quarters during the year. The data shows the normal fluctuations in gross beta activity levels expected during the year. Figures 2a through 2e show bar graphs of gross beta activity (fCi/cubic meter *vs.* sampling quarters per year). The highest gross beta activity observed was 19.9 $fCiM^{-3}$ at the Environmental Health & Safety Center station during the week of 08/14/01 to 08/21/01. The annual campus average was 11.4 $fCiM^{-3}$.

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.

A passive track-etch detector was placed at the D.H. Hill Library station during the period 05/10/01 to 12/12/01 to determine if some previously higher dosimeter exposures were attributable to radon gas. The detector analysis provided by Key Technology Inc. indicated an average radon level of 0.9 pCi/liter during the period. The average radon level in U.S. homes is reported to be ~ 1.3 pCi/liter.

TABLE 2.1 LOCATION OF AIR MONITORING STATIONS

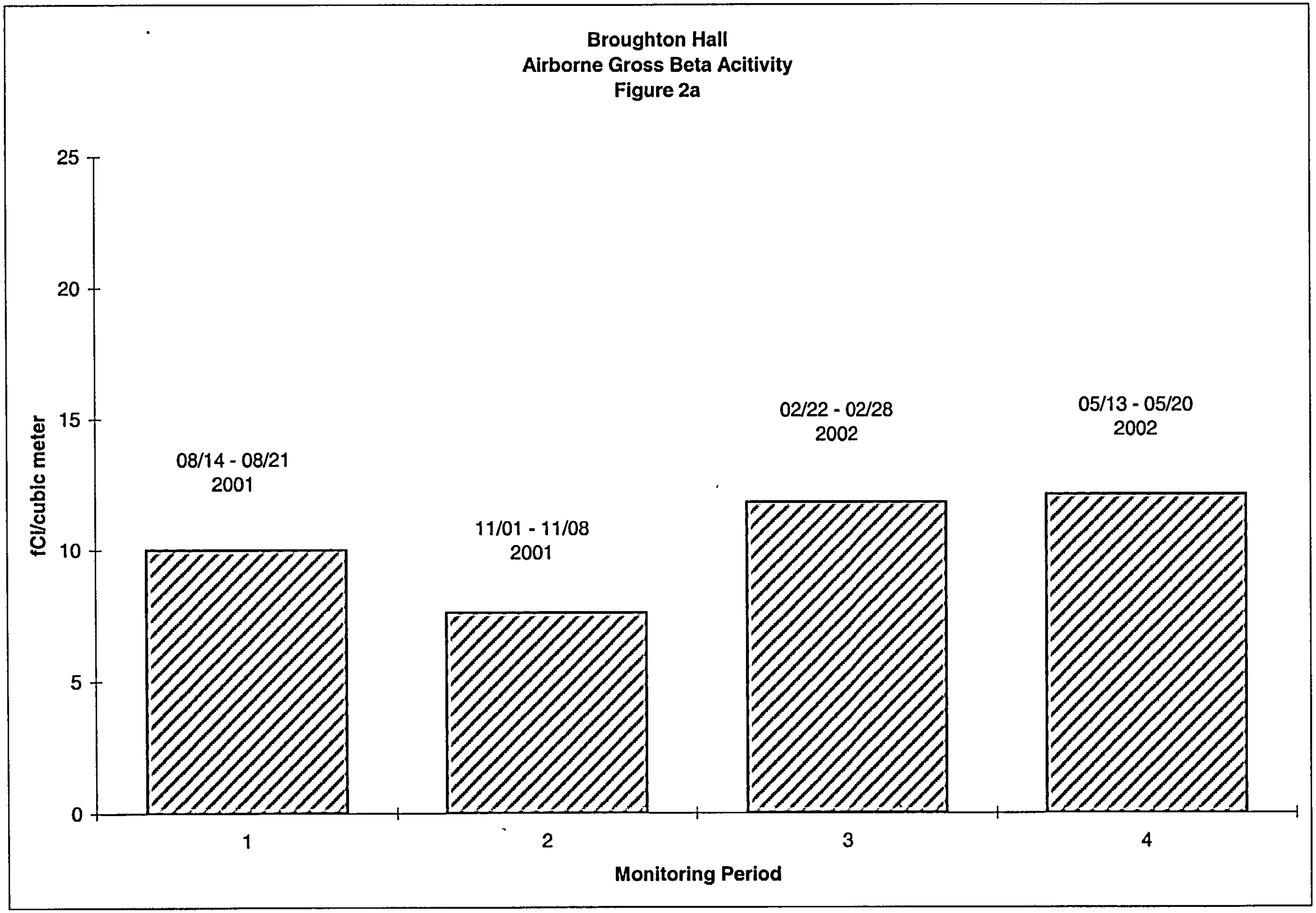
SITE	DIRECTION[1]	DISTANCE[2] (meters)	ELEVATION[3] (meters)
BROUGHTON	SOUTHWEST	125	-17
*DAVID CLARK LABS	WEST	500	-18
LIBRARY	NORTHWEST	192	+11
RIDDICK	SOUTHEAST	99	-14
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3
NORTH HALL	NORTHEAST	402	-4

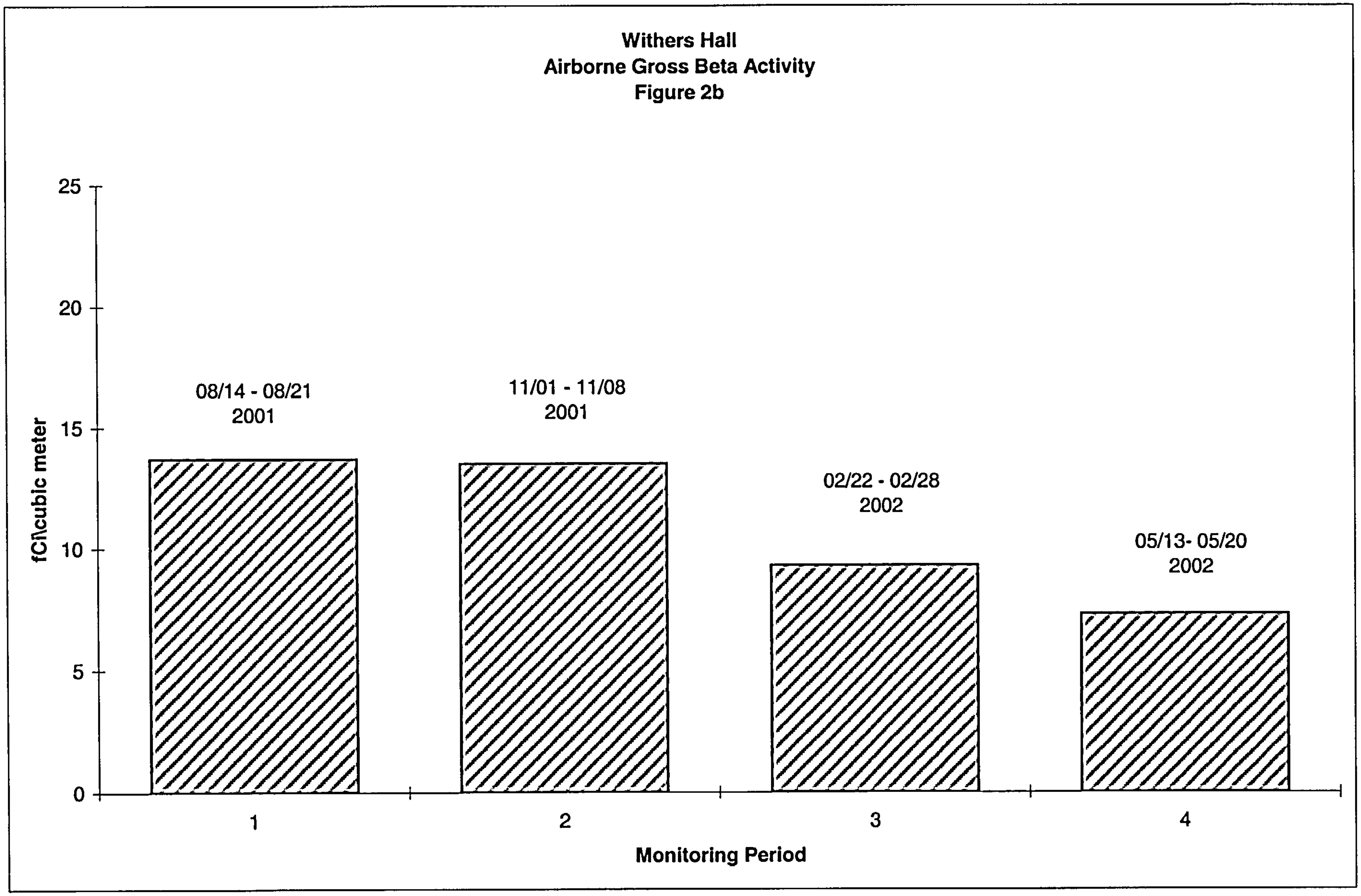
[1]DIRECTION - DIRECTION FROM REACTOR STACK
[2]DISTANCE - DISTANCE FROM REACTOR STACK
[3]ELEVATION - ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

*The station at David Clark Labs was relocated to the EH & S Center in January 1996, however a TLD monitor is maintained at David Clark Labs for the State of N.C. Division of Radiation Protection.

A wind rose is included in Appendix 2 to indicate the prevailing wind direction trends for the years 1961-1990.

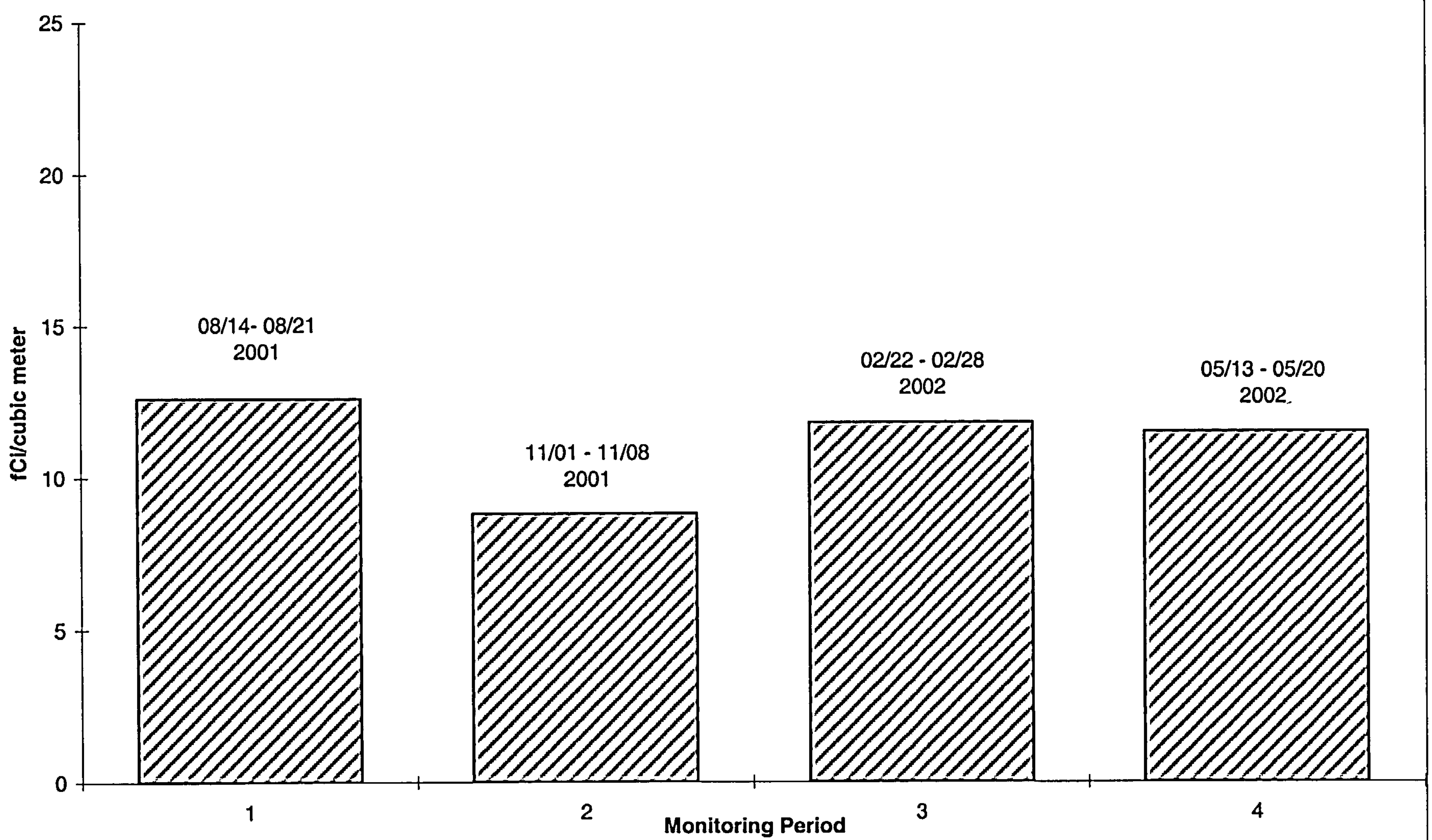
Table 2.2 Aerially Transported Gamma Activity				LLD values fCi/cubic meter					
					NUCLIDES				
SAMPLING PERIOD	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
2001									
08/14 - 08/21	0.21	0.44	0.29	0.46	0.27	2.25	0.33	0.36	1.21
11/01 - 11/08	0.21	0.44	0.28	0.48	0.28	2.48	0.35	0.34	1.28
2002									
02/22-02/28	0.17	0.37	0.32	0.53	0.32	2.49	0.23	0.42	1.42
05/13-05/20	0.17	0.31	0.31	0.51	0.36	2.43	0.26	0.38	1.41


Broughton Hall
Airborne Gross Beta Acitivity
Figure 2a
25
20
15
10
5
0
fCi/cubic meter
08/14 - 08/21
2001
11/01 - 11/08
2001
02/22 - 02/28
2002
05/13 - 05/20
2002
1
2
3
4
Monitoring Period

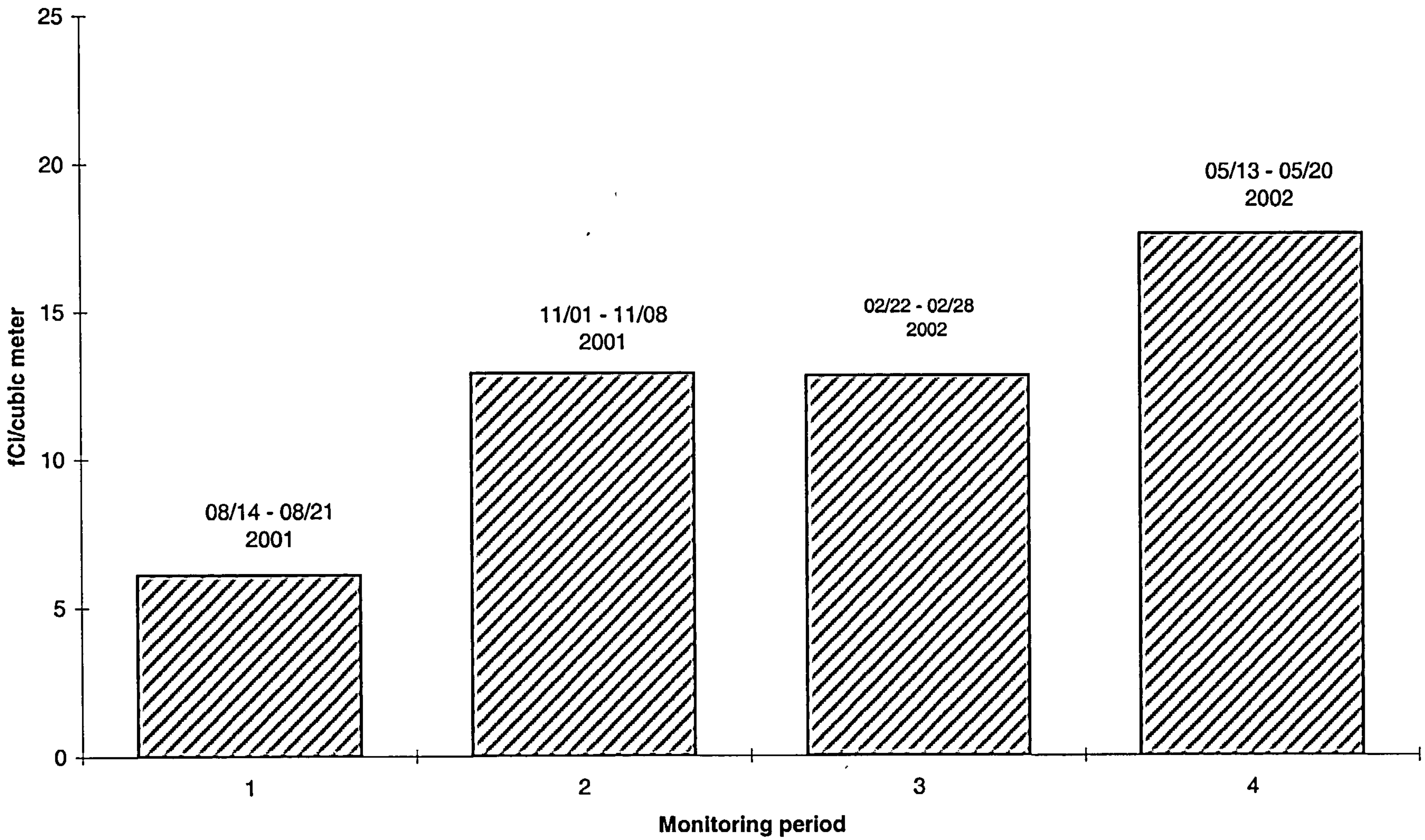


Withers Hall
Airborne Gross Beta Activity
Figure 2b
fCi\cubic meter
25
20
15
10
5
0
08/14 - 08/21
2001
11/01 - 11/08
2001
02/22 - 02/28
2002
05/13- 05/20
2002
1
2
3
4
Monitoring Period

Riddick Hall
Airborne Gross Beta Activity
Figure 2c



D. H. Hill Library
Airborne Gross Beta Activity
Figure 2d



Environmental Health & Safety Center
Airborne Gross Beta Activity
Figure 2e

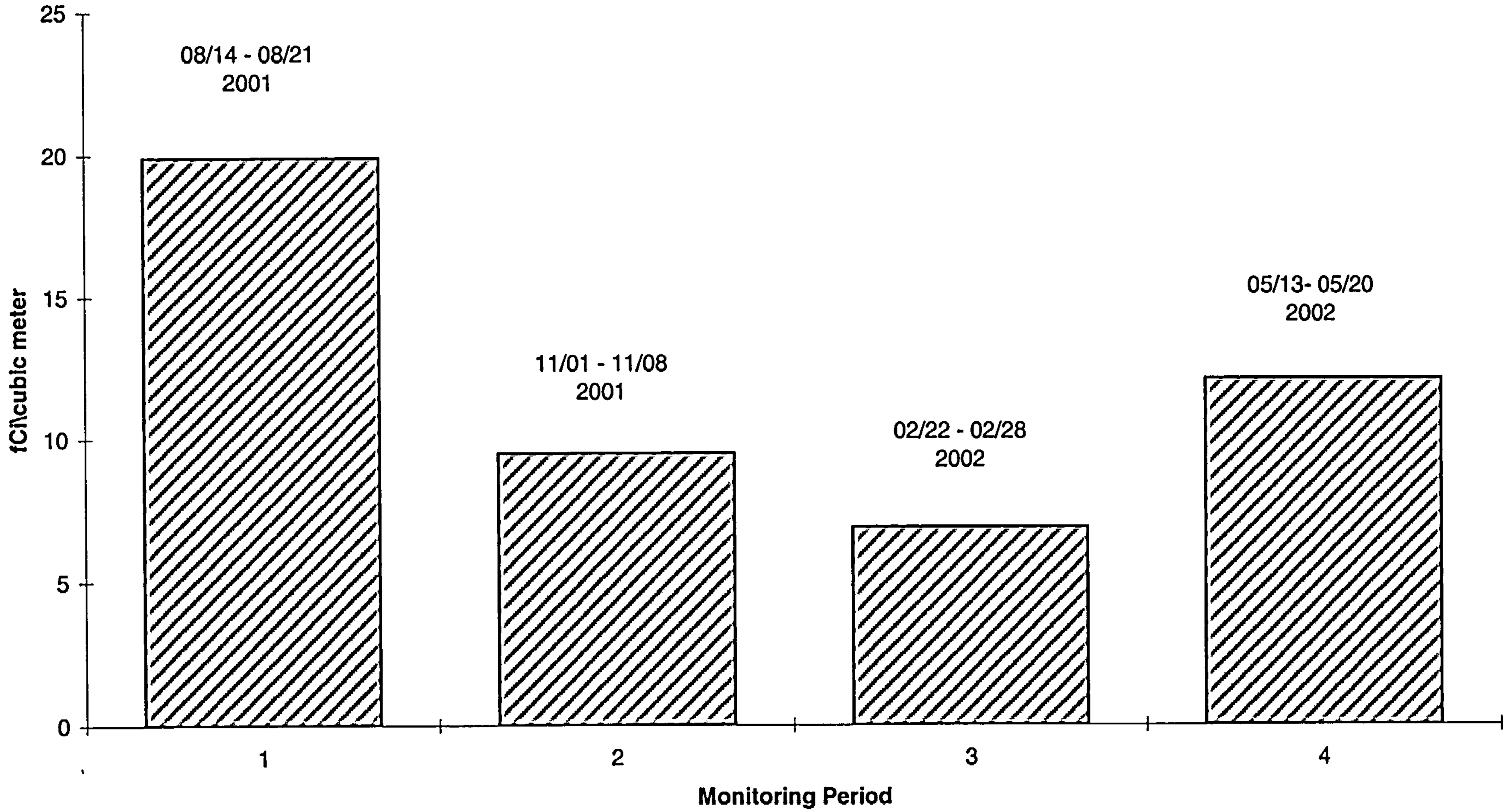


TABLE 2.3 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS FOR AIRBORNE RADIOACTIVITY (fCi M^{-3}).

NUCLIDE	REGULATORY LIMIT	ALERT LEVEL	AVERAGE N.C. BACKGROUND LEVEL
GROSS ALPHA	20	10	4
GROSS BETA*	1000	500	14.7 ; 3.1*
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

* These data represent a range of annual average values measured in North Carolina. Data courtesy of Dale Dusenbury of the N.C. Division of Radiation Protection.

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

3. MILK (TABLES 3.1A and 3.1B)

Milk samples are collected in alternate years from the Campus Creamery and the Lake Wheeler Road Dairy and analyzed for I-131. Data given for the years 2001 and 1999 shows that no I-131 activity was detected. The next sample collection will be in 2003.

TABLE 3.1A I-131 IN COW'S MILK (pCi $Liter^{-1} \pm 2\sigma$) LLD ~ 3 pCi $Liter^{-1}$

	pCi $Liter^{-1}$	
DATE	Campus Creamery	Lake Wheeler
May 2001	< 3	< 3

TABLE 3.1B I-131 IN COW'S MILK (pCi $Liter^{-1} \pm 2\sigma$) LLD ~ 3 pCi $Liter^{-1}$

	pCi $Liter^{-1}$	
DATE	Campus Creamery	Lake Wheeler
April 1999	< 3	< 3

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 value for gross alpha and beta activities is ~ 0.4 pCi Liter^{-1}. 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. All the results are consistent with the presence of naturally-occurring radionuclides and none of the gamma emitters listed in Table 4.2 were detected.

TABLE 4.1 GROSS ALPHA AND BETA ACTIVITY IN SURFACE WATER (pCi Liter^{-1} ± 2σ)

*LLD_α ~ 0.4 pCi Liter^{-1} LLD_β ~ 0.4 pCi Liter^{-1}

DATE	LOCATION	GROSS ALPHA (pCi Liter^{-1})	GROSS BETA (pCi Liter^{-1})
THIRD QUARTER 2001	ON	< 0.4	3.3 ± 0.7
	OFF	1.6 ± 0.5	2.9 ± 0.7
FOURTH QUARTER 2001	ON	< 0.4	2.6 ± 0.7
	OFF	< 0.4	2.4 ± 0.7
FIRST QUARTER 2002	ON	< 0.4	2.8 ± 0.7
	OFF	< 0.4	2.6 ± 0.7
SECOND QUARTER 2002	ON	2.6 ± 0.6	10.4 ± 1.0
	OFF	3.6 ± 0.4	10.7 ± 1.0

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

5. VEGETATION (TABLE 5.1A, 5.1B AND 5.2)

Tables 5.1A and 5.1B give gross beta activities for grass samples collected on the NCSU Campus. Table 5.2 lists LLD values for several gamma emitters. The vegetation sampling is performed in alternate years. The data given is for the years 2001 and 1999 for comparison. All the results are consistent with the presence of naturally-occurring radionuclides and none of the gamma emitters listed in Table 5.2 were detected. The next sample collection will be in 2003.

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

SAMPLE DATE	SAMPLE LOCATION	(pCi g^{-1} ± 2σ)
05/03/2001	NORTH CAMPUS	10.7 ± 0.5
05/03/2001	SOUTH CAMPUS	5.0 ± 0.4
05/03/2001	EAST CAMPUS	12.7 ± 0.6
05/03/2001	WEST CAMPUS	7.4 ± 0.5

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

SAMPLE DATE	SAMPLE LOCATION	(pCi g^{-1} ± 2σ)
04/15/1999	NORTH CAMPUS	2.3 ± 0.1
04/15/1999	SOUTH CAMPUS	2.6 ± 0.1
04/15/1999	EAST CAMPUS	2.5 ± 0.1
04/15/1999	WEST CAMPUS	2.6 ± 0.1

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

6. THERMOLUMINESCENT DOSIMETERS (TLDs) (TABLE 6.1)

TLD analysis is contracted to Landauer, Inc. for determination of ambient gamma exposures. Exposures are integrated over a three-month period at each of the five air monitor stations listed in Table 2.1 and inside the PULSTAR Reactor stack and at North Hall. A control station is located in Room 107 of the Environmental Health & Safety Center. Table 6.1 gives the data for these eight (8) locations.
The exposures (dose equivalents) are reported as millirem per quarter year. Readings which fall below the dosimeters' minimum measurable quantities (i.e., 1 millirem for gamma radiations and 10 millirems for beta radiations) are reported by the contract vendor with the designation "M ".

Historically, dosimeter readings for D.H. Hill Library monitoring station have often been higher than those for the other campus stations. Pursuant to a recommendation made in the "NCSU PULSTAR 2001 Annual Self Assessment", two additional TLDs have been added to the D.H. Hill Library station to supplement the existing dosimeter. These two additional dosimeters will become a routine part of the quarterly monitoring schedule.

TABLE 6.1 ENVIRONMENTAL TLD EXPOSURES (mrem/QUARTER YEAR)

DATE	WITHERS	RIDDICK	BROUGHTON	DH HILL	EH&S	PULSTAR STACK	NORTH	CONTROL
2001								
07/01-09/30	M	6	M	11	2	1	M	M,M
10/01-12/31	M	7	M	12	5	5	M	M,M
2002								
01/01-03/31	2	2	M	6	M	M	M	M,M
04/01-06/30	M	10	2	9	M	6	M	M,2
04/15-06/30				3*				

*The entry for D.H. Hill during the period 04/15/02 to 06/30/02 reflects an additional dosimeter reading for that station. The third dosimeter could not be found and had apparently been vandalized.

The "CONTROL" column indicates the use of multiple control dosimeters for four of the monitoring quarters.

The designation "M" is used by the contract vendor for reporting dose equivalents below the minimum measurable quantity which is 1 millirem for gamma radiation and 10 millirem for beta radiation

7. QUALITY CONTROL INTERCOMPARISON PROGRAM

The Environmental Radiation Surveillance Laboratory (ERSL) of the Radiation Safety Division has analyzed samples provided by the U.S. DOE Environmental Measurements Laboratory Quality Assurance Division Program (QAP 55) 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 'EML value' listed in the Tables 7.1 (a-d) to which the ERSL results are compared is the mean of replicate determinations for each nuclide. The EML uncertainty is the standard error of the mean. All other uncertainties are as reported by the participants.

The control limit was established from percentiles of historic data distributions (1982-1992). The evaluation of historic data and the development of the control limits are presented in DOE report EML-564. The control limits for QAP 55 were developed from the percentiles of data distributions for the years 1993-1999.

Participants' analytical performance is evaluated based on the historical analytical capabilities for individual analyte/matrix pairs. The criteria for acceptable performance, "A", has been chosen to be between the 15th and 85th percentile of the cumulative normalized distribution, which can be viewed as the middle 70% of all historic measurements. The acceptable with warning criteria, "W", is between the 5th and 15th percentile and between the 85th and 95th percentile. In other words, the middle 90% of all reported values are acceptable, while the outer 5th-15th (10%) and 85th-95th percentiles (10%) are in the warning area. The not acceptable criteria, "N", is established at less than the 5th percentile and greater than the 95th percentile, that is, the outer 10% of the historical data.

The following are recommended performance criteria for analysis of environmental levels of analytes:

Acceptable: Lower Middle Limit $\leq$ A $\leq$ Upper Middle Limit
Acceptable with Warning: Lower Limit $\leq$ W $<$ Lower Middle Limit or
Upper Middle Limit $<$ W $\leq$ Upper Limit
Not Acceptable: N $<$ Lower Limit or N $>$ Upper Limit

Control Limits are reported as the ratio of Reported Value vs. EML Value. The results of the intercomparison studies are given in Table 7.1 (a-d), and are stated in the SI unit becquerel (Bq) as required by the EML reporting protocol.

In addition to the EML Quality Assurance Program, the ERSL conducts an intralaboratory QC program to track the performance of routine radioactivity measurements. The types of calculations employed for this program are shown in an example calculation in Appendix 1.

TABLE 7.1a
GROSS ALPHA & BETA ACTIVITY AIR FILTER--INTERCOMPARISON STUDY
01 September 2001

The sample consists of one 50 mm diameter simulated filter spiked with a matrix-free solution containing a single alpha and a single beta emitting nuclide. The reported values and the known values are given in Bq/filter.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radionuclide	*Reported Value	*Reported Error	EML Value	EML Error	Reported / EML
Gross Alpha	4.973	0.188	5.362	0.536	0.927
Gross Beta	10.416	0.543	12.770	1.277	0.816

QAP 55 Statistical Summary

Radionuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Gross Alpha	5.362	0.536	1.014	0.908	0.160	83
Gross Beta	12.770	1.277	0.908	0.903	0.077	78

QAP 55 Control Limits by Matrix

Radionuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Gross Alpha	0.57	0.83	1.24	1.47
Gross Beta	0.76	0.88	1.29	1.52

Control Limits are reported as: the ratio of Reported Value vs. EML Value

TABLE 7.1b

MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY

01 September 2001

The sample consists of one 7 cm diameter glass fiber filter which has been spiked with 0.10 gram of solution and dried. The reported values and the known values are given in Bq/filter.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radionuclide	*Reported Value	*Reported Error	EML Value	EML Error	Reported / EML
Cs134	12.240	0.330	12.950	0.362	0.945
Co60	16.790	0.520	17.500	0.470	0.959
Cs137	18.060	0.880	17.100	0.580	1.056
Mn54	85.360	3.410	81.150	4.760	1.052

QAP 55 Statistical Summary

Radionuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Cs134	12.950	0.362	0.976	1.001	0.103	126
Co60	17.500	0.470	1.019	1.017	0.076	136
Cs137	17.100	0.580	1.069	1.061	0.086	133
Mn54	81.150	4.760	1.074	1.059	0.097	128

QAP 55 Control Limits by Matrix

Radionuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Cs134	0.74	0.82	1.10	1.21
Co60	0.79	0.87	1.13	1.30
Cs137	0.78	0.88	1.16	1.35
Mn54	0.80	0.89	1.20	1.36

Control Limits are reported as: the ratio of Reported Value vs. EML Value

TABLE 7.1c
MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 September 2001

The sample consists of a spiked, 455 mL aliquot of acidified water (~1 N HCl). The reported values and the known values are given in Bq/Liter.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radionuclide	*Reported Value	*Reported Error	EML Value	EML Error	Reported / EML
Co60	211.717	6.130	209.000	7.590	1.013
Cs137	44.421	2.711	45.133	2.467	0.984

QAP 55 Statistical Summary

Radionuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Co60	209.000	7.590	1.000	1.000	0.054	136
Cs137	45.133	2.467	1.041	1.041	0.058	135

QAP 55 Control Limits by Matrix

Radionuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Co60	0.80	0.90	1.12	1.20
Cs137	0.80	0.90	1.15	1.24

Control limits are reported as: the ratio of Reported Value vs. EML Value

TABLE 7.1d
GROSS ALPHA AND BETA WATER SAMPLE - INTERCOMPARISON STUDY
01 September 2001

The sample consists of a 4 mL aliquot of ~1 N HCl matrix free solution. The reported values and the known values are given in Bq/Liter.

*NCSU - ENVIRONMENTAL LABORATORY RESULTS

Radionuclide	*Reported Value	*Reported Error	EML Value	EML Error	Reported / EML
Gross Alpha	1139.190	125.840	1150.000	115.000	0.991
Gross Beta	7397.050	718.630	7970.000	800.000	0.928

QAP 55 Statistical Summary

Radionuclide	EML Value	EML Error	Mean	Median	Std. Dev.	No. Of Reported Values
Gross Alpha	1150.000	115.000	0.982	1.000	0.137	73
Gross Beta	7970.000	800.000	0.961	0.951	0.105	82

QAP 55 Control Limits by Matrix

Radionuclide	Lower Limit	Lower Middle Limit	Upper Middle Limit	Upper Limit
Gross Alpha	0.58	0.79	1.12	1.26
Gross Beta	0.56	0.75	1.33	1.50

Control limits are reported as: the ratio of Reported Value vs. EML Value

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 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.

APPENDIX 1

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. 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 = $\bar{x}$

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

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 = $\bar{R}$

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

$= (1.693)(357)$

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

Control limit = CL

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

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

$= (2.575)(604.4)$

CL = 1556 pCi/liter

Standard error of the range = σ_R

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

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

$= (1556 - 604.4) \div 3$

$\sigma_R = 317.2$ pCi/liter

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

Define normalized range $= w + x$

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

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

or $$x = \frac{r - \bar{R}}{\sigma_R}$$

therefore $$w + x = 1 + x = 1 + \frac{r - \bar{R}}{\sigma_R}$$

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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 $r \le \bar{R}$, $x = 0$

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

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

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

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

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

$$w + x = 0.30$$

Normalized deviation of the mean from the known value = ND

Deviation of mean from the known value = D

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

$$= 3120 - 3273$$

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

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'

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

$= 3120 - 3290$

D' = -170 pCi/liter

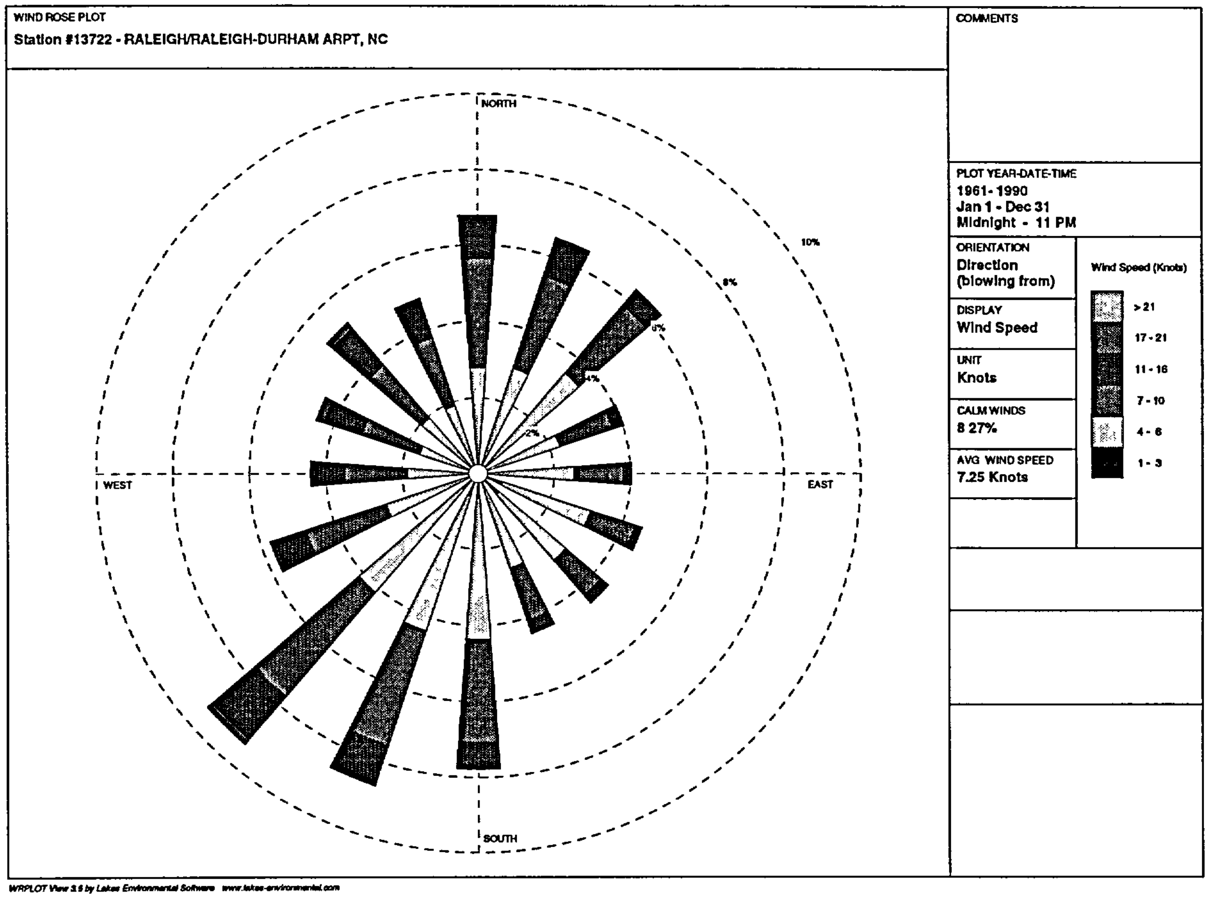
$$ND' = \frac{D'}{\sigma_m}$$

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

ND' = - 0.8

Appendix 2

Prevailing Wind Directions At Raleigh-Durham Airport 1961-1990



1 knot = 1.15155 miles per hour

Winds are mainly from the SouthWest (225 degrees) with a frequency ~ 9 % .

** Wind Rose courtesy of Ryan Boyles of the State Climate Office of North Carolina