PILGRIM NUCLEAR POWER STATION

Facility Operating License DPR-35

Annual Radioactive Effluent Release Report

January 1 through December 31, 2021

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PILGRIM NUCLEAR POWER STATION
Facility Operating License DPR-35

ANNUAL RADIOACTIVE EFFLUENT RELEASE REPORT

JANUARY 01 THROUGH DECEMBER 31, 2021

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TABLE OF CONTENTS

LIST OF TABLES

1.0 EXECUTIVE SUMMARY

INTRODUCTION

This report quantifies the radioactive gaseous, liquid, and radwaste releases, and summarizes the local meteorological data for the period from January 01 through December 31, 2021. This document has been prepared in accordance with the requirements set forth in the Pilgrim Nuclear Power Station (PNPS) Technical Specifications and Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Material in Liquid and Gaseous Effluents from Light Water Cooled Nuclear Power Plants". This document has been prepared in accordance with the requirements of PNPS Facility Licensing Basis.

The quantity of radioactive material released from PNPS was determined from sample analyses and continuous on-line monitoring of gaseous releases from the reactor building vent, various decontamination facilities, and liquid releases into the discharge canal.

The quantity and volume of radioactive waste shipped offsite from PNPS for processing and burial were determined from data contained on the radwaste shipping documentation. The meteorological data was obtained from monitoring instruments located on the 220-foot tower located at Pilgrim Station.

GASEOUS EFFLUENTS

Gaseous radioactive releases for the reporting period are quantified in Tables 2.2-A, 2.2-B, and 2.2-C. Radioactive noble gases released during the period totaled 0.0 Curies. Releases of radioactive particulates with half-life of greater than 8 days totaled 0.000017 Curies and tritium releases totaled 8.0 Curies. No gross alpha radioactivity was detected in gaseous effluents.

There were no noble gas releases during 2021, therefore all quarterly and annual dose consequences are zero. The release of radioactive particulates and tritium in gaseous effluents from PNPS during the reporting period resulted in a total body dose and to any organ to the maximum-exposed hypothetical individual of approximately 0.00024 mrem.

The maximum individual doses from gaseous radioactive effluents were compared to the applicable ODCM dose limits. Noble gas doses were 0.00% of the corresponding 10CFR50 dose objectives. Maximum doses resulting from releases of particulates and tritium in gaseous effluents were less than 0.0016% of corresponding 10CFR50 objectives.

LIQUID EFFLUENTS

Liquid radioactive releases for the reporting period are quantified in Tables 2.3-A and 2.3-B. No discharges of liquid effluents occurred during the reporting period. The resulting maximum total body dose was 0.00 mrem, with a corresponding organ dose of 0.00 mrem. All doses from liquid discharges were less than 0.00% of corresponding 10CFR50 objectives.

METEOROLOGICAL DATA

Meteorological joint frequency distributions are no longer listed within this report as RG 1.21 rev 2 , June 2009 does not require them to be included. The site adopted revision 2 in the latest revision of the ODCM. Meteorological data is retained on site for reference use. Data recovery for the entire annual period was 99.9% for the 33-ft and 99.5% for the 220-ft levels of the tower. The predominant wind direction was from the south-southwest, which occurred approximately 13% of the time during the reporting period. The predominant stability class was Class E, which occurred approximately 44% of the time during the reporting period

OFFSITE AMBIENT RADIATION MEASUREMENTS

Ambient radiation exposure was evaluated to complete the assessment of radiological impact on humans. In past reports the dose to the maximum-exposed member of the public at the PNPS Health Club was used showing a fraction (and sometimes less) of a mrem of exposure even though that TLD is within the owner-controlled area. As this dose value is calculated using the nearest TLD to the PNPS Health Club (TC) reading average over the 4 quarters of 2021 multiplied by 4. Then the Zone 4 (background) is subtracted from it. That annual average net value is then multiplied by 500/8760 to show the exposure per 500 hr period in mR/yr. In the past this area was accessible to the public and that dose would be an accurate calculation. Since 2010 (and the installataion of the Mac 8 security gates), this area is not accessible to persons without a site badge. To that effect there is no longer any area on the site proper that would be considered “recreational” or accessible to the general public. The entirety of the site proper (areas accessible through the three enrances off Rocky Hill Road) is considered “for business purposes only” and therefore not accessible through means of fencing (i.e fences, jersey barriers, gates), signage, or security monitoring (i.e tours, cameras). The more accurate dose to an actual MEMBER OF THE PUBLIC as defined in NUREG 1302 would be that calculated from ISF-1 TLD located on the public roadway across from the same parking lot entrance as the previously accessible health club. ISF-1 TLD dose calculated in the same manner as explained above to result in 0.30 mrem/year. There was no significant increase during 2021 in ambient radiation measurements at the location of the nearest resident 0.8 km southeast of PNPS.

COMBINED DOSE IMPACT

The collective total body dose to a maximum-exposed hypothetical member of the public from airborne radioactivity, liquid-borne radioactivity, and ambient radiation exposure resulting from PNPS operation during 2021 was calculated as being approximately 0.30 mrem. This amount is approximately 0.05% of the typical dose of 620 mrem received each year by an average person from other sources of natural and man-made radiation. Although this calculated collective dose occurs to a maximum-exposed hypothetical individual, it is also well below the NRC dose limit of 100 mrem/yr specified in 10CFR20.1301, as well as the EPA dose limit of 25 mrem/yr specified in 40CFR190. Both of these limits are to be applied to real members of the general public, so the fact that the dose to the hypothetical maximum-exposed individual is within the limits ensures that any dose received by a real member of the public would be smaller and well within any applicable limit.

RADIOACTIVE SOLID WASTE DISPOSAL

Solid radioactive wastes shipped offsite for processing and disposal during the reporting period are described in Table 7.0. A sum of all low-level waste of approximately 1610 cubic meters of solid waste, containing 933 Curies of radioactivity, was shipped from the site during the 2021 reporting period.

ONSITE GROUNDWATER MONITORING PROGRAM

In response to the Nuclear Energy Institute Groundwater Protection Initiative, Pilgrim Station instituted a groundwater monitoring program during 2007. Four monitoring wells were installed onsite during the fourth quarter of 2007, and the first samples were collected in late November 2007. Additional

sampling wells were added in 2010, 2011, 2012, 2013, and 2014. As of the end of 2021, samples are being collected from a total of 23 monitoring wells. Low levels of tritium, a radioactive isotope of hydrogen, were detected in several of these onsite wells. No other plant-related radioactivity was detected in the groundwater samples. The average concentration of tritium detected in these onsite monitoring wells during 2021 was well below the voluntary communications reporting level established by the EPA Drinking Water Standard of 20,000 pCi/L. Although the EPA Standard provides a standard for comparison, no drinking water sources are affected by this tritium. The maximum hypothetical dose resulting from tritium in groundwater presumed to enter Cape Cod Bay is calculated to be 0.00000016 mrem/yr. Results of the groundwater monitoring program are presented in Appendix B.

CONCLUSION

The PNPS Offsite Dose Calculation Manual contains effluent controls to limit doses resulting from releases of radioactivity to the environment. None of the effluent controls associated with liquid or gaseous effluents were exceeded during the reporting period, as confirmed by conservative dose assessments performed at weekly and monthly intervals. Conformance to the PNPS ODCM effluent control limits ensures that releases of radioactivity in liquid and gaseous effluents are kept as low as reasonably achievable in accordance with 10 CFR Part 50, Appendix I. Compliance with the ODCM also demonstrates that requirements of the Environmental Protection Agency's nuclear fuel cycle standard, 40CFR190.10, Subpart B, have been met. Based on the dose assessment results for 2021, there was no significant radiological impact on the general public from PNPS operation or decommissioning activities.

2.0 RADIOACTIVE EFFLUENT DATA

Radioactive gaseous and liquid releases for the reporting period are given in the standard format presented in Tables 1A, 1B, 1C, 2A, 2B, and Supplemental Information table from NRC Regulatory Guide 1.21 (Reference 1) format.

2.1 Supplemental Effluent Release Data

Supplemental information related to radioactive gaseous and liquid releases for the reporting period are given in the standard NRC Regulatory Guide 1.21 format in Table 2.1.

2.2 Gaseous Effluent Data

Gaseous radioactivity is released from Pilgrim Station to the atmosphere from the reactor building vent and various decontamination facilities. Combined gaseous effluent releases from all release points are summarized in Table 2.2-A. No alpha activity was detected on any of the particulate filters collected during the reporting period. The total gaseous releases for various categories of radionuclides, as well as the corresponding average release rates, can be summarized as follows:

- Particulates with half-life greater than 8 days: 0.0000166 Ci, 0.000000527 μCi/sec
- Tritium: 8.00 Ci, 0.254 μCi/sec
- Noble gases: 0.00 Ci , no longer producing due to plant condition
- Carbon-14: 0.00 Ci, no longer producing due to plant condition

The main stack effluent was removed as a pathway at the end of 2019 and since removed from the ODCM. There were no releases out of the main stack in 2021 as detailed in Table 2.2-B

Ground-level effluent releases are detailed in Table 2.2-C. Data in this table include releases from the reactor building vent and assorted equipment decontamination facilities (e.g., carbon dioxide pellet decon trailer, plastic media decon trailer, etc.) used during the period. Due to the close proximity of the reactor building, all of these release points are considered to be mixed-mode/ground level release points.

Table 3.1-2 of the PNPS ODCM requires that if any of the gaseous effluent monitors are inoperable for more than 30-days, such events are to be reported in the Annual Radioactive Effluent Release Report with an explanation of why the affected monitor was not returned to operable status in a timely manner. There were no instances in 2021 when both channels of a dual-channel effluent monitor (Reactor Building Vent) were out of service at the same time during a 30 consecutive day period. The RBV effluent monitor was removed from the ODCM in Revision 15. The effluent monitor and its surveileances became a part of the Emergency Planning (E-plan) program until such a time as the spent fuel was offloaded into canisters and placed onto the Independent Spent Fuel Storage Installation (ISFSI) II pad. That effort was completed in December of 2021.

2.3 Liquid Effluent Data

Liquid radioactivity (when discharged) is released from PNPS to Cape Cod Bay via the site discharge canal. These effluents enter Cape Cod Bay at the outfall of the canal, which is located approximately 1100 feet north of the reactor building.

Liquid effluent releases are summarized in Table 2.3-A. Detailed breakdowns for individual radionuclides are listed in Table 2.3-B. There were no discharges of liquid effluents containing radioactivity during the reporting period. Total releases for the various categories of radionuclides, as well as their corresponding mean concentrations, can be summarized as follows:

- Total Effluent Volume: 0 Liters
- Total Dilution Volume: 0 Liters
- Fission/Activation products: 0.00 Ci, 0.00 μCi/mL
- Tritium: 0.00 Ci, 0.00 μCi/mL
- Dissolved/entrained noble gases: 0.00 Ci, 0.00 μCi/mL

Table 2.1
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Supplemental Information
January-December 2021

FACILITY: PILGRIM NUCLEAR POWER STATION **LICENSE: DPR-35**

1. REGULATORY LIMITS					
a. Fission and activation gases:	500 mrem/yr total body and 3000 mrem/yr for skin at site boundary				
b,c. Iodines, particulates with half-life: >8 days, tritium	1500 mrem/yr to any organ at site boundary				
d. Liquid effluents:	0.06 mrem/month for whole body and 0.2 mrem/month for any organ (without radwaste treatment) 1.5 mrem/qtr, 3 mrem/yr TB and 5 mrem/qtr, 10 mrem/yr Max Organ				
2. EFFLUENT CONCENTRATION LIMITS					
a. Fission and activation gases:	10CFR20 Appendix B Table II				
b. Iodines:	Not Applicable				
c. Particulates with half-life > 8 days:	10CFR20 Appendix B Table II				
d. Liquid effluents:	2E-04 μCi/mL for entrained noble gases; 10CFR20 Appendix B Table II values for all other radionuclides				
3. AVERAGE ENERGY	Not Applicable				
4. MEASUREMENTS AND APPROXIMATIONS OF TOTAL RADIOACTIVITY					
a. Fission and activation gases: b. Iodines: c. Particulates: d. Liquid effluents:	High purity germanium gamma spectroscopy for all gamma emitters; radiochemistry analysis for H-3, Fe-55 (liquid effluents), Sr-89, and Sr-90				
5. BATCH RELEASES	Jan-Mar 2021	Apr-Jun 2021	Jul-Sep 2021	Oct-Dec 2021	Jan-Dec 2021
a. Liquid Effluents					
1. Total number of releases:	N/A	N/A	N/A	N/A	N/A
2. Total time period (minutes):	N/A	N/A	N/A	N/A	N/A
3. Maximum time period (minutes):	N/A	N/A	N/A	N/A	N/A
4. Average time period (minutes):	N/A	N/A	N/A	N/A	N/A
5. Minimum time period (minutes):	N/A	N/A	N/A	N/A	N/A
6. Average stream flow during periods of release of effluents into a flowing stream (Liters/min):	N/A	N/A	N/A	N/A	N/A
b. Gaseous Effluents	None	None	None	None	None
6. ABNORMAL RELEASES					
a. Liquid Effluents	None	None	None	None	None
b. Gaseous Effluents	None	None	None	None	None

Table 2.2-A
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents - Summation of All Releases
January-December 2021

RELEASE PERIOD	Jan-Mar 2021	Apr-Jun 2021	Jul-Sep 2021	Oct-Dec 2021	Jan-Dec 2021	Est. Total Error
A. FISSION AND ACTIVATION GASES						
Total Release: Ci	NDA	NDA	N/A	N/A	NDA	±22%
Average Release Rate: μCi/sec	0.00E+00	0.00E+00	N/A	N/A	0.00E+00	
Percent of Effluent Control Limit*	*	*	*	*	*	
B. IODINE-131						
Total Iodine-131 Release: Ci	N/A	N/A	N/A	N/A	N/A	±20%
Average Release Rate: μCi/sec	N/A	N/A	N/A	N/A	N/A	
Percent of Effluent Control Limit*	*	*	*	*	*	
C. PARTICULATES WITH HALF-LIVES > 8 DAYS						
Total Release: Ci	5.48E-06	0.00E+00	9.62E-06	1.52E-06	1.66E-05	±21%
Average Release Rate: μCi/sec	6.95E-07	0.00E+00	1.22E-06	1.93E-07	5.27E-07	
Percent of Effluent Control Limit*	*	*	*	*	*	
Gross Alpha Radioactivity: Ci	NDA	NDA	NDA	NDA	NDA	
D. TRITIUM						
Total Release: Ci	4.32E+00	1.76E+00	9.58E-01	9.63E-01	8.00E+00	±20%
Average Release Rate: μCi/sec	5.48E-01	2.23E-01	1.21E-01	1.22E-01	2.54E-01	
Percent of Effluent Control Limit*	*	*	*	*	*	
E. CARBON-14						
Total Release: Ci	N/A	N/A	N/A	N/A	N/A	N/A
Average Release Rate: μCi/sec	N/A	N/A	N/A	N/A	N/A	
Percent of Effluent Control Limit*	*	*	*	*	*	

Notes for Table 2.2-A:

* Percent of Effluent Control Limit values based on dose assessments are provided in Section 6 of this report.

1. NDA stands for No Detectable Activity.
2. LLD for airborne gross alpha activity listed as NDA is 1E-11 μCi/cc.
3. N/A stands for not applicable.

Table 2.2-B
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents – Elevated Release
January-December 2021

There was no elevated release during 2021. The elevated release through the PNPS Main Stack was secured in 2019 and is no longer a pathway.

Table 2.2-C
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents – Ground-Level Release
January-December 2021

CONTINUOUS MODE RELEASES FROM GROUND-LEVEL RELEASE POINT					
Nuclide Released	Jan-Mar 2021	Apr-Jun 2021	Jul-Sep 2021	Oct-Dec 2021	Jan-Dec 2021
1. FISSION AND ACTIVATION GASES: Ci					
Ar-41	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Kr-85	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Kr-85m	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Kr-87	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Kr-88	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Xe-131m	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Xe-133	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Xe-133m	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Xe-135	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Xe-135m	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Xe-137	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Xe-138	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
Total for period	0.00E+00	0.00E+00	N/A	N/A	0.00E+00
2. IODINES: Ci					
I-131	N/A	N/A	N/A	N/A	N/A
I-133	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
3. PARTICULATES WITH HALF-LIVES > 8 DAYS: Ci					
Cr-51	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn-54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-60	5.48E-06	0.00E+00	0.00E+00	0.00E+00	5.48E-06
Zn-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	0.00E+00	0.00E+00	9.62E-06	1.52E-06	1.11E-05
Ba/La-140	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total for period	5.48E-06	0.00E+00	9.62E-06	1.52E-06	1.66E-05
4. TRITIUM: Ci					
H-3	4.32E+00	1.76E+00	9.58E-01	9.63E-01	8.00E+00
5. CARBON-14: Ci					
C-14	N/A	N/A	N/A	N/A	N/A

Notes for Table 2.2-C:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for airborne radionuclides listed as NDA are as follows:
   Fission Gases: 1E-04 μCi/cc
   Particulates: 1E-11 μCi/cc
4. An increase in Cs-137 was detected on RBV filters due to activities of fuel removal.

Table 2.2-C (continued)
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents – Ground-Level Release
January-December 2021

BATCH MODE RELEASES FROM GROUND-LEVEL RELEASE POINT					
Nuclide Released	Jan-Mar 2021	Apr-Jun 2021	Jul-Sep 2021	Oct-Dec 2021	Jan-Dec 2021
1. FISSION AND ACTIVATION GASES: Ci					
Ar-41	N/A	N/A	N/A	N/A	N/A
Kr-85	N/A	N/A	N/A	N/A	N/A
Kr-85m	N/A	N/A	N/A	N/A	N/A
Kr-87	N/A	N/A	N/A	N/A	N/A
Kr-88	N/A	N/A	N/A	N/A	N/A
Xe-131m	N/A	N/A	N/A	N/A	N/A
Xe-133	N/A	N/A	N/A	N/A	N/A
Xe-133m	N/A	N/A	N/A	N/A	N/A
Xe-135	N/A	N/A	N/A	N/A	N/A
Xe-135m	N/A	N/A	N/A	N/A	N/A
Xe-137	N/A	N/A	N/A	N/A	N/A
Xe-138	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
2. IODINES: Ci					
I-131	N/A	N/A	N/A	N/A	N/A
I-133	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
3. PARTICULATES WITH HALF-LIVES > 8 DAYS: Ci					
Cr-51	N/A	N/A	N/A	N/A	N/A
Mn-54	N/A	N/A	N/A	N/A	N/A
Fe-59	N/A	N/A	N/A	N/A	N/A
Co-58	N/A	N/A	N/A	N/A	N/A
Co-60	N/A	N/A	N/A	N/A	N/A
Zn-65	N/A	N/A	N/A	N/A	N/A
Sr-89	N/A	N/A	N/A	N/A	N/A
Sr-90	N/A	N/A	N/A	N/A	N/A
Ru-103	N/A	N/A	N/A	N/A	N/A
Cs-134	N/A	N/A	N/A	N/A	N/A
Cs-137	N/A	N/A	N/A	N/A	N/A
Ba/La-140	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
4. TRITIUM: Ci					
H-3	N/A	N/A	N/A	N/A	N/A
5. CARBON-14: Ci					
C-14	N/A	N/A	N/A	N/A	N/A

Notes for Table 2.2-C:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for airborne radionuclides listed as NDA are as follows:
   Fission Gases: 1E-04 μCi/cc
   Particulates: 1E-11 μCi/cc

Table 2.3-A
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Liquid Effluents - Summation of All Releases
January-December 2021

RELEASE PERIOD	Jan-Mar 2021	Apr-Jun 2021	Jul-Sep 2021	Oct-Dec 2021	Jan-Dec 2021	Est. Total Error
A. FISSION AND ACTIVATION PRODUCTS						
Total Release (not including tritium, gases, alpha): Ci	N/A	N/A	N/A	N/A	N/A	±12%
Average Diluted Concentration During Period: μCi/mL	N/A	N/A	N/A	N/A	N/A	
Percent of Effluent Concentration Limit*	N/A	N/A	N/A	N/A	N/A	
B. TRITIUM						
Total Release: Ci	N/A	N/A	N/A	N/A	N/A	±9.4%
Average Diluted Concentration During Period: μCi/mL	N/A	N/A	N/A	N/A	N/A	
Percent of Effluent Concentration Limit*	N/A	N/A	N/A	N/A	N/A	
C. DISSOLVED AND ENTRAINED GASES						
Total Release: Ci	N/A	N/A	N/A	N/A	N/A	±16%
Average Diluted Concentration During Period: μCi/mL	N/A	N/A	N/A	N/A	N/A	
Percent of Effluent Concentration Limit*	N/A	N/A	N/A	N/A	N/A	
D. GROSS ALPHA RADIOACTIVITY						
Total Release: Ci	N/A	N/A	N/A	N/A	N/A	±34%
E. VOLUME OF WASTE RELEASED PRIOR TO DILUTION						
Waste Volume: Liters	N/A	N/A	N/A	N/A	N/A	±5.7%
F. VOLUME OF DILUTION WATER USED DURING PERIOD						
Dilution Volume: Liters	2.15E+08	7.17E+08	1.51E+09	1.37E+09	3.81E+09	±10%

Notes for Table 2.3-A:

* Additional percent of Effluent Control Limit values based on dose assessments are provided in Section 6 of this report.

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLD for dissolved and entrained gases listed as NDA is 1E-05 μCi/mL.
4. LLD for liquid gross alpha activity listed as NDA is 1E-07 μCi/mL.

Table 2.3-B
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Liquid Effluents
January-December 2021

CONTINUOUS MODE RELEASES					
Nuclide Released	Jan-Mar 2021	Apr-Jun 2021	Jul-Sep 2021	Oct-Dec 2021	Jan-Dec 2021
1. FISSION AND ACTIVATION PRODUCTS: Ci					
Cr-51	N/A	N/A	N/A	N/A	N/A
Mn-54	N/A	N/A	N/A	N/A	N/A
Fe-55	N/A	N/A	N/A	N/A	N/A
Fe-59	N/A	N/A	N/A	N/A	N/A
Co-58	N/A	N/A	N/A	N/A	N/A
Co-60	N/A	N/A	N/A	N/A	N/A
Zn-65	N/A	N/A	N/A	N/A	N/A
Zn-69m	N/A	N/A	N/A	N/A	N/A
Sr-89	N/A	N/A	N/A	N/A	N/A
Sr-90	N/A	N/A	N/A	N/A	N/A
Zr/Nb-95	N/A	N/A	N/A	N/A	N/A
Mo/Tc-99	N/A	N/A	N/A	N/A	N/A
Ag-110m	N/A	N/A	N/A	N/A	N/A
Sb-124	N/A	N/A	N/A	N/A	N/A
Cs-134	N/A	N/A	N/A	N/A	N/A
Cs-137	N/A	N/A	N/A	N/A	N/A
Ba/La-140	N/A	N/A	N/A	N/A	N/A
Ce-141	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
2. DISSOLVED AND ENTRAINED GASES: Ci					
Xe-133	N/A	N/A	N/A	N/A	N/A
Xe-135	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A

Notes for Table 2.3-B:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for liquid radionuclides listed as NDA are as follows:
   - Strontium: 5E-08 μCi/mL
   - Noble Gases: 1E-05 μCi/mL
   - All Others: 5E-07 μCi/mL

Table 2.3-B (continued)
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Liquid Effluents
January-December 2021

BATCH MODE RELEASES					
Nuclide Released	Jan-Mar 2021	Apr-Jun 2021	Jul-Sep 2021	Oct-Dec 2021	Jan-Dec 2021
1. FISSION AND ACTIVATION PRODUCTS: Ci					
Na-24	N/A	N/A	N/A	N/A	N/A
Cr-51	N/A	N/A	N/A	N/A	N/A
Mn-54	N/A	N/A	N/A	N/A	N/A
Fe-55	N/A	N/A	N/A	N/A	N/A
Fe-59	N/A	N/A	N/A	N/A	N/A
Co-58	N/A	N/A	N/A	N/A	N/A
Co-60	N/A	N/A	N/A	N/A	N/A
Zn-65	N/A	N/A	N/A	N/A	N/A
Zn-69m	N/A	N/A	N/A	N/A	N/A
Sr-89	N/A	N/A	N/A	N/A	N/A
Sr-90	N/A	N/A	N/A	N/A	N/A
Zr/Nb-95	N/A	N/A	N/A	N/A	N/A
Mo/Tc-99	N/A	N/A	N/A	N/A	N/A
Ag-110m	N/A	N/A	N/A	N/A	N/A
Sb-124	N/A	N/A	N/A	N/A	N/A
Cs-134	N/A	N/A	N/A	N/A	N/A
Cs-137	N/A	N/A	N/A	N/A	N/A
Ba/La-140	N/A	N/A	N/A	N/A	N/A
Ce-141	N/A	N/A	N/A	N/A	N/A
Ce-144	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
2. DISSOLVED AND ENTRAINED GASES: Ci					
Xe-133	N/A	N/A	N/A	N/A	N/A
Xe-135	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A

Notes for Table 2.3-B:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for liquid radionuclides listed as NDA are as follows:
   Strontium: 5E-08 μCi/mL
   Noble Gases: 1E-05 μCi/mL
   All Others: 5E-07 μCi/mL

3.0 METEOROLOGICAL DATA

Meteorological data are summarized for the reporting period in Appendix A, in the standard joint frequency distribution format as given in NRC Regulatory Guide 1.21.

The predominant meteorological conditions observed during the annual reporting period can be summarized with their corresponding frequencies as follows:

- Stability Class: Class E, 44.4%
- 33-ft Wind Direction (from): South-west, 12.4%
- 33-ft Wind Speed: 3.5-7.5 mph, 55.1%
- 220-ft Wind Direction (from): South-southwest, 13.4%
- 220-ft Wind Speed: 12.5-18.5 mph, 35.6%

Joint data recovery for the 33-ft level was 99.9% and for the 220-ft level of the tower was 99.5%, both of which meet the 90% annual data recovery goal specified by the NRC. No major problems were encountered in 2021. There were a couple if instances in January, February, and December 2021 when a winter storm interfered with the sensors. Issues with ultrasonic wind sensor heaters were typical for the reporting period winter months. Ice and snow occasionally plugged the sensors until the low current heaters melted the ice pack, the weather subsided or the sensors.

4.0 MAXIMUM INDIVIDUAL DOSES

Doses to the maximum exposed individual resulting from radionuclides in effluents released offsite were calculated using methods presented in the PNPS Offsite Dose Calculation Manual (ODCM, Reference 2), NRC Regulatory Guide 1.109 (Reference 3), NRC Regulatory Guide 1.111 (Reference 4), and the Pilgrim Station Unit 1 Appendix I Evaluation (Reference 5). Maximum individual doses are calculated separately for: (1) noble gases in gaseous effluents, (2) particulates and tritium in gaseous effluents; and, (3) liquid effluents. Maximum consumption and use factors for various pathways from Table E-5 of the PNPS ODCM are used for calculating the doses to the maximum exposed individual.

Information related to liquid and gaseous effluent releases are summarized Section 2 of this report. These effluent release data were used as input to computer programs to calculate the resulting doses. PNPS ODCM methodologies were used to calculate the dose contributions to the various organs in each age class from major exposure pathways.

4.1 Doses From Noble Gas Releases

Gaseous effluent release data presented in Tables 2.2-A, 2.2-B, and 2.2-C from this effluent release report are no longer used as input to a dose assessment computer program to calculate radiation doses. Though data from gaseous releases from the PNPS reactor building vent are still used for particulate results (as seen in the next section), they no longer contain any Noble Gases due to current plant condition and therefore the table sections listed above are not applicable (NA). All noble gas inventory on site has decayed away. The only Noble Gas still in existence is Kr-85 trapped in the spent fuel assembly gaps, but the remaining spent fuel has been sealed in dry casks and moved to the Independent Spent Fuel Storage Installation (ISFSI) II pad.

All noble gas detector instrument and surveillance requirements were removed from the ODCM in revision 15. As the commitment was made by Emergency Planning to maintain the detectors until the spent fuel was transferred to the ISFSI pad, the surveaullenaces were driven by the Defuel Emergency Plan. All spent fuel was transferred in December of 2021. As explained above the majority of noble gases have decayed away. The remaining gas (Kr-85) is a beta emmiter with one gamma released for every 250 decays, the detectors would not have detected it even in a Designed Basis Accident (DBA) scenario. Furthermore Pilgrim Engineering DBA Calculation No. M1422, “Radiological

Consequences of a Design Basis Fuel Handling Accident Based on the Alternate Source Term Methodology – Update for Permanent Shutdown", June 5, 2018 assessed the offsite dose impact of a dropped fuel canister with a damaged fuel assembly assumed to contain 150 fuel rods. The LPZ TEDE dose at 30 days is 92 mrem. The dose proportionally projected out to one year is 0.18 mrem (assuming the DBA occurred one year post permant shutdown, which the site is beyond after shutting down permantly on May, 31, 2019).

The maximum individual doses resulting from radioactive noble gases released in gaseous effluents are presented in Table 4.1 no longer apply, therefore the table has been removed.

Sampling of Noble Gas continued into June 2021, until the revision of the ODCM was complete removing sampling requirements. There was no noble gas dose during 2021, therefore all quarterly and annual dose consequences are zero.

4.2 Doses From Gaseous Effluent Releases

Gaseous effluent release data presented in Tables 2.2-A, 2.2-B, and 2.2-C from this effluent release report were used as input to a dose assessment computer program to calculate radiation doses. These data include gaseous releases from the PNPS reactor building vent. Meteorological data obtained from the PNPS 220-foot meteorological tower during the 10-year period from 2005 through 2014 were used as input to the NRC XOQDOQ computer program (Reference 7). This program was used to calculate the annual average atmospheric dispersion and deposition factors used in the dose assessment computer program to calculate maximum individual doses.

The maximum individual doses resulting from radioactive particulates and tritium released in gaseous effluents are presented in Tables 4.2-A through 4.2-E. These tables cover the individual calendar quarters and the total calendar year, respectively.

Tables 4.2-A through 4.2-E summarize the maximum total body and organ doses for the adult, teen, child, and infant age classes resulting from the major gaseous exposure pathways. These tables present the dose data according to specific receptor location and the exposure pathways assumed to occur at that location. For example, the second column of the tables presents the information for the hypothetical maximum-exposed at the most restrictive site boundary location, where only inhalation and ground deposition exposure pathways are assumed to occur. Since this is a shoreline location controlled by Holtec, the other pathways of garden vegetable production, milk production, and meat production are assumed not to occur. Doses for other offsite locations not under Holtec control, where other exposure pathways can and do occur, are presented in subsequent columns of the tables, and represent the potential maximum doses to individuals at these locations. For consistency, all distances listed in the first row of Tables 4.2-A through 4.2-E are measured from the Reactor Building Vent. However, doses at the specific receptor locations are calculated based on the actual distances from the applicable release points (PNPS reactor building vent).

Radioactivity (particulates and tritium) released in gaseous effluents from PNPS during 2021 resulted in a maximum total body and organ dose of 0.000235 mrem (child age class at nearest cow-goat) Carbon-14 contributed 0% of dose for 2021 as Carbon-14 is only generated during the operation of the plant.

Table 4.2-A

Maximum Individual Organ Dose at Receptor Location -- mrem
From Gaseous Release Period: Jan-Mar 2021

Receptor: Direction: Distance[1]: Pathway[2]:	Bound WNW 0.24km DI	Resident S 2.22 km DI	Garden S 3.44 km DIV[3]	Cow/Goat W 3.75 km DIVCG[3]	Cow/Meat W 5.17 km DIVCM[3]	Meat S 3.82 km DIVM[3]
Age Class: Adult						
Bone	2.64E-10	3.17E-10	2.69E-10	2.24E-10	1.79E-10	2.47E-11
GI-LLI	1.67E-05	6.35E-06	6.07E-05	5.75E-05	7.34E-05	4.56E-06
Kidney	1.67E-05	6.34E-06	6.04E-05	5.70E-05	7.31E-05	4.55E-06
Liver	1.67E-05	6.34E-06	6.04E-05	5.70E-05	7.31E-05	4.55E-06
Lung	1.69E-05	6.41E-06	6.06E-05	5.72E-05	7.33E-05	4.60E-06
Thyroid	1.67E-05	6.34E-06	6.04E-05	5.70E-05	7.31E-05	4.55E-06
T.Body	1.67E-05	6.34E-06	6.04E-05	5.71E-05	7.31E-05	4.55E-06
Age Class: Teen						
Bone	2.64E-10	3.17E-10	2.69E-10	2.24E-10	1.79E-10	2.47E-11
GI-LLI	1.69E-05	6.40E-06	6.71E-05	6.07E-05	8.43E-05	4.60E-06
Kidney	1.69E-05	6.40E-06	6.67E-05	6.03E-05	8.41E-05	4.59E-06
Liver	1.69E-05	6.40E-06	6.68E-05	6.03E-05	8.41E-05	4.59E-06
Lung	1.71E-05	6.49E-06	6.70E-05	6.05E-05	8.43E-05	4.66E-06
Thyroid	1.69E-05	6.40E-06	6.67E-05	6.03E-05	8.41E-05	4.59E-06
T.Body	1.69E-05	6.40E-06	6.68E-05	6.04E-05	8.41E-05	4.59E-06
Age Class: Child						
Bone	2.64E-10	3.17E-10	2.69E-10	2.24E-10	1.79E-10	2.47E-11
GI-LLI	1.49E-05	5.65E-06	9.24E-05	8.29E-05	1.21E-04	4.06E-06
Kidney	1.49E-05	5.65E-06	9.21E-05	8.27E-05	1.20E-04	4.06E-06
Liver	1.49E-05	5.65E-06	9.22E-05	8.27E-05	1.21E-04	4.06E-06
Lung	1.51E-05	5.73E-06	9.23E-05	8.29E-05	1.21E-04	4.11E-06
Thyroid	1.49E-05	5.65E-06	9.21E-05	8.27E-05	1.20E-04	4.06E-06
T.Body	1.49E-05	5.65E-06	9.23E-05	8.28E-05	1.21E-04	4.06E-06
Age Class: Infant						
Bone	2.64E-10	3.17E-10	2.69E-10	2.24E-10	1.79E-10	2.47E-11
GI-LLI	8.57E-06	3.25E-06	8.73E-06	7.47E-06	6.03E-05	2.33E-06
Kidney	8.57E-06	3.25E-06	8.73E-06	7.47E-06	6.03E-05	2.33E-06
Liver	8.57E-06	3.25E-06	8.73E-06	7.47E-06	6.03E-05	2.33E-06
Lung	8.70E-06	3.30E-06	8.86E-06	7.58E-06	6.04E-05	2.37E-06
Thyroid	8.57E-06	3.25E-06	8.73E-06	7.47E-06	6.03E-05	2.33E-06
T.Body	8.57E-06	3.25E-06	8.73E-06	7.47E-06	6.03E-05	2.33E-06

[1] Distances are measured with respect to the reactor building vent.

[2] Pathway designations are as follows, note not all these pathways exist at Pilgrim Station:
D = Deposition (Ground Plane) I = Inhalation V = Vegetable Garden
C = Cow Milk G = Goat Milk M = Meat

[3] Doses are conservative since it is unlikely for vegetables to be grown outside or for animals to be fed on pasture during winter months.

Table 4.2-B

Maximum Individual Organ Dose at Receptor Location -- mrem
From Gaseous Release Period: Apr-Jun 2021

Receptor:	Bound	Resident	Garden	Cow/Goat	Cow/Meat	Meat
Direction:	WNW	S	S	W	W	S
Distance[1]:	0.24km	2.22 km	3.44 km	3.75 km	5.17 km	3.82 km
Pathway[2]:	DI	DI	DIV[3]	DIVCG[3]	DIVCM[3]	DIVM[3]
Age Class: Adult						
Bone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GI-LLI	9.61E-06	7.42E-06	2.14E-05	2.98E-05	1.99E-05	2.32E-05
Kidney	9.61E-06	7.42E-06	2.14E-05	2.98E-05	1.99E-05	2.32E-05
Liver	9.61E-06	7.42E-06	2.14E-05	2.98E-05	1.99E-05	2.32E-05
Lung	9.61E-06	7.42E-06	2.14E-05	2.98E-05	1.99E-05	2.32E-05
Thyroid	9.61E-06	7.42E-06	2.14E-05	2.98E-05	1.99E-05	2.32E-05
T.Body	9.61E-06	7.42E-06	2.14E-05	2.98E-05	1.99E-05	2.32E-05
Age Class: Teen						
Bone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GI-LLI	9.70E-06	7.48E-06	2.36E-05	3.42E-05	2.19E-05	2.46E-05
Kidney	9.70E-06	7.48E-06	2.36E-05	3.42E-05	2.19E-05	2.46E-05
Liver	9.70E-06	7.48E-06	2.36E-05	3.42E-05	2.19E-05	2.46E-05
Lung	9.70E-06	7.48E-06	2.36E-05	3.42E-05	2.19E-05	2.46E-05
Thyroid	9.70E-06	7.48E-06	2.36E-05	3.42E-05	2.19E-05	2.46E-05
T.Body	9.70E-06	7.48E-06	2.36E-05	3.42E-05	2.19E-05	2.46E-05
Age Class: Child						
Bone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GI-LLI	8.56E-06	6.61E-06	3.26E-05	4.91E-05	3.10E-05	3.37E-05
Kidney	8.56E-06	6.61E-06	3.26E-05	4.91E-05	3.10E-05	3.37E-05
Liver	8.56E-06	6.61E-06	3.26E-05	4.91E-05	3.10E-05	3.37E-05
Lung	8.56E-06	6.61E-06	3.26E-05	4.91E-05	3.10E-05	3.37E-05
Thyroid	8.56E-06	6.61E-06	3.26E-05	4.91E-05	3.10E-05	3.37E-05
T.Body	8.56E-06	6.61E-06	3.26E-05	4.91E-05	3.10E-05	3.37E-05
Age Class: Infant						
Bone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GI-LLI	4.93E-06	3.80E-06	3.09E-06	2.45E-05	1.34E-05	3.04E-06
Kidney	4.93E-06	3.80E-06	3.09E-06	2.45E-05	1.34E-05	3.04E-06
Liver	4.93E-06	3.80E-06	3.09E-06	2.45E-05	1.34E-05	3.04E-06
Lung	4.93E-06	3.80E-06	3.09E-06	2.45E-05	1.34E-05	3.04E-06
Thyroid	4.93E-06	3.80E-06	3.09E-06	2.45E-05	1.34E-05	3.04E-06
T.Body	4.93E-06	3.80E-06	3.09E-06	2.45E-05	1.34E-05	3.04E-06

[1] Distances are measured with respect to the reactor building vent.

[2] Pathway designations are as follows, note not all these pathways exist at Pilgrim Station:

D = Deposition (Ground Plane) I = Inhalation V = Vegetable Garden
C = Cow Milk G = Goat Milk M = Meat

Table 4.2-C

Maximum Individual Organ Dose at Receptor Location -- mrem
From Gaseous Release Period: Jul-Sep 2021

Receptor: Direction: Distance[1]: Pathway[2]:	Bound WNW 0.24km DI	Resident S 2.22 km DI	Garden S 3.44 km DIV[3]	Cow/Goat W 3.75 km DIVCG[3]	Cow/Meat W 5.17 km DIVCM[3]	Meat S 3.82 km DIVM[3]
Age Class: Adult						
Bone	3.54E-08	2.67E-08	1.09E-06	2.59E-06	1.30E-06	1.25E-06
GI-LLI	5.24E-06	4.04E-06	1.17E-05	1.63E-05	1.09E-05	1.27E-05
Kidney	5.25E-06	4.05E-06	1.21E-05	1.74E-05	1.14E-05	1.32E-05
Liver	5.28E-06	4.08E-06	1.31E-05	1.98E-05	1.26E-05	1.44E-05
Lung	5.24E-06	4.05E-06	1.18E-05	1.66E-05	1.10E-05	1.28E-05
Thyroid	5.24E-06	4.04E-06	1.16E-05	1.62E-05	1.08E-05	1.27E-05
T.Body	5.27E-06	4.06E-06	1.26E-05	1.85E-05	1.20E-05	1.38E-05
Age Class: Teen						
Bone	4.89E-08	3.73E-08	1.73E-06	4.51E-06	2.16E-06	1.86E-06
GI-LLI	5.28E-06	4.08E-06	1.29E-05	1.87E-05	1.20E-05	1.34E-05
Kidney	5.31E-06	4.09E-06	1.36E-05	2.07E-05	1.29E-05	1.42E-05
Liver	5.34E-06	4.12E-06	1.52E-05	2.46E-05	1.48E-05	1.58E-05
Lung	5.29E-06	4.08E-06	1.32E-05	1.94E-05	1.23E-05	1.37E-05
Thyroid	5.28E-06	4.08E-06	1.29E-05	1.87E-05	1.19E-05	1.34E-05
T.Body	5.31E-06	4.09E-06	1.37E-05	2.07E-05	1.29E-05	1.42E-05
Age Class: Child						
Bone	6.54E-08	5.04E-08	4.06E-06	1.08E-05	5.11E-06	4.27E-06
GI-LLI	4.67E-06	3.60E-06	1.78E-05	2.68E-05	1.69E-05	1.84E-05
Kidney	4.69E-06	3.62E-06	1.90E-05	3.01E-05	1.85E-05	1.97E-05
Liver	4.72E-06	3.65E-06	2.16E-05	3.70E-05	2.18E-05	2.24E-05
Lung	4.67E-06	3.61E-06	1.82E-05	2.79E-05	1.75E-05	1.88E-05
Thyroid	4.67E-06	3.60E-06	1.77E-05	2.67E-05	1.69E-05	1.83E-05
T.Body	4.68E-06	3.61E-06	1.83E-05	2.82E-05	1.76E-05	1.89E-05
Age Class: Infant						
Bone	4.03E-08	3.06E-08	2.42E-08	1.21E-05	5.01E-06	2.39E-08
GI-LLI	2.69E-06	2.07E-06	1.68E-06	1.34E-05	7.32E-06	1.66E-06
Kidney	2.70E-06	2.08E-06	1.69E-06	1.72E-05	8.87E-06	1.66E-06
Liver	2.73E-06	2.11E-06	1.71E-06	2.75E-05	1.32E-05	1.68E-06
Lung	2.69E-06	2.08E-06	1.68E-06	1.49E-05	7.94E-06	1.66E-06
Thyroid	2.69E-06	2.07E-06	1.68E-06	1.34E-05	7.30E-06	1.66E-06
T.Body	2.69E-06	2.07E-06	1.68E-06	1.44E-05	7.71E-06	1.66E-06

[1] Distances are measured with respect to the reactor building vent.

[2] Pathway designations are as follows, note not all these pathways exist at Pilgrim Station:

D = Deposition (Ground Plane) I = Inhalation V = Vegetable Garden
C = Cow Milk G = Goat Milk M = Meat

Table 4.2-D

Maximum Individual Organ Dose at Receptor Location -- mrem
From Gaseous Release Period: Oct-Dec 2021

Receptor: Direction: Distance[1]: Pathway[2]:	Bound WNW 0.24km DI	Resident S 2.22 km DI	Garden S 3.44 km DIV[3]	Cow/Goat W 3.75 km DIVCG[3]	Cow/Meat W 5.17 km DIVCM[3]	Meat S 3.82 km DIVM[3]
Age Class: Adult						
Bone	5.59E-09	4.22E-09	1.72E-07	4.10E-07	2.06E-07	1.98E-07
GI-LLI	5.27E-06	4.06E-06	1.17E-05	1.63E-05	1.09E-05	1.27E-05
Kidney	5.27E-06	4.07E-06	1.18E-05	1.65E-05	1.10E-05	1.28E-05
Liver	5.27E-06	4.07E-06	1.19E-05	1.69E-05	1.12E-05	1.30E-05
Lung	5.27E-06	4.06E-06	1.17E-05	1.64E-05	1.09E-05	1.28E-05
Thyroid	5.27E-06	4.06E-06	1.17E-05	1.63E-05	1.09E-05	1.27E-05
T.Body	5.27E-06	4.07E-06	1.19E-05	1.67E-05	1.11E-05	1.29E-05
Age Class: Teen						
Bone	7.72E-09	5.90E-09	2.74E-07	7.12E-07	3.42E-07	2.93E-07
GI-LLI	5.31E-06	4.10E-06	1.29E-05	1.88E-05	1.20E-05	1.35E-05
Kidney	5.32E-06	4.10E-06	1.31E-05	1.91E-05	1.22E-05	1.36E-05
Liver	5.32E-06	4.11E-06	1.33E-05	1.97E-05	1.25E-05	1.38E-05
Lung	5.31E-06	4.10E-06	1.30E-05	1.89E-05	1.21E-05	1.35E-05
Thyroid	5.31E-06	4.10E-06	1.29E-05	1.88E-05	1.20E-05	1.35E-05
T.Body	5.32E-06	4.10E-06	1.31E-05	1.91E-05	1.22E-05	1.36E-05
Age Class: Child						
Bone	1.03E-08	7.96E-09	6.41E-07	1.70E-06	8.08E-07	6.75E-07
GI-LLI	4.69E-06	3.62E-06	1.79E-05	2.69E-05	1.70E-05	1.85E-05
Kidney	4.70E-06	3.62E-06	1.80E-05	2.74E-05	1.73E-05	1.87E-05
Liver	4.70E-06	3.63E-06	1.85E-05	2.85E-05	1.78E-05	1.91E-05
Lung	4.69E-06	3.62E-06	1.79E-05	2.71E-05	1.71E-05	1.85E-05
Thyroid	4.69E-06	3.62E-06	1.78E-05	2.69E-05	1.70E-05	1.85E-05
T.Body	4.69E-06	3.62E-06	1.79E-05	2.71E-05	1.71E-05	1.85E-05
Age Class: Infant						
Bone	6.37E-09	4.84E-09	3.83E-09	1.91E-06	7.92E-07	3.77E-09
GI-LLI	2.70E-06	2.08E-06	1.69E-06	1.35E-05	7.34E-06	1.67E-06
Kidney	2.70E-06	2.08E-06	1.69E-06	1.40E-05	7.59E-06	1.67E-06
Liver	2.71E-06	2.09E-06	1.69E-06	1.57E-05	8.27E-06	1.67E-06
Lung	2.70E-06	2.08E-06	1.69E-06	1.37E-05	7.44E-06	1.67E-06
Thyroid	2.70E-06	2.08E-06	1.69E-06	1.34E-05	7.34E-06	1.67E-06
T.Body	2.70E-06	2.08E-06	1.69E-06	1.36E-05	7.41E-06	1.67E-06

[1] Distances are measured with respect to the reactor building vent.

[2] Pathway designations are as follows, note not all these pathways exist at Pilgrim Station:
D = Deposition (Ground Plane) I = Inhalation V = Vegetable Garden
C = Cow Milk G = Goat Milk M = Meat

[3] Doses are conservative since it is unlikely for vegetables to be grown outside or for animals to be fed on pasture during winter months.

Table 4.2-E

Maximum Individual Organ Dose at Receptor Location -- mrem
From Gaseous Release Period: Jan-Dec 2021

Receptor: Direction: Distance[1]: Pathway[2]:	Bound WNW 0.24km DI	Resident S 2.22 km DI	Garden S 3.44 km DIV[3]	Cow/Goat W 3.75 km DIVCG[3]	Cow/Meat W 5.17 km DIVCM[3]	Meat S 3.82 km DIVM[3]
Age Class: Adult						
Bone	4.31E-08	3.13E-08	1.26E-06	3.00E-06	1.51E-06	1.45E-06
GI-LLI	4.37E-05	3.37E-05	9.74E-05	1.36E-04	9.07E-05	1.06E-04
Kidney	4.37E-05	3.38E-05	9.77E-05	1.37E-04	9.11E-05	1.06E-04
Liver	4.38E-05	3.38E-05	9.88E-05	1.40E-04	9.25E-05	1.08E-04
Lung	4.40E-05	3.39E-05	9.74E-05	1.36E-04	9.08E-05	1.06E-04
Thyroid	4.37E-05	3.37E-05	9.71E-05	1.35E-04	9.04E-05	1.06E-04
T.Body	4.38E-05	3.38E-05	9.83E-05	1.38E-04	9.18E-05	1.07E-04
Age Class: Teen						
Bone	5.87E-08	4.36E-08	2.01E-06	5.22E-06	2.50E-06	2.15E-06
GI-LLI	4.41E-05	3.40E-05	1.08E-04	1.56E-04	9.98E-05	1.12E-04
Kidney	4.41E-05	3.41E-05	1.08E-04	1.58E-04	1.01E-04	1.13E-04
Liver	4.42E-05	3.41E-05	1.10E-04	1.63E-04	1.03E-04	1.15E-04
Lung	4.45E-05	3.43E-05	1.08E-04	1.57E-04	1.00E-04	1.12E-04
Thyroid	4.41E-05	3.40E-05	1.07E-04	1.56E-04	9.96E-05	1.12E-04
T.Body	4.41E-05	3.41E-05	1.08E-04	1.58E-04	1.01E-04	1.13E-04
Age Class: Child						
Bone	7.79E-08	5.87E-08	4.70E-06	1.25E-05	5.92E-06	4.95E-06
GI-LLI	3.90E-05	3.01E-05	1.48E-04	2.23E-04	1.41E-04	1.53E-04
Kidney	3.90E-05	3.01E-05	1.50E-04	2.27E-04	1.43E-04	1.55E-04
Liver	3.90E-05	3.01E-05	1.53E-04	2.35E-04	1.47E-04	1.58E-04
Lung	3.92E-05	3.03E-05	1.49E-04	2.25E-04	1.42E-04	1.54E-04
Thyroid	3.90E-05	3.01E-05	1.48E-04	2.23E-04	1.41E-04	1.53E-04
T.Body	3.90E-05	3.01E-05	1.49E-04	2.25E-04	1.42E-04	1.54E-04
Age Class: Infant						
Bone	4.89E-08	3.58E-08	2.83E-08	1.40E-05	5.80E-06	2.78E-08
GI-LLI	2.24E-05	1.73E-05	1.40E-05	1.12E-04	6.10E-05	1.38E-05
Kidney	2.24E-05	1.73E-05	1.40E-05	1.16E-04	6.28E-05	1.38E-05
Liver	2.25E-05	1.73E-05	1.41E-05	1.28E-04	6.77E-05	1.39E-05
Lung	2.26E-05	1.74E-05	1.41E-05	1.14E-04	6.18E-05	1.39E-05
Thyroid	2.24E-05	1.73E-05	1.40E-05	1.12E-04	6.09E-05	1.38E-05
T.Body	2.24E-05	1.73E-05	1.40E-05	1.13E-04	6.14E-05	1.38E-05

[1] Distances are measured with respect to the reactor building vent.

[2] Pathway designations are as follows, note not all these pathways exist at Pilgrim Station:
D = Deposition (Ground Plane) I = Inhalation V = Vegetable Garden
C = Cow Milk G = Goat Milk M = Meat

[3] Doses are conservative since it is unlikely for vegetables to be grown outside or for animals to be fed on pasture during winter months.

4.3 Doses From Liquid Effluent Releases

Liquid effluent release data presented in Tables 2.3-A and 2.3-B were used as input to the dose assessment computer program to calculate radiation doses. The maximum individual doses resulting from radionuclides released in liquid effluents are presented in Tables 4.3-A through 4.3-E. These tables cover the individual calendar quarters and the total calendar year, respectively.

Tables 4.3-A through 4.3-E summarize the maximum total body and organ doses for the adult, teen, and child age classes resulting from the major liquid exposure pathways. NRC Regulatory Guide 1.109 does not recognize the infant age class as being exposed to the liquid effluent pathways. Therefore, doses for this age class are not included in any of the tables.

It should be noted that doses calculated for the entire year might not equal the sum of the doses for the individual quarters. Doses from liquid effluents are based on the concentration (activity divided by volume) of radionuclides released in the effluent, as prescribed by the NRC in Regulatory Guide 1.109. If a larger proportion of activity is released with a relatively smaller volume of dilution water during a given quarter, the resulting concentration for that quarter will be higher than concentrations from other quarters. This will result in a proportionally higher dose for that quarter. However, when that quarter's activity values are included in the annual sum, and divided by the total annual dilution flow, the resulting dose contribution will be smaller. In such a situation, the annual dose will actually be less than the sum of the individual quarterly doses.

There were no liquid Effluent releases from PNPS during 2021, therefore the Radioactivity released in liquid effluents from PNPS during the reporting period resulted in a maximum total body dose (teen age class) of 0.00 mrem. The maximum organ dose (teen age class, Liver) was 0.00 mrem.

Table 4.3-A

Maximum Individual Organ Doses -- mrem
From Liquid Release Period: Jan-Mar 2021

Organ	Age Class Organ Dose – mrem *		
	Adult	Teen	Child
Bone	N/A	N/A	N/A
GI-LLI	N/A	N/A	N/A
Kidney	N/A	N/A	N/A
Liver	N/A	N/A	N/A
Lung	N/A	N/A	N/A
Thyroid	N/A	N/A	N/A
T.Body	N/A	N/A	N/A

Table 4.3-B

Maximum Individual Organ Doses -- mrem
From Liquid Release Period: Apr-Jun 2021

Organ	Age Class Organ Dose – mrem		
	Adult	Teen	Child
Bone	N/A	N/A	N/A
GI-LLI	N/A	N/A	N/A
Kidney	N/A	N/A	N/A
Liver	N/A	N/A	N/A
Lung	N/A	N/A	N/A
Thyroid	N/A	N/A	N/A
T.Body	N/A	N/A	N/A

Table 4.3-C

Maximum Individual Organ Doses -- mrem
From Liquid Release Period: Jul-Sep 2021

Organ	Age Class Organ Dose – mrem		
	Adult	Teen	Child
Bone	N/A	N/A	N/A
GI-LLI	N/A	N/A	N/A
Kidney	N/A	N/A	N/A
Liver	N/A	N/A	N/A
Lung	N/A	N/A	N/A
Thyroid	N/A	N/A	N/A
T.Body	N/A	N/A	N/A

Table 4.3-D

Maximum Individual Organ Doses -- mrem
From Liquid Release Period: Oct-Dec 2021

Organ	Age Class Organ Dose – mrem *		
	Adult	Teen	Child
Bone	N/A	N/A	N/A
GI-LLI	N/A	N/A	N/A
Kidney	N/A	N/A	N/A
Liver	N/A	N/A	N/A
Lung	N/A	N/A	N/A
Thyroid	N/A	N/A	N/A
T.Body	N/A	N/A	N/A

Table 4.3-E

Maximum Individual Organ Doses -- mrem
From Liquid Release Period: Jan-Dec 2021

Organ	Age Class Organ Dose – mrem *		
	Adult	Teen	Child
Bone	N/A	N/A	N/A
GI-LLI	N/A	N/A	N/A
Kidney	N/A	N/A	N/A
Liver	N/A	N/A	N/A
Lung	N/A	N/A	N/A
Thyroid	N/A	N/A	N/A
T.Body	N/A	N/A	N/A

5.0 OFFSITE AMBIENT RADIATION MEASUREMENTS

The PNPS ODCM does not contain control limits related specifically to offsite ambient radiation exposure. However, Regulatory Guide 1.21 (Reference 1) recommends calculation of ambient radiation exposure as part of the overall assessment of radiological impact on man.

Thermoluminescent dosimeters (TLDs) are located at 40 sites beyond the boundary of the PNPS restricted/protected area. A number of these TLDs are located within the site boundary, on Holtec property in close proximity to the station proper. The TLDs are collected on a quarterly basis and used to calculate the ambient radiation exposure in milliRoentgen (mR) over the exposure period. These TLDs are grouped into four zones of increasing distance from the station. Average exposure values for each of these zones were calculated for each calendar quarter and the total year. The average exposure values (mR) for the four zones are presented in Table 5.0.

In addition to responding to ambient radiation exposure, TLDs will also record radiation resulting from noble gases (plume and immersion exposure), particulate materials deposited on the ground, cosmic rays from outer space, and from naturally-occurring radioactivity in the soil and air. Typically, the exposure from cosmic rays and other natural radioactivity components is approximately 40 to 70 mR/year. As calculated in Sections 4.1 and 4.2 of this report, the ambient radiation component of doses from PNPS effluent emissions are below 1 mrem/yr and would not be discernible above the natural radiation exposure levels.

The major source of ambient radiation exposure from PNPS include radiation emitted from contained radioactive materials and/or radwaste at the facility. Despite these sources of ambient radiation exposure at PNPS, increases in exposure from ambient radiation are typically not observable above background levels at locations beyond station controlled property.

The average exposure values presented in Table 5.0 appear to indicate an elevation in ambient exposures in Zone 1, those TLDs within 2 miles of PNPS. Most of this elevation is due to increases in exposure levels measured at TLD locations on station property in close proximity to the station proper. For example, the annual exposure at TLD location (BLE), located at the East Boat Launch near the PNPS Trash Compaction Facility (TCF), was 329 mR for the entire year. This location is immediately adjacent to the station proper and overlooks the radiological waste building. This area during 2021 has also experienced multiple moves of type A waste containers by the TLD location, therefore receiving the highest direct ambient exposure of all TLD locations outside the protected area. When the near-site TLDs (those located within 0.6 km of the Reactor Building) are removed from the calculation of averages, the mean annual exposure in Zone 1 falls from 90.5 ± 70.6 mR/yr to 64.7 ± 8.9 mR/yr. Such a corrected dose is not statistically different from the Zone 4 average of 72.4 ± 4.0 mR/yr, and is indicative of natural background radiation.

Although the annual exposure at TLD location BLE was 256 mR above the average Zone 4 exposure, members of the general public do not continuously occupy this area. When adjusted for such occupancy, a hypothetical member of the public who was at this location for 40 hours per year would only receive an incremental dose of 1.17 mrem over natural background radiation levels. At the nearest residence 0.8 kilometers (0.5 miles) southeast of the PNPS Reactor Building, the annual exposure was calculated as being 58.2 ± 2.0 mR (based on continuous occupancy at this location), which is even lower than the Zone 4 annual average background radiation level of 72.4 ± 4.0 mR.

During 2021 Pilgrim Station was activlely moving spent fuel to the Independent Spent Fuel Storage Installation (ISFSI) located within the protected area immediately west of the PNPS Reactor Building. Three new TLDs were installed at the beginning of 2016 to monitor any incremental dose from this facility. TLD ISF-1 was located on Rocky Hill Road 0.35 km (0.21 mi) southwest of the reactor building. The annual exposure at this location was calculated as being 75.4 ± 2.7 mR (based on continuous occupancy at this location), or 3.5 mR above the Zone 4 average of 71.9 mR. However, the area is not continuously occupied, and when corrected for an exposure time of 365 hours/year, the estimated exposure to a person walking along this section of Rocky Hill Road would be 0.14 mR/year.

It must be emphasized that the projected ambient exposures discussed above and on the previous page are calculated to occur to a maximum-exposed hypothetical individual. Even though conservative assumptions are made in the projection of these dose consequences, all of the projected doses are well below the NRC dose limit of 100 mrem/yr specified in 10CFR20.1301, as well as the EPA dose limit of 25 mrem/yr specified in 40CFR190. Both of these limits are to be applied to real members of the general public, so the fact that the dose to the hypothetical maximum-exposed individual is within the limits ensures that any dose received by a real member of the public would be smaller and well within any applicable limit.

Table 5.0

Average TLD Exposures By Distance Zone During 2021

Exposure Period	Average Exposure ± Standard Deviation: mR/period			
	Zone 1* 0-3 km	Zone 2 3-8 km	Zone 3 8-15 km	Zone 4 >15 km
Jan-Mar	21.0 ± 14.4	14.8 ± 2.2	14.6 ± 2.1	17.8 ± 1.1
Apr-Jun	21.9 ± 13.6	15.4 ± 2.3	15.3 ± 1.9	17.5 (1)
Jul-Sep	21.8 ± 13.1	17.2 ± 0.5	Removed ***	18.2 ± 1.4
Oct-Dec	25.8 ± 26.6	16.6 ± 0.8	Removed ***	18.6 ± 1.5
Jan-Dec	90.5 ± 70.6	61.6 ± 8.5	59.8 ± 7.6	72.4 ± 4.0

* Zone 1 extends from the PNPS restricted/protected area boundary outward to 3 kilometers (2 miles), and includes several TLDs located within the site boundary.

** When corrected for TLDs located within the site boundary, the Zone 1 annual average is calculated to be 64.7 ± 8.9 mR/yr.

*** TLDs beyond 3 km (with the exception of Manomet Elementary and control locations) were removed from the REMP program in revision 15 of the ODCM.

(1) Note: No Standard Deviation due to lack of data points.

6.0 PERCENT OF ODCM EFFLUENT CONTROL LIMITS

The PNPS ODCM contains dose and concentration limits for radioactive effluents. In addition, the effluent controls specified ensure that radioactive releases are maintained as low as reasonably achievable. The percentage of the PNPS ODCM Control limit values were determined from doses calculated in Section 4, the effluent releases summarized in Section 2, and the ODCM Control limits/objectives listed in Tables 6.1 and 6.2.

The percent of applicable control limit values are provided to supplement the information provided in the Section 2 of this report. The format for the percent of applicable limits is modified from that prescribed in Regulatory Guide 1.21 (Reference 1) to accommodate the Radioactive Effluents Technical Specifications (RETS) that became effective March 01, 1986. The percentages have been grouped according to whether the releases were via liquid or gaseous effluent pathways.

6.1 Gaseous Effluent Releases

Dose-based effluent controls related to exposures arising from gaseous effluent releases are presented in Table 6.1. The maximum quarterly air doses and annual whole body doses listed in Table 4.1 were used to calculate the percentage values shown in Table 6.1.

Organ dose limits for the maximum-exposed individual from radioactive particulates and tritium from the PNPS ODCM are also shown in Table 6.1. The maximum quarterly and annual organ doses from Tables 4.2-A through 4.2-E were used to calculate the percentages shown in Table 6.1. The resulting organ doses from Pilgrim Station's gaseous releases during 2021 were a small percentage of the corresponding effluent control.

Table 6.1

Percent of ODCM Effluent Control Limits
for Gaseous Effluent Releases During 2021

A. Instantaneous Dose Rate Limit - Noble Gases
PNPS ODCM Control 3.3.1.a
Limit: 500 mrem/yr Total Body Dose

Period	Value - mrem/yr	Fraction of Limit
Jan-Dec	0.00E+0	0.00%

B. Instantaneous Dose Rate Limit - Noble Gases
PNPS ODCM Control 3.3.1.a
Limit: 3000 mrem/yr Skin Dose

Period	Value - mrem/yr	Fraction of Limit
Jan-Dec	0.00E+0	0.00%

C. Instantaneous Dose Rate Limit - Particulates, Iodines, & Tritium
PNPS ODCM Control 3.3.1.b
Limit: 1500 mrem/yr Organ Dose

Period	Value - mrem/yr	Fraction of Limit
Jan-Dec	2.35E-04	1.57E-03%

D. Quarterly Dose Objective - Noble Gas Gamma Air Dose
PNPS ODCM Control 3.3.2.a
Objective: 5 mrad Gamma Air Dose

Period	Value – mrad	Fraction of Limit
Jan-Mar	0.00E+0	0.00%
Apr-Jun	0.00E+0	0.00%
Jul-Sep	NA	NA
Oct-Dec	NA	NA

E. Annual Dose Objective - Noble Gas Gamma Air Dose
PNPS ODCM Control 3.3.2.b
Objective: 10 mrad Gamma Air Dose

Period	Value - mrad/yr	Fraction of Limit
Jan-Dec	0.00E+0	0.00%

Table 6.1 (continued)

Percent of ODCM Effluent Control Limits
for Gaseous Effluent Releases During 2021

F. Quarterly Dose Objective - Noble Gas Beta Air Dose
PNPS ODCM Control 3.3.2.a
Objective: 10 mrad Beta Air Dose

Period	Value - mrad	Fraction of Limit
Jan-Mar	0.00E+0	0.00%
Apr-Jun	0.00E+0	0.00%
Jul-Sep	NA	NA
Oct-Dec	NA	NA

G. Annual Dose Objective - Noble Gas Beta Air Dose
PNPS ODCM Control 3.3.2.b
Objective: 20 mrad Beta Air Dose

Period	Value - mrad/yr	Fraction of Limit
Jan-Dec	0.00E+0	0.00%

H. Quarterly Dose Objective - Particulates, Iodines, Tritium, and Carbon-14
PNPS ODCM Control 3.3.3.a
Objective: 7.5 mrem Organ Dose

Period	Value - mrem	Fraction of Limit
Jan-Mar	1.21E-04	1.61E-03%
Apr-Jun	4.91E-05	6.54E-04%
Jul-Sep	3.70E-05	4.94E-04%
Oct-Dec	2.85E-05	3.80E-04%

I. Annual Dose Objective - Particulates, Iodines, Tritium, and Carbon-14
PNPS ODCM Control 3.3.3.b
Objective: 15 mrem Organ Dose

Period	Value - mrem/yr	Fraction of Limit
Jan-Dec	2.35E-04	1.57E-03%

Note:
As stated earlier in report Noble Gas onsite has decayed away. Noble gas sampling was terminated in June 2021 after the requirement was removed from the ODCM in Revision 15.

6.2 Liquid Effluent Releases

Liquid effluent concentration limits and dose objectives from the PNPS ODCM are shown in Table 6.2. The quarterly average concentrations from Table 2.3-A were used to calculate the percent concentration limits. The maximum quarterly and annual whole body and organ doses from Tables 4.3-A through 4.3-E were used to calculate the percentages shown in Table 6.2. The resulting concentrations, as well as organ and total body doses from Pilgrim Station's liquid releases during the reporting period were zero as there were no radioactive liquid discharges in 2021.

Table 6.2

Percent of ODCM Effluent Control Limits
for Liquid Effluent Releases During 2021

A. Fission and Activation Product Effluent Concentration Limit
PNPS ODCM Control 3.2.1
Limit: 10CFR20 Appendix B, Table 2, Column 2 Value

Period	Value - μCi/mL	Fraction of Limit
Jan-Mar	N/A	N/A
Apr-Jun	N/A	N/A
Jul-Sep	N/A	N/A
Oct-Dec	N/A	N/A
Jan-Dec	N/A	N/A

B. Tritium Average Concentration Limit
PNPS ODCM Control 3.2.1
Limit: 1.0E-03 μCi/mL

Period	Value - μCi/mL	Fraction of Limit
Jan-Mar	N/A	N/A
Apr-Jun	N/A	N/A
Jul-Sep	N/A	N/A
Oct-Dec	N/A	N/A
Jan-Dec	N/A	N/A

C. Dissolved and Entrained Noble Gases Concentration Limit
PNPS ODCM Control 3.2.1
Limit: 2.0E-04 μCi/mL

Period	Value - μCi/mL	Fraction of Limit
Jan-Mar	N/A	N/A
Apr-Jun	N/A	N/A
Jul-Sep	N/A	N/A
Oct-Dec	N/A	N/A
Jan-Dec	N/A	N/A

Table 6.2 (continued)

Percent of ODCM Effluent Control Limits
for Liquid Effluent Releases During 2021

D. Quarterly Total Body Dose Objective
PNPS ODCM Control 3.2.2.a
Objective: 1.5 mrem Total Body Dose

Period	Value - mrem	Fraction of Limit
Jan-Mar	N/A	N/A
Apr-Jun	N/A	N/A
Jul-Sep	N/A	N/A
Oct-Dec	N/A	N/A

E. Annual Total Body Dose Objective
PNPS ODCM Control 3.2.2.b
Objective: 3 mrem Total Body Dose

Period	Value - mrem	Fraction of Limit
Jan-Dec	N/A	N/A

F. Quarterly Organ Dose Objective
PNPS ODCM Control 3.2.2.a
Objective: 5 mrem Organ Dose

Period	Value - mrem	Fraction of Limit
Jan-Mar	N/A	N/A
Apr-Jun	N/A	N/A
Jul-Sep	N/A	N/A
Oct-Dec	N/A	N/A

G. Annual Organ Dose Objective
PNPS ODCM Control 3.2.2.b
Objective: 10 mrem Organ Dose

Period	Value - mrem	Fraction of Limit
Jan-Dec	N/A	N/A

7.0 RADIOACTIVE WASTE DISPOSAL DATA

Radioactive wastes that were shipped offsite for processing and disposal during the reporting period are described in Table 7.0, in the standard NRC Regulatory Guide 1.21 format.

The total quantity of radioactivity in Curies and the total volume in cubic meters are summarized in Table 7.0 for the following waste categories:

- Spent resins, filter sludges, and evaporator bottoms;
- Dry activated wastes, contaminated equipment, etc.;
- Irradiated components, control rods, etc.; and,
- Other.

During the reporting period approximately 2.52 cubic meters of spent resins, filter sludges, etc., containing a total activity of approximately 847 Curies were shipped from PNPS for processing and disposal. Dry activated wastes and contaminated equipment shipped during the period totaled 1570 cubic meters and contained 19.5 Curies of radioactivity. Shipments of irradiated components during the reporting period contained 29.6 cubic meters and contained 66.4 Curies of radioactivity.. Shipments of ”Other wastes” during the reporting period included 3.68 cubic meters and contained 0.00175 Curies of radioactivity. There were no shipments of irradiated fuel during the reporting period.

Estimates of principal radionuclides, those comprising greater than 1% of the total activity in each waste category shipped, are listed in Table 7.0. There were 12 shipments to Waste Control Specialists, Compact Waste Disposal Facility and 47 shipments to Waste Control Specialists, TSD Facility.

Table 7.0
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Solid Waste and Irradiated Fuel Shipments
January-December 2021

A. SOLID WASTE SHIPPED OFFSITE FOR BURIAL OR DISPOSAL (Not irradiated fuel)

1. Estimate of volume and activity content by type of waste

Type of waste	Jan-Dec 2021		
	Volume - m^3	Curies	Total Error
a. Spent resins, filters, filter sludges, evaporator bottoms, etc.	2.52E+00	8.47E+02	± 25%
b. Dry activated waste, contaminated equipment, etc.	1.57E+03	1.95E+01	± 25%
c. Irradiated components, control rods, etc.	2.96E+01	6.64E+01	± 25%
d. Other (describe):	3.68E+00	1.75E-03	± 25%

2. Estimate of major nuclide composition by type of waste[1]

Type of waste	Radionuclide	Abundance	Total Error
a. Spent resins, filters, filter sludge's, evaporator bottoms, etc.	Mn-54	4.51%	± 25%
	Fe-55	79.12%	± 25%
	Co-60	14.08%	± 25%
b. Dry activated waste, contaminated equipment, etc.	Zn-65	1.34%	± 25%
	Mn-54	13.85%	± 25%
	Fe-55	59.38%	± 25%
	Co-60	24.43%	± 25%
	Ni-63	1.45%	± 25%
c. Irradiated components, control rods, etc.	Mn-54	7.38%	± 25%
	Fe-55	56.09%	± 25%
	Co-60	34.13%	± 25%
	Ni-63	1.96%	± 25%
d. Other (describe): Contaminated oil and water	Fe-55	79.53%	± 25%
	Co-60	18.31%	± 25%
	Ni-63	1.88%	± 25%

[1] *"Major" is defined as any radionuclide comprising >1% of the total activity in the waste category.*

3. Solid Waste Disposition

Number of Shipments	Mode of Transportation	Destination
1	Goulet Trucking, Inc	Waste Control Specialists, LLC Compact Waste Disposal Facility
39	Goulet Trucking, Inc	Waste Control Specialists, LLC TSD Facility
11	INTERSTATE VENTURES	Waste Control Specialists, LLC Compact Waste Disposal Facilty
8	INTERSTATE VENTURES	Waste Control Specialists, LLC TSD Facility

B. IRRADIATED FUEL SHIPMENTS & DISPOSITION

Number of Shipments	Mode of Transportation	Destination
None	N/A	N/A

8.0 OFFSITE DOSE CALCULATION MANUAL REVISIONS

The PNPS Offsite Dose Calculation Manual (ODCM) was revised one time during the calendar year of 2021. A full copy of the ODCM is attached to this report with revision changes noted.

9.0 PROCESS CONTROL PROGRAM REVISIONS

The following list summarizes changes made during 2021 to various procedures related to the Process Control Program (PCP). Any changes made to EN procedures were not adopted by PNPS following the shutdown of the plant at the end of May 2019.

EN-RW-102, "Radioactive Shipping Procedure", Rev. 19-22:

- Major change to include WCS as a radwaste receiver. No revision bars included due to the volume of changes
- Major change to require a 'Peer Check' of RW Shipping documentation, add several Precautions and Limitations, add steps clarifying advance notifications to Insurance Carriers (ANI), and Federal and State regulators, and `corrected references to Pilgrim procedures versus Entergy Fleet procedures. Revision bars not included due to the volume of changes.
- Minor editorial change to implement improvements following an effectiveness review performed and documented in IR PIL-03157.
- Minor editorial change to include contact information for shipments, and implement improvements recommended by MA State regulators. New Attachment 20 was added as a consequence.
- This procedure was already Excluded from future PAD Reviews in a previous revision. Current PAD Exclusion remains valid

EN-RW-101, "Radioactive Waste Management":

- No changes

EN-RW-103, "Radioactive Waste Tracking Procedure":

- No changes

EN-RW-104, "Scaling Factors":

- No changes

EN-RW-105, "Process Control Program":

- No changes

EN-RW-106, "Integrated Transportation Security Plan":

- No changes

EN-RW-108, "Radioactive Shipment Accident Response":

- No changes

10.0 REFERENCES

1. U.S. Nuclear Regulatory Commission, “Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water Cooled Nuclear Power Plants”, Regulatory Guide 1.21, Revision 1, June 1974.

2. “Pilgrim Nuclear Power Station Offsite Dose Calculation Manual”.

3. U.S. Nuclear Regulatory Commission, “Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR50 Appendix I”, Regulatory Guide 1.109, Revision 1, October 1977.

4. U.S. Nuclear Regulatory Commission, “Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors”, Regulatory Guide 1.111, July 1977.

5. Boston Edison Company, “Pilgrim Station Unit 1 Appendix I Evaluation”, April 1977.

6. Entech Engineering Inc., P100-R19, "AEOLUS-3 - A Computer Code for the Determination of Atmospheric Dispersion and Deposition of Nuclear Power Plant Effluents During Continuous, Intermittent and Accident Conditions in Open-Terrain Sites, Coastal Sites and Deep-River Valleys".

7. U.S. Nuclear Regulatory Commission, “XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations”, NUREG/CR2919, September 1982.

APPENDIX A

Results of Onsite Groundwater Monitoring Program

In response to the Nuclear Energy Institute (NEI) Groundwater Protection Initiative, Pilgrim Station instituted a groundwater monitoring program during 2007. Four monitoring wells were installed inside the protected area fence during the fourth quarter of 2007. The first samples were collected in November 2007. Since these are onsite wells, they are not considered part of the Radiological Environmental Monitoring Program (REMP), and data from these wells are being reported in the annual Radiological Effluent Release Report. Two pre-existing wells were incorporated into the groundwater monitoring program in early 2008. Additional wells were added to the program in 2010 (12 wells), 2011 (2 wells), 2012 (1 well), 2013 (3 wells), and 2014 (1 well). A total of 23 wells are being sampled on a routine basis.

In addition to sampling the onsite monitoring wells, samples of surface water are collected from a location in the PNPS Intake Canal. These locations are along the shoreline in the same direction as the groundwater flow gradient.

All samples collected are analyzed for tritium, a radioactive isotope of hydrogen, and also for gamma emitting radionuclides. In accordance with industry practice established under the NEI initiative, lower limits of detection (LLDs) used for analysis of REMP samples were used when assessing these samples for the presence of radioactivity. Low levels of tritium were detected in 3 of the 23 onsite wells. Although gamma spectroscopy indicated the presence of naturally-occurring radioactivity, such as Potassium-40 and radon daughters from the uranium/thorium decay chains, there was no indication of any plant-related radioactivity in the groundwater samples, other than tritium. Such levels of natural radioactivity are expected as these radionuclides are dissolved into the groundwater from the rocks and soil. The fact that these low levels of naturally-occurring radioactivity can be detected demonstrates the ability of the gamma spectroscopy analyses to detect radioactivity in groundwater. Analyses are also performed for hard-to-detect radionuclides, including Iron-55, Nickel-63, Strontium-89, and Strontium-90 on a less frequent basis. These hard-to-detect radionuclides were also non-detectable in all of the wells sampled and analyzed during 2021.

A summary of the results of the tritium analyses conducted in 2021 are presented in the following table. In this table, a value of “NDA < xx” in the columns indicates that no activity was detected in the sample when analyzed to the minimum-detectable level following the “<” sign. For example, if a sample collected from MW201 contained no detectable tritium, and a minimum detectable concentration of 295 pCi/L was achieved on that sample. The achieved sensitivity of 295 pCi/L is well below the required REMP LLD of 3000 pCi/L, and no tritium was detected even when counted to this more sensitive level of detection. No plant-related radioactivity (other than tritium) was detected in any of the monitoring wells, and no tritium or plant-related radioactivity was detected in surface water samples collected from the intake canal.

Monitoring Well ID	Installation Date	Number of Samples	Number of Positive Results	Minimum Concentration pCi/L	Maximum Concentration pCi/L
MW201	Nov-2007	3	0	NDA < 348	NDA< 579
MW202	Nov-2007	4	0	NDA<355	NDA<522
MW202-I	Apr-2010	4	0	NDA < 347	NDA< 542
MW203	Nov-2007	Well decommissioned in 2013 during construction of ISFSI pad			
MW204	Nov-2007	4	0	NDA< 351	NDA<546
MW205	Apr-2010	4	0	NDA< 356	NDA<534
MW206	Apr-2010	4	0	NDA < 365	NDA<553
MW207	Apr-2010	4	0	NDA < 362	NDA< 542
MW208-S	Apr-2010	4	0	NDA < 353	NDA < 556
MW208-I	Apr-2010	4	0	NDA < 350	NDA < 539
MW209	Aug-2010	12	0	NDA< 165	NDA<575
MW210	Aug-2010	4	0	NDA< 352	NDA<527
MW211	Aug-2010	4	0	NDA<353	NDA<560
MW212	Aug-2010	4	0	NDA< 360	NDA< 562
MW213	Aug-2010	4	0	NDA< 357	NDA<551
MW214	Aug-2010	4	0	NDA< 355	NDA<557
MW215	Dec-2011	4	2	NDA<508	693
MW216	Sep-2012	12	7	NDA<358	913
MW217	Dec-2011	4	0	NDA< 355	NDA< 548
MW218	Nov-2013	4	1	NDA<475	367
MW219	Dec-2013	12	0	NDA< 177	NDA<604
MW220	Dec-2014	5	0	NDA< 367	NDA<554
MW3	Jul-1987	4	0	NDA< 373	NDA< 539
MW4	Jul-1997	Well decommissioned in 2013 during installation of MW4R			
MW4-R	Nov-2013	4	0	NDA< 360	NDA<554
All Wells	--	116	10	NDA < 165	913
Intake Canal West	--	35	0	NDA < 172	NDA <572
Intake Canal East	--	Discontinued sampling in 2016 for sampling safety concerns			

Concentrations of tritium detected in the onsite wells ranged from non-detectable at less than 165 pCi/L, up to a maximum concentration of 913 pCi/L. The average quarterly concentrations from these onsite wells are well below the voluntary communication reporting level of 20,000 pCi/L as established by the EPA Drinking Water Standard. Although the EPA Standard provides a baseline for comparison, no drinking water sources are affected by this tritium. All of the affected wells are onsite, and the general groundwater flow pathway is under Pilgrim Station and out into the salt water of Cape Cod Bay. As such, there is no potential to influence any off-site drinking water wells. Even if worst-case assumptions were made and the water from monitoring well with an average concentration of 1000 pCi/L was consumed as drinking water for an entire year, the maximum dose consequence would be less than 0.000074 mrem/yr. In actuality, any dose consequence would be much less than this, as any tritium-laden water potentially leaving the site would be diluted into the seawater of Cape Cod Bay before being incorporated into any ingestion pathways. No drinking water ingestion pathway exists at the Pilgrim Station site.

Although there are no indications that the groundwater containing detectable tritium is actually migrating offsite, a bounding calculation was performed to assess the potential dose impact of such a scenario. Based on the tritium concentrations detected during 2021, the annual average concentrations of tritium in groundwater in the four monitoring wells most closely adjacent to the shoreline (MW204, MW205, MW202, and MW201) were used to estimate potential tritium migration into the intake bay. Hydrological characteristics of the compacted backfill in the vicinity of these wells were measured in 2010 and indicate the hydraulic conductivity ranges from 0.002 cm/sec to approximately 0.006 cm/sec. When coupled with the hydraulic slope of 0.014 and average porosity of 0.3, the flow velocity was calculated as being between 0.08 and 0.23 meters per day. Using an assumed horizontal shoreline interface area 236 meters long by 3 meters deep that could potentially transmit groundwater into the intake bay, the annual discharge of groundwater would be approximately 12.5 million Liters of water per year. Assuming this volume of 12.5 million liters contained the segment-weighted average concentration of 468 pCi/L, the annual discharge of tritium into the intake bay under this hypothetical scenario would be 0.00585 Curies. This activity represents less than 0.073% of the annual airborne effluent of tritium released from the reactor building vent (see Table 2.2-C). Such airborne effluents can be washed down to the ground surface during precipitation events and infiltrate into the ground, thereby introducing tritium into the groundwater.

In the hypothetical scenario described above, the 0.00585 Curies of tritium entering the intake bay would be further diluted into the cooling water flow of the plant. As documented in Table 2.3-A, the total volume of cooling water flow during 2021 was 3.81 billion Liters, yielding an effective concentration of tritium in the intake bay of approximately 1.55 pCi/L. Such a concentration would be well below the detection sensitivity of approximately 450 pCi/L used to analyze water collected from the discharge canal as part of the radiological environmental monitoring program (REMP). The calculated dose to the maximum-exposed member of the public from such a hypothetical release would be 0.00000088 millirem, resulting from ingestion of tritium incorporated into fish and shellfish. Since the tritium would be incorporated into seawater, there is no drinking water ingestion pathway in the described scenario.

The following table lists the hydrological characteristics in the vicinity of each of the monitoring wells used to estimate tritium migration. Predicted flow velocities, annual discharge volumes, average tritium concentrations, and hypothetical tritium discharges are listed for each shoreline segment represented by each monitoring well.

Shoreline Segment Number	1	2	3	4
Monitoring Well Number	MW204	MW205	MW202	MW201
Hydraulic Conductivity - cm/sec	1.99E-03	4.27E-03	3.13E-03	5.64E-03
Hydraulic Slope	0.014	0.014	0.014	0.014
Porosity	0.300	0.300	0.300	0.300
Flow Velocity - m/day	8.02E-02	1.72E-01	1.26E-01	2.27E-01
Flow Velocity - ft/yr	9.61E+01	2.06E+02	1.51E+02	2.72E+02
Length of Shoreline Segment – m	61.0	38.1	45.7	91.4
Thickness of Water Layer – m	3.0	3.0	3.0	3.0
Volumetric Discharge - m^3/day	4.40E+00	5.90E+00	5.19E+00	1.87E+01
Volumetric Discharge - Liter/yr	1.61E+06	2.16E+06	1.90E+06	6.84E+06
Annual Average H-3 Concentration - pCi/L	4.65E+02	4.67E+02	4.70E+02	4.79E+02
Annual Segment Tritium Discharge - Ci/yr	7.48E-04	1.01E-03	8.91E-04	3.28E-03
Total Volumetric Discharge - L/yr	1.25E+07			
Total H-3 Discharge - Ci/yr	5.92E-03			
Annual Circulating Water Flow - Liter/yr	3.81E+09			
Discharge Canal H-3 Concentration - Ci/L	1.55E-12			
Discharge Canal H-3 Concentration - pCi/L	1.55E+00			
Max. Indiv. Dose Factor - mrem/yr per Ci/L	5.73E+05			
Maximum Individual Dose - mrem/yr	8.87E-07			

In conclusion, the only radionuclide detected in groundwater during the 2021 monitoring effort that is attributable to Pilgrim Station operations is tritium. Although some previous soil samples near the separation in the underground discharge line from the neutralizing sump years ago indicated the presence of low-level gamma radioactivity, such activity has not been detected in the groundwater and indicates the radioactivity is immobile and confined to the soil. Even in the case of the three reportable events that occurred in 2013 and subsequent sample results in 2016, the total dose impact to a maximally-exposed member of the public would have been much less than 1 mrem/yr.

APPENDIX B

CORRECTIONS TO PREVIOUS EFFLUENT REPORTS

There were no corrections made to the previous effluent (ARERR) report during the calendar-year of 2021. Some wording referencing equipment no longer used due to plant condition found in the annual report for the 2020 timeframe has been been removed in this report, but it bore no consequence to dose calculations or other result values.

APPENDIX C

CHANGES TO PNPS
OFFSITE DOSE CALCULATION MANUAL

The PNPS Offsite Dose Calculation Manual (ODCM) was revised once during calendar year 2021. The changes are as listed below:

In summary the ODCM was revised to add guidance for sample and analysis of construction dewatering and open air demolition, add a new pathway for liquid discharge involving the use of the Torus, remove sampling/analysis requirements for Noble Gas, remove remaining reference to Circ Water (no longer in use), removeTB GEMS, RBV and RBCCW PRM surveillances, remove isotopes that had decayed past the 10 half-life mark, remove Land Use Census and vegetation sampling, and removed any TLD/ Air sample station locations beyond 3 km. Actual change log can be seen below.

REV. NO.	IDENTIFICATION OF CHANGE	DOCUMENT SECTION AND PAGE
15	Revision Change from 14 to 15	All
	Deleted reference to gaseous alarm and trip setpoint calculations	1-1
	Table 1.1: Removed deleted sections (replaced original TZ with ODCM Control sections) pertaining to the use and control of PRMs, instrumentation and dose/dose rates, alarm and trip setpoints, and surveillances to maintain these. Removed Land Use Census	1-1 to 1-3
	Added definition 2.4-5, Construction Dewatering as an approved liquid effluent pathway subject to the same control as all liquid effluent discharges in terms of dose and concentration	2-1
	Added definition 2.6-5, Open Air Demolition monitoring criteria for different stages	2-2
	In Definition section 2.6, removed reference to gaseous alarm/trip setpoints and definition for Gaseous Radwaste Treatment System (permanently removed from service).	2-2
	Table 3.1-1 Instrumentation: Removed reference to Circulating Water pumps (permanently removed from service) Removed RBCCW A/B PRMs (closed system, not a discharge pathway). Removed Action 4 note. Corrected Action 3 note to reflect effluent flow estimate method with loss of flow instrumentation.	3/4-3
	Table 4.1-1 Instrument Surveillances: Removed RBCCW A/B PRM surveillances (closed system, not a discharge pathway). Removed note 3.	3/4-4
	Removed control, applicability surveillances and bases for Noble gas detectors from instrumentation control for reasons specified in Technical Changes sectinons above	3/4-5
	Table 3.1-2: Removed monitoring from Turbine Building GEMS (removed from service, no longer a effluent pathway). Removed Noble Gas instrumentation for RBV and Action note 1.	3/4-6
	Table 4.1-2: Removed surveillance for RBV Noble gas monitor and Turbine Building GEMS Effuent monitoring	3/4-7
	Removed entrained Noble gas from Liquid Effluent Controls	3/4-8

Table 4.2-1: Removed dissolved and entrained gasses requirements/LLD, added Torus functioning as a treatable tank for releases, added construction dewatering as a new release type, added continouse liquid effluent releases (for discharges lasting longer than a day to complete)	3/4-9
Figure 4.2-1: Updated to refect changes to liquid effluent discharges	3/4-12
Revised Gaseous Effluent Dose Rate control by removing Noble gas dose rate and adding alternative method for quantifying gaseous tritium releases	3/4-13
Table 4.3-1: Removed Noble gas sample and analysis for RBV, removed Turbine Building GEMS monitoring, added alternative method of calulating tritium release (using Spent Fuel pool tritium levels and evaporation rate)	3/4-14
Removed Noble Gas Dose Control (Noble gas no longer produced or detectable and Kr-85 remaining in spent fuel gaps would not be detected by gas detectors but calculated in a DBA)	3/4-15
Figure 4.3-1: Removed reference to gaseous effluent treatment system (permanently removed from service)	3/4-16
Removed Environmental Monitoring Program Control Action c. for broadleaf vegitation	3/4-19
Table 3.5-1: Removed broadleaf vegitation, updated locations of air sample stations and TLDs to reflect the consolidation of sampling to 3km due to reduction in gaseous effluent releases and the range of impact, removed Note 5 pertaining to Land Use Census.	3/4-20 to 22
Table 3.5-2: Updated table and removed TLDs beyond 3 km (exception being controls and Manomet Elementary TLD)	3/4-23
Table 3.5-3: Removed Manomet Substation air sampler (outside 3km), removed vegitation samples, removed Note 1	3/4-24
Consolidated Figure 3.5-1	3/4-25
Figure 3.5-2: Removed Manomet Substation air sampler (outside 3km), removed vegitation samples	3/4-26 to 27
Figure 3.5-3: Updated to reflect the collapse of sampling to 3km	3/4-28 to 29
Figure 3.5-4: Updated to reflect the collapse of sampling to 3km (only control remain)	3/4-30 to 31
Figure 3.5-5: Removed vegetation locations	3/4-32 to 33
Figure 3.5-6: Removed vegetation locations	3/4-34 to 35
Table 3.5-4: Removed isotopes decayed >than 10 half lives (Fe-59, Co-58, Zr-65, Nb-95)	3/4-36
Table 4.5-1: Removed LLD for isotopes decayed >than 10 half lives (Fe-59, Co-58, Zr-65, Nb-95), Removed Land Use Census control	3/4-37
Removed reference to Noble Gas dose control 3/4.3.2 and dose limits for exposure	5-1 to 5-2
Added description of liquid radwaste treatment systems for TWT line ups, added use of Torus as a high volume TWT, added construction dewatering, removed treated gaseous radwaste systems removed from service	6-1
Removed sections 7.1.4 and 7.2.4 relating to Turbine Building ventilation releases, removed RBV Noble gas monitor	7-2
Table 7-1: Removed RBV effluent monitor (controlled by EP not ODCM)	7-3

Revised section 7.3.2 Gaseous Effluent to remove continuous Noble gas monitor and Turbine Building monitoring, added alternative method of estimating tritium (using spent fuel pool as source)	7-4
Revised section 8.2 to remove description and dose calculation for Noble gas effluent releases	8-2
Removed reference to Circulating water pumps (permanently removed from service)	9-1 to 9-5
Removed discussion of Noble gas dose calculation and Iodine deposition on vegetation and resulting dose	9-6
Removed reference to C-14 dose contribution (only produced during plant operation)	9-7
Removed equation terms used to calculate Noble gas dose	9-8 to 9-9
Removed Noble gas immersion as exposure pathway for receptor locations, hydrology, and meteorology	10-1
Table 10: Removed Noble gas receptor location	10-2
Removed vegetation as a sample media, removed Garden/ Land Use Census (principal driver for census, Iodine, is no longer produced or detectable)	11-1
Removed reference to sample for Iodine	11-2
Adopted Reg Guide 1.21, Revision 2 to simplify annual reports and more accurately reflect current practices	13-2
Table A-4: Deleted (dose conversion factors no longer needed due to plant condition)	A-4
Removed Noble gas structure attenuation factor	A-43

PILGRIM NUCLEAR POWER STATION
OFFSITE DOSE CALCULATION MANUAL

APPROVED BY: _____ 6.8.21
RADIATION PROTECTION/CHEMISTRY MANAGER — Date

REVIEWED BY: _____ 6/8/21
OSRC CHAIRMAN — Date
OSRC MEETING 21-001

APPROVED BY: _____ 06/08/2021
SITE VICE PRESIDENT — Date

OSRC REVIEW REQUIRED
EP REVIEW REQUIRED
SAFETY REVIEW REQUIRED

RECORD OF DOCUMENT CHANGES

REV. NO.	IDENTIFICATION OF CHANGE	DOCUMENT SECTION AND PAGE
15	Revision Change from 14 to 15	All
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	Removed control, applicability surveillances and bases for Noble gas detectors from instrumentation control for reasons specified in Technical Changes sectinons above	3/4-5
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evaporation rate)	
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Table 3.5-1: Removed broadleaf vegitation, updated locations of air sample stations and TLDs to reflect the consolidation of sampling to 3km due to reduction in gaseous effluent releases and the range of impact, removed Note 5 pertaining to Land Use Census.	3/4-20 to 22
Table 3.5-2: Updated table and removed TLDs beyond 3 km (exception being controls and Manomet Elementary TLD)	3/4-23
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Consolidated Figure 3.5-1	3/4-25
Figure 3.5-2: Removed Manomet Substation air sampler (outside 3km), removed vegitation samples	3/4-26 to 27
Figure 3.5-3: Updated to reflect the collapse of sampling to 3km	3/4-28 to 29
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Figure 3.5-5: Removed vegetation locations	3/4-32 to 33
Figure 3.5-6: Removed vegetation locations	3/4-34 to 35
Table 3.5-4: Removed isotopes decayed >than 10 half lives (Fe-59, Co-58, Zr-65, Nb-95)	3/4-36
Table 4.5-1: Removed LLD for isotopes decayed >than 10 half lives (Fe-59, Co-58, Zr-65, Nb-95), Removed Land Use Census control	3/4-37
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14

Removed Main Stack from Table 3.1-2	3/4-6
Removed Main Stack from Table 4.1-2	3/4-7
Removed Ce-141 from Table 4.2-1 Note	3/4-9
Changed FSAR reference to DSAR reference in section 3.3.1	3/4-13
Removed Main Stack from Table 4.3-1	3/4-14
Removed Ce-141 from Table 4.3-1 Note	3/4-14
Removed Drywell to Main Stack pathway in Figure 4.3-1	3/4-18
Reduced the TLD and air sample station location number in Table 3.5-1	3/4-27
Updated Table 3.5-2 to current TLD locations	3/4-25
Removed deleted air sample stations from Table 3.5-3	3/4-26
Updated Figure 3.5-1 to current TLD and Air Sample Station Locations	3/4-28 and 29
Removed unneeded Air Sample Station from Figure 3.5-3	3/4-32
Removed TLD and Air Sample Station locations from Figure 3.5-4	3/4-34 and 35
Removed reference to Main Stack and SBGT in Section 6.2	6-1
Removed section referencing Main Stack in section 7.1.2	7-1
Removed section referencing Main Stack in section 7.2.2	7-3
Removed reference to iodine and charcoal cartridge	7-3 and 7-4
Removed Main Stack from Table 7-1	7-5
Removed reference to Main Stack in Section 8-2	8-3
Removed reference to Main Stack in Section 9.3	9-6
Removed Main Stack from Table 10-1	10-2
Removed reference to Entergy	11-1
Added DSAR to Reference Section	13-2

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (continued)

1.0 INTRODUCTION

This manual contains the current methodology, parameters, data, and information used in the calculation of offsite doses due to radioactive gaseous and liquid effluents, in the calculation of the liquid effluent monitor alarm/trip setpoint, and in the conduct of the radiological environmental monitoring program.

All effluent controls contained in the Offsite Dose Calculation Manual (ODCM) were originally part of the PNPS Technical Specifications (Reference 1). In response to Generic Letter 89-01 (Reference 2) from the Nuclear Regulatory Commission, these Radiological Effluent Technical Specifications (RETS) were removed from the main body of the Technical Specifications and relocated to the ODCM.

The effluent controls previously existed as parts of Section 3/4.8 and Section 7/8 of the PNPS Technical Specifications. In conjunction with the transfer of the effluent controls from the RETS to the ODCM, the numbering scheme for the individual effluent controls were changed to agree with the numbering scheme present in NUREG-1302, "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling Water Reactors" (reference 27).

In conjunction with the GL89-01 change, the ODCM was restructured from that which previously existed. None of the requirements or methodologies were changed. Rather, the various sections were reorganized to facilitate support of the effluent controls relocated from the Technical Specifications. Descriptions of effluent monitoring systems and setpoint calculations were moved to the sections immediately following the controls, followed by dose calculation methodologies, and finally by the environmental monitoring program section. Supporting information is listed in the appendices at the rear of the manual.

TABLE 1.1

EFFLUENT CONTROLS CROSS-REFERENCE

Effluent Control Topic	Original Technical Specification Section	Revised ODCM Control Section
Liquid Effluents Concentration	3.8.A.1 4.8.A.1 4.8.A.2 Table 4.8-1	3.2.1 4.2.1.a 4.2.1.b Table 4.2-1
Radioactive Liquid Effluent Instrumentation	3.8.B.1 4.8.B.1 4.8.B.2 Table 3.8-1 Table 4.8-2	3.1.1 4.1.1.a 4.1.1.b Table 3.1-1 Table 4.1-1
Liquid Radwaste Treatment	3.8.C.1 4.8.C.1 4.8.C.2 Figure 4.8-1	3.2.3 4.2.3.a 4.2.3.b Figure 4.2-1
Gaseous Effluents Dose Rate	3.8.D.1 DELETED 4.8.D.2 Table 4.8-3	3.3.1 DELETED 4.3.1.b Table 4.3-1
Radioactive Gaseous Effluent Instrumentation	3.8.E.1 DELETED 4.8.E.2 Table 3.8-2 (partial) Table 4.8-4 (partial)	3.1.2 DELETED 4.1.2.b Table 3.1-2 Table 4.1-2
Gaseous Effluent Treatment	Figure 4.8-2	Figure 4.3-1
Environmental Monitoring	7.1.A 8.1.A Table 7.1-1 Table 8.1-1 Table 8.1-2 Table 8.1-3 Table 8.1-4	3.5.1 4.5.1 Table 3.5-4 Table 3.5-1 Table 3.5-3 Table 3.5-2 Table 4.5-1

TABLE 1.1 (continued)

EFFLUENT CONTROLS CROSS-REFERENCE

Effluent Control Topic	Original Technical Specification Section	Revised ODCM Control Section
Dose - Liquids	7.2.A 8.2.A	3.2.2 4.2.2
DELETED	Deleted Deleted	Deleted Deleted
Dose - Radioactive Material in Particulate Form, and Tritium	7.4.A 8.4.A	3.3.3 4.3.3
Total Dose	7.5.A 8.5.A	3.4.1 4.4.1

2.0 DEFINITIONS

This section lists definitions which are unique to the ODCM. Other definitions pertaining to actions and surveillance requirements for the various controls can be found in the Technical Specifications (Reference 1).

2.1 ACTION – ACTION shall be that part of a Control that prescribes remedial measures required under designated conditions.

2.2 CHANNEL CALIBRATION – A CHANNEL CALIBRATION shall be the adjustment, as necessary, of the channel such that it responds within the required range and accuracy to known values of input. The CHANNEL CALIBRATION shall encompass the entire channel including the sensor and alarm, interlock and/or trip functions, and shall include the CHANNEL FUNCTIONAL TEST. The CHANNEL CALIBRATION may be performed by any series of sequential, overlapping, or total channel steps such that the entire channel is calibrated.

2.3 CHANNEL CHECK – A CHANNEL CHECK shall be the qualitative assessment of channel behavior during operation by observation. This determination shall include, where possible, comparison of the channel indication and/or status with other indications and/or status derived from independent channels measuring the same parameter.

2.4 CHANNEL FUNCTIONAL TEST – A CHANNEL FUNCTIONAL TEST shall be:

a. Analog channels – the injection of a simulated signal into the channel as close to the sensor as practicable to verify OPERABILITY including alarm and/or trip functions and channel failure trips.

b. Bistable channels – the injection of a simulated signal into the sensor to verify OPERABILITY including alarm and/or trip functions.

The CHANNEL FUNCTIONAL TEST may be performed by any series of sequential, overlapping, or total channel steps such that the entire channel is tested.

2.4 - 5 CONSTRUCTION DEWATERING - The evacuation of accumulated precipitation, surface water runoff and groundwater infiltration from subsurface basement structures directly to receiving waters or tanks for treatment and discharge. This process supports collection of core samples, survey gridding, performance of radiation surveys and other demolition and decommissioning activities. With low to no detectable levels of radionuclide concentrations expected (typically leached from the concrete and metal surfaces in subsurface structures) this water can be discharged within the vicinity of the service water discharge to preserve liquid effluent dose modelling assumptions, or the intake if groundwater infiltration only. In all cases, a liquid discharge permit must be completed in accordance with station procedures, the requirements of Control 3.11.1.1 and the station's NPDES permit. The pathway is nearly identical to that for discharge of Treated Water Tanks or the Neutralizer Sump, except for the source location (building structure basements) and flexibility in selecting discharge locations (intake if the source is groundwater only, the SSW Sparger, or within the vicinity of the Service Water Discharge point) to the extent these do not challenge liquid effluent discharge off site dose calculation assumptions.

2.5 MEMBER(S) OF THE PUBLIC – MEMBER(S) OF THE PUBLIC shall include all persons who are not occupationally associated with the plant. This category does not include employees of the licensee, its contractors, or vendors. Also excluded from this category are persons who enter the site to service equipment or to make deliveries. This category

does include persons who use portions of the site for recreational, occupational or other purposes not associated with the site.

2.6 OFFSITE DOSE CALCULATION MANUAL (ODCM) – The OFFSITE DOSE CALCULATION MANUAL (ODCM) shall contain the methodology and parameters used in the calculation of offsite doses resulting from radioactive gaseous and liquid effluents, in the calculation of liquid effluent monitoring Alarm/Trip Setpoint, and in the conduct of the Radiological Environmental Monitoring Program. The ODCM shall also contain: (1) the Radioactive Effluent Controls and Radiological Environmental Monitoring Programs required by Technical Specifications Administrative Controls 5.5.1 and 5.5.4; and, (2) descriptions of the information that should be included in the Annual Radiological Environmental Operating and Annual Radioactive Effluent Release Reports required by Technical Specifications Administrative Controls 5.6.2 and 5.6.3.

2.6-5 OPEN AIR DEMOLITION EFFLUENT MONITORING - Open Air Demolition Monitoring is the particulate sampling of concrete and demolition dust leaving structures undergoing demolition activities at exit points and openings in structures (overhead doors, personnel doors, equipment hatches, etc.). The sampler is positioned at the opening and run continuously while work is performed. To quantify plant related activity in effluents leaving the openings, exit air velocity out of the structure is quantified daily/shiftly (handheld anemometer, e.g.) is used with the opening dimensions to calculate the effluent concentration and rate of release to project off site dose assuming a ground level release. These are established at each opening of structure undergoing internal demolition and component removal with known levels of radioactivity present and fixed/loose contamination. The same method is used to quantify effluents generated from the demolition of structures and walls and moving debris piles by positioning the REMP like air particulate samplers in the vicinity of the activity and standardizing the cone of release geometry. For dose modelling, with the wind velocity and release geometry established, it is assumed to be a ground level release from the reactor building.

2.7 OPERABLE – OPERABILITY – A system, subsystem, train, component, or device shall be OPERABLE or have OPERABILITY when it is capable of performing its specified function(s), and when all necessary attendant instrumentation, controls, electrical power, cooling or seal water, lubrication, or other auxiliary equipment that are required for the system, subsystem, train, component, or device to perform its function(s) are also capable of performing their related support function(s).

2.8 RADWASTE TREATMENT SYSTEM - Liquid Radwaste Treatment System - The liquid radwaste treatment system is that system identified in Figure 4.2-1.

2.9 REPORTABLE EVENT – A REPORTABLE EVENT shall be any of those conditions specified in Section 50.73 of 10CFR Part 50.

2.10 SITE BOUNDARY – The SITE BOUNDARY is shown in Figure 1.6-1 in the FSAR (Reference 3).

2.11 SOURCE CHECK – A SOURCE CHECK shall be the qualitative assessment of channel response when the channel sensor is exposed to a source of increased radioactivity.

2.1 UNRESTRICTED AREA – An UNRESTRICTED AREA shall be any area at or beyond the SITE BOUNDARY, access to which is not controlled by the licensee for the purposes of protection of individuals from exposure to radiation and radioactive materials, or any area within the SITE BOUNDARY used for residential quarters or for industrial, commercial, institutional, and/or recreational purposes.

3/4.0 EFFLUENT AND ENVIRONMENTAL CONTROLS

This section includes the effluent and environmental controls that were originally part of the PNPS Technical Specifications. With the exception of the environmental monitoring program previously listed in the Technical Specifications (Reference 1), these controls were relocated into the ODCM without any substantial changes, in accordance with Generic Letter 89-01 (Reference 2). Text and tables were reformatted to the style of the ODCM. The various controls were renumbered from the original numbering scheme of the Technical Specifications. A cross-reference of the old Technical Specifications section to the new ODCM section is presented in Table 1.1.

Prior to the Generic Letter 89-01 change to the ODCM (Revision 8), the ODCM contained an enhanced radiological environmental monitoring program (REMP), above that required by the Technical Specifications. To prevent confusion and capture the more inclusive monitoring program that existed in the ODCM, the original Technical Specification REMP was replaced with the REMP described in the ODCM. Therefore, the monitoring program listed in section 3/4.5 contains more samples and monitoring locations than existed in the Technical Specifications REMP prior to the Generic Letter 89-01 change.

In addition to the changes in the REMP program described above, all of the tables were revised with the latest distance and direction information available. The global positioning system (GPS) was used to verify the locations of the various sampling and monitoring stations, and the tables were updated accordingly. In keeping with governmental efforts to adopt the metric system of measurement, all distances have been listed in metric units (meters and/or kilometers) in the various tables and figures.

Any changes in distances and directions to the various monitoring locations from those originally listed in the Technical Specifications REMP are corrections based on new information. None of the locations of the sampling stations were actually changed. Some of the verbal descriptions, especially those for near-plant TLDs, have been updated to reflect current names of buildings and other areas near Pilgrim Station. Again, none of the physical locations were altered, and the change merely reflects up-to-date place names adopted by station management.

In 1977, Boston Edison Company was pursuing construction of a second unit on the PNPS site. As part of the preliminary licensing efforts for this second unit, Pilgrim Station committed to a special and aggressive marine sampling program under the REMP for a period not to exceed 10 years. Following an evaluation of results obtained from this specialized marine sampling program over the past 25 years, it has been determined that the analyses have shown that the impact of radioactivity in liquid discharges on the general public and environment is negligible and the program was once again reduced to follow guidance from NUREG-1302 (reference 27) and the Branch Technical Position on Environmental Monitoring (reference 28).

PNPS ceased operation on May 31,2019. The site’s Effluent and Environmental Programs have been reduced to match the plant condition and its reduced pathways.

In order to streamline the flow of information for each of the applicable effluent controls, the technical bases for the controls were relocated from the end of Section 3/4 to within the applicable control. As is the case with Technical Specifications, the bases are not considered to be part of the control or its requirements. Rather, the bases provide the technical rationale behind the applicable control, and are listed to provide additional clarification regarding the specific control.

3/4.1 INSTRUMENTATION

3/4.1.1 Radioactive Liquid Effluent Instrumentation

CONTROLS

3.1.1 The radioactive liquid effluent monitoring instrumentation channels shown in Table 3.1-1 shall be OPERABLE with their alarm/trip setpoints set to ensure that the limits of Controls 3.2.1 are not exceeded during periods when liquid wastes are being discharged via the radwaste discharge header.

For releases other than the radwaste discharge header, the above specification does not apply, these releases shall be made in accordance with Action 1 of Table 3.1-1.

APPLICABILITY: As shown in Table 3.1-1.

ACTION:

a. With a radioactive liquid effluent monitoring instrumentation channel alarm/trip setpoint less conservative than a value which will ensure that the limits of Control 3.2.1 are met, without delay suspend the release of radioactive liquid effluents monitored by the affected channel or change the setpoint so that it is acceptably conservative or declare the channel inoperable.

b. With one or more radioactive liquid effluent monitoring instrumentation channels inoperable, take the action shown in Table 3.1-1.

SURVEILLANCE REQUIREMENTS

4.1.1.a The setpoints for monitoring instrumentation shall be determined in accordance with the ODCM.

4.1.1.b Each radioactive liquid effluent monitoring instrumentation channel shall be demonstrated OPERABLE at the frequencies shown in Table 4.1-1.

BASES

3/4.1.1 Radioactive Liquid Effluent Instrumentation

The radioactive liquid effluent instrumentation is provided to monitor and control, as applicable, the releases of radioactive materials in liquid effluents during actual or potential releases of liquid effluents. The alarm/trip setpoints for these instruments shall be calculated in accordance with NRC approved methods in the Offsite Dose Calculation Manual (ODCM) to ensure that the alarm/trip will occur prior to exceeding the limits of 10CFR20. The OPERABILITY and use of this instrumentation is consistent with the requirements of General Design Criteria 60, 63, and 64 of Appendix A to 10CFR50.

TABLE 3.1-1

RADIOACTIVE LIQUID EFFLUENT MONITORING INSTRUMENTATION

Instrument	Minimum Channels Operable	Applicability	Action(1)
1. GROSS RADIOACTIVITY MONITORS PROVIDING ALARM AND AUTOMATIC TERMINATION OF RELEASE			
a. Liquid Radwaste Effluent Line	1	During actual discharge of liquid wastes	1
2. FLOW RATE MEASUREMENT DEVICES			
a. Liquid Radwaste Effluent Line	1	During actual discharge of liquid wastes	2
b. Discharge Canal	N/A	During actual discharge of liquid wastes	3
3. DELETED			

(1) Actions Required --

ACTION 1: With the number of OPERABLE channels less than required by the minimum channels OPERABLE requirement, effluent releases may be resumed provided that prior to initiating a release:

a. At least two independent samples are analyzed in accordance with Control 4.2.1.a; and,

b. An independent verification of the release rate calculations is performed; and,

c. An independent verification of the discharge line valving is performed.

ACTION 2: With the number of OPERABLE channels less than required by the minimum channels OPERABLE requirement, effluent releases via this pathway may continue provided that the flow rate is verified at least once per 4 hours during actual releases. Flow will be estimated based on design flow rate of the operating effluent discharge pump rate and/or tank level drop over per unit time.

ACTION 3: Flow will be estimated based on the sum of the operating waste discharge pumps and/or operating salt service water pumps.

TABLE 4.1-1

RADIOACTIVE LIQUID EFFLUENT MONITORING INSTRUMENTATION
SURVEILLANCE REQUIREMENTS

Instrument	Channel Check	Source Check	Channel Calibration	Channel Functional Test
1. GROSS RADIOACTIVITY MONITORS PROVIDING ALARM AND AUTOMATIC TERMINATION OF RELEASE				
a. Liquid Radwaste Effluents Line	(1)	N/A	Once per 24 months(2)	Quarterly
2. FLOW RATE MEASUREMENT DEVICES				
a. Liquid Radwaste Effluents Line	(1)	N/A	Once per 24 months	Quarterly
3. DELETED				

(1) During or prior to release via this pathway.

(2) Previously established calibration procedures will be used for these requirements.

3/4.1 INSTRUMENTATION

3/4.1.2 Radioactive Gaseous Effluent Instrumentation

CONTROLS

3.1.2 The radioactive gaseous effluent monitoring instrumentation channels shown in Table 3.1-2 shall be OPERABLE to ensure that the limits of Control 3.3.1 are not exceeded.

APPLICABILITY: As shown in Table 3.1-2

ACTION:

a. DELETED.

b. With one or more radioactive gaseous effluent monitoring instrumentation channels inoperable, take the action shown in Table 3.1-2.

SURVEILLANCE REQUIREMENTS

4.1.2.a DELETED.

4.1.2.b Each radioactive gaseous effluent monitoring instrumentation channel shall be demonstrated OPERABLE at the frequencies shown in Table 4.1-2.

BASES

3/4.1.2 Radioactive Gaseous Effluent Instrumentation

The radioactive gaseous effluent instrumentation is provided to monitor and control, as applicable, the releases of radioactive materials in gaseous effluents during actual or potential releases of gaseous effluents. The OPERABILITY and use of this instrumentation is consistent with the requirements of General design Criteria 60, 63, and 64 of Appendix A to 10CFR50.

TABLE 3.1-2

RADIOACTIVE GASEOUS EFFLUENT MONITORING INSTRUMENTATION

Instrument	Minimum Channels Operable	Applicability	Parameter	Action(1)
1. REACTOR BUILDING VENTILATION EFFLUENT MONITORING SYSTEM				
a. DELETED				
b. Particulate Sampler Filter	1	(2)	Collect Particulate Sample	2
c. Effluent System Flow Rate Measuring Device	1	(2)	System Flow Rate Measurement	3
d. Sampler Flow Rate Measuring Device	1	(2)	System Flow Rate Measurement	3

(1) Actions Required --

ACTION 2*: With the number of OPERABLE channels less than required by the minimum channels OPERABLE requirement, effluent releases via this pathway may continue provided samples are continuously collected with auxiliary sampling equipment as required in Table 4.3-1.

ACTION 3*: With the number of OPERABLE channels less than required by the minimum channels OPERABLE requirement, effluent releases via this pathway may continue provided the flow rate is estimated at least once per 4 hours.

* Note: (For Actions 2-3) If the instruments are not returned to OPERABLE status within 30 days, explain in the next Annual Radioactive Effluent Release Report why the inoperability was not corrected in a timely manner.

(2) During releases via this pathway.

TABLE 4.1-2

RADIOACTIVE GASEOUS EFFLUENT MONITORING INSTRUMENTATION
SURVEILLANCE REQUIREMENTS

Instrument	Channel Check	Source Check	Channel Calibration	Channel Functional Test
1. REACTOR BUILDING VENTILATION EFFLUENT MONITORING SYSTEM				
a. DELETED				
b. Particulate Sampler Filter	N/A	N/A	N/A	N/A
c. Effluent System Flow Rate Measuring Device	Daily(1)	N/A	Once per 24 months	Quarterly
d. Sampler Flow Rate Measuring Device	Daily(1)	N/A	Once per 24 months	Quarterly

(1) During releases via this pathway.

3/4.2 RADIOACTIVE LIQUID EFFLUENTS

3/4.2.1 Liquid Effluents Concentration

CONTROLS

3.2.1 The concentration of radioactive material released in liquid effluents to areas at and beyond the SITE BOUNDARY shall be limited to ten times the concentration values specified in Appendix B, Table 2, Column 2, to 10 CFR 20.1001-20.2402.

APPLICABILITY: At all times.

ACTION:

With the concentration of radioactive material released from the site to areas at and beyond the SITE BOUNDARY exceeding the above limits, without delay restore concentration within the above limits.

SURVEILLANCE REQUIREMENTS

4.2.1.a The radioactivity content of each batch of radioactive liquid waste to be discharged shall be determined prior to release by sampling and analysis in accordance with Table 4.2-1.

4.2.1.b The results of pre-release analyses shall be used with calculational methods in the Offsite Dose Calculation Manual (ODCM) to assure that the concentration at the point of release is limited to the values in Control 3.2.1.

BASES

3/4.2.1 Liquid Effluents Concentration

This control is provided to ensure that the concentration of radioactive materials released in liquid waste effluents to areas at and beyond the SITE BOUNDARY will be less than ten times the concentration values specified in Appendix B, Table 2, Column 2, to 10 CFR 20.1001-20.2402. This limitation provides additional assurance that the levels of radioactive materials in bodies of water at and beyond the SITE BOUNDARY will result in exposures within (1) the Section II.A design objectives of Appendix I, 10CFR50, to a MEMBER OF THE PUBLIC and (2) restrictions authorized by 10 CFR 20.1301(e).

TABLE 4.2-1

RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

Liquid Release Type	Sampling Frequency	Minimum Analysis Frequency	Type of Activity Analysis	Lower Limit of Detection(1) μCi/mL
1. Batch Waste Release Tanks(2) a. Non-treatable Releases (e.g., Neutralizer Sumps), AND b. Treatable Releases (e.g., Radwaste Tanks, Torus as TWT) c. Construction Dewatering	Each Batch	Prior to Each Batch Release	Principal Gamma Emitters(3)	5E-07
	Composite from Each Batch	Monthly Composite(4)	H-3	1E-05
			Gross Alpha	1E-07
		Quarterly Composite(4)	Sr-90	5E-08
			Fe-55	1E-06
2. Continuous Releases a. Salt Service Water	Weekly Grab Sample	Weekly	Principal Gamma Emitters(3)	5E-07
3. Continuous Releases(5) a. Torus as TWT b. Construction Dewatering				

(1) Refer to Appendix B of the ODCM for definition of lower limit of detection (LLD).

(2) A batch release is the discharge of liquid wastes of a discrete volume.

(3) The principal gamma emitters for which the LLD control applies exclusively are the following radionuclides: Mn-54, Fe-59, Co-58, Co-60, Zn-65, Cs-134, Cs-137, and Ce-144. This list does not mean that only these nuclides are to be considered. Other gamma peaks that are identifiable, together with those of the above nuclides, shall be analyzed and reported in the Annual Radioactive Effluent Release Report.

(4) A composite sample is one in which the quantity of liquid sampled is proportional to the quantity of liquid waste discharged and in which the method of sampling employed results in a specimen which is representative of the liquids released.

(5) For Torus as a TWT, recirculation, sampling and analysis of tank prior to discharge, with a subsequent grab on each day shift past the first day to be composited for offsite analyses, or a composite sampler in lieu of this. Construction Dewatering is identical for each day the discharge continues past day one. On day one, three grabs are taken from different locations in the volume to assure a representative sample, followed by one grab sample per day until the release is terminated.

3/4.2 RADIOACTIVE LIQUID EFFLUENTS

3/4.2.2 Dose - Liquids

CONTROLS

3.2.2 The dose or dose commitment to a MEMBER OF THE PUBLIC from radioactive materials in liquid effluents released at and beyond the SITE BOUNDARY shall be limited:

a. During any calendar quarter to ≤ 1.5 mrem to the total body and to ≤ 5 mrem to any organ; and,

b. During any calendar year to ≤ 3 mrem to the total body and to ≤ 10 mrem to any organ.

APPLICABILITY: At all times

ACTION:

With the calculated dose from the release of radioactive materials in liquid effluents exceeding any of the above limits, prepare and submit to the Commission within 30 days, a special report that identifies the cause(s), corrective actions taken, and corrective actions to be taken.

SURVEILLANCE REQUIREMENTS

4.2.2 Dose Calculations - Cumulative dose contributions from liquid effluents shall be determined in accordance with the ODCM for each calendar month during which releases occurred.

BASES

3/4.2.2 Dose - Liquids

This section is provided to implement the requirements of Sections II.A, III.A, and IV.A of 10CFR50, Appendix I, to assure that the releases of radioactive material in liquid effluents will be kept "as low as is reasonably achievable." Because Pilgrim is not a site where plant operations can conceivably affect drinking water, none of these requirements are intended to assure compliance with 40CFR141. The dose calculations in the ODCM implement the requirements of 10CFR50, Appendix I, Section III.A to ensure that the actual exposure of a MEMBER OF THE PUBLIC through appropriate pathways is unlikely to be substantially underestimated. The equations specified in the ODCM for calculating the doses due to the actual release rates of radioactive materials in liquid effluents will be consistent with the methodology provided in Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR50, Appendix I," Revision 1, October 1977 and Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," April 1977. NUREG-0133 provides methods for dose calculations consistent with Regulatory Guides 1.109 and 1.113.

3/4.2 RADIOACTIVE LIQUID EFFLUENTS

3/4.2.3 Liquid Radwaste Treatment

CONTROLS

3.2.3 The liquid radwaste treatment system shall be maintained and used to reduce the radioactive materials in liquid wastes prior to their discharge when the dose due to liquid effluent releases to areas at and beyond the SITE BOUNDARY averaged over a 31-day period would exceed 0.06 mrem to the total body or 0.20 mrem to any organ.

APPLICABILITY: At all times.

ACTION:

With radioactive liquid waste being discharged without treatment and in excess of the above limits, prepare and submit to the Commission within 30 days a special report which includes the following information:

1. Explanation of why liquid radwaste was being discharged without treatment, identification of any inoperable equipment or subsystems, and the reason for the inoperability; and,

2. Action(s) taken to restore the inoperable equipment to OPERABLE status; and,

3. Summary description of action(s) taken to prevent a recurrence.

SURVEILLANCE REQUIREMENTS

4.2.3.a Doses due to liquid releases at and beyond the SITE BOUNDARY shall be calculated at least once per 31-day period in accordance with the ODCM, only if releases in that period have occurred.

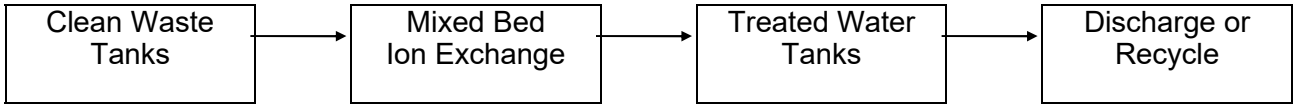
4.2.3.b The liquid radwaste treatment system schematic is shown in Figure 4.2-1.

BASES

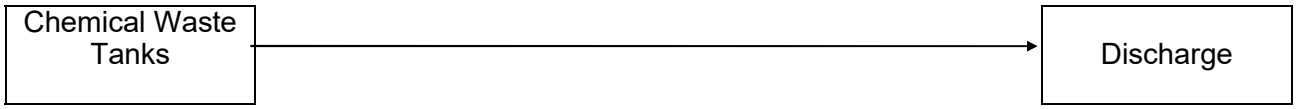
3/4.2.3 Liquid Radwaste Treatment

The requirement that the appropriate portions of this system be used when specified provides assurance that the releases of radioactive materials in liquid effluents will be kept "as low as is reasonably achievable." This control implements the requirements of 10CFR50.36a, General Design Criteria 60 of Appendix A to 10CFR50 and design objective Section II.D of Appendix I to 10CFR50. The specified limits governing the use of appropriate portions of the liquid radwaste treatment system were specified as a suitable fraction of the guide set forth in Section II.A of Appendix I, 10CFR50, for liquid effluents.

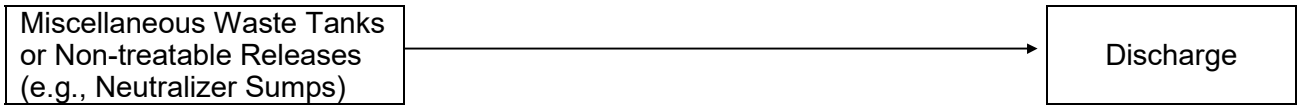
HIGH PURITY WASTE SYSTEM



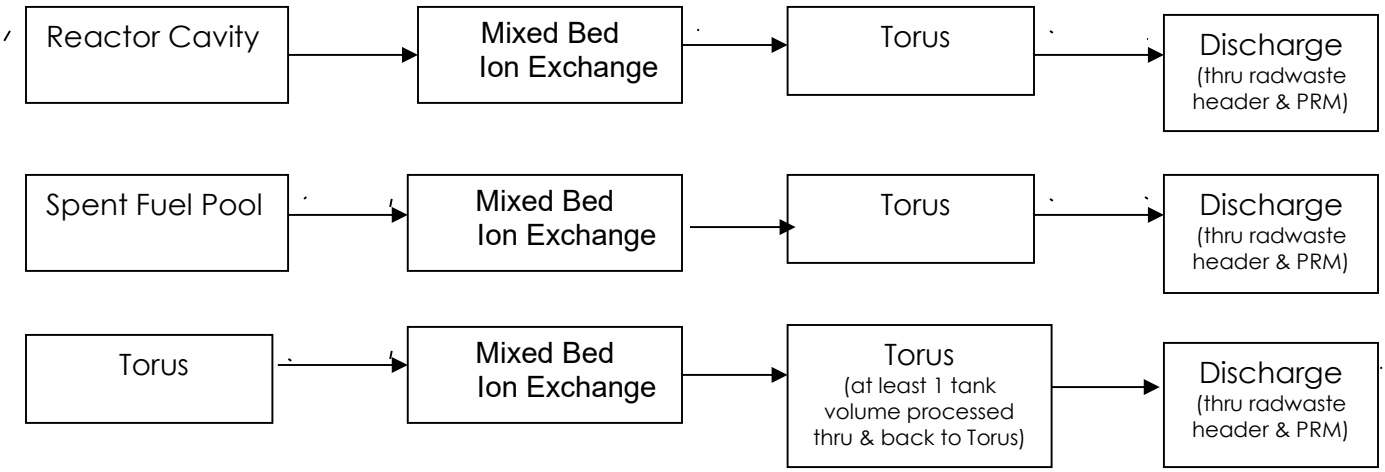
LOW PURITY WASTE SYSTEM



DETERGENT WASTE SYSTEM (Decon Areas)



DECOMMISSIONING WATER PROCESSING – TORUS AS TREATED WATER TANK



CONSTRUCTION DEWATERING (System will be functionally equivalent to depiction below)

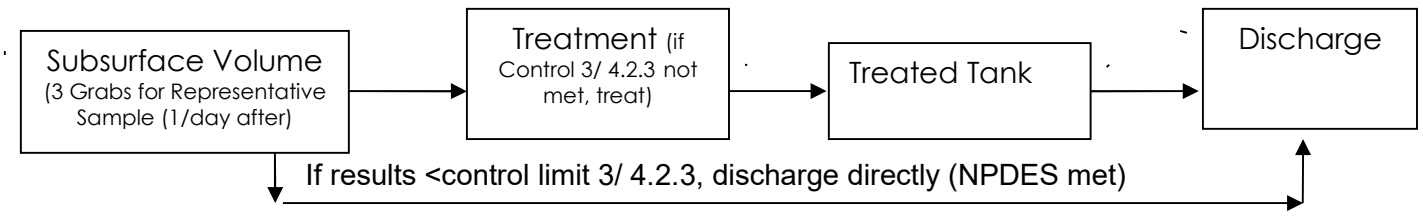


Figure 4.2-1
Liquid Radwaste Treatment System Schematic

3/4.3 RADIOACTIVE GASEOUS EFFLUENTS

3/4.3.1 Gaseous Effluents Dose Rate

CONTROLS

3.3.1 The instantaneous dose rate due to radioactive materials released in gaseous effluents from the site boundary to areas at and beyond the SITE BOUNDARY (see DSAR Figure 1.3-1) shall be limited to the following:

b. For tritium, and all radionuclides in particulate form with half-lives greater than 8 days: Less than or equal to 1500 mrem/yr to any organ.

APPLICABILITY: At all times.

ACTION:

With the instantaneous dose rate(s) exceeding the above limits, without delay restore the release rate to within the above limit(s).

SURVEILLANCE REQUIREMENTS

4.3.1.a DELETED

4.3.1.b The instantaneous dose rate due to tritium, and all radionuclides in particulate form with half-lives greater than 8 days in gaseous effluents shall be determined to be within the limits of Control 3.3.1.b in accordance with the ODCM by obtaining representative samples (or estimating evaporative tritium releases - see reference 31) and performing analyses in accordance with the sampling and analysis program specified in Table 4.3-1.

BASES

3/4.3.1 Gaseous Effluents Dose Rate

This control is provided to ensure that the dose rate at anytime at and beyond the SITE BOUNDARY from gaseous effluents from all units on the site will be within the annual dose limits of 10CFR20. The annual dose limits are the doses associated with the concentration of 10CFR20, Appendix B, Table 2. These limits provide reasonable assurance that radioactive material discharged in gaseous effluents will not result in the exposure of a MEMBER OF THE PUBLIC outside the SITE BOUNDARY to annual average concentrations exceeding the limits specified in Appendix B, Table 2 of 10CFR20.1001-20.2402. For MEMBERS OF THE PUBLIC who may at times be within the SITE BOUNDARY, the occupancy of the individual will usually be sufficiently low to compensate for any increase in the atmospheric diffusion factor above that for the SITE BOUNDARY. The specified release rate limits restrict, at all times, the corresponding gamma and beta dose rates above background to a MEMBERS OF THE PUBLIC at or beyond the SITE BOUNDARY to $\leq$ 500 mrem/year to the total body or to $\leq$ 3000 mrem/year to the skin. These release rate limits also restrict, at all times, the corresponding thyroid dose rate above background to an infant via the cow-milk-infant pathway to $\leq$ 1500 mrem/year for the nearest cow to the plant.

TABLE 4.3-1

RADIOACTIVE GASEOUS WASTE SAMPLING AND ANALYSIS PROGRAM

Gaseous Release Type	Sampling Frequency	Minimum Analysis Frequency	Type of Activity Analysis	Lower Limit of Detection(1) μCi/mL
Reactor Building Vent	Monthly Grab Sample or Estimate	Monthly	H-3(5)	1E-06
	Continuous(3)	Weekly(4) Particulate Sample	Principal Gamma Emitters(2)	1E-11
	Continuous(3)	Monthly Composite Particulate Sample	Gross Alpha	1E-11
	Continuous(3)	Quarterly Composite Particulate Sample	Sr-89, Sr-90	1E-11

(1) Refer to Appendix B of the ODCM for definition of lower limit of detection (LLD).

(2) The principal gamma emitters for which the LLD control applies are the following radionuclides: Mn-54, Fe-59, Co-60, Zn-65, Cs-134, Cs-137, and Ce-144 in particulate releases. This list does not mean that only these nuclides are to be considered. Other gamma peaks that are identifiable, together with those of the above nuclides, shall be analyzed and reported in the Annual Radioactive Effluent Release Report.

(3) The ratio of the sample flow rate to the sampled stream flow rate shall be known for the time period covered by each dose or dose rate calculation made in accordance with Controls 3.3.1, 3.3.2, and 3.3.3.

(4) Samples shall be changed at least once per 7 days and analyses shall be completed within 48 hours after changing, or after removal from the sampler.

(5) Tritium is and has historically been sampled by collection of condensate in a cold trap from RBV sample stream flowing through it. As the only remaining source of gaseous tritium in effluent is from evaporation of Spent Fuel Pool Water and that from the Cavity, tritium releases may also be estimated by calculating the evaporative release rates correlated to the SFP and Cavity concentrations. Reference 31 provides the bases and method for accomplishing this.

3/4.3 RADIOACTIVE GASEOUS EFFLUENTS

3/4.3.2 DELETED

CONTROLS

3.3.2 DELETED

3/4.3 RADIOACTIVE GASEOUS EFFLUENTS

3/4.3.3 Dose - Radioactive Material in Particulate Form, and Tritium

CONTROLS

3.3.3 The dose to a MEMBER OF THE PUBLIC from radioactive materials in particulate form with half-lives greater than 8 days, and tritium in gaseous effluents released to areas at and beyond the SITE BOUNDARY shall be limited to the following:

a. During any calendar quarter to $\leq$ 7.5 mrem to any organ; and,

b. During any calendar year to $\leq$ 15 mrem to any organ.

APPLICABILITY: At all times

ACTION:

With the calculated dose from the release of radioactive materials in particulate form, and tritium in gaseous effluents exceeding any of the above limits; prepare and submit to the Commission within 30 days, a special report which identifies the cause(s), corrective actions taken, and the corrective actions to be taken.

SURVEILLANCE REQUIREMENTS

4.3.3 Dose Calculations - Cumulative dose contributions for the total time period shall be determined radioactive material in particulate form with half-lives greater than 8 days, and tritium in accordance with the ODCM for each calendar month during which releases occurred.

BASES

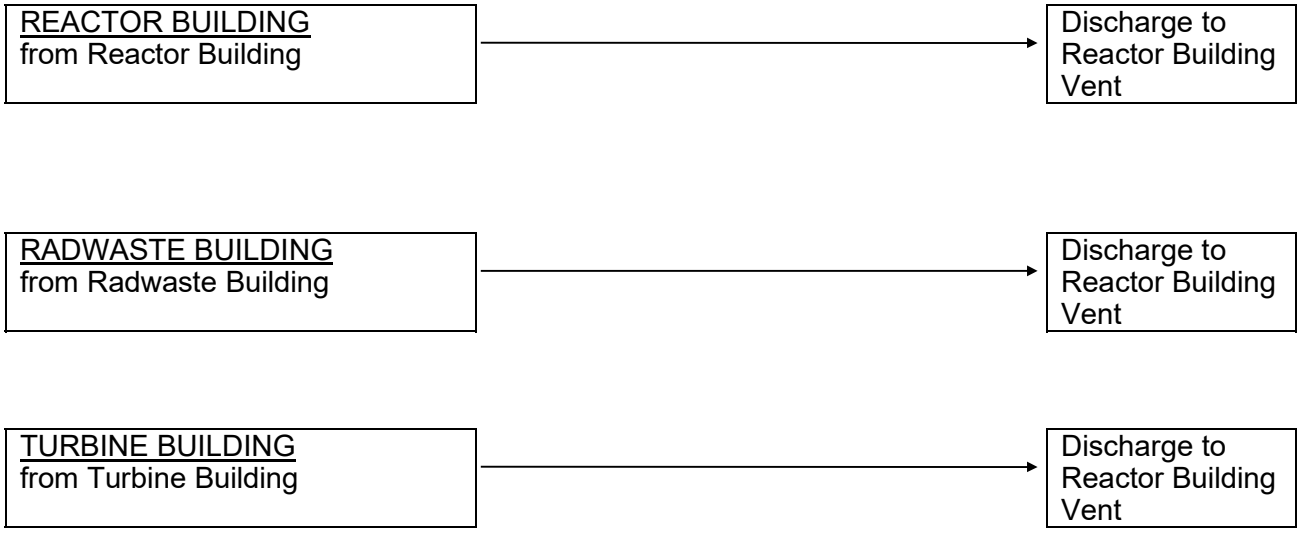
3/4.3.3 Dose - Radioactive Material In Particulate Form, And Tritium

This section is provided to implement the requirements of Sections II.C, III.A and IV.A of 10CFR50, Appendix I, to assure that the releases of radioactive materials in gaseous effluents will be kept "as low as is reasonably achievable." The ODCM calculational methods specified in the surveillance requirements implement the requirements of 10CFR50, Appendix I, Section III.A to ensure that the actual exposure of a MEMBER OF THE PUBLIC through appropriate pathways is unlikely to be substantially underestimated. The ODCM calculational methods approved by the NRC for calculating the doses due to the actual release rates of the subject materials are required to be consistent with the methodology provided in Regulatory Guides 1.109 and 1.111. These equations also provide for determining the actual doses based upon the historical average atmospheric conditions. The release rate specifications for radioactive material in particulate form with half-lives greater than 8 days are dependent on the existing radionuclide pathways to man, in areas at and beyond the SITE BOUNDARY. The pathways which are examined in the development of these calculations are: 1) individual inhalation of airborne radionuclides, 2) deposition of radionuclides onto green leafy vegetation with subsequent consumption by man, and 3) deposition on the ground with subsequent exposure of man.

3/4.3 RADIOACTIVE GASEOUS EFFLUENTS

3/4.3.4 DELETED

Figure 4.3-1
Gaseous Effluent System Flow Schematic



3/4.4 TOTAL DOSE

3/4.4.1 Total Dose

CONTROLS

3.4.1 The dose or dose commitment to any MEMBER OF THE PUBLIC beyond the SITE BOUNDARY from Pilgrim Station sources is limited to ≤ 25 mrem to the total body or any organ (except the thyroid, which is limited to ≤ 75 mrem) over a period of any calendar year.

APPLICABILITY: At all times

ACTION:

With the calculated dose from the release of radioactive materials in liquid or gaseous effluents exceeding twice the limits of Controls 3.2.2, 3.3.2 or 3.3.3; prepare and submit a special report to the Commission and limit the subsequent releases such that the dose or dose commitment to any MEMBER OF THE PUBLIC beyond the SITE BOUNDARY from all uranium fuel cycle sources is limited to ≤ 25 mrem to the total body or any organ (except thyroid, which is limited to ≤ 75 mrem) over any calendar year. This special report shall include an analysis which demonstrates that radiation exposures to all members of the public from all uranium fuel cycle sources (including all effluent pathways and direct radiation) are less than the 40CFR190 standard. Otherwise, obtain a variance from the Commission to permit releases which exceed the 40CFR190 standard.

SURVEILLANCE REQUIREMENTS

4.4.1 Dose Calculations - Cumulative dose contributions from liquid and gaseous effluents shall be determined in accordance with Controls 3.2.2, 3.3.2, and 3.3.3; and in accordance with the ODCM.

BASES

3/4.4.1 Total Dose

This section is provided to meet the dose limitations of 40CFR190 that have now been incorporated into 10CFR20 by 46FR18525. The control requires the preparation and submittal of a special report whenever the calculated doses from plant radioactive effluents exceed twice the design objective doses of 10CFR50, Appendix I. For sites containing up to 4 reactors, it is highly unlikely that the resultant dose to a MEMBER OF THE PUBLIC beyond the SITE BOUNDARY will exceed the dose limits of 40CFR190 if the individual reactors remain within the reporting requirement level. The special report will describe a course of action that should result in the limitation of the annual dose to a MEMBER OF THE PUBLIC beyond the SITE BOUNDARY to within the 40CFR190 limits. For the purposes of the special report, it may be assumed that the dose commitment to the MEMBER OF THE PUBLIC beyond the SITE BOUNDARY from other uranium fuel cycle sources is negligible, except dose contributions from other nuclear fuel cycle facilities at the same site or within a radius of 8 km must be considered. If the dose to any MEMBER OF THE PUBLIC beyond the SITE BOUNDARY is estimated to exceed the limits of 40CFR190, a request for a variance in a special report in accordance with 40CFR190.11 and 10CFR20.2203(a)(4) is considered to be a timely request and fulfills the requirements of 40CFR190 until NRC staff action is completed. This is provided that the release conditions resulting in violation of 40CFR190 have not already been corrected. The variance only relates to the limits of 40CFR190, and does not apply in any way to the other requirements for dose limitation of 10CFR20. An individual is not considered a MEMBER OF THE PUBLIC during any period in which he/she is engaged in any operation that is part of the nuclear fuel cycle.

3/4.5 RADIOLOGICAL ENVIRONMENTAL MONITORING

3/4.5.1 Environmental Monitoring Program

CONTROLS

3.5.1 An environmental monitoring program shall be conducted to evaluate the effects of station operation on the environs and to verify the effectiveness of the source controls on radioactive materials

The radiological environmental monitoring program shall be conducted as specified in Tables 3.5-1 through 3.5-3.

APPLICABILITY: At all times.

ACTION:

a. With the radiological environmental monitoring program not being conducted as specified in Tables 3.5-1 through 3.5-3, prepare and submit to the Commission, in the Annual Radiological Environmental Monitoring Report required by Technical Specifications Administrative Control 5.6.2, a description of the reasons for not conducting the program as required and the plans for preventing a recurrence.

b. With the level of radioactivity as the result of plant effluents in an environmental sampling medium at a specified location exceeding the reporting levels of Table 3.5-4 when averaged over any calendar quarter, prepare and submit to the Commission within 30 days, a special report that identifies the cause(s) for exceeding the limit(s) and defines the corrective actions to be taken to reduce radioactive effluents so that the potential annual dose to a MEMBER OF THE PUBLIC is less than the calendar year limits of Controls 3.2.2, 3.3.2, or 3.3.3. When more than one of the radionuclides in Table 3.5-4 are detected in the sampling medium, this report shall be submitted if:

$$\frac{\text{Concentration (1)}}{\text{Reporting Level (1)}} + \frac{\text{Concentration (2)}}{\text{Reporting Level (2)}} + \ldots\ldots \geq 1.0$$

When radionuclides other than those in Table 3.5-4 are detected and are the result of plant effluents, this report shall be submitted if the potential annual dose to a MEMBER OF THE PUBLIC is equal to or greater than the calendar year limits of Controls 3.2.2, 3.3.2, or 3.3.3. This report is not required if the measured level of radioactivity was not the result of plant effluents; however, in such an event, the condition shall be reported and described in the Annual Radiological Environmental Monitoring Report.

3/4.5 RADIOLOGICAL ENVIRONMENTAL MONITORING

3/4.5.1 Environmental Monitoring Program (Continued)

CONTROLS

ACTION: (continued)

c. DELETED

SURVEILLANCE REQUIREMENTS

4.5.1 The radiological environmental monitoring samples shall be collected pursuant to Tables 3.5-1 through 3.5-3 in the Offsite Dose Calculation Manual (ODCM) and shall be analyzed pursuant to the requirements of Table 3.5-1 and the detection capabilities required by Table 4.5-1.

1. Cumulative dose contributions from the current calendar year from radionuclides detected in environmental samples shall be determined in accordance with the methodology and parameters in the ODCM. These results will be reported in the Annual Radiological Environmental Monitoring Report.

BASES

3/4.5.1 Environmental Monitoring Program

An environmental radiological monitoring program is conducted to verify the adequacy of in-plant controls on the release of radioactive materials. The program is designed to detect radioactivity concentrations to ensure that radiation doses to individuals do not exceed the levels set forth in 10CFR50, Appendix I.

Groundwater flow at the plant site is into Cape Cod Bay; therefore, terrestrial monitoring of groundwater is not included in this program.

Detection capabilities for environmental sample analyses are tabulated in terms of the lower limits of detection (LLD). The LLD in Table 4.5-1 is considered optimum for routine environmental measurements in industrial laboratories. It should be recognized that the LLD is defined as an *a priori* (before the fact) limit representing the capability of a measurement system and not as an *a posteriori* (after the fact) limit for a particular measurement.

Detailed discussion of the LLD, and other detection limits can be found in HASL Procedures Manual, HASL-300 (revised annually); Currie, L.A., "Limits for Qualitative Detection and Quantitative Determination - Application to Radiochemistry", Anal. Chem. 40, 586-93 (1968); and Hartwell, J.K., "Detection Limits for Radioanalytical Counting Techniques," Atlantic Richfield Hanford Company Report ARH-SA-215 (June 1975).

TABLE 3.5-1

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Exposure Pathway, Sample, or Measurement Type	**Sampling, Measurement, and/or Collection Locations(1)**	**Sampling, Measurement, and/or Collection Frequency**	**Type and Frequency of Analysis or Measurement**
DIRECT RADIATION			
Environmental TLD	44 Locations, See Table 3.5-2	Quarterly Collection	Gamma exposure (2); Quarterly
AIRBORNE			
Particulates	6 Locations, See Table 3.5-3	Continuous sampling with particulate filter; Weekly Collection	Gross beta radioactivity analysis 24 hours or more after weekly filter change (3); Weekly AND Gamma isotopic (4) of composite by location; Quarterly

TABLE 3.5-1 (continued)

OPERATIONAL RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Exposure Pathway, Sample, or Measurement Type	Sampling, Measurement, and/or Collection Locations[1]	Sampling, Measurement, and/or Collection Frequency	Type and Frequency of Analysis or Measurement
MARINE/AQUATIC			
Surface Water [7]	Discharge Canal, --- Powder Point Control [5]	Continuous Composite Sample --- Weekly grab sample	Gamma isotopic [4], analysis of monthly composite samples; AND H-3 analysis of quarterly composite samples
Sediment	Discharge Canal Outfall, Manomet Point, Plymouth Beach, Plymouth Harbor, Green Harbor Control [5]	Semiannual Collection	Gamma isotopic analysis [4]
Mussels	Discharge Canal Outfall, Plymouth Harbor, Green Harbor Control (5)	Semiannual Collection	Gamma isotopic analysis [4] on edible portions
Soft-shelled clams	Plymouth Harbor, Duxbury Bay Control [5]	Semiannual Collection	Gamma isotopic analysis [4] on edible portions
Lobster	Discharge Canal Outfall --- Offshore Control	Four times per season, from May through October --- Once per season	Gamma isotopic analysis [4] on edible portions
Fishes	Discharge Canal Outfall --- Offshore Control [3]	Semiannual for Group I[7]; annually in season for Groups II, III, and IV [7] --- Annually for each group [7];	Gamma isotopic analysis on edible portions

TABLE 3.5-1 (continued)

NOTES

(1) Specific parameters of distance and direction sector from centerline of the reactor, and additional description where pertinent, are provided for each sample location in Table 3.5-1 in a subsequent tables and figures in the ODCM. Deviations are permitted from the required sampling schedule if samples are unobtainable due to circumstances such as hazardous conditions, extreme inclement weather, seasonable unavailability, and malfunction of automatic sampling equipment. If samples are unobtainable due to sampling equipment malfunction, efforts shall be made to complete corrective action prior to the end of the next sampling period. All deviations from the sampling schedule shall be documented in the Annual Radiological Environmental Operating Report pursuant to PNPS Technical Specification Administrative Control 5.6.2. It is recognized that, at times, it may not be possible or practicable to continue to obtain samples of the media of choice at the most desired location or time. In these instances suitable alternative media and locations may be chosen for the particular pathway in question and appropriate substitutions made within 30 days in the Radiological Environmental Monitoring Program outlined in ODCM Table 3.5-1 and subsequent tables. Pursuant to PNPS Technical Specification Administrative Control 5.5.1, submit in the next Annual Radioactive Effluent Release Report documentation for a change in the ODCM including revised figure(s) and table(s) for the ODCM reflecting the new location(s) with supporting information identifying the cause of the unavailability of samples for the pathway and justifying the selection of the new location(s) for obtaining samples.

(2) Minimum sensitivity for TLD exposure measurements is 1 μR/hr, or 2.19 mR/standard quarter.

(3) Airborne particulate sample filters shall be analyzed for gross beta radioactivity 24 hours or more after sampling to allow of radon and thoron daughter decay. If gross beta activity in air particulate samples is greater than 10 times the yearly mean of control samples, gamma isotopic analysis shall be performed on the individual samples.

(4) Gamma isotopic analysis means the identification and quantification of gamma-emitting radionuclides that may be attributable to the effluents from the facility.

(5) DELETED

(6) Indicates control location.

(6) Groundwater flow at the plant site is into Cape Cod Bay; therefore, terrestrial monitoring of groundwater and/or drinking water is not included in this program.

(7) Fish analyses will be performed on samples from each of the following groups:

I. Bottom Oriented	II. Near Bottom Distribution	III. Anadromous	IV. Coastal Migratory
Winter Flounder	Tautog	Alewife	Bluefish
Yellowtail Flounder	Cunner	Rainbow Smelt	Atlantic Herring
	Atlantic Cod	Striped Bass	Atlantic Menhaden
	Pollock		Atlantic Mackerel
	Hakes		

TABLE 3.5-2

ENVIRONMENTAL TLD LOCATIONS

TLD Station		Location[1]
Description	Code	Distance/Direction
TLDs Within Protected Area to 3 km		
Within Protected Area FENCE-EXEC.BUILDING	P17	107 m W
FENCE-TCF GATE	P11	183 m ESE
FENCE-TCF/BOAT RAMP	P27	185 m ESE
FENCE-TCF/INTAKE BAY	P10	223 m E
Zone 1 TLDs: 0-3 km		
BOAT LAUNCH WEST	BLW	0.11 km E
OVERLOOK AREA	OA	0.15 km W
HEALTH CLUB	TC	0.15 km WSW
BOAT LAUNCH EAST	BLE	0.16 km ESE
ISFSI DOSE #3	ISF-3	0.21 km W
SHOREFRONT SECURITY	P01	0.22 km NNW
ISFSI DOSE #2	ISF-2	0.29 km W
ISFSI DOSE #1	ISF-1	0.35 km SW
SHOREFRONT PARKING	PA	0.35 km NNW
ISFSI DOSE #4	ISF-4	0.35 km WSW
ISFSI DOSE #5	ISF-5	0.37 km WSW
STATION A	A	0.37 km WSW
ISFSI DOSE #6	ISF-6	0.41 km WSW
STATION B	B	0.44 km S
EAST BREAKWATER	EB	0.44 km ESE
PNPS MET TOWER	PMT	0.44 km WNW
ISFSI DOSE #7	ISF-7	0.45 km W
STATION L	L	0.50 km ESE
STATION G	G	0.53 km W
PROPERTY LINE	PL	0.54 km NNW
HALL'S BOG	HB	0.63 km SE
GREENWOOD HOUSE	GH	0.65 km ESE
W ROCKY HILL ROAD	WR	0.83 km WNW
E ROCKY HILL ROAD	ER	0.89 km SE
CLEFT ROCK	CR	1.27 km SSW
BAYSHORE/GATE RD	BD	1.34 km WNW
EMERSON ROAD	EM	1.53 km SSE
EMERSON/PRISCILLA	EP	1.55 km SE
BAYSHORE	BS	1.76 km W
JOHN GAULEY	JG	1.99 km W
STATION J	J	2.04 km SSE
PLYMOUTH YMCA	RC	2.09 km WSW
TAYLOR/THOMAS	TT	2.26 km SE
YANKEE VILLAGE	YV	2.28 km WSW
GOODWIN PROPERTY	GN	2.38 km SW
RIGHT OF WAY	RW	2.83 km S
TAYLOR/PEARL	TP	2.98 km SE

TLD Station		Location[1]
Description	Code	Distance/Direction
Zone 2 TLDs: 3-8 km		
MANOMET ELEM	ME	3.29 km SE
Zone 4 TLDs: >15 km[2]		
DIV MARINE FISH	DMF	20.97 km SSE
EAST WEYMOUTH SUBST	EW	39.69 km NW

(1) Distance and direction are measured from the centerline of the Reactor Building to the monitoring location.
(2) Indicates control locations.

TABLE 3.5-3

ROUTINE RADIOLOGICAL ENVIRONMENTAL SAMPLING LOCATIONS

Description	No.	Code	Distance	Direction
Air Particulate Filters				
Pedestrian Bridge	07	PB	0.2 km	N
East Breakwater	09	EB	0.5 km	ESE
Property Line	06	PL	0.5 km	NNW
East Rocky Hill Road	01	ER	0.9 km	SE
Cleft Rock	10	CR	1.3 km	SSW
East Weymouth Control	21	EW	40 km	NW
Surface Water				
Discharge Canal	11	DIS	0.2 km	N
Powder Point Control	23	PP	13 km	NNW
Sediment				
Discharge Canal Outfall	11	DIS	0.8 km	NE
Manomet Point	15	MP	3.3 km	ESE
Plymouth Beach	14	PLB	4.0 km	WNW
Plymouth Harbor	12	Ply-H	4.1 km	W
Green Harbor Control	24	GH	16 km	NNW
Mussels				
Discharge Canal Outfall	11	DIS	0.7 km	NNE
Plymouth Harbor	12	Ply-H	4.1 km	W
Green Harbor Control	24	GH	16 km	NNW
Soft-shelled Clams				
Plymouth Harbor	12	Ply-H	4.1 km	W
Duxbury Bay Control	13	Dux-Bay	13 km	NNW
Lobster				
Discharge Canal Outfall	11	DIS	0.5 km	N
Duxbury Bay Control	13	Dux-Bay	11 km	NNW
Fishes				
Discharge Canal Outfall	11	DIS	0.5 km	N
Cape Cod Bay Control	98	CC-Bay	24 km	ESE
Buzzard’s Bay Control	90	BB	40 km	SSW
Vineyard Sound Control	92	MV	64 km	SSW

Figure 3.5-1
Environmental TLD Locations Within the PNPS Protected Area

TLD Station		Location*
Description	Code	Distance/Direction
TLDs Within Protected Area		
FENCE-EXEC.BUILDING	P17	107 m W
FENCE-TCF GATE	P11	183 m ESE
FENCE-TCF/BOAT RAMP	P27	185 m ESE
FENCE-TCF/INTAKE BAY	P10	223 m E

* Distance and direction are measured from the centerline of the Reactor Building to the monitoring location.

Figure 3.5-2

TLD and Air Sampling Locations: Within 1 Kilometer

TLD Station		Location*	Air Sampling Station		Location*
Description	Code	Distance/Direction	Description	Code	Distance/Direction
Zone 1 TLDs: 0-3 km					
BOAT LAUNCH WEST	BLW	0.11 km E	PEDESTRIAN BRIDGE	PB	0.21 km N
OVERLOOK AREA	OA	0.15 km W	EAST BREAKWATER	EB	0.44 km ESE
HEALTH CLUB	TC	0.15 km WSW	PROPERTY LINE	PL	0.54 km NNW
BOAT LAUNCH EAST	BLE	0.16 km ESE	E ROCKY HILL ROAD	ER	0.89 km SE
ISFSI DOSE #3	ISF-3	0.21 km W			
SHOREFRONT SECURITY	P01	0.22 km NNW			
ISFSI DOSE #2	ISF-2	0.29 km W			
ISFSI DOSE #1	ISF-1	0.35 km SW			
SHOREFRONT PARKING	PA	0.35 km NNW			
ISFSI DOSE #4	ISF-4	0.35 km WSW			
ISFSI DOSE #5	ISF-5	0.37 km WSW			
STATION A	A	0.37 km WSW			
ISFSI DOSE #6	ISF-6	0.41 km WSW			
STATION B	B	0.44 km S			
EAST BREAKWATER	EB	0.44 km ESE			
PNPS MET TOWER	PMT	0.44 km WNW			
ISFSI DOSE #7	ISF-7	0.45 km W			
STATION L	L	0.50 km ESE			
STATION G	G	0.53 km W			
PROPERTY LINE	PL	0.54 km NNW			
HALL'S BOG	HB	0.63 km SE			
GREENWOOD HOUSE	GH	0.65 km ESE			
W ROCKY HILL ROAD	WR	0.83 km WNW			
E ROCKY HILL ROAD	ER	0.89 km SE			

* Distance and direction are measured from the centerline of the Reactor Building to the monitoring location.

Figure 3.5-2 (continued)

TLD and Air Sampling Locations: Within 1 Kilometer

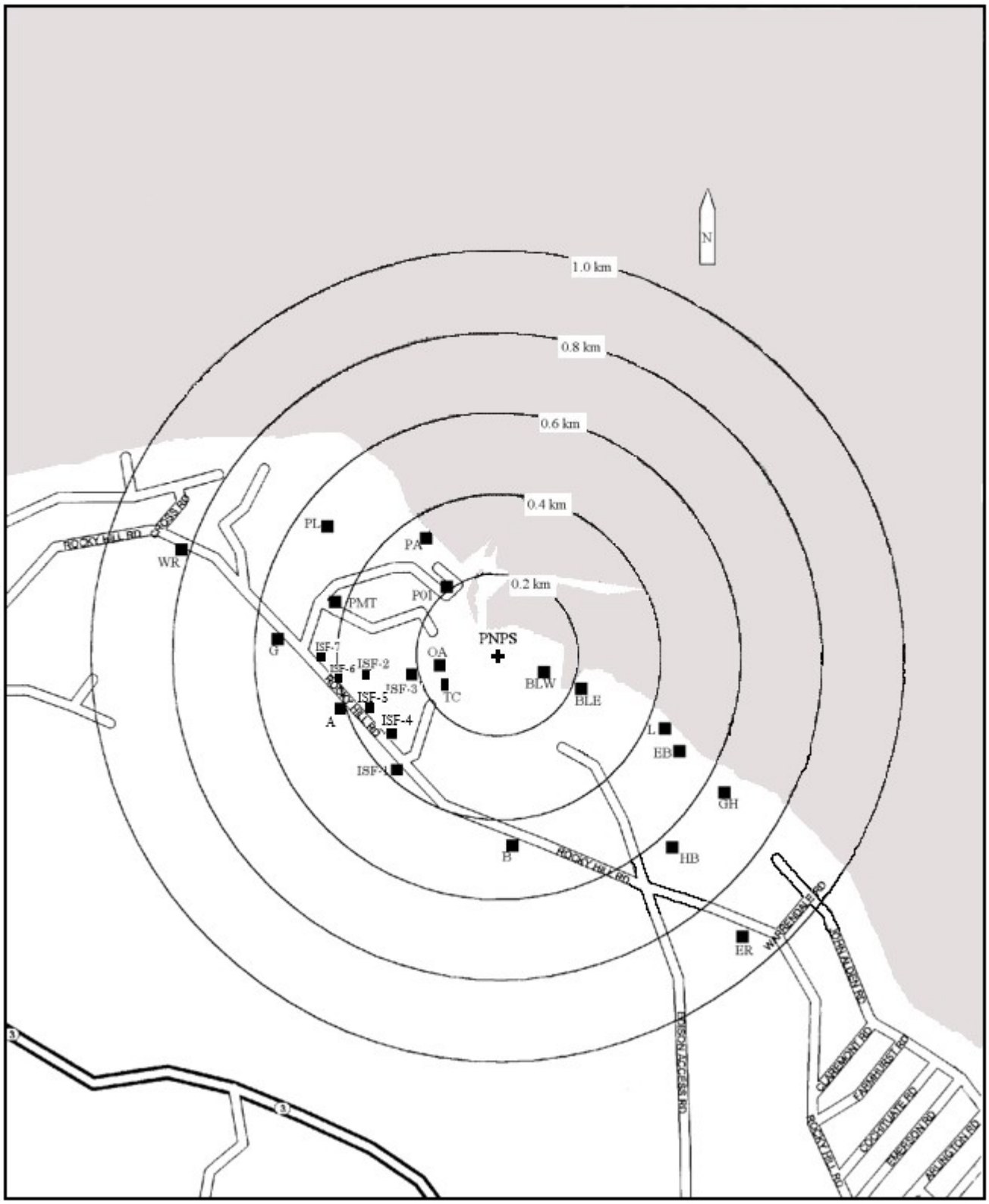


Figure 3.5-3

TLD Locations: 1 to 5 Kilometers

TLD Station		Location*	Air Sampling Station		Location*
Description	Code	Distance/Direction	Description	Code	Distance/Direction
Zone 1 TLDs: 0-3 km			CLEFT ROCK	CR	1.27 km SSW
CLEFT ROCK	CR	1.27 km SSW			
BAYSHORE/GATE RD	BD	1.34 km WNW			
EMERSON ROAD	EM	1.53 km SSE			
EMERSON/PRISCILLA	EP	1.55 km SE			
BAYSHORE	BS	1.76 km W			
JOHN GAULEY	JG	1.99 km W			
STATION J	J	2.04 km SSE			
PLYMOUTH YMCA	RC	2.09 km WSW			
TAYLOR/THOMAS	TT	2.26 km SE			
YANKEE VILLAGE	YV	2.28 km WSW			
GOODWIN PROPERTY	GN	2.38 km SW			
RIGHT OF WAY	RW	2.83 km S			
TAYLOR/PEARL	TP	2.98 km SE			
Zone 2 TLDs: 3-8 km					
MANOMET ELEM	ME	3.29 km SE			

* Distance and direction are measured from the centerline of the Reactor Building to the monitoring location.

Figure 3.5-3 (continued)

TLD and Air Sampling Locations: 1 to 5 Kilometers

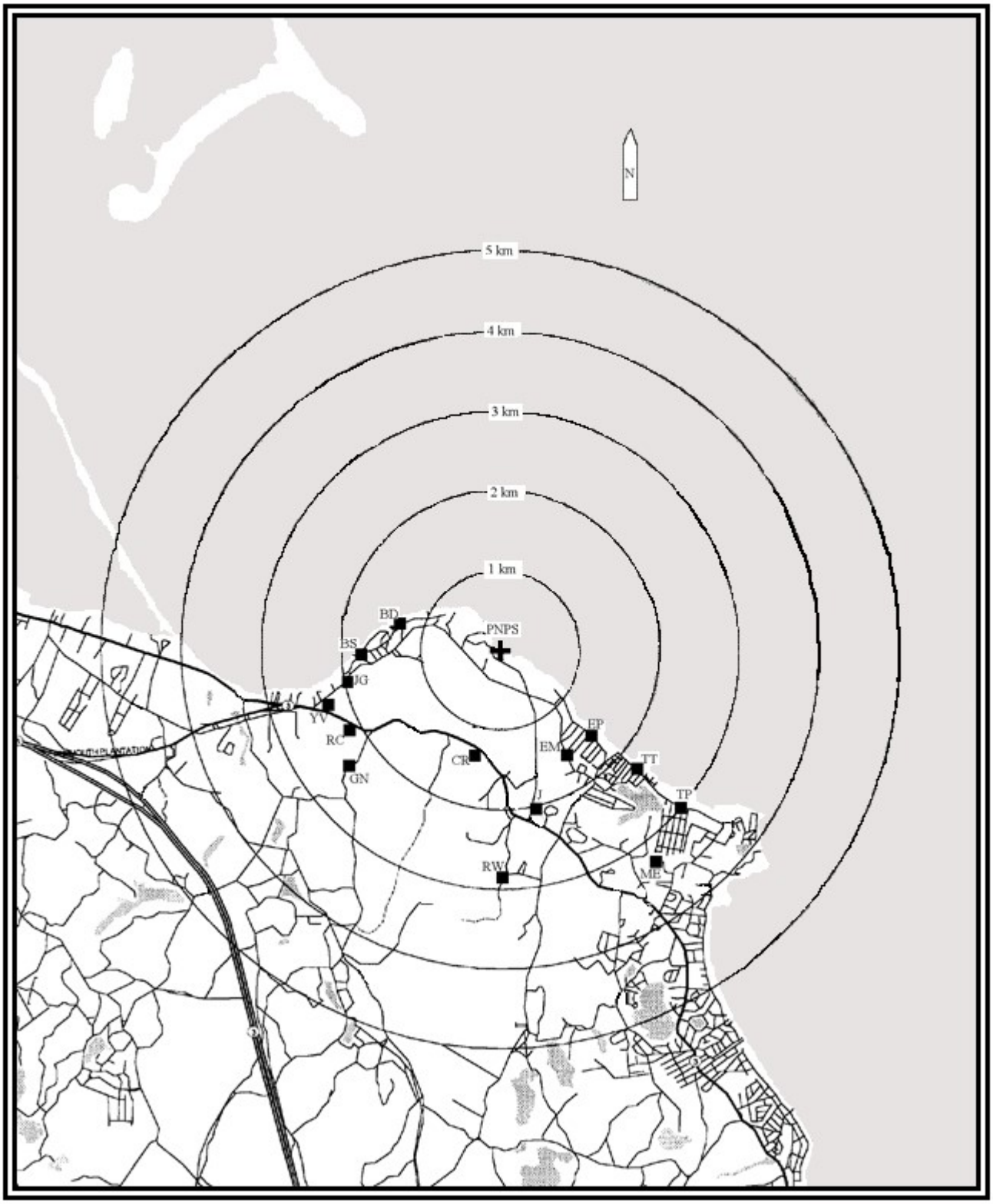


Figure 3.5-4

TLD and Air Sampling Locations: Greater Than 5 Kilometers

TLD Station		Location*	Air Sampling Station		Location*
Description	Code	Distance/Direction	Description	Code	Distance/Direction
Zone 4 TLDs: >15 km			EAST WEYMOUTH SUBST	EW	39.69 km NW
DIV MARINE FISH	DMF	20.97 km SSE			
EAST WEYMOUTH SUBST	EW	39.69 km NW			

* Distance and direction are measured from the centerline of the Reactor Building to the monitoring location.

Figure 3.5-4 (continued)

TLD and Air Sampling Locations: Greater Than 5 Kilometers

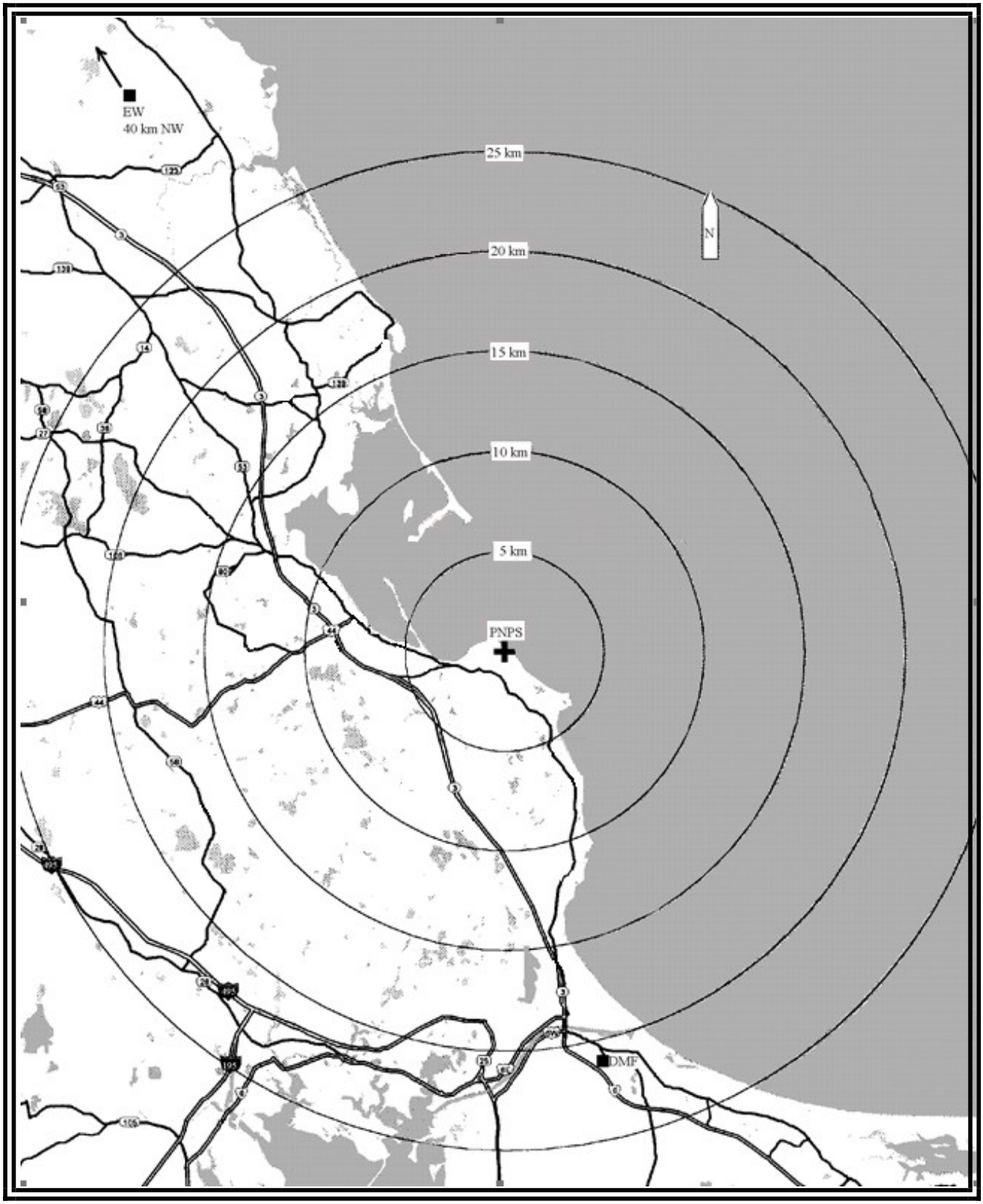


Figure 3.5-5

Marine/Aquatic Sampling Locations

Description	Code	Distance/Direction*
SURFACE WATER		
Discharge Canal	DIS	0.2 km N
Powder Point Control	PP	13 km NNW
SEDIMENT		
Discharge Canal Outfall	DIS	0.8 km NE
Manomet Point	MP	3.3 km ESE
Plymouth Beach	PLB	4.0 km WNW
Plymouth Harbor	PLY-H	4.1 km W
Green Harbor Control	GH	16 km NNW
MUSSELS		
Discharge Canal Outfall	DIS	0.7 km NNE
Plymouth Harbor	PLY-H	4.1 km W
Green Harbor Control	GH	16 km NNW
SOFT-SHELLED CLAMS		
Plymouth Harbor	PLY-H	4.1 km W
Duxbury Bay Control	DUX-BAY	13 km NNW
LOBSTER		
Discharge Canal Outfall	DIS	0.5 km N
Duxbury Bay Control	DUX-BAY	11 km NNW
FISHES		
Discharge Canal Outfall	DIS	0.5 km N
Cape Cod Bay Control	CC-BAY	24 km ESE
Buzzards Bay Control	BB	40 km SSW
Vineyard Sound Control	MV	64 km SSW

* Distance and direction are measured from the centerline of the Reactor Building to the sampling/monitoring location.

Figure 3.5-5 (continued)

Marine/Aquatic Sampling Locations

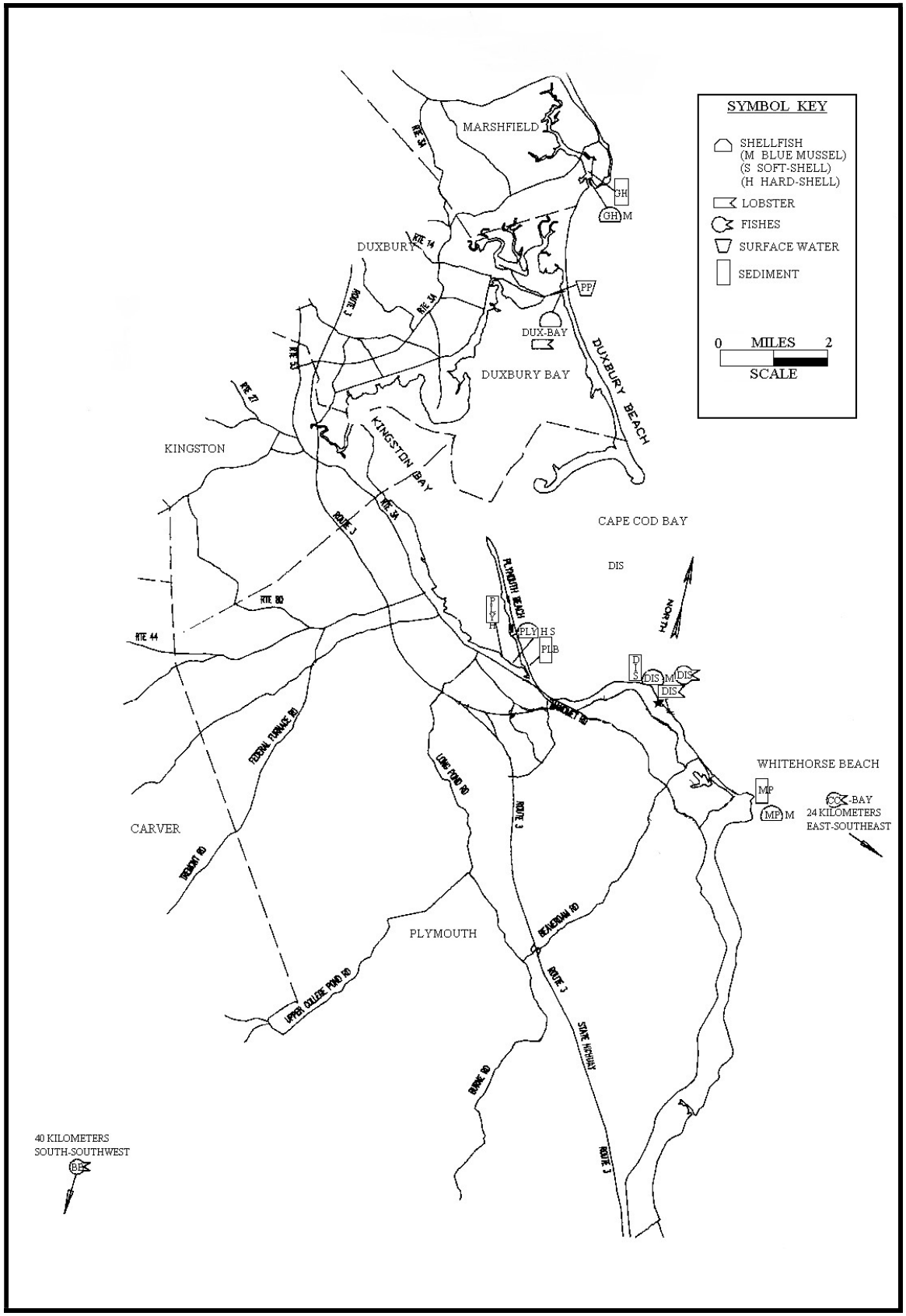


Figure 3.5-6

Environmental Sampling And Measurement Control Locations

Description	Code	Distance/Direction*	Description	Code	Distance/Direction*
TLD (Controls)			SURFACE WATER		
Div. Marine Fisheries	DMF	21 km SSE	Powder Point Control	PP	13 km NNW
East Weymouth Substation	EW	40 km NW			
			SEDIMENT		
AIR SAMPLING (Control)			Green Harbor Control	GH	16 km NNW
East Weymouth Substation	EW	40 km NW			
			MUSSELS		
			Green Harbor Control	GH	16 km NNW
			SOFT-SHELLED CLAMS		
			Duxbury Bay Control	DUX-BAY	13 km NNW
			LOBSTER		
			Duxbury Bay Control	DUX-BAY	11 km NNW
			FISHES		
			Cape Cod Bay Control	CC-BAY	24 km ESE
			Buzzards Bay Control	BB	40 km SSW
			Vineyard Sound Control	MV	64 km SSW

* Distance and direction are measured from the centerline of the Reactor Building to the sampling/monitoring location.

Figure 3.5-6 (continued)

Environmental Sampling And Measurement Control Locations

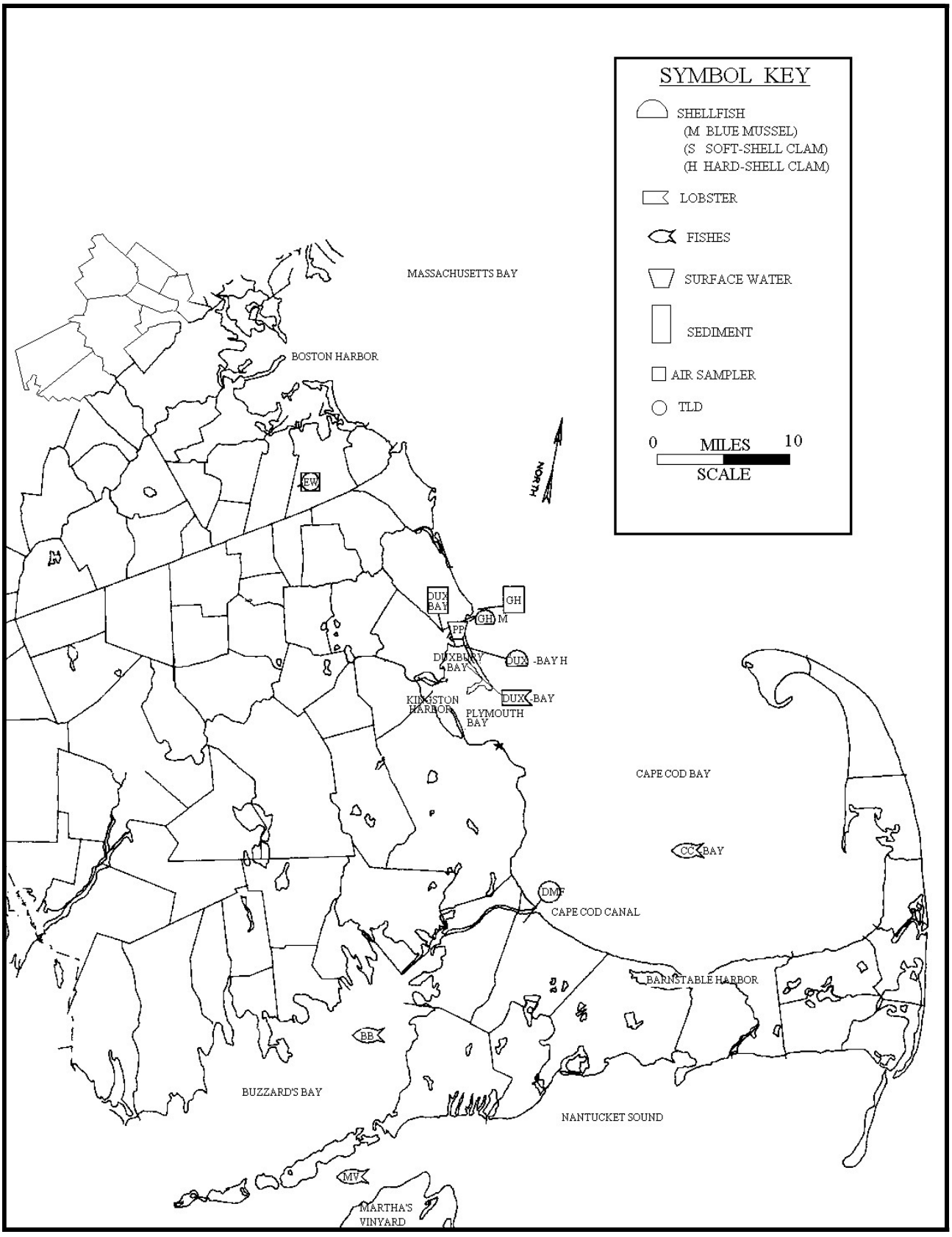


TABLE 3.5-4

REPORTING LEVELS FOR RADIOACTIVITY CONCENTRATIONS
IN ENVIRONMENTAL SAMPLES

Analysis	Water pCi/L	Airborne Particulate or Gases pCi/m^3	Fish pCi/kg, wet	Food Products pCi/kg, wet
H-3	30,000 (1)	--	--	--
Mn-54	1,000	--	30,000	--
Co-60	300	--	10,000	--
Zn-65	300	--	20,000	--
Cs-134	30	10	1,000	1,000
Cs-137	50	20	2,000	2,000

(1) Value adjusted for fact that no drinking water pathway exists at Pilgrim Station.

TABLE 4.5-1

DETECTION CAPABILITIES FOR ENVIRONMENTAL SAMPLE ANALYSIS

LOWER LIMIT OF DETECTION (LLD)[1]

Analysis	Surface Water pCi/L	Airborne Particulate or Gases pCi/m^3	Marine and Aquatic Foods pCi/kg,wet	Food Products pCi/kg,wet	Sediment pCi/kg,dry
Gross Beta	--	0.01	--	--	--
H-3	3000 [2]	--	--	--	--
Mn-54	15	--	130	--	--
Co-60	15	--	130	--	--
Zn-65	30	--	260	--	--
Cs-134	15	0.05	130	60	150
Cs-137	18	0.06	150	80	180

[1] Refer to Appendix B of the ODCM for definition of lower limit of detection (LLD).

[2] Value adjusted for fact that no drinking water pathway exists at Pilgrim Station.

3/4.5 RADIOLOGICAL ENVIRONMENTAL MONITORING

3/4.5.2 DELETED

CONTROLS

3.5.2 DELETED

5.0 RADIOLOGICAL EFFLUENT CONTROLS CROSS REFERENCE

Table 5-1 presents a summary of the limits contained in the PNPS Effluent Controls, Sections 3/4.2.1, 3/4.2.2, 3/4.2.3, 3/4.3.1, 3/4.3.3, and 3/4.4.1. This table also presents cross-references to applicable portions of Methodology Section 9.0.

This table is intended to serve as a summary of the PNPS Effluent Controls and does not, in itself, establish limits. The specific effluent controls presented in Section 3/4 should be consulted for exact wording and specifics.

TABLE 5-1

PNPS EFFLUENT CONTROLS AND METHODOLOGY CROSS-REFERENCE

Effluent Control Section	Methodology Section	Applicable Limit or Objective	Exposure Period	Required Action
3/4.2.1 Liquid Effluent Concentration	9.1	10CFR20, App. B, Table 2 Column 2, and	Instantaneous	Restore concentration to within limits
3/4.2.2 Dose- Liquids	9.2	1.5 mrem T.B. 5 mrem Organ ..... 3 mrem T.B. 10 mrem Organ	Calendar Quarter ..... Calendar Year	30-day report if exceeded
3/4.2.3 Liquid Radwaste Treatment	9.2	0.06 mrem T.B. 0.2 mrem Organ	Projected for 31 days	Operate Liquid Waste Treatment System
3/4.3.1 Gaseous Effluents Dose Rate	---------- 9.3.2	..... 1500 mrem/yr Organ from particulates with T½ > 8d. and tritium	Instantaneous	Restore release rates to within specifications
3/4.3.3 Particulates, H-3	9.3.2	7.5 mrem Organ ..... 15 mrem Organ	Calendar Quarter ..... Calendar Year	30-day report if exceeded
3/4.4.1 Total Dose	9.2, 9.3.1, 9.3.2, and 9.4	25 mrem T.B. 25 mrem Organ 75 mrem Thyroid	Calendar Year	30-day report if controls 3/4.2.2, 3/4.3.2, or 3/4.3.3 are exceeded by a factor of 2. Restore dose to public to within the applicable EPA limit(s) or obtain a variance.

NOTE: T.B. means total body.

6.0 DESCRIPTION OF RADWASTE SYSTEMS

6.1 Liquid Radwaste System

Liquid wastes from Pilgrim Station originates from a variety of sources which have a considerable disparity in chemical and radio-chemical composition and concentration (see section 9.2 of Reference 3). Normally these wastes are collected and treated separately. The liquid wastes fall into the following categories:

1) High Purity

2) Low Purity

3) Detergent

High purity clean wastes are typically characterized by having variable solids content, low conductivity, and variable radioactivity. They come from equipment drain sumps, ultrasonic resin cleaner (URC) operation, and the backwash and resin transfer water used to change out the condensate demineralizers. Reuse of processed high-purity waste is highly desirable.

Low purity chemical wastes have moderate conductivity and solids content. They come from building floor sumps and are generally high-purity wastes which have been contaminated by dirt, oil, etc. When processed, this stream may or may not be reused depending on the water balance in the plant and the quality of the product.

Detergent wastes are low radioactivity concentration wastes that have the potential to contain detergents. This waste is generated from washing and decontamination of equipment, the plant, and personnel. This detergent waste is collected in the miscellaneous waste tank and is not treatable. The waste is passed through strainers, prior to discharge through the radwaste discharge header and into the circulating water discharge canal.

A schematic of the system as determined in Reference 4 is shown in Figure 4.2-1, in Section 3/4.2. In the system, the high purity waste is collected in one of two 15,000-gal clean waste tanks. Low purity waste is collected in one of two 15,000 gallon chemical waste tanks. This low purity waste is batched to the clean waste tanks where both types of waste are processed through a mixed bed ion exchange demineralizer and/or reverse osmosis unit. The processed liquid is collected in one of four 18,000 gal treated water holdup tanks. It is reused to the greatest extent possible. In Decommissioning, two of these treated water holdup tanks may be lined up and valved to be recirculated, sampled and over boarded as a single volume of 36,000 gallons.

Additionally, as the last of plant system water is treated in preparation for discharge, the use of the Torus (600,000 gallons) as a large capacity treated water tank provides advantages for processing the current inventory of the Torus, Rx Cavity and Spent Fuel Pool and where these discharges may go longer than one day, will be treated as continuous discharges with composite sampling during discharge or grab samples for compositing at least once every 8 hour day shift.

Construction Dewatering is the voiding of subsurface structures filled with groundwater infiltration, stormwater runoff and/or precipitation when survey gridding, surveys, and/or core samples need to be performed or collected. In most cases, this water will meet all requirements for direct discharge without treatment, but capacity must be available to permit treatment if conditions warrant and must also meet NPDES permit discharge requirements for the relevant outfall.

6.2 DELETED.

7.0 RELEASE POINT AND MONITOR DESCRIPTION

7.1 Radioactive Effluent Release Point Description (Reference 3)

7.1.1 Liquid Radioactive Waste Effluent Release

The liquid radwaste discharge header receives discharge from the chemical radwaste monitor tank pumps, the clean radwaste treated water transfer pumps, and the miscellaneous waste drain tank pump (see Figure 4.2-1). The header provides controlled discharge through either a low flow discharge path or a high flow discharge path. The high flow path is normally used with a variable liquid radwaste effluent flow from 1-200 gpm. The common discharge header extends from both the low and high flow-paths and is monitored for radiation prior to discharge (see Section 7.2.1).

The monitor trips the discharge pumps, closes the flow control valves, and provides an alarm on high radiation. The liquid radwaste effluent is finally discharged to the circulating water discharge canal. Liquid effluent releases enter the Cape Cod Bay at the outfall of the discharge canal which is located about 1100 feet north from the center of the reactor building.

In addition, batch releases from sources other than the radwaste tanks are permitted provided at least two independent samples are analyzed in accordance with PNPS Effluent Control Section 4.1.1.a, an independent verification of the release rate calculations is performed, and an independent verification of the discharge valving is performed. Concentrations released to unrestricted areas must be limited to the values specified in 10CFR20.

All batch releases which are not processed through the liquid radwaste treatment system are also discharged through an outlet to the circulating water discharge canal. These untreated liquid effluent releases also enter the Cape Cod Bay at the outfall of the discharge canal.

7.1.2 DELETED

7.1.3 Reactor Building Exhaust Vent Release

Air from areas containing potential sources of radioactive contamination such as the reactor building, radwaste building basement, and turbine building basement are discharged through the reactor building exhaust vent (see Figure 4.3-1). Normal airflow is routed from lesser to progressively greater areas of radioactive contamination potential prior to final exhaust. The reactor building exhaust vent is continuously monitored by a radiation monitor (see Section 7.2.3).

The operating floor ventilation is normally supplied with 40,000 cfm of filtered and tempered outside air which enters the reactor building through louvers in the east wall. Air is exhausted from the operating floor through ducts located in the roof truss area and the south wall; adjacent to the floor (54,000 cfm per fan). Additional exhaust ducts are located above the water level in the fuel pool, steam dryer/separator storage pool, and the reactor cavity.

Two contaminated area exhaust fans (25,000 cfm per fan), each rated at design capacity, are located in the reactor building. The fans discharge to the main exhaust plenum at the base of the reactor building. An additional smaller exhaust fan (5,000 cfm), located in the reactor building, exhausts only from the control rod drive maintenance shop and discharges to the main exhaust plenum. Constant volume control is maintained by inlet vanes which are automatically positioned.

The reactor building exhaust vent is a square plenum extending from the top of the west corner of the reactor building. The exhaust plenum releases to the atmosphere at an elevation of 182 feet MSL.

7.1.4 DELETED

7.2 Radioactive Effluent Monitoring System Description (References 3, 5, and 6)

7.2.1 Liquid Radioactive Waste Effluent Monitoring System

The liquid radiation waste effluent monitoring system consists of a single channel (see Section 7.12 of Reference 3). This channel includes a scintillation detector, a seven decade logarithmic radiation monitor, and a strip chart recorder. The detector is located in a shielded sampler that is located in a section of the radwaste liquid discharge header to minimize background radiation. The meter and recorder are located in the main control room. This channel is connected to the 24 volt DC power bus.

The channel has an upscale trip to indicate high radiation level and a downscale trip to indicate instrument trouble. The upscale trip alarms in the main control room (see Section 8.1 for liquid effluent monitor setpoints), trips the monitor tank pumps, and terminates the discharge. The downscale trip alarms in the main control room. The waste discharge valve is the isolation control device for the liquid radwaste effluent stream and it is automatically closed when the alarm is tripped. There are two waste discharge valves, one is situated on a two inch line and the other is situated on a one inch line. Both valves are located prior to the radiation waste effluent monitor and prior to the discharge canal. The valves are air operated valves. The waste discharge valves are: AO7216A and SV7216A, which are on the 2 inch line; and AO7216B and SV7216B, on the 1 inch line. The power source is the 24 volt DC power bus.

Alarm trip circuits can be tested using test signals. The channel is calibrated by laboratory analysis of a grab sample from the liquid radwaste system.

7.2.2 DELETED

7.2.3 Reactor Building Exhaust Vent Monitoring System

The reactor building exhaust vent monitoring system consists of two channels (see Section 7.12 of Reference 3). Each channel consists of a gamma-sensitive detector and a seven decade logarithmic count rate monitor that includes a power supply and a meter. Both channels are recorded on a two-pen recorder located in the main control room. Both channels are connected to the 24 volt DC power bus and the AC radiation protection system via a transfer switch to the emergency diesel generators.

Each monitor has two upscale alarms and one downscale alarm. Exceeding a setpoint initiates an alarm in the main control room, but no control action is provided. The upscale alarms indicate high radiation and the downscale alarm indicates instrument trouble.

To monitor particulates the gaseous effluent in the reactor building exhaust vent, a sample is drawn through an isokinetic probe which is located to assure representative sampling. The sample passes through a particulate filter.

The system also provides for sampling of particulates by the use of a filter located upstream of the gas being monitored in the shielded chamber. The filter is routinely analyzed in a chemistry laboratory in accordance with PNPS Effluent Controls.

7.2.4 DELETED

TABLE 7-1

RADIOACTIVE EFFLUENT MONITOR DATA

Item	Liquid Effluent
Manufacturer	GE
Model Number	194X900G9
Serial Number	6,342,995 PPA 6,342,788 PRM
Scale	cps
Range	1E-1 to 1E+6
Power	24 VDC
Location	Panel C910
Installation Date	9/13/71
Surveillance Test a. Daily ..... b. Monthly ..... c. Quarterly	 Channel Check ..... --- ..... Channel Functional Test
Calibration a. Quarterly ..... b. 24-month	 Check Source ..... Known radiation source
Alarm Set Points ..... a. Hi Alarm ..... b. Hi-Hi Alarm	 See Section 8.1
Isolation Control Device	Waste Discharge Valve

7.3 Measurement Method During Release (References 3 and 7)

7.3.1 Liquid Effluent

Prior to the release of any liquid waste, a sample of the release is collected and the specific activity is determined by isotopic analysis. The waste discharge tank is recirculated at least 60 minutes prior to the collection of a sample. The release of any liquid waste is controlled on a mixed effluent concentration limit (ECL) basis, where the sum of the ratios between the isotopic concentration and the ECL is less than one. The specified waste discharge flow rate must be at least 10% less than the maximum waste discharge flow rate which shall not exceed 200 gpm. The discharge of the liquid effluent is made from the liquid radwaste discharge header.

7.3.2 Gaseous Effluent

. Continuous samples are collected from the reactor building vent changed out on routine frequencies. The particulate filters, and condensed water samples (if H-3 gaseous release estimates are not used) are analyzed for isotopic identification and quantification, in accordance with the PNPS Effluent Controls.

7.3.3 Limitations

a. Gaseous Effluent

1) PNPS Effluent Controls for gaseous release values.

b. Liquid Effluent

1) PNPS Effluent Controls for liquid release values.

2) If one pump is used to discharge the liquid waste and fails, the release is immediately discontinued.

3) If the discharge flow rate recorder fails, the release is immediately discontinued.

8.0 MONITOR SET POINTS

Radiation monitors are typically used to measure levels of radioactivity in given process and effluent streams. In the case of effluent monitors, various setpoints can be established to cause an annunciator alarm to sound to warn an operator to take a specific action, or in other cases to cause an automated system to isolate the system to curtail the release of radioactivity from that system.

In most cases, two levels of alarm are established. Typically, the highest level, or 'Hi-Hi' alarm, is established at or below the level that would correspond to exceeding one of the effluent controls in Section 3/4. In the cases of the liquid radwaste effluent monitor such a high level alarm would cause the system to automatically isolate to prevent additional release.

A second level of alert, or 'Hi' alarm, is often set at a lower level to provide early warning of unanticipated elevated levels of radioactivity in the system. This level of alarm is meant to alert the operators of the level of radioactivity, so that evaluations can be performed or additional samples collected to characterize the effluent or process stream. This 'Hi' alarm is typically set at some level that is a fraction of the limit, and is often administratively controlled through procedure guidance.

8.1 Liquid Effluent Monitor

The setpoint for the liquid effluent monitor (see Section 7.2.1) is established as follows:

1) Prior to a liquid batch release, the waste discharge tank is recirculated for at least 60 minutes and a sample is taken.

2) The liquid effluent sample is analyzed (see Section 7.3) to determine the concentrations of each detectable isotope in μCi/mL. (See Appendix B for the definitions of lower limit of detection.)

3) The efficiency (in counts/sec per μCi/mL) of the liquid discharge monitor is calculated based on prior release experience.

4) The setpoint for the liquid effluent monitor is calculated as follows:

   a) Monitor setpoint based on activity concentration

$$c = \frac{C\left(F + f\right)}{f}$$

where:

c = the setpoint of the radioactivity monitor measuring the radioactivity concentration in the effluent line prior to dilution and subsequent release; the setpoint, which is proportional to the volumetric flow of the effluent line and inversely proportional to the volumetric flow of the dilution stream plus the effluent stream, represents a value, which if exceeded, would result in concentrations exceeding the limits of 10CFR20 in the unrestricted area, (μCi/mL);

C = the effluent concentration limit implementing10CFR20 for the site (μCi/mL);

F = the dilution water flow setpoint as measured at the release point, (gpm);

f = the effluent flow setpoint as measured at the radiation monitor location, (gpm);

where:

$$C = \frac{\sum_i C_{wi}}{\sum_i \frac{C_{wi}}{ECL_i}}$$

C_{wi} = concentration of nuclide i in the liquid waste discharge volume prior to any dilution as determined by current isotopic analysis for gamma emitting nuclides and most recent results from pure beta emitters as specified in Table 4.2-1 of PNPS Effluent Controls, (μCi/mL);

ECL_i = Effluent Concentration Limit of each nuclide i from 10CFR20 Appendix B, Table 2, Column 2, (μCi/mL);

b) Monitor setpoint based on monitor count rate

$$c_s = (c * x) + z$$

where:

c_s = the setpoint of the radioactivity monitor measuring the radionuclide concentration in the effluent line prior to dilution, (counts/sec);

c = the liquid effluent monitor setpoint based on activity concentration as calculated in step 4.a above, (μCi/mL);

x = the liquid effluent monitor efficiency/conversion factor for activity concentration to count rate, (counts-mL/μCi-sec);

z = the liquid effluent monitor background count rate, (counts/sec).

The setpoint will ensure that the concentration of liquid effluents discharged does not increase above the value for which the maximum permissible discharge flow rate was established (see Section 9.1 of this manual).

8.2 DELETED

8.3 DELETED

8.4 DELETED

9.0 CALCULATIONAL METHODS

This section presents the calculational specifics required to demonstrate compliance with each of the Effluent Controls identified in Section 3/4 of this document.

The equations in this section are based on the equations and calculational methods described in Reference 8, unless otherwise specified. These equations have, in some cases, been presented in a slightly different form in an effort to simplify their use. The subscripts used are "a" for age group, "j" for organ, "i" for radionuclide, "p" for pathway and "l" for location. Capital letters have been used on the dose/dose rate, use factor, concentration, and dose conversion factor abbreviations to designate pathways. "A" is for aquatic foods, "S" for shoreline deposits, "W" for swimming, "Y" for yachting/boating, "G" for ground plane deposition, "B" for breathing/inhalation, "L" for leafy vegetation, and "R" for root crops/non-leafy vegetation.

The descriptions of constants, variables, and parameters in this section are also based on those described in Reference 8, unless otherwise specified. The descriptions have, in some cases, been modified to describe the constant, variable, and parameter specific application in the corresponding equation. In addition, some of the constant and variable values have been revised to include more site specific values, to include more technically correct information, or to provide uniformity (e.g., λ_i values always presented in hr^{-1}). Values for parameters which only have a single value will appear along with the definition. For those parameters which can take on different values for different conditions, the appropriate value will appear in the referenced tables. All numerical constants have been derived from the indicated base conversion factors and are represented in scientific notation to the third significant digit.

9.1 Concentrations of Liquid Effluents

The following equation shall be used to determine the discharge flow rate such that concentrations of radioactive effluents released to unrestricted areas do not exceed the concentration limits specified in 10CFR20 Appendix B, Table 2, Column 2:

$$DFR = \frac{CW}{\sum_i \frac{C_{wi}}{ECL_i}}$$

where:

DFR = Maximum discharge release rate of liquid effluent, (gal/min).

CW = Flow rate of dilution water, (sum of waste discharge pumps and/or salt service water pumps), (gal/min).

C_{wi} = Concentration of nuclide i in the liquid waste discharge volume prior to any dilution as determined by current isotopic analysis for gamma emitting nuclides and most recent results from pure beta and alpha emitters, (μCi/mL).

ECL_i = Effluent Concentration Limit of each nuclide *i* from 10CFR20 Appendix B, Table 2, Column 2, (μCi/mL).

9.2 Liquid Effluents Dose Assessment Methodology

The following equations shall be used to estimate the annual dose rates due to a release of radioactive liquid effluents. All input parameters (i.e., activity and volume) must be normalized to a 1 year release period. Modification of the final results is necessary for comparison to dose rate limits for periods different than one year. For comparison to monthly limits and quarterly limits, results would be scaled by 1/12 and 1/4, respectively. To determine the dose or dose commitment for a desired period, multiply the annual dose rate by the fraction of the year for the dose period desired. For purposes of projecting resulting dose estimates for the subsequent month, the release rates and concentrations are assumed to be equal to the previous month's release.

Pathways assuming internal deposition of radionuclides (i.e., ingestion) involve the use of a 50-year committed dose conversion factor. This entire prospective dose will be assigned to the individual for the year of intake (Reference 8). In the original version of the ODCM, values from Regulatory Guide 1.109 (Reference 8) were used for calculating doses. Upon incorporation of the Generic Letter 89-01 change (Revision 8), and conversion to an electronic document, dose conversion factors were obtained from updated tables used by the NRC in the computer program GASPAR-II (Reference 9). For pathways involving external radiation to the total body (i.e., shoreline activity, swimming, boating), the dose to all other organs is assumed equal to that for the total body (Reference 8, Appendix E).

Summation of the dose rates from the equations below should be performed for all significant pathways.

9.2.1 Liquid Pathways Annual Dose Rates

9.2.1.1 Aquatic Food Ingestion (Fish, Shellfish)

$$DA_{ajp} = UA_{ap} \sum_i \left[CA_{ip} \; DFI_{aij} \right]$$

where:

$$CA_{ip} = CW_{il} \; B_{ip} \; e^{-\lambda_i t_h}$$

$$CW_{il} = \frac{1.00E12 \; Q_i \; M_l \; e^{-\lambda_i t_l}}{V}$$

Above equations derived from Reference 8, equations 2 and A-3.

9.2.1.2 Shoreline Deposits (Discharge Canal and Recreational Area)

$$DS_{ajl} = US_{al}\ W_l\ \sum_i \left[CS_{il}\ DFG_{ij} \right]$$

where:

$$CS_{il} = 2.89\ CW_{il}\ \frac{\left(1 - e^{-\lambda_i t_b}\right)}{\lambda_i}$$

CW_{il} = same as indicated in Equation 9.2.1.1

Above equation derived from Reference 8, equations A-4 through A-7.

9.2.1.3 Swimming (White Horse Beach)

$$DW_{ajl} = UW_{al}\ \sum_i \left[CW_{il}\ DFW_{ij} \right]$$

where:

CW_{il} = same as indicated in Equation 9.2.1.1

Above equations derived from Reference 10, equation 41 on page 151.

9.2.1.4 Yachting/Boating (Cape Cod Bay)

$$DY_{ajl} = 0.5\ UY_{al}\ \sum_i \left[CW_{il}\ DFW_{ij} \right]$$

where:

CW_{il} = same as indicated in Equation 9.2.1.1

Above equations derived from Reference 10, equation 41 on page 151.

9.2.2 Definitions:

B_{ip} = equilibrium bioaccumulation factor for radionuclide i, in aquatic foods pathway p, expressed as the concentration in biota (pCi/kg), divided by the concentration in water (pCi/liter) from Table A-1, (liters/kg);

Ca_{ip} = concentration of radionuclide i in pathway p of aquatic foods, (pCi/kg);

CS_{il} = effective surface concentration of radionuclide i in sediments at location l, (pCi/m^2);

CW_{il} = concentration of radionuclide i in seawater at location l, (pCi/liter);

DA_{ajp} = total annual dose rate from ingestion of aquatic foods to organ j, of individuals of age group a, from pathway p, (mrem/yr);

DFG_{ij} = open field ground plane dose conversion factor for organ j, from radionuclide i, from Table A-10, (mrem-m^2/pCi-hr);

DFI_{aij} = ingestion 50-year committed dose conversion factor for organ j, of individuals in age group a, from radionuclide i, from Table A-15 through A-18 (mrem/pCi ingested);

DFW_{ij} = submersion dose conversion factor in water, for organ j, of individuals in age group a, from radionuclide i, from Table A-2, (mrem-liter/pCi-hr);

DS_{ajl} = total annual dose rate from exposure received during shoreline activities, to organ j, of individuals of age group a, at location l, (mrem/yr);

DW_{ajl} = total annual dose rate from exposure received during swimming, to organ j, of individuals of age group a, at location l, (mrem/yr);

DY_{ajl} = total annual dose rate from exposure received during yachting/boating, to organ j, of individuals in age group a, at location l, (mrem/yr);

M_l = mixing ratio (reciprocal of dilution factor) at location l of exposure or harvest of aquatic food, from Table A-3, (dimensionless);

Q_i = annual release rate of radionuclide i in liquid effluents, (Ci/yr);

t_b = period of time for which sediment is exposed to radionuclides in seawater, including buildup, (hr, assumed to be 1.31E5 hr = 15y);

t_h = time between exposure of aquatic foods to radionuclides in sea water and their consumption by an individual, from Table A-3, (hr);

t_l = transit time required for radionuclides to reach location l, (hr, assumed to be 0.0 hr from the liquid waste tank to the discharge canal);

UA_{ap} = use factor of aquatic foods from pathway p, by individuals in age group a, from Table A-9 for maximum individual, Table A-8 for average individual, (kg/yr);

US_{al} = use factor (amount of time) an individual in age group a, engages in shoreline activities at location l, from Table A-9 for maximum individual, Table A-8 for average individual, (hr/yr);

UW_{al} = use factor (amount of time) an individual in age group a, engages in swimming at location l, from Table A-9 for maximum individual, Table A-8 for average individual, (hr/yr);

UY_{al} = use factor (amount of time) an individual in age group a, engages in yachting/boating at location l, from Table A-9 for maximum individual, Table A-8 for average individual, (hr/yr);

V = total annual discharge rate of liquids, represented by the sum of liquid effluents and/or salt service water pumps, (liters/yr);

W_l = shoreline width factor for location l, from Table A-3, (dimensionless);

λ_i = radioactive decay constant of radionuclide i, (hr^{-1});

0.50 = scaling factor for yachting/boating assuming that doses received while on the surface of the water are 1/2 of doses received while immersed in water from Reference 10, (dimensionless);

2.89 = factor to convert for transfer of nuclides from water to sediment, equal to 100 liters/m^2-day from Reference 11 multiplied by 1 day/24 hr and by natural log of 2 (to convert reciprocal λ_i to half-life), as calculated in Reference 8, equation A-5, (liter/m^2-hr);

1.00E12 = factor to convert from Ci to pCi, (pCi/Ci);

9.3 Gaseous Effluents Dose Assessment Methodology

The following equations shall be used to estimate the annual dose rates due to release of radioactive gaseous effluents. All input parameters (i.e., activity and volume) must be normalized to a 1 year release period. Modification of final results is necessary for comparison to dose rate limits for periods different than one year. For comparison to monthly limits and quarterly limits, results would be scaled by 1/12 and 1/4, respectively. To determine the dose or dose commitment for a desired period multiply the annual dose rate by the fraction of the year for the dose period desired.

Pathways assuming internal deposition of radionuclides (i.e., inhalation, ingestion) involve the use of a 50-year committed dose conversion factor. This entire prospective dose will be assigned to the individual for the year of intake (Reference 8). In the original version of the ODCM, values from Regulatory Guide 1.109 (Reference 8) were used for calculating doses. Upon incorporation of the Generic Letter 89-01 change (Revision 8), and conversion to an electronic document, dose conversion factors were obtained from updated tables used by the NRC in the computer program GASPAR-II (Reference 9). For pathways involving external radiation to the total body (i.e., ground plane deposition), the dose to all other organs is assumed equal to that for the total body (Reference 8, Appendix E).

Summation of the doses rates from the equations below should be performed for all significant pathways and all release points from which significant radioactive effluent releases have occurred (i.e., Reactor Building Exhaust Vent).

9.3.1 DELETED

9.3.2 Gaseous Pathways Annual Dose Rates from Particulates with a Half-life Greater than 8 Days and Tritium

.

9.3.2.1 Ground Plane Deposition

$$DG_j = S \sum_i \left[CG_i \; DFG_{ij} \right]$$

where:

$$CG_i = 1.00E12 \left[D/Q \right] Q_i \; \frac{\left(1 - e^{-\lambda_i t_b} \right)}{\lambda_i}$$

Above equations derived from Reference 8 equations 12, C-1, and C-2.

9.3.2.2 Breathing/Inhalation

$$DB_{aj} = UB_a \; \sum_i \left[CB_i \; DFB_{aij} \right]$$

where:

$$CB_i = 3.17E4 \left[\chi/Q \right]_c \; Q_i \quad \text{for H-3}$$

$$CB_i = 3.17E4 \left[\chi/Q\right]_d \; Q_i$$ for particulates with T½ >8d

Above equations derived from Reference 8, equations 13, C-3, and C-4.

9.3.2.3 Leafy Vegetation Ingestion

$$DL_{aj} = UL_a \; f_l \; \sum_i \left[CL_i \; DFI_{aij}\right]$$

where:

CL_i = leafy vegetation concentration as calculated below.

Above equation derived from Reference 8, equations 14 and C-13.

where:

$$CH_i, CL_i, CP_i, CR_i = \frac{1.19E7 \; Q_i \; \left[\chi/Q\right]_c}{H}$$ for H-3

$$CH_i, CL_i, CP_i, CR_i = 1.14E8 \; Q_i \left[D/Q\right] * \left[\frac{r_p \left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_v \; \lambda_{Ei}} + \frac{B_{iv} \left(1 - e^{-\lambda_i t_b}\right)}{\mathrm{P} \; \lambda_i}\right] * e^{-\lambda_i t_h}$$

for particulates with T½ >8 days,

Above equations derived from Reference 8, equations C-5 through C-9.

9.3.2.4 Root Crop Non-Leafy Vegetation Ingestion

$$DR_{aj} = UR_a \; f_r \; \sum_i \left[CR_i \; DFI_{aij}\right]$$

where:

CR_i = root crop concentration as calculated in Equation 9.3.2.3.

Above equations derived from Reference 8, equations 14 and C-13.

9.3.2.5 DELETED

9.3.2.6 DELETED

9.3.3 Definitions

B_{iv} = concentration factor for uptake of radionuclide i, from soil in the edible portions of crops, in pCi/kg (wet weight) per pCi/kg dry soil, from Table A-5, (kg/kg);

CB_i = ground-level airborne concentration of radionuclide i, (pCi/m^3);

CG_i = ground plane concentration of radionuclide i, (pCi-hr/m^2-yr);

CH_i = concentration of radionuclide i on harvested/stored feed, (pCi/kg);

CL_i = concentration of radionuclide i in leafy vegetables, (pCi/kg);

CR_i = concentration of radionuclide i in root crops/non-leafy vegetables, (pCi/kg);

DB_{aj} = total annual dose rate from breathing/ inhalation to organ j, of an individual in age group a, (mrem/yr);

DFB_{aij} = inhalation 50-year committed dose conversion factor for organ j, of individuals in age group a, from radionuclide i, from Tables A-11 through A-14, (mrem/pCi);

DFG_{ij} = open field ground plane dose conversion factor for organ j, from radionuclide i, from Table A-10, (mrem -m^2/pCi-hr);

DFI_{aij} = ingestion 50-year committed dose conversion factor for organ j, for individuals in age group a, from radionuclide i, from Tables A-15 through A-18, (mrem/pCi);

DG_j = total annual dose rate to organ j from direct exposure to the contaminated ground plane from all radionuclides, (mrem/yr);

DL_{aj} = total annual dose rate from ingestion of leafy vegetables to organ j, of an individual in age group a, (mrem/yr);

DR_{aj} = total annual dose rate from ingestion of root crop or non-leafy vegetables to organ j, of an individual in age group a, (mrem/yr);

$[D/Q]$ = deposition rate considering depletion at the receptor location in question, from Table 10-1, (m^{-2});

f_l = fraction of the ingestion rate of a leafy vegetable that is produced in the garden of interest, (dimensionless; assumed to be 1.0);

f_r = fraction of root crops/non-leafy vegetable that are produced in the garden of interest, (dimensionless; assumed to be 0.76);

H = absolute humidity of the atmosphere from Reference 15, (g/m^3; assumed to be 5.6 g/m^3);

p = fractional equilibrium ratio, (dimensionless; assumed to be 1.0 for continuous release);

P = effective surface density for dry soil, (kg/m^2; assumed to be 240 kg/m^2);

Q_i = annual release rate of radionuclide i in gaseous effluents (Ci/yr);

r_p = fraction of deposited particulates retained on crops, (dimensionless; assumed to be 0.2 from References 20 and 21);

S = attenuation factor that accounts for the dose reduction due to shielding provided by residential structures from Table A-19, (dimensionless);

t_b = time period over which the radionuclide buildup is evaluated, (hr; assumed to be 1.31E5 hr = 15 yr);

t_e = time period that crops are exposed to radionuclide deposition during the growing season, from Table A-19, (hr);

t_h = holdup time that represents the time interval between harvest and consumption of the food, from Table A-19, (hr);

UB_a = annual breathing rate, for individuals in the age group a, from Table A-9 for maximum individual, Table A-8 for average individual, (m^3/yr);

UL_a = annual intake of leafy vegetables, for individuals in the age group a, from Table A-9 for maximum individual, Table A-8 for average individual, (kg/yr);

UR_a = annual intake of root crops/non-leafy vegetables, for individuals in the age group a, from Table A-9 for maximum individual, Table A-8 for average individual, (kg/yr);

Y_v = agricultural productivity/yield, from Table A-19, (kg/m^2, wet weight);

$[\chi/Q]_c$ = appropriate value of undepleted atmospheric dispersion factor used to estimate ground level airborne concentration of gaseous, (i.e., non-particulate) radionuclides, from Table 10-1, (sec/m^3);

$[\chi/Q]_d$ = appropriate value of the average gaseous dispersion factor corrected for depletion of particulates, from Table 10-1, (sec/m^3);

$[\chi/Q]_\gamma$ = appropriate value of gamma atmospheric dispersion factor used to estimate ground level gamma dose rate from an elevated or ground level plume as calculated in References 13 and 14, from Table 10-1, (sec/m^3);

λ_i = radioactive decay constant of radionuclide i, (hr^{-1});

λ_{Ei} = effective removal rate constant for radionuclide i from crops, in hr^{-1}, where $\lambda_{Ei} = \lambda_i + \lambda_w$. λ_i is the radioactive decay constant, and λ_w is the removal rate constant for physical loss by weathering. $\lambda_w = 0.0021\ hr^{-1}$, ($hr^{-1}$);

1.11 = average ratio of the tissue to air energy absorption coefficients, (mrem/mrad);

3.17E4 = 1.00E12 pCi/Ci divided by 3.15E7 sec/yr, (pCi-yr/Ci-Sec)

1.19E7 = 1.00E12 pCi/Ci divided by 3.15E7 sec/yr and multiplied by 1.00E3 g/kg and by 0.5 g H-3 in plant water per g H-3 in atmospheric water from Reference 22 (dimensionless) and by 0.75 g water per g plant (dimensionless), as calculated in Reference 8 equation C-9, (pCi-yr-g/Ci-sec-kg);

2.18E7 = 1.00E12 pCi/Ci divided by 3.15E7 sec/yr and multiplied by 1.00E3 g/kg and by 0.11 g Carbon/g plant mass from References 23 and 24 divided by 0.16 g Carbon/m^3 of air, as calculated in Reference 8 equation C-8, (pCi-yr-m^3/Ci-sec-kg):

1.14E8 = conversion factor to correct activity units and time units for particulate radionuclides, equal to 1.00E12 pCi/Ci multiplied by 1 yr/8760 hr, (pCi-yr/Ci-hr);

1.00E12 = conversion factor to correct for activity units, (pCi/Ci);

9.4 Total Dose to a Member of the Public

The purpose of this section is to describe the method used to calculate the cumulative dose contributions from liquid and gaseous effluents in accordance with PNPS Effluent Controls for total dose. This method can also be used to demonstrate compliance with the Environmental Protection Agency (EPA) 40CFR190, "Environmental Standards for the Uranium Fuel Cycle".

Compliance with the PNPS Effluent Controls dose objectives for the maximum individual demonstrates compliance with the EPA limits to any member of the public, since the design dose objectives from 10CFR50 Appendix I are much lower than the 40CFR190 dose limits to the general public. With the operational objectives in PNPS Effluent Controls Sections 3.2.2, 3.3.2, and/or 3.3.3 being exceeded by a factor of two, a special analysis must be performed. The purpose of this special analysis is to demonstrate if the total dose to any member of the public (real individual) from all uranium fuel cycle sources (including all real pathways and direct radiation) is limited to less than or equal to 25 mrem per year to the total body or any organ except for the thyroid which is limited to 75 mrem per year.

If required, the total dose to a member of the public will be calculated for all significant effluent release points for all real pathways including direct radiation. Only effluent releases from PNPS (Pilgrim Station) need to be considered since no other nuclear fuel cycle facilities exist within a 50 mile radius. The calculations will be based on the equations contained in this section, with the exception that the usage factors and other site specific parameters will be modified using more realistic assumptions, where appropriate.

The direct radiation component from the facility can be determined by using environmental TLD results. These results will be corrected for natural background and for actual occupancy time of the recreational areas accessible to the general public at the location of maximum direct radiation. It is recognized that by including the results from the environmental TLDs into the sum of total dose component, the direct radiation dose may be overestimated. The TLD measurements may include the exposure from ground plane deposition, and shoreline deposition, which have already been included in the summation of the significant dose pathways to the general public. However, this conservative method can be used, if required, as well as any other method for estimating the direct radiation dose from contained radioactive sources within the facility. The methodology used to incorporate the direct radiation component into total dose estimates will be outlined whenever total doses are reported.

Therefore, the total dose will be determined based on the most realistic site specific data and parameters to assess the real dose to any member of the general public.

10.0 RECEPTOR LOCATIONS, HYDROLOGY, AND METEOROLOGY

The purpose of this section is to identify those receptor locations which represent critical pathway locations and the methods used to estimate dilution and dispersion factors for these locations.

For the dose calculations from liquid effluents, the maximum individual is assumed to: 1) ingest fish and shellfish from the discharge canal, 2) receive direct radiation from shoreline deposits at both the discharge canal and PNPS shoreline recreational area, and 3) receive external radiation while swimming at White Horse Beach as well as while boating on the Cape Cod Bay. The doses are calculated for the various age groups (i.e., infant, child, teenager and adult), as well as for the various organs, (i.e., bone, liver, thyroid, kidney, lung, gastrointestinal tract/lower large intestine, skin, and total body). The maximum total body and organ doses are selected from the totals of the various age groups and organ doses calculated as described above.

For liquid effluent pathways, Table A-3 lists the conservative values for the mixing ratio and shore width factor for the various aquatic receptor locations.

For the dose calculations for gaseous effluents, the maximum individual is assumed to reside at the receptor location that provides the highest dose from the dose contributions from all gaseous release points where significant releases have occurred. The locations selected in Table 10-1 are the site boundary and a garden at the site boundary. The dose calculations are performed for each release point and totaled for the following dose pathways; 1) ground plane deposition, 2) inhalation, and 3) ingestion of leafy vegetable, and root crops/non-leafy vegetables. The doses are also calculated for the various age groups and for the various organs as described for liquid effluents. The maximum total body, skin, and organ doses are selected from the totals of the various age groups and organ doses calculated as described above.

In order to estimate atmospheric dispersion and deposition factors for each of these locations, a computer code supplied by the Yankee Atomic Electric Company was used. The code, AEOLUS (Reference 13), was used to calculate quarterly average values of dispersion and deposition factors.

Meteorological data for a ten year period, January 1, 2005 to December 31, 2014, were used for these analyses. The most conservative quarterly average values of ground level average atmospheric dispersion factor before depletion $[\chi/Q]_C$, ground level average atmospheric dispersion factor after depletion $[\chi/Q]_d$, average gamma dilution factor $[\chi/Q]_\gamma$, and average deposition rate [D/Q] for the ten year period were chosen for each of the critical receptor locations.

The technique used to estimate ground level gamma doses from an elevated or ground level plume is based on the sector average finite cloud model of Regulatory Guide 1.109 (Reference 8). The equation has been rearranged into a form similar to the standard semi-infinite cloud equation thereby allowing the use of a "gamma Chi/Q" which includes the effects of plume dimensions, gamma energy mix, atmospheric and geometric attenuation, etc. (See References 13 and 14 for a detailed discussion.)

For gaseous effluent pathways, Table10-1 lists the critical locations for receptors and conservative atmospheric dispersion factors for each atmospheric receptor location.

TABLE 10-1

CRITICAL RECEPTOR LOCATIONS AND ATMOSPHERIC DISPERSION FACTORS

Effluent Control Section	$[\chi/Q]_c$ (sec/m^3)	$[\chi/Q]_d$ (sec/m^3)	$[\chi/Q]^\gamma$ (sec/m^3)	[D/Q] (1/m^2)
GROUND-LEVEL RELEASES: Reactor Building Vent, Turbine Building, etc.				
3/4.3.1: Gaseous Effluent Dose Rate				
Site Boundary (1)	7.40E-06	7.04E-06	4.69E-06	5.22E-08
Nearest Garden (2)	7.40E-06	7.04E-06	4.69E-06	5.22E-08
3/4.3.3: Dose - Radioactive Materials in Particulate Form, and Tritium				
Site Boundary (1)	7.40E-06	7.04E-06	N/A	5.22E-08
Nearest Garden (2)	7.40E-06	7.04E-06	N/A	5.22E-08
3/4.4.1: Total Dose				
Site Boundary (1)	7.40E-06	7.04E-06	4.69E-06	5.22E-08
Nearest Garden (2)	7.40E-06	7.04E-06	4.69E-06	5.22E-08

(1) "Site Boundary" means the location at or beyond the boundary of the restricted area with the highest calculated dispersion and/or deposition factor.

(2) "Nearest Garden" is considered to be the same as the site boundary due to the abundance of small gardens near Pilgrim Station.

11.0 RADIOLOGICAL ENVIRONMENTAL SAMPLING AND MEASUREMENT LOCATIONS

Sampling and measurement locations have been established for Pilgrim Station considering meteorology, population distribution, hydrology, and land use characteristics of the Plymouth area. The sampling locations are divided into two classes: indicator and control. Indicator locations are those which are expected to show effects from PNPS operations, if any exist. These locations were selected primarily on the basis of where the highest predicted environmental concentrations were calculated to occur. While the indicator locations are typically within a few kilometers of the plant, the control stations are generally located so as to be outside the influence of Pilgrim Station. They provide a basis on which to evaluate fluctuations at indicator locations relative to natural background radiation, natural radioactivity, and fallout from prior nuclear weapons tests.

The environmental sampling media collected in the vicinity of Pilgrim Station include air particulate filters, seawater, shellfish, American lobster, fishes, and sediment. The media, sample designation location, description, distance, and direction for indicator and control samples are listed in Tables 3.5-1 and 3.5-3 under Control 3/4.5.1. These sampling locations are also displayed on the maps shown in Figures 3.5-1 through 3.5-5. The frequency of collection and types of radioactivity analysis are described in the PNPS Effluent Control 3/4.5.1, Table 3.5-1. The maximum lower limits of detection (LLD) for the analytical measurements are specified in the PNPS Effluent Controls Table 4.5-1 (see Appendix B for the definitions of the lower limit of detection).

The environmental TLD location designations, distance, and direction from the reactor are listed in Table 3.5-2. The radiation measurement locations for the environmental TLDs are shown in Figures 3.5-1 through 3.5-5. The frequency and type of radiation measurement is described in the PNPS Effluent Control 3/4.5.1, Table 3.5-1.

The particulate measurement locations, distance, and direction from the reactor are listed in Table 3.5-2 through 3.5-4. The frequency and type of radiation measurement is described in PNPS Effluent Control 3/4.5.1, Table 3.5-1.

The atmospheric and land-based samples are collected by station personnel. The aquatic samples are collected by an external contractor experienced with diving and marine sampling. The radioactivity analyses of samples and the processing of the environmental TLDs are performed by external laboratories certified to perform these types of analyses.

The PNPS staff reviews the radioactivity analysis results from the contractor laboratory. Reporting levels for radioactivity concentrations in environmental samples are listed in PNPS Effluent Controls Table 3.5-4. If the radioactivity concentrations are above the reporting levels, the NRC is notified in writing within 30 days. A determination of the cumulative dose contribution for the current year will be performed for radioactivity which is detected that is attributable to PNPS operation. Depending upon the circumstances, a special study may also be conducted.

If radioactivity levels in the environment become elevated as a result of the station's operation, an investigation is performed, and corrective actions are recommended to reduce the amount of radioactivity to as far below the legal limits as is reasonably achievable.

The radiological environmental sampling and measurement locations are reviewed annually, and modified if necessary.

The original radiological monitoring program was modeled after guidance from the NRC presented in Regulatory Guide 4.8 (reference 29). Shortly after the inception of Regulatory Guide 4.8 in 1975, the NRC began to solicit comments on the environmental monitoring guidelines. The NRC working group modified the environmental monitoring guidelines, and issued the revised guidance in the form of Revision 1 to the Branch Technical Position on an acceptable radiological

environmental monitoring program (reference 28). In turn, the Branch Technical Position became the model for environmental monitoring put forth in NUREG-1302. Notable changes in the Branch Technical Position were the elimination of soil sampling, and increased reliance on direct radiation monitoring using environmental thermoluminescent dosimeters (TLDs).

Upon review of the PNPS radiological environmental monitoring program in 2002, several departures from the model program outlined in NUREG-1302 were noted. PNPS was still using the soil sampling program of once per three years outlined in Regulatory Guide 4.8. Also, PNPS was using an annual assessment of direct radiation at six locations using a pressurized ion chamber, in addition to the 113 TLDs posted around the plant. Based on the extensive monitoring of airborne particulates above and beyond that prescribed by NUREG-1302, any buildup of plant-related activity in soil would be first indicated in airborne monitoring. Due to the extent and sensitivity of the airborne monitoring efforts, soil sampling and analysis was dropped from the sampling program. In a similar fashion, the integrating nature of TLDs makes this approach to monitoring direct radiation the preferred method, and industry standard. Again, since the PNPS TLD placement far exceeds that prescribed by NUREG-1302, assessment of direct radiation through use of pressurized ion chamber measurements was dropped in lieu of the extensive TLD monitoring effort.

In 1977, Boston Edison Company was pursuing construction of a second unit on the PNPS site. As part of the preliminary licensing efforts for this second unit, Pilgrim Station committed to an special marine sampling program under the REMP. This program was much more aggressive than that outlined in standard NRC guidance for an environmental monitoring program. This specialized sampling program was agreed to by Boston Edison Company for a period not to exceed 10 years.

Following an evaluation of results obtained by this specialized marine sampling program over the past 25 years, it has been determined that the results have shown that the impact of radioactivity in liquid discharges on the general public and environment is negligible. In light of the fact that the terms of the sampling program have expired, the specialized program is no longer warranted. Furthermore, replacement of the specialized program with a marine sampling program such as that prescribed by the NRC in NUREG-1302 and the Branch Technical Position on Environmental Monitoring will still allow PNPS personnel to evaluate the impact of its operations on the environment and general public. Therefore, PNPS has dropped most of the specialized requirements and has adopted the standard model for marine sampling prescribed by the NRC.

12.0 ANNUAL REPORT PREPARATION

12.1 Radioactive Effluent Release Report

The annual Radioactive Effluent Release Report covering the operation of Pilgrim Nuclear Power Station during the previous calendar year shall be submitted by May 15 of each year. The report shall include a summary of the quantities of radioactive liquid and gaseous effluents and solid wastes released from the facility. This report shall be submitted in accordance with 10CFR50.36a.

General guidance for the preparation of this report can be found in Regulatory Guide 1.21 (Reference 26). In addition to effluent and disposal data, this report should also include summaries of meteorological data in the form of joint frequency distribution tables. This report should present an evaluation of the doses received by members of the public resulting from operation of Pilgrim Station. Liquid and airborne effluent pathways, as discussed in ODCM Section 9, should be used to assess the doses, as well as ambient (direct) radiation exposure resulting from plant operation.

In addition to summarizing effluents and their resulting doses, the annual Radioactive Effluent Release Report serves as the vehicle to notify the NRC of any changes in the ODCM. Changes to the ODCM during the previous calendar year shall be submitted in the annual Radioactive Effluent Release Report.

12.2 Annual Radiological Environmental Operating Report

The Annual Radiological Environmental Operating Report covering the operation of Pilgrim Nuclear Power Station during the previous calendar year shall be submitted by May 15 of each year. The report shall include summaries, interpretations, and analyses of trends of the results of the Radiological Environmental Monitoring Program for the reporting period. The material provided shall be consistent with the objectives outlined in other sections of the ODCM, as well as 10CFR50 Appendix I, Sections IV.B.2, IV.B.3, and IV.C.

The Annual Radiological Environmental Operating Report shall include tables summarizing the results of analyses of radiological environmental samples and environmental radiation measurements taken during the period, pursuant to the locations specified in Section 3/4.5 of the ODCM. Summarized and tabulated results of these analyses and measurements shall be similar in format to guidance provided in the Radiological Assessment Branch Technical Position, Revision 1, November 1979. In the event that some individual results are not available for inclusion in the report, the report shall be submitted noting and explaining the reasons for the missing results. The missing data shall be submitted in a supplementary report as soon as possible.

13.0 REFERENCES

1) PNPS Technical Specifications.

2) U. S. Nuclear Regulatory Commission, Generic Letter 89-01, “Implementation of Programmatic Controls for Radioactive Effluent Technical Specifications in the Administrative Controls Section of the Technical Specifications and the Relocation of Procedural Details of RETS to the Offsite Dose Calculation Manual or to the Process Control Program”, January 1989.

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4) Boston Edison Company, Pilgrim Station Unit 1 Appendix I Evaluation, April, 1977.

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6) PNPS Maintenance Department Recalibration and Malfunction Records.

7) PNPS Operations Manual, Volume 7, Book 2: Chemical and Radiochemical Procedures.

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25) U.S. Nuclear Regulatory Commission, NUREG-75/021, "Detailed Measurement of I-131 in Air, Vegetation and Milk Around Three Operating Reactor Sites," March 1975.

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29) U.S. Nuclear Regulatory Commission, Regulatory Guide 4.8, "Environmental Technical Specifications for Nuclear Power Plants", December 1975.

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APPENDIX A

DATA REQUIRED FOR EFFLUENT CALCULATIONS

TABLE A-1

BIOACCUMULATION FACTORS TO BE USED IN THE ABSENCE OF SITE-SPECIFIC DATA

pCi/kg per pCi/liter[1]

ELEMENT	FRESHWATER		SALTWATER	
	FISH	INVERTEBRATE	FISH	INVERTEBRATE
H	9.0E-01	9.0E-01	9.0E-01	9.3E-01
C	4.6E+03	9.1E+03	1.8E+03	1.4E+03
Na	1.0E+02	2.0E+02	6.7E-02	1.9E-01
P	1.0E+05	2.0E+04	2.9E+04	3.0E+04
Cr	2.0E+02	2.0E+03	4.0E+02	2.0E+03
Mn	4.0E+02	9.0E+04	5.5E+02	4.0E+02
Fe	1.0E+02	3.2E+03	3.0E+03	2.0E+04
Co	5.0E+01	2.0E+02	1.0E+02	1.0E+03
Ni	1.0E+02	1.0E+02	1.0E+02	2.5E+02
Cu	5.0E+01	4.0E+02	6.7E+02	1.7E+03
Zn	2.0E+03	1.0E+04	2.0E+03	5.0E+04
Br	4.2E+02	3.3E+02	1.5E-02	3.1E+00
Rb	2.0E+03	1.0E+03	8.3E+00	1.7E+01
Sr	3.0E+01	1.0E+02	2.0E+00	2.0E+01
Y	2.5E+01	1.0E+03	2.5E+01	1.0E+03
Zr	3.3E+00	6.7E+00	2.0E+02	8.0E+01
Nb	3.0E+04	1.0E+02	3.0E+04	1.0E+02
Mo	1.0E+01	1.0E+01	1.0E+01	1.0E+01
Tc	1.5E+01	5.0E+00	1.0E+01	5.0E+01
Ru	1.0E+01	3.0E+02	3.0E+00	1.0E+03
Rh	1.0E+01	3.0E+02	1.0E+01	2.0E+03
Te	4.0E+02	6.1E+03	1.0E+01	1.0E+02
Cs	2.0E+03	1.0E+03	4.0E+01	2.5E+01
Ba	4.0E+00	2.0E+02	1.0E+01	1.0E+02
La	2.5E+01	1.0E+03	2.5E+01	1.0E+03
Ce	1.0E+00	1.0E+03	1.0E+01	6.0E+02
Pr	2.5E+01	1.0E+03	2.5E+01	1.0E+03
Nd	2.5E+01	1.0E+03	2.5E+01	1.0E+03
W	1.2E+03	1.0E+01	3.0E+01	3.0E+01
Np	1.0E+01	4.0E+02	1.0E+01	1.0E+01

[1] Data presented in this table are from Reference 8.

TABLE A-2

DOSE FACTORS FOR IMMERSION IN WATER[1]

mrem/hr per pCi/Liter[2]

NUCLIDE	SKIN	TOTAL BODY[3]
H-3[4]	0.0E+00	0.0E+00
N-13	2.6E-06	1.9E-06
C-14[4]	3.8E-06	0.0E+00
Na-22	4.8E-06	4.0E-06
Na-24	9.3E-06	7.8E-06
Cr-51	6.4E-08	5.2E-08
Mn-54	1.8E-06	1.5E-06
Fe-55[5]	3.6E-10	6.4E-11
Fe-59	2.6E-06	2.2E-06
Co-58	2.3E-06	1.8E-06
Co-60	5.4E-06	4.6E-06
Ni-63	0.0E+00	0.0E+00
Cu-64	5.2E-07	3.7E-07
Zn--65	1.2E-06	1.1E-06
Sr-89[5]	5.4E-07	4.6E-09
Sr-90[5]	1.5E-07	5.4E-10
Y-90[5]	9.6E-07	1.3E-08
Sr+Y-90[5],[6]	1.1E-06	1.3E-08
Zr-95	1.8E-06	1.5E-06
Nb-95	1.6E-06	1.4E-06
Mo-99	9.1E-07	4.7E-07
Ru-103	1.1E-06	8.9E-07
Ru-106	1.9E-06	3.8E-07
Te-132	4.8E-07	4.0E-07
Cs-134	3.5E-06	2.9E-06
Cs-137	1.4E-06	1.0E-06
Ba-140	7.6E-07	4.6E-07
La-140	5.3E-06	4.1E-06
Ce-141	2.4E-07	1.3E-07
Ce-144	6.2E-08	3.0E-08
Pr-144	1.3E-06	5.6E-08
Ce+Pr-144[7]	1.4E-06	8.6E-08

(1) Data presented in this table are from Reference 10.
(2) The same factors apply to adult, teenager, and child.
(3) Total body factors also apply to other internal organs.
(4) Not including penetration of oxide into skin.
(5) Includes bremsstrahlung.
(6) Use these factors for Sr-90 unless Y-90 concentration is given separately.
(7) Use these factors for Ce-144 unless Pr-144 concentration is given separately.

TABLE A-3

RECOMMENDED VALUES FOR LIQUID EFFLUENTS[1]

Parameter Symbol	Parameter Description	Values
M_l	Mixing ratio at location l of exposure or harvest of aquatic foods**	0.2 (Aquatic foods taken from Discharge Canal Outfall) [2]
		0.05 (Shoreline, Pilgrim Station Recreational Area) [3]
		1.0 (Shoreline, Discharge Canal)
		0.03 (Swimming, White Horse Beach)
		0.03 (Boating, Cape Cod Bay)
t_h	Period of time between exposure of aquatic foods to radionuclides in water and their consumption	24 hr for maximum individual
		168 hr for average individual, sport fish doses
		240 hr for average individual, commercial fish doses
W_l	Shoreline width factor for location l	0.5 (Recreational Area) [4]
		0.1 (Discharge Canal) [4]

[1] Data presented in this table are from Reference 8 unless otherwise noted.

[2] Collection of aquatic foods from within the Discharge Canal is prohibited.

[3] Swimming is prohibited at Pilgrim Station Recreational Area.

[4] From Reference 4.

TABLE A-4 - DELETED

TABLE A-5

STABLE ELEMENT TRANSFER DATA(1)

Element	B_{iv} Veg/Soil	F_m(Cow) Milk (day/liter)	F_f Meat (day/kg)
H	4.8E+00	1.0E-02	1.2E-02
C	5.5E+00	1.2E-02	3.1E-02
Na	5.2E-02	4.0E-02	3.0E-02
P	1.1E+00	2.5E-02	4.6E-02
Cr	2.5E-04	2.2E-03	2.4E-03
Mn	2.9E-02	2.5E-04	8.0E-04
Fe	6.6E-04	1.2E-03	4.0E-02
Co	9.4E-03	1.0E-03	1.3E-02
Ni	1.9E-02	6.7E-03	5.3E-02
Cu	1.2E-01	1.4E-02	8.0E-03
Zn	4.0E-01	3.9E-02	3.0E-02
Rb	1.3E-01	3.0E-02	3.1E-02
Sr	1.7E-02	8.0E-04	6.0E-04
Y	2.6E-03	1.0E-05	4.6E-03
Zr	1.7E-04	5.0E-06	3.4E-02
Nb	9.4E-03	2.5E-03	2.8E-01
Mo	1.2E-01	7.5E-03	8.0E-03
Tc	2.5E-01	2.5E-02	4.0E-01
Ru	5.0E-02	1.0E-06	4.0E-01
Rh	1.3E+01	1.0E-02	1.5E-03
Ag	1.5E-01	5.0E-02	1.7E-02
Te	1.3E+00	1.0E-03	7.7E-02
Cs	1.0E-02	1.2E-02	4.0E-03
Ba	5.0E-03	4.0E-04	3.2E-03
La	2.5E-03	5.0E-06	2.0E-04
Ce	2.5E-03	1.0E-04	1.2E-03
Pr	2.5E-03	5.0E-06	4.7E-03
Nd	2.4E-03	5.0E-06	3.3E-03
W	1.8E-02	5.0E-04	1.3E-03
Np	2.5E-03	5.0E-06	2.0E-04

(1) Data presented in this table are from Reference 8.

TABLE A-6- DELETED

TABLE A-7 DELETED

TABLE A-8

RECOMMENDED USE FACTORS TO BE APPLIED FOR THE AVERAGE INDIVIDUAL[1], [2]

Pathway	Adult	Teen	Child	Infant
Fruits, vegetables, & grain (kg/yr)	190	240	200	-
Fish (kg/yr)	6.9	5.2	2.2	-
Seafood (kg/yr)	1.0	0.75	0.33	-
Drinking Water (liter/yr)	370	260	260	330
Shoreline recreation (hr/yr) [3]				
Discharge Canal	8.3	47	9.5	-
Pilgrim Station Recreational Area	8.3	47	9.5	-
Swimming (hr/yr) [3] White Horse Beach	52	52	29	-
Boating - Cape Cod Bay (hr/yr) [3]	52	52	29	-
Inhalation (m^3/yr)	8000	8000	3700	1400

[1] Data presented in this table are from Reference 8, unless otherwise indicated.

[2] Usage factors for the average individual are used to determine the annual dose to the total body and thyroid of an average individual and the annual integrated dose to the population within a 50 mile radius.

[3] From Reference 4.

TABLE A-9

RECOMMENDED USE FACTORS TO BE APPLIED FOR THE MAXIMUM EXPOSED INDIVIDUAL[1]

Pathway	Adult	Teen	Child	Infant
Fruits, vegetables, & grain (kg/yr)	520	630	520	-
Leafy Vegetables (kg/yr))	64	42	26	-
Fish (fresh or salt) (kg/yr)	21	16	6.9	-
Shellfish (kg/yr) [2]	9	6	3	-
Drinking Water (liter/yr)	730	510	510	330
Shoreline recreation (hr/yr) [2]				
Discharge Canal	12	67	14	-
Pilgrim Station Recreational Area	12	67	14	-
Swimming (hr/yr) [2] White Horse Beach	52	52	29	-
Boating-Cape Cod Bay (hr/yr) [2]	52	52	29	-
Inhalation (m^3/yr)	8000	8000	3700	1400

[1] Data presented in this table are from Reference 8, unless otherwise indicated.

[2] From Reference 4.

TABLE A-10

EXTERNAL DOSE FACTORS FOR STANDING ON CONTAMINATED GROUND [1]

mrem/hr per pCi/m^2

Nuclide	Total Body	Skin	Nuclide	Total Body	Skin
H-3	0.00E+00	0.00E+00	Zr-93	0.00E+00	0.00E+00
Be-10	0.00E+00	0.00E+00	Zr-95	5.00E-09	5.80E-09
C-14	0.00E+00	0.00E+00	Zr-97	5.50E-09	6.40E-09
N-13	7.60E-09	8.80E-09	Nb-93m	8.20E-13	1.00E-10
F-18	6.80E-09	8.00E-09	Nb-95	5.10E-09	6.00E-09
Na-22	1.60E-08	1.80E-08	Nb-97	4.60E-09	5.40E-09
Na-24	2.50E-08	2.90E-08	Mo-93	2.29E-11	9.32E-10
P-32	0.00E+00	0.00E+00	Mo-99	1.90E-09	2.20E-09
Ca-41	3.41E-09	4.01E-09	Tc-99m	9.60E-10	1.10E-09
Sc-46	1.30E-08	1.50E-08	Tc-99	0.00E+00	0.00E+00
Cr-51	2.20E-10	2.60E-10	Tc-101	2.70E-09	3.00E-09
Mn-54	5.80E-09	6.80E-09	Ru-103	3.60E-09	4.20E-09
Mn-56	1.10E-08	1.30E-08	Ru-105	4.50E-09	5.10E-09
Fe-55	0.00E+00	0.00E+00	Ru-106	1.50E-09	1.80E-09
Fe-59	8.00E-09	9.40E-09	Rh-105	6.60E-10	7.70E-10
Co-57	9.10E-10	1.00E-09	Pd-107	0.00E+00	0.00E+00
Co-58	7.00E-09	8.20E-09	Pd-109	3.50E-11	4.00E-11
Co-60	1.70E-08	2.00E-08	Ag-110m	1.80E-08	2.10E-08
Ni-59	0.00E+00	0.00E+00	Ag-111	1.80E-10	2.10E-10
Ni-63	0.00E+00	0.00E+00	Cd-113m	2.30E-12	2.60E-12
Ni-65	3.70E-09	4.30E-09	Cd-115m	0.00E+00	0.00E+00
Cu-64	1.50E-09	1.70E-09	Sn-123	0.00E+00	6.46E-08
Zn-65	4.00E-09	4.60E-09	Sn-125	5.70E-10	6.60E-10
Zn-69m	2.90E-09	3.40E-09	Sn-126	9.00E-09	1.00E-08
Zn-69	0.00E+00	0.00E+00	Sb-124	1.30E-08	1.50E-08
Se-79	0.00E+00	0.00E+00	Sb-125	3.10E-09	3.50E-09
Br-82	1.90E-08	2.20E-08	Sb-126	8.90E-09	1.00E-08
Br-83	6.40E-11	9.30E-11	Sb-127	5.70E-09	6.60E-09
Br-84	1.20E-08	1.40E-08	Te-125m	3.50E-11	4.80E-11
Br-85	0.00E+00	0.00E+00	Te-127m	1.10E-12	1.30E-12
Rb-86	6.30E-10	7.20E-10	Te-127	1.00E-11	1.10E-11
Rb-87	0.00E+00	0.00E+00	Te-129m	7.70E-10	9.00E-10
Rb-88	3.50E-09	4.00E-09	Te-129	7.10E-10	8.40E-10
Rb-89	1.50E-08	1.80E-08	Te-131m	8.40E-09	9.90E-09
Sr-89	5.60E-13	6.50E-13	Te-131	2.20E-09	2.60E-06
Sr-90	0.00E+00	0.00E+00	Te-132	1.70E-09	2.00E-09
Sr-91	7.10E-09	8.30E-09	Te-133m	1.50E-08	1.70E-08
Sr-92	9.00E-09	1.00E-08	Te-134	1.00E-09	1.20E-09
Y-90	2.20E-12	2.60E-12			
Y-91m	3.80E-09	4.40E-09			
Y-91	2.40E-11	2.70E-11			
Y-92	1.60E-09	1.90E-09			
Y-93	5.70E-10	7.80E-10			

[1] Data presented in this table are from Reference 9.

TABLE A-10 (continued)

EXTERNAL DOSE FACTORS FOR STANDING ON CONTAMINATED GROUND [1]

mrem/hr per pCi/m^2

Nuclide	Total Body	Skin	Nuclide	Total Body	Skin
Cs-134m	6.20E-10	7.30E-10	Pb-210	1.30E-11	1.70E-11
Cs-134	1.20E-08	1.40E-08	Bi-210	0.00E+00	0.00E+00
Cs-135	0.00E+00	0.00E+00	Po-210	5.40E-14	6.20E-14
Cs-136	1.50E-08	1.70E-08	Ra-223	1.50E-09	1.80E-09
Cs-137	4.20E-09	4.90E-09	Ra-224	8.90E-09	1.00E-08
Cs-138	2.10E-08	2.40E-08	Ra-225	8.40E-11	1.20E-10
Cs-139	6.30E-09	7.20E-09	Ra-226	6.40E-09	7.40E-09
Ba-139	2.40E-09	2.70E-09	Ra-228	1.20E-08	1.40E-08
Ba-140	2.10E-09	2.40E-09	Ac-225	1.60E-09	1.80E-09
Ba-141	4.30E-09	4.90E-09	Ac-227	2.00E-09	2.40E-09
Ba-142	7.90E-09	9.00E-09	Th-227	5.10E-10	6.30E-10
La-140	1.50E-08	1.70E-08	Th-228	8.90E-09	1.00E-08
La-141	2.50E-10	2.80E-10	Th-229	2.20E-09	2.70E-09
La-142	1.50E-08	1.80E-08	Th-230	6.50E-09	7.50E-09
Ce-141	5.50E-10	6.20E-10	Th-232	3.00E-09	4.00E-09
Ce-143	2.20E-09	2.50E-09	Th-234	1.10E-10	1.30E-10
Ce-144	3.20E-10	3.70E-10	Pa-231	2.20E-09	2.70E-09
Pr-143	0.00E+00	0.00E+00	Pa-233	1.30E-09	1.50E-09
Pr-144	2.00E-10	2.30E-10	U-232	2.59E-12	2.69E-11
Nd-147	1.00E-09	1.20E-09	U-233	2.30E-09	2.80E-09
Pm-147	0.00E+00	0.00E+00	U-234	6.32E-13	1.59E-10
Pm-148m	1.41E-08	8.16E-08	U-235	3.20E-09	4.00E-09
Pm-148	4.60E-09	5.30E-09	U-236	2.10E-14	1.80E-11
Pm-149	2.50E-11	2.90E-11	U-237	1.00E-09	1.30E-09
Pm-151	2.20E-09	2.30E-09	U-238	1.10E-10	1.50E-10
Sm-151	4.80E-11	2.10E-10	Np-237	1.40E-09	1.60E-09
Sm-153	2.70E-10	3.00E-10	Np-238	2.80E-09	3.20E-09
Eu-152	7.37E-09	8.53E-09	Np-239	9.50E-10	1.10E-09
Eu-154	7.80E-09	9.00E-09	Pu-238	1.30E-12	1.80E-11
Eu-155	3.81E-10	4.33E-10	Pu-239	7.90E-13	7.70E-12
Eu-156	7.60E-09	8.70E-09	Pu-240	1.30E-12	1.80E-11
Tb-160	8.60E-09	1.00E-08	Pu-241	4.60E-12	6.80E-12
Ho-166m	8.90E-09	1.00E-08	Pu-242	1.10E-12	1.60E-11
W-181	2.10E-12	2.80E-12	Pu-244	8.95E-10	9.62E-10
W-185	0.00E+00	0.00E+00	Am-241	1.80E-10	2.60E-10
W-187	3.10E-09	3.60E-09	Am-242m	2.60E-11	1.80E-10
			Am-243	1.30E-09	1.50E-09
			Cm-242	5.50E-12	2.30E-11
			Cm-243	2.30E-09	2.90E-09
			Cm-244	2.90E-12	1.80E-11
			Cm-245	9.50E-10	1.20E-09
			Cm-246	1.00E-12	1.50E-11
			Cm-247	2.20E-09	2.60E-09
			Cm-248	6.81E-09	5.23E-09
			Cf-252	6.60E-08	7.20E-08

[1] Data presented in this table are from Reference 9.

TABLE A-11

INHALATION DOSE FACTORS FOR ADULT[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	No Data	8.98E-08	8.98E-08	8.98E-08	8.98E-08	8.98E-08	8.98E-08
Be-10	1.98E-04	3.06E-05	4.96E-06	No Data	No Data	2.22E-04	1.67E-05
C-14	2.27E-06	4.26E-07	4.26E-07	4.26E-07	4.26E-07	4.26E-07	4.26E-07
N-13	6.27E-09	6.27E-09	6.27E-09	6.27E-09	6.27E-09	6.27E-09	6.27E-09
F-18	4.71E-07	No Data	5.19E-08	No Data	No Data	No Data	9.24E-09
Na-22	1.30E-05	1.30E-05	1.30E-05	1.30E-05	1.30E-05	1.30E-05	1.30E-05
Na-24	1.28E-06	1.28E-06	1.28E-06	1.28E-06	1.28E-06	1.28E-06	1.28E-06
P-32	1.65E-04	9.64E-06	6.26E-06	No Data	No Data	No Data	1.08E-05
Ca-41	3.83E-05	No Data	4.13E-06	No Data	No Data	3.83E-06	2.86E-07
Sc-46	5.51E-05	1.07E-04	3.11E-05	No Data	9.99E-05	No Data	3.23E-05
Cr-51	No Data	No Data	1.25E-08	7.44E-09	2.85E-09	1.80E-06	4.15E-07
Mn-54	No Data	4.95E-06	7.87E-07	No Data	1.23E-06	1.75E-04	9.67E-06
Mn-56	No Data	1.55E-10	2.29E-11	No Data	1.63E-10	1.18E-06	2.53E-06
Fe-55	3.07E-06	2.12E-06	4.93E-07	No Data	No Data	9.01E-06	7.54E-07
Fe-59	1.47E-06	3.47E-06	1.32E-06	No Data	No Data	1.27E-04	2.35E-05
Co-57	No Data	8.65E-08	8.39E-08	No Data	No Data	4.62E-05	3.93E-06
Co-58	No Data	1.98E-07	2.59E-07	No Data	No Data	1.16E-04	1.33E-05
Co-60	No Data	1.44E-06	1.85E-06	No Data	No Data	7.46E-04	3.56E-05
Ni-59	4.06E-06	1.46E-06	6.77E-07	No Data	No Data	8.20E-06	6.11E-07
Ni-63	5.40E-05	3.93E-06	1.81E-06	No Data	No Data	2.23E-05	1.67E-06
Ni-65	1.92E-10	2.62E-11	1.14E-11	No Data	No Data	7.00E-07	1.54E-06
Cu-64	No Data	1.83E-10	7.69E-11	No Data	5.78E-10	8.48E-07	6.12E-06
Zn-65	4.05E-06	1.29E-05	5.82E-06	No Data	8.62E-06	1.08E-04	6.68E-06
Zn-69m	1.02E-09	2.45E-09	2.24E-10	No Data	1.48E-09	2.38E-06	1.71E-05
Zn-69	4.23E-12	8.14E-12	5.65E-13	No Data	5.27E-12	1.15E-07	2.04E-09
Se-79	No Data	3.83E-07	6.09E-08	No Data	5.69E-07	4.47E-05	3.33E-06
Br-82	No Data	No Data	1.69E-06	No Data	No Data	No Data	1.30E-06
Br-83	No Data	No Data	3.01E-08	No Data	No Data	No Data	2.90E-08
Br-84	No Data	No Data	3.91E-08	No Data	No Data	No Data	2.05E-13
Br-85	No Data	No Data	1.60E-09	No Data	No Data	No Data	No Data
Rb-86	No Data	1.69E-05	7.37E-06	No Data	No Data	No Data	2.08E-06
Rb-87	No Data	9.86E-06	3.21E-06	No Data	No Data	No Data	2.88E-07
Rb-88	No Data	4.84E-08	2.41E-08	No Data	No Data	No Data	4.18E-19
Rb-89	No Data	3.20E-08	2.12E-08	No Data	No Data	No Data	1.16E-21
Sr-89	3.80E-05	No Data	1.09E-06	No Data	No Data	1.75E-04	4.37E-05
Sr-90	3.59E-03	No Data	7.21E-05	No Data	No Data	1.20E-03	9.02E-05
Sr-91	7.74E-09	No Data	3.13E-10	No Data	No Data	4.56E-06	2.39E-05
Sr-92	8.43E-10	No Data	3.64E-11	No Data	No Data	2.06E-06	5.38E-06
Y-90	2.61E-07	No Data	7.01E-09	No Data	No Data	2.12E-05	6.32E-05
Y-91m	3.26E-11	No Data	1.27E-12	No Data	No Data	2.40E-07	1.66E-10
Y-91	5.78E-05	No Data	1.55E-06	No Data	No Data	2.13E-04	4.81E-05
Y-92	1.29E-09	No Data	3.77E-11	No Data	No Data	1.96E-06	9.19E-06
Y-93	1.18E-08	No Data	3.26E-10	No Data	No Data	6.06E-06	5.27E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-11 (continued)

INHALATION DOSE FACTORS FOR ADULT[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Zr-93	5.22E-05	2.92E-06	1.37E-06	No Data	1.11E-05	2.13E-05	1.51E-06
Zr-95	1.34E-05	4.30E-06	2.91E-06	No Data	6.77E-06	2.21E-04	1.88E-05
Zr-97	1.21E-08	2.45E-09	1.13E-09	No Data	3.71E-09	9.84E-06	6.54E-05
Nb-93m	3.10E-05	1.01E-05	2.49E-06	No Data	1.16E-05	3.11E-05	2.38E-06
Nb-95	1.76E-06	9.77E-07	5.26E-07	No Data	9.67E-07	6.31E-05	1.30E-05
Nb-97	2.78E-11	7.03E-12	2.56E-12	No Data	8.18E-12	3.00E-07	3.02E-08
Mo-93	No Data	1.17E-06	3.17E-08	No Data	3.55E-07	5.11E-05	3.79E-06
Mo-99	No Data	1.51E-08	2.87E-09	No Data	3.64E-08	1.14E-05	3.10E-05
Tc-99m	1.29E-13	3.64E-13	4.63E-12	No Data	5.52E-12	9.55E-08	5.20E-07
Tc-99	3.13E-08	4.64E-08	1.25E-08	No Data	5.85E-07	1.01E-04	7.54E-06
Tc-101	5.22E-15	7.52E-15	7.38E-14	No Data	1.35E-13	4.99E-08	1.36E-21
Ru-103	1.91E-07	No Data	8.23E-08	No Data	7.29E-07	6.31E-05	1.38E-05
Ru-105	9.88E-11	No Data	3.89E-11	No Data	1.27E-10	1.37E-06	6.02E-06
Ru-106	8.64E-06	No Data	1.09E-06	No Data	1.67E-05	1.17E-03	1.14E-04
Rh-105	9.24E-10	6.73E-10	4.43E-10	No Data	2.86E-09	2.41E-06	1.09E-05
Pd-107	No Data	8.27E-08	5.87E-09	No Data	6.57E-07	9.47E-06	7.06E-07
Pd-109	No Data	4.63E-10	1.16E-10	No Data	2.35E-09	1.85E-06	1.52E-05
Ag-110m	1.35E-06	1.25E-06	7.43E-07	No Data	2.46E-06	5.79E-04	3.78E-05
Ag-111	4.25E-08	1.78E-08	8.87E-09	No Data	5.74E-08	2.33E-05	2.79E-05
Cd-113m	No Data	1.54E-04	4.97E-06	No Data	1.71E-04	2.08E-04	1.59E-05
Cd-115m	No Data	2.46E-05	7.95E-07	No Data	1.98E-05	1.76E-04	4.80E-05
Sn-123	3.02E-05	6.67E-07	9.82E-07	5.67E-07	No Data	2.88E-04	3.92E-05
Sn-125	1.16E-06	3.12E-08	7.03E-08	2.59E-08	No Data	7.37E-05	6.81E-05
Sn-126	1.58E-04	4.18E-06	6.00E-06	1.23E-06	No Data	1.17E-03	1.59E-05
Sb-124	3.90E-06	7.36E-08	1.55E-06	9.44E-09	No Data	3.10E-04	5.08E-05
Sb-125	6.67E-06	7.44E-08	1.58E-06	6.75E-09	No Data	2.18E-04	1.26E-05
Sb-126	4.50E-07	9.13E-09	1.62E-07	2.75E-09	No Data	9.57E-05	6.01E-05
Sb-127	3.30E-08	7.22E-10	1.27E-08	3.97E-10	No Data	2.05E-05	3.77E-05
Te-125m	4.27E-07	1.98E-07	5.84E-08	1.31E-07	1.55E-06	3.92E-05	8.83E-06
Te-127m	1.58E-06	7.21E-07	1.96E-07	4.11E-07	5.72E-06	1.20E-04	1.87E-05
Te-127	1.75E-10	8.03E-11	3.87E-11	1.32E-10	6.37E-10	8.14E-07	7.17E-06
Te-129m	1.22E-06	5.84E-07	1.98E-07	4.30E-07	4.57E-06	1.45E-04	4.79E-05
Te-129	6.22E-12	2.99E-12	1.55E-12	4.87E-12	2.34E-11	2.42E-07	1.96E-08
Te-131m	8.74E-09	5.45E-09	3.63E-09	6.88E-09	3.86E-08	1.82E-05	6.95E-05
Te-131	1.39E-12	7.44E-13	4.49E-13	1.17E-12	5.46E-12	1.74E-07	2.30E-09
Te-132	3.25E-08	2.69E-08	2.02E-08	2.37E-08	1.82E-07	3.60E-05	6.37E-05
Te-133m	7.24E-12	5.40E-12	4.17E-12	6.27E-12	3.74E-11	5.51E-07	7.65E-09
Te-134	3.84E-12	3.22E-12	1.57E-12	3.44E-12	2.18E-11	4.34E-07	2.97E-11

[1] Data presented in this Table are from Reference 9.

TABLE A-11 (continued)

INHALATION DOSE FACTORS FOR ADULT[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Cs-134m	1.59E-08	3.20E-08	1.72E-08	No Data	1.83E-08	2.93E-09	7.92E-09
Cs-134	4.66E-05	1.06E-04	9.10E-05	No Data	3.59E-05	1.22E-05	1.30E-06
Cs-135	1.46E-05	1.29E-05	5.99E-06	No Data	5.11E-06	1.57E-06	2.11E-07
Cs-136	4.88E-06	1.83E-05	1.38E-05	No Data	1.07E-05	1.50E-06	1.46E-06
Cs-137	5.98E-05	7.76E-05	5.35E-05	No Data	2.78E-05	9.40E-06	1.05E-06
Cs-138	4.14E-08	7.76E-08	4.05E-08	No Data	6.00E-08	6.07E-09	2.33E-13
Cs-139	2.56E-08	3.63E-08	1.39E-08	No Data	3.05E-08	2.84E-09	5.49E-31
Ba-139	1.17E-10	8.32E-14	3.42E-12	No Data	7.78E-14	4.70E-07	1.12E-07
Ba-140	4.88E-06	6.13E-09	3.21E-07	No Data	2.09E-09	1.59E-04	2.73E-05
Ba-141	1.25E-11	9.41E-15	4.20E-13	No Data	8.75E-15	2.42E-07	1.45E-17
Ba-142	3.29E-12	3.38E-15	2.07E-13	No Data	2.86E-15	1.49E-07	1.96E-26
La-140	4.30E-08	2.17E-08	5.73E-09	No Data	No Data	1.70E-05	5.73E-05
La-141	5.34E-10	1.66E-10	2.71E-11	No Data	No Data	1.35E-06	7.31E-06
La-142	8.54E-11	3.88E-11	9.65E-12	No Data	No Data	7.91E-07	2.64E-07
Ce-141	2.49E-06	1.69E-06	1.91E-07	No Data	7.83E-07	4.52E-05	1.50E-05
Ce-143	2.33E-08	1.72E-08	1.91E-09	No Data	7.60E-09	9.97E-06	2.83E-05
Ce-144	4.29E-04	1.79E-04	2.30E-05	No Data	1.06E-04	9.72E-04	1.02E-04
Pr-143	1.17E-06	4.69E-07	5.80E-08	No Data	2.70E-07	3.51E-05	2.50E-05
Pr-144	3.76E-12	1.56E-12	1.91E-13	No Data	8.81E-13	1.27E-07	2.69E-18
Nd-147	6.59E-07	7.62E-07	4.56E-08	No Data	4.45E-07	2.76E-05	2.16E-05
Pm-147	8.37E-05	7.87E-06	3.19E-06	No Data	1.49E-05	6.60E-05	5.54E-06
Pm-148m	9.82E-06	2.54E-06	1.94E-06	No Data	3.85E-06	2.14E-04	4.18E-05
Pm-148	3.84E-07	6.37E-08	3.20E-08	No Data	1.20E-07	3.91E-05	5.80E-05
Pm-149	3.44E-08	4.87E-09	1.99E-09	No Data	9.19E-09	7.21E-06	2.50E-05
Pm-151	8.50E-09	1.42E-09	7.21E-10	No Data	2.55E-09	3.94E-06	2.00E-05
Sm-151	8.59E-05	1.48E-05	3.55E-06	No Data	1.66E-05	4.45E-05	3.25E-06
Sm-153	1.70E-08	1.42E-08	1.04E-09	No Data	4.59E-09	4.14E-06	1.58E-05
Eu-152	2.38E-04	5.41E-05	4.76E-05	No Data	3.35E-04	3.43E-04	1.59E-05
Eu-154	7.40E-04	9.10E-05	6.48E-05	No Data	4.36E-04	5.84E-04	3.40E-05
Eu-155	1.01E-04	1.43E-05	9.21E-06	No Data	6.59E-05	9.46E-05	5.95E-06
Eu-156	1.93E-06	1.48E-06	2.40E-07	No Data	9.95E-07	8.56E-05	4.50E-05
Tb-160	2.21E-05	No Data	2.75E-06	No Data	9.10E-06	1.92E-04	2.68E-05
Ho-166m	3.37E-04	1.05E-04	8.00E-05	No Data	1.57E-04	3.94E-04	1.59E-05
W-181	6.23E-09	2.03E-09	2.17E-10	No Data	No Data	1.71E-06	2.53E-07
W-185	1.95E-07	6.47E-08	6.81E-09	No Data	No Data	5.57E-05	1.07E-05
W-187	1.06E-09	8.85E-10	3.10E-10	No Data	No Data	3.63E-06	1.94E-05
Pb-210	2.64E-02	6.73E-03	8.37E-04	No Data	2.12E-02	2.62E-02	1.51E-06
Bi-210	2.31E-07	1.59E-06	1.32E-07	No Data	1.92E-05	1.11E-03	2.95E-05
Po-210	3.97E-04	8.60E-04	9.58E-05	No Data	2.95E-03	3.14E-02	4.19E-05
Ra-223	1.80E-04	2.77E-07	3.60E-05	No Data	7.85E-06	2.55E-02	2.84E-04
Ra-224	1.98E-05	4.78E-08	3.96E-06	No Data	1.35E-06	8.77E-03	3.01E-04
Ra-225	3.00E-04	3.56E-07	5.99E-05	No Data	1.01E-05	2.92E-02	2.71E-04
Ra-226	1.25E-01	2.39E-06	9.14E-02	No Data	6.77E-05	1.17E-01	2.94E-04
Ra-228	4.41E-02	1.23E-06	4.78E-02	No Data	3.48E-05	1.61E-01	5.00E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-11 (continued)

INHALATION DOSE FACTORS FOR ADULT[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Ac-225	4.23E-04	5.82E-04	2.84E-05	No Data	6.63E-05	2.21E-02	2.52E-04
Ac-227	2.30E+00	3.05E-01	1.36E-01	No Data	9.82E-02	2.41E-01	5.08E-05
Th-227	2.17E-04	3.92E-06	6.25E-06	No Data	2.22E-05	3.77E-02	3.34E-04
Th-228	2.00E-01	3.39E-03	6.77E-03	No Data	1.89E-02	1.01E+00	3.49E-04
Th-229	1.51E+01	4.34E-01	2.51E-01	No Data	2.13E+00	3.62E+00	4.83E-05
Th-230	2.29E+00	1.31E-01	6.36E-02	No Data	6.40E-01	6.21E-01	3.73E-05
Th-232	2.56E+00	1.12E-01	9.04E-04	No Data	5.47E-01	5.96E-01	3.17E-05
Th-234	1.63E-06	9.56E-08	4.70E-08	No Data	5.41E-07	1.89E-04	7.03E-05
Pa-231	5.08E+00	1.91E-01	1.98E-01	No Data	1.07E+00	5.75E-02	4.44E-05
Pa-233	1.21E-06	2.42E-07	2.09E-07	No Data	9.15E-07	3.52E-05	1.02E-05
U-232	5.14E-02	No Data	3.66E-03	No Data	5.56E-03	2.22E-01	4.21E-05
U-233	1.09E-02	No Data	6.60E-04	No Data	2.54E-03	5.32E-02	3.89E-05
U-234	1.04E-02	No Data	6.46E-04	No Data	2.49E-03	5.22E-02	3.81E-05
U-235	1.00E-02	No Data	6.07E-04	No Data	2.34E-03	4.90E-02	4.84E-05
U-236	1.00E-02	No Data	6.20E-04	No Data	2.39E-03	5.00E-02	3.57E-05
U-237	3.67E-08	No Data	9.77E-09	No Data	1.51E-07	1.02E-05	1.20E-05
U-238	9.58E-03	No Data	5.67E-04	No Data	2.18E-03	4.58E-02	3.41E-05
Np-237	1.56E+00	1.00E+00	6.87E-02	No Data	5.10E-01	5.22E-02	4.92E-05
Np-238	2.96E-07	7.20E-08	4.61E-09	No Data	2.72E-08	1.02E-05	2.13E-05
Np-239	2.87E-08	2.54E-08	1.55E-09	No Data	8.75E-09	4.70E-06	1.49E-05
Pu-238	1.43E+00	9.71E-01	6.90E-02	No Data	2.96E-01	1.82E-01	4.52E-05
Pu-239	1.66E+00	1.07E+00	7.75E-02	No Data	3.30E-01	1.72E-01	4.13E-05
Pu-240	1.65E+00	1.07E+00	7.73E-02	No Data	3.29E-01	1.72E-01	4.21E-05
Pu-241	3.42E-02	8.69E-03	1.29E-03	No Data	5.93E-03	1.52E-04	8.65E-07
Pu-242	1.53E+00	1.03E+00	7.46E-02	No Data	3.17E-01	1.65E-01	4.05E-05
Pu-244	1.79E+00	1.18E+00	8.54E-02	No Data	3.64E-01	1.89E-01	6.03E-05
Am-241	1.68E+00	1.13E+00	6.71E-02	No Data	5.04E-01	6.06E-02	4.60E-05
Am-242m	1.70E+00	1.06E+00	6.73E-02	No Data	5.01E-01	2.44E-02	5.79E-05
Am-243	1.68E+00	1.10E+00	6.57E-02	No Data	4.95E-01	5.75E-02	5.40E-05
Cm-242	2.22E-02	1.77E-02	9.84E-04	No Data	4.48E-03	3.92E-02	4.91E-05
Cm-243	1.10E+00	7.61E-01	4.61E-02	No Data	2.15E-01	6.31E-02	4.84E-05
Cm-244	8.37E-01	5.88E-01	3.51E-02	No Data	1.64E-01	6.06E-02	4.68E-05
Cm-245	1.74E+00	1.14E+00	7.14E-02	No Data	3.33E-01	5.85E-02	4.36E-05
Cm-246	1.73E+00	1.14E+00	7.13E-02	No Data	3.33E-01	5.96E-02	4.29E-05
Cm-247	1.68E+00	1.12E+00	7.03E-02	No Data	3.28E-01	5.85E-02	5.63E-05
Cm-248	1.40E+01	9.26E+00	5.79E-01	No Data	2.70E+00	4.82E-01	9.09E-04
Cf-252	5.43E-01	No Data	2.33E-02	No Data	No Data	1.99E-01	1.78E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-12

INHALATION DOSE FACTORS FOR TEEN[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	No Data	9.06E-08	9.06E-08	9.06E-08	9.06E-08	9.06E-08	9.06E-08
Be-10	2.78E-04	4.33E-05	7.09E-06	No Data	No Data	3.84E-04	1.77E-05
C-14	3.25E-06	6.09E-07	6.09E-07	6.09E-07	6.09E-07	6.09E-07	6.09E-07
N-13	8.65E-09	8.65E-09	8.65E-09	8.65E-09	8.65E-09	8.65E-09	8.65E-09
F-18	6.52E-07	No Data	7.10E-08	No Data	No Data	No Data	3.89E-08
Na-22	1.76E-05	1.76E-05	1.76E-05	1.76E-05	1.76E-05	1.76E-05	1.76E-05
Na-24	1.72E-06	1.72E-06	1.72E-06	1.72E-06	1.72E-06	1.72E-06	1.72E-06
P-32	2.36E-04	1.37E-05	8.95E-06	No Data	No Data	No Data	1.16E-05
Ca-41	4.05E-05	No Data	4.38E-06	No Data	No Data	1.01E-01	3.03E-07
Sc-46	7.24E-05	1.41E-04	4.18E-05	No Data	1.35E-04	No Data	2.98E-05
Cr-51	No Data	No Data	1.69E-08	9.37E-09	3.84E-09	2.62E-06	3.75E-07
Mn-54	No Data	6.39E-06	1.05E-06	No Data	1.59E-06	2.48E-04	8.35E-06
Mn-56	No Data	2.12E-10	3.15E-11	No Data	2.24E-10	1.90E-06	7.18E-06
Fe-55	4.18E-06	2.98E-06	6.93E-07	No Data	No Data	1.55E-05	7.99E-07
Fe-59	1.99E-06	4.62E-06	1.79E-06	No Data	No Data	1.91E-04	2.23E-05
Co-57	No Data	1.18E-07	1.15E-07	No Data	No Data	7.33E-05	3.93E-06
Co-58	No Data	2.59E-07	3.47E-07	No Data	No Data	1.68E-04	1.19E-05
Co-60	No Data	1.89E-06	2.48E-06	No Data	No Data	1.09E-03	3.24E-05
Ni-59	5.44E-06	2.02E-06	9.24E-07	No Data	No Data	1.41E-05	6.48E-07
Ni-63	7.25E-05	5.43E-06	2.47E-06	No Data	No Data	3.84E-05	1.77E-06
Ni-65	2.73E-10	3.66E-11	1.59E-11	No Data	No Data	1.17E-06	4.59E-06
Cu-64	No Data	2.54E-10	1.06E-10	No Data	8.01E-10	1.39E-06	7.68E-06
Zn-65	4.82E-06	1.67E-05	7.80E-06	No Data	1.08E-05	1.55E-04	5.83E-06
Zn-69m	1.44E-09	3.39E-09	3.11E-10	No Data	2.06E-09	3.92E-06	2.14E-05
Zn-69	6.04E-12	1.15E-11	8.07E-13	No Data	7.53E-12	1.98E-07	3.56E-08
Se-79	No Data	5.43E-07	8.71E-08	No Data	8.13E-07	7.71E-05	3.53E-06
Br-82	No Data	No Data	2.28E-06	No Data	No Data	No Data	No Data
Br-83	No Data	No Data	4.30E-08	No Data	No Data	No Data	No Data
Br-84	No Data	No Data	5.41E-08	No Data	No Data	No Data	No Data
Br-85	No Data	No Data	2.29E-09	No Data	No Data	No Data	No Data
Rb-86	No Data	2.38E-05	1.05E-05	No Data	No Data	No Data	2.21E-06
Rb-87	No Data	1.40E-05	4.58E-06	No Data	No Data	No Data	3.05E-07
Rb-88	No Data	6.82E-08	3.40E-08	No Data	No Data	No Data	3.65E-15
Rb-89	No Data	4.40E-08	2.91E-08	No Data	No Data	No Data	4.22E-17
Sr-89	5.43E-05	No Data	1.56E-06	No Data	No Data	3.02E-04	4.64E-05
Sr-90	4.14E-03	No Data	8.33E-05	No Data	No Data	2.06E-03	9.56E-05
Sr-91	1.10E-08	No Data	4.39E-10	No Data	No Data	7.59E-06	3.24E-05
Sr-92	1.19E-09	No Data	5.08E-11	No Data	No Data	3.43E-06	1.49E-05
Y-90	3.73E-07	No Data	1.00E-08	No Data	No Data	3.66E-05	6.99E-05
Y-91m	4.63E-11	No Data	1.77E-12	No Data	No Data	4.00E-07	3.77E-09
Y-91	8.26E-05	No Data	2.21E-06	No Data	No Data	3.67E-04	5.11E-05
Y-92	1.84E-09	No Data	5.36E-11	No Data	No Data	3.35E-06	2.06E-05
Y-93	1.69E-08	No Data	4.65E-10	No Data	No Data	1.04E-05	7.24E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-12 (continued)

INHALATION DOSE FACTORS FOR TEEN[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Zr-93	6.83E-05	3.38E-06	1.84E-06	No Data	1.16E-05	3.67E-05	1.60E-06
Zr-95	1.82E-05	5.73E-06	3.94E-06	No Data	8.42E-06	3.36E-04	1.86E-05
Zr-97	1.72E-08	3.40E-09	1.57E-09	No Data	5.15E-09	1.62E-05	7.88E-05
Nb-93m	4.14E-05	1.36E-05	3.41E-06	No Data	1.59E-05	5.36E-05	2.52E-06
Nb-95	2.32E-06	1.29E-06	7.08E-07	No Data	1.25E-06	9.39E-05	1.21E-05
Nb-97	3.92E-11	9.72E-12	3.55E-12	No Data	1.14E-11	4.91E-07	2.71E-07
Mo-93	No Data	1.66E-06	4.52E-08	No Data	5.06E-07	8.81E-05	3.99E-06
Mo-99	No Data	2.11E-08	4.03E-09	No Data	5.14E-08	1.92E-05	3.36E-05
Tc-99m	1.73E-13	4.83E-13	6.24E-12	No Data	7.20E-12	1.44E-07	7.66E-07
Tc-99	4.48E-08	6.58E-08	1.79E-08	No Data	8.35E-07	1.74E-04	7.99E-06
Tc-101	7.40E-15	1.05E-14	1.03E-13	No Data	1.90E-13	8.34E-08	1.09E-16
Ru-103	2.63E-07	No Data	1.12E-07	No Data	9.29E-07	9.79E-05	1.36E-05
Ru-105	1.40E-10	No Data	5.42E-11	No Data	1.76E-10	2.27E-06	1.13E-05
Ru-106	1.23E-05	No Data	1.55E-06	No Data	2.38E-05	2.01E-03	1.20E-04
Rh-105	1.32E-09	9.48E-10	6.24E-10	No Data	4.04E-09	4.09E-06	1.23E-05
Pd-107	No Data	1.17E-07	8.39E-09	No Data	9.39E-07	1.63E-05	7.49E-07
Pd-109	No Data	6.56E-10	1.66E-10	No Data	3.36E-09	3.19E-06	1.96E-05
Ag-110m	1.73E-06	1.64E-06	9.99E-07	No Data	3.13E-06	8.44E-04	3.41E-05
Ag-111	6.07E-08	2.52E-08	1.26E-08	No Data	8.17E-08	4.00E-05	3.00E-05
Cd-113m	No Data	2.17E-04	7.10E-06	No Data	2.43E-04	3.59E-04	1.68E-05
Cd-115m	No Data	3.48E-05	1.14E-06	No Data	2.82E-05	3.03E-04	5.10E-05
Sn-123	4.31E-05	9.44E-07	1.40E-06	7.55E-07	No Data	4.96E-04	4.16E-05
Sn-125	1.66E-06	4.42E-08	9.99E-08	3.45E-08	No Data	1.26E-04	7.29E-05
Sn-126	2.18E-04	5.39E-06	8.24E-06	1.42E-06	No Data	1.72E-03	1.68E-05
Sb-124	5.38E-06	9.92E-08	2.10E-06	1.22E-08	No Data	4.81E-04	4.98E-05
Sb-125	9.23E-06	1.01E-07	2.15E-06	8.80E-09	No Data	3.42E-04	1.24E-05
Sb-126	6.19E-07	1.27E-08	2.23E-07	3.50E-09	No Data	1.55E-04	6.01E-05
Sb-127	4.64E-08	9.92E-10	1.75E-08	5.21E-10	No Data	3.31E-05	3.94E-05
Te-125m	6.10E-07	2.80E-07	8.34E-08	1.75E-07	No Data	6.70E-05	9.38E-06
Te-127m	2.25E-06	1.02E-06	2.73E-07	5.48E-07	8.17E-06	2.07E-04	1.99E-05
Te-127	2.51E-10	1.14E-10	5.52E-11	1.77E-10	9.10E-10	1.40E-06	1.01E-05
Te-129m	1.74E-06	8.23E-07	2.81E-07	5.72E-07	6.49E-06	2.47E-04	5.06E-05
Te-129	8.87E-12	4.22E-12	2.20E-12	6.48E-12	3.32E-11	4.12E-07	2.02E-07
Te-131m	1.23E-08	7.51E-09	5.03E-09	9.06E-09	5.49E-08	2.97E-05	7.76E-05
Te-131	1.97E-12	1.04E-12	6.30E-13	1.55E-12	7.72E-12	2.92E-07	1.89E-09
Te-132	4.50E-08	3.63E-08	2.74E-08	3.07E-08	2.44E-07	5.61E-05	5.79E-05
Te-133m	1.01E-11	7.33E-12	5.71E-12	8.18E-12	5.07E-11	8.71E-07	1.23E-07
Te-134	5.31E-12	4.35E-12	3.64E-12	4.46E-12	2.91E-11	6.75E-07	1.37E-09

[1] Data presented in this Table are from Reference 9.

TABLE A-12 (continued)

INHALATION DOSE FACTORS FOR TEEN[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Cs-134m	2.20E-08	4.35E-08	2.35E-08	No Data	2.54E-08	4.56E-09	2.02E-08
Cs-134	6.28E-05	1.41E-04	6.86E-05	No Data	4.69E-05	1.83E-05	1.22E-06
Cs-135	2.08E-05	1.82E-05	4.47E-06	No Data	7.30E-06	2.70E-06	2.23E-07
Cs-136	6.44E-06	2.42E-05	1.71E-05	No Data	1.38E-05	2.22E-06	1.36E-06
Cs-137	8.38E-05	1.06E-04	3.89E-05	No Data	3.80E-05	1.51E-05	1.06E-06
Cs-138	5.82E-08	1.07E-07	5.58E-08	No Data	8.28E-08	9.84E-09	3.38E-11
Cs-139	3.65E-08	5.12E-08	1.97E-08	No Data	4.34E-08	4.86E-09	1.66E-23
Ba-139	1.67E-10	1.18E-13	4.87E-12	No Data	1.11E-13	8.08E-07	8.06E-07
Ba-140	6.84E-06	8.38E-09	4.40E-07	No Data	2.85E-09	2.54E-04	2.86E-05
Ba-141	1.78E-11	1.32E-14	5.93E-13	No Data	1.23E-14	4.11E-07	9.33E-14
Ba-142	4.62E-12	4.63E-15	2.84E-13	No Data	3.92E-15	2.39E-07	5.99E-20
La-140	5.99E-08	2.95E-08	7.82E-09	No Data	No Data	2.68E-05	6.09E-05
La-141	7.63E-10	2.35E-10	3.87E-11	No Data	No Data	2.31E-06	1.54E-05
La-142	1.20E-10	5.31E-11	1.32E-11	No Data	No Data	1.27E-06	1.50E-06
Ce-141	3.55E-06	2.37E-06	2.71E-07	No Data	1.11E-06	7.67E-05	1.58E-05
Ce-143	3.32E-08	2.42E-08	2.70E-09	No Data	1.08E-08	1.63E-05	3.19E-05
Ce-144	6.11E-04	2.53E-04	3.28E-05	No Data	1.51E-04	1.67E-03	1.08E-04
Pr-143	1.67E-06	6.64E-07	8.28E-08	No Data	3.86E-07	6.04E-05	2.67E-05
Pr-144	5.37E-12	2.20E-12	2.72E-13	No Data	1.26E-12	2.19E-07	2.94E-14
Nd-147	9.83E-07	1.07E-06	6.41E-08	No Data	6.28E-07	4.65E-05	2.28E-05
Pm-147	1.15E-04	1.10E-05	4.50E-06	No Data	2.10E-05	1.14E-04	5.87E-06
Pm-148m	1.32E-05	3.35E-06	2.62E-06	No Data	5.07E-06	3.20E-04	4.10E-05
Pm-148	5.44E-07	8.88E-08	4.48E-08	No Data	1.60E-07	6.52E-05	6.14E-05
Pm-149	4.91E-08	6.89E-09	2.84E-09	No Data	1.31E-08	1.24E-05	2.79E-05
Pm-151	1.20E-08	1.99E-09	1.01E-09	No Data	3.57E-09	6.56E-06	2.27E-05
Sm-151	1.07E-04	2.10E-05	4.86E-06	No Data	2.27E-05	7.68E-05	3.53E-06
Sm-153	2.43E-08	2.01E-08	1.47E-09	No Data	6.56E-09	7.11E-06	1.77E-05
Eu-152	2.96E-04	7.19E-05	6.30E-05	No Data	3.34E-04	5.01E-04	1.35E-05
Eu-154	9.43E-04	1.23E-04	8.60E-05	No Data	5.44E-04	9.12E-04	3.34E-05
Eu-155	2.00E-04	1.96E-05	1.21E-05	No Data	7.65E-05	1.51E-03	5.97E-05
Eu-156	2.70E-06	2.03E-06	3.30E-07	No Data	1.36E-06	1.37E-04	4.56E-05
Tb-160	3.04E-05	No Data	3.79E-06	No Data	1.20E-05	2.97E-04	2.60E-05
Ho-166m	4.40E-04	1.36E-04	9.87E-05	No Data	2.00E-04	6.24E-04	1.68E-05
W-181	8.90E-09	2.88E-09	3.01E-10	No Data	No Data	2.95E-06	2.69E-07
W-185	2.78E-07	9.17E-08	9.73E-09	No Data	No Data	9.60E-05	1.14E-05
W-187	1.50E-09	1.22E-09	4.29E-10	No Data	No Data	5.92E-06	2.21E-05
Pb-210	3.09E-02	8.28E-03	1.07E-03	No Data	2.95E-02	4.52E-02	1.60E-06
Bi-210	3.30E-07	2.26E-06	1.89E-07	No Data	2.74E-05	1.91E-03	3.19E-05
Po-210	5.68E-04	1.22E-03	1.37E-04	No Data	4.21E-03	5.41E-02	4.45E-05
Ra-223	2.57E-04	3.93E-07	5.14E-05	No Data	1.12E-05	4.39E-02	3.04E-04
Ra-224	2.83E-05	6.77E-08	5.65E-06	No Data	1.93E-06	1.51E-02	3.29E-04
Ra-225	4.28E-04	5.04E-07	8.56E-05	No Data	1.44E-05	5.04E-02	2.89E-04
Ra-226	1.33E-01	3.38E-06	9.87E-02	No Data	9.67E-05	2.02E-01	3.11E-04
Ra-228	5.34E-02	1.74E-06	5.88E-02	No Data	4.97E-05	2.78E-01	5.30E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-12 (continued)

INHALATION DOSE FACTORS FOR TEEN[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Ac-225	6.04E-04	8.25E-04	4.06E-05	No Data	9.47E-05	3.81E-02	2.70E-04
Ac-227	2.49E+00	3.69E-01	1.48E-01	No Data	1.07E-01	4.16E-01	5.38E-05
Th-227	3.09E-04	5.56E-06	8.93E-06	No Data	3.18E-05	6.50E-02	3.57E-04
Th-228	2.60E-01	4.37E-03	8.78E-03	No Data	2.45E-02	1.69E+00	3.70E-04
Th-229	1.54E+01	4.44E-01	2.56E-01	No Data	2.18E+00	5.24E+00	5.12E-05
Th-230	2.34E+00	1.34E-01	6.49E-02	No Data	6.55E-01	8.98E-01	3.95E-05
Th-232	2.61E+00	1.14E-01	9.21E-04	No Data	5.60E-01	8.60E-01	3.36E-05
Th-234	2.32E-06	1.35E-07	6.71E-08	No Data	7.73E-07	3.26E-04	7.49E-05
Pa-231	5.32E+00	2.00E-01	2.07E-01	No Data	1.12E+00	9.91E-02	4.71E-05
Pa-233	1.68E-06	3.24E-07	2.89E-07	No Data	1.22E-06	5.39E-05	1.00E-05
U-232	7.31E-02	No Data	5.23E-03	No Data	7.94E-03	3.84E-01	4.46E-05
U-233	1.55E-02	No Data	9.42E-04	No Data	3.63E-03	9.18E-02	4.12E-05
U-234	1.48E-02	No Data	9.23E-04	No Data	3.55E-03	8.99E-02	4.04E-05
U-235	1.42E-02	No Data	8.67E-04	No Data	3.34E-03	8.44E-02	5.13E-05
U-236	1.42E-02	No Data	8.86E-04	No Data	3.41E-03	8.62E-02	3.79E-05
U-237	5.25E-08	No Data	1.40E-08	No Data	2.16E-07	1.76E-05	1.29E-05
U-238	1.36E-02	No Data	8.10E-04	No Data	3.12E-03	7.89E-02	3.62E-05
Np-237	1.64E+00	1.06E+00	7.21E-02	No Data	5.35E-01	8.99E-02	5.22E-05
Np-238	4.23E-07	1.02E-07	6.59E-09	No Data	3.88E-08	1.75E-05	2.38E-05
Np-239	4.23E-08	3.60E-08	2.21E-09	No Data	1.25E-08	8.11E-06	1.65E-05
Pu-238	1.50E+00	1.03E+00	7.22E-02	No Data	3.10E-01	3.12E-01	4.79E-05
Pu-239	1.73E+00	1.12E+00	8.05E-02	No Data	3.44E-01	2.93E-01	4.37E-05
Pu-240	1.72E+00	1.12E+00	8.04E-02	No Data	3.43E-01	2.93E-01	4.46E-05
Pu-241	3.74E-02	9.56E-03	1.40E-03	No Data	6.47E-03	2.60E-04	9.17E-07
Pu-242	1.60E+00	1.08E+00	7.75E-02	No Data	3.31E-01	2.82E-01	4.29E-05
Pu-244	1.87E+00	1.24E+00	8.88E-02	No Data	3.79E-01	3.23E-01	6.39E-05
Am-241	1.77E+00	1.20E+00	7.10E-02	No Data	5.32E-01	1.05E-01	4.88E-05
Am-242m	1.79E+00	1.13E+00	7.15E-02	No Data	5.30E-01	4.21E-02	6.14E-05
Am-243	1.77E+00	1.17E+00	6.95E-02	No Data	5.21E-01	9.91E-02	5.72E-05
Cm-242	3.17E-02	2.51E-02	1.41E-03	No Data	6.40E-03	6.76E-02	5.21E-05
Cm-243	1.19E+00	8.30E-01	5.00E-02	No Data	2.34E-01	1.09E-01	5.13E-05
Cm-244	9.19E-01	6.53E-01	3.88E-02	No Data	1.81E-01	1.05E-01	4.96E-05
Cm-245	1.83E+00	1.22E+00	7.53E-02	No Data	3.52E-01	1.01E-01	4.63E-05
Cm-246	1.81E+00	1.22E+00	7.52E-02	No Data	3.51E-01	1.03E-01	4.54E-05
Cm-247	1.77E+00	1.19E+00	7.41E-02	No Data	3.46E-01	1.01E-01	5.97E-05
Cm-248	1.47E+01	9.83E+00	6.11E-01	No Data	2.85E+00	8.32E-01	9.63E-04
Cf-252	7.16E-01	No Data	3.07E-02	No Data	No Data	3.43E-01	1.89E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-13

INHALATION DOSE FACTORS FOR CHILD[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	No Data	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07
Be-10	8.43E-04	9.83E-05	2.12E-05	No Data	No Data	7.41E-04	1.72E-05
C-14	9.70E-06	1.82E-06	1.82E-06	1.82E-06	1.82E-06	1.82E-06	1.82E-06
N-13	2.33E-08	2.33E-08	2.33E-08	2.33E-08	2.33E-08	2.33E-08	2.33E-08
F-18	1.88E-06	No Data	1.85E-07	No Data	No Data	No Data	3.37E-07
Na-22	4.41E-05	4.41E-05	4.41E-05	4.41E-05	4.41E-05	4.41E-05	4.41E-05
Na-24	4.35E-06	4.35E-06	4.35E-06	4.35E-06	4.35E-06	4.35E-06	4.35E-06
P-32	7.04E-04	3.09E-05	2.67E-05	No Data	No Data	No Data	1.14E-05
Ca-41	7.06E-05	No Data	7.70E-06	No Data	No Data	7.21E-02	2.94E-07
Sc-46	1.97E-04	2.70E-04	1.04E-04	No Data	2.39E-04	No Data	2.45E-05
Cr-51	No Data	No Data	4.17E-08	2.31E-08	6.57E-09	4.59E-06	2.93E-07
Mn-54	No Data	1.16E-05	2.57E-06	No Data	2.71E-06	4.26E-04	6.19E-06
Mn-56	No Data	4.48E-10	8.43E-11	No Data	4.52E-10	3.55E-06	3.33E-05
Fe-55	1.28E-05	6.80E-06	2.10E-06	No Data	No Data	3.00E-05	7.75E-07
Fe-59	5.59E-06	9.04E-06	4.51E-06	No Data	No Data	3.43E-04	1.91E-05
Co-57	No Data	2.44E-07	2.88E-07	No Data	No Data	1.37E-04	3.58E-06
Co-58	No Data	4.79E-07	8.55E-07	No Data	No Data	2.99E-04	9.29E-06
Co-60	No Data	3.55E-06	6.12E-06	No Data	No Data	1.91E-03	2.60E-05
Ni-59	1.66E-05	4.67E-06	2.83E-06	No Data	No Data	2.73E-05	6.29E-07
Ni-63	2.22E-04	1.25E-05	7.56E-06	No Data	No Data	7.43E-05	1.71E-06
Ni-65	8.08E-10	7.99E-11	4.44E-11	No Data	No Data	2.21E-06	2.27E-05
Cu-64	No Data	5.39E-10	2.90E-10	No Data	1.63E-09	2.59E-06	9.92E-06
Zn-65	1.15E-05	3.06E-05	1.90E-05	No Data	1.93E-05	2.69E-04	4.41E-06
Zn-69m	4.26E-09	7.28E-09	8.59E-10	No Data	4.22E-09	7.36E-06	2.71E-05
Zn-69	1.81E-11	2.61E-11	2.41E-12	No Data	1.58E-11	3.84E-07	2.75E-06
Se-79	No Data	1.23E-06	2.60E-07	No Data	1.71E-06	1.49E-04	3.43E-06
Br-82	No Data	No Data	5.66E-06	No Data	No Data	No Data	No Data
Br-83	No Data	No Data	1.28E-07	No Data	No Data	No Data	No Data
Br-84	No Data	No Data	1.48E-07	No Data	No Data	No Data	No Data
Br-85	No Data	No Data	6.84E-09	No Data	No Data	No Data	No Data
Rb-86	No Data	5.36E-05	3.09E-05	No Data	No Data	No Data	2.16E-06
Rb-87	No Data	3.16E-05	1.37E-05	No Data	No Data	No Data	2.96E-07
Rb-88	No Data	1.52E-07	9.90E-08	No Data	No Data	No Data	4.66E-09
Rb-89	No Data	9.33E-08	7.83E-08	No Data	No Data	No Data	5.11E-10
Sr-89	1.62E-04	No Data	4.66E-06	No Data	No Data	5.83E-04	4.52E-05
Sr-90	1.04E-02	No Data	2.07E-04	No Data	No Data	3.99E-03	9.28E-05
Sr-91	3.28E-08	No Data	1.24E-09	No Data	No Data	1.44E-05	4.70E-05
Sr-92	3.54E-09	No Data	1.42E-10	No Data	No Data	6.49E-06	6.55E-05
Y-90	1.11E-06	No Data	2.99E-08	No Data	No Data	7.07E-05	7.24E-05
Y-91m	1.37E-10	No Data	4.98E-12	No Data	No Data	7.60E-07	4.64E-07
Y-91	2.47E-04	No Data	6.59E-06	No Data	No Data	7.10E-04	4.97E-05
Y-92	5.50E-09	No Data	1.57E-10	No Data	No Data	6.46E-06	6.46E-05
Y-93	5.04E-08	No Data	1.38E-09	No Data	No Data	2.01E-05	1.05E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-13 (continued)

INHALATION DOSE FACTORS FOR CHILD[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Zr-93	2.07E-04	7.80E-06	5.55E-06	No Data	3.00E-05	7.10E-05	1.47E-06
Zr-95	5.13E-05	1.13E-05	1.00E-05	No Data	1.61E-05	6.03E-04	1.65E-05
Zr-97	5.07E-08	7.34E-09	4.32E-09	No Data	1.05E-08	3.06E-05	9.49E-05
Nb-93m	1.27E-04	3.17E-05	1.04E-05	No Data	3.44E-05	1.04E-04	2.45E-06
Nb-95	6.35E-06	2.48E-06	1.77E-06	No Data	2.33E-06	1.66E-04	1.00E-05
Nb-97	1.16E-10	2.08E-11	9.74E-12	No Data	2.31E-11	9.23E-07	7.52E-06
Mo-93	No Data	3.76E-06	1.35E-07	No Data	1.06E-06	1.70E-04	3.78E-06
Mo-99	No Data	4.66E-08	1.15E-08	No Data	1.06E-07	3.66E-05	3.42E-05
Tc-99m	4.81E-13	9.41E-13	1.56E-11	No Data	1.37E-11	2.57E-07	1.30E-06
Tc-99	1.34E-07	1.49E-07	5.35E-08	No Data	1.75E-06	3.37E-04	7.75E-06
Tc-101	2.19E-14	2.30E-14	2.91E-13	No Data	3.92E-13	1.58E-07	4.41E-09
Ru-103	7.55E-07	No Data	2.90E-07	No Data	1.90E-06	1.79E-04	1.21E-05
Ru-105	4.13E-10	No Data	1.50E-10	No Data	3.63E-10	4.30E-06	2.69E-05
Ru-106	3.68E-05	No Data	4.57E-06	No Data	4.97E-05	3.87E-03	1.16E-04
Rh-105	3.91E-09	2.10E-09	1.79E-09	No Data	8.39E-09	7.82E-06	1.33E-05
Pd-107	No Data	2.65E-07	2.51E-08	No Data	1.97E-06	3.16E-05	7.26E-07
Pd-109	No Data	1.48E-09	4.95E-10	No Data	7.06E-09	6.16E-06	2.59E-05
Ag-110m	4.56E-06	3.08E-06	2.47E-06	No Data	5.74E-06	1.48E-03	2.71E-05
Ag-111	1.81E-07	5.68E-08	3.75E-08	No Data	1.71E-07	7.73E-05	2.98E-05
Cd-113m	No Data	4.93E-04	2.12E-05	No Data	5.13E-04	6.94E-04	1.63E-05
Cd-115m	No Data	7.88E-05	3.39E-06	No Data	5.93E-05	5.86E-04	4.97E-05
Sn-123	1.29E-04	2.14E-06	4.19E-06	2.27E-06	No Data	9.59E-04	4.05E-05
Sn-125	4.95E-06	9.94E-08	2.95E-07	1.03E-07	No Data	2.43E-04	7.17E-05
Sn-126	6.23E-04	1.04E-05	2.36E-05	2.84E-06	No Data	3.02E-03	1.63E-05
Sb-124	1.55E-05	2.00E-07	5.41E-06	3.41E-08	No Data	8.76E-04	4.43E-05
Sb-125	2.66E-05	2.05E-07	5.59E-06	2.46E-08	No Data	6.27E-04	1.09E-05
Sb-126	1.72E-06	2.62E-08	6.16E-07	1.00E-08	No Data	2.86E-04	5.67E-05
Sb-127	1.36E-07	2.09E-09	4.70E-08	1.51E-09	No Data	6.17E-05	3.82E-05
Te-125m	1.82E-06	6.29E-07	2.47E-07	5.20E-07	No Data	1.29E-04	9.13E-06
Te-127m	6.72E-06	2.31E-06	8.16E-07	1.64E-06	1.72E-05	4.00E-04	1.93E-05
Te-127	7.49E-10	2.57E-10	1.65E-10	5.30E-10	1.91E-09	2.71E-06	1.52E-05
Te-129m	5.19E-06	1.85E-06	8.22E-07	1.71E-06	1.36E-05	4.76E-04	4.91E-05
Te-129	2.64E-11	9.45E-12	6.44E-12	1.93E-11	6.94E-11	7.93E-07	6.89E-06
Te-131m	3.63E-08	1.60E-08	1.37E-08	2.64E-08	1.08E-07	5.56E-05	8.32E-05
Te-131	5.87E-12	2.28E-12	1.78E-12	4.59E-12	1.59E-11	5.55E-07	3.60E-07
Te-132	1.30E-07	7.36E-08	7.12E-08	8.58E-08	4.79E-07	1.02E-04	3.72E-05
Te-133m	2.93E-11	1.51E-11	1.50E-11	2.32E-11	1.01E-10	1.60E-06	4.77E-06
Te-134	1.53E-11	8.81E-12	9.40E-12	1.24E-11	5.71E-11	1.23E-06	4.87E-07

[1] Data presented in this Table are from Reference 9.

TABLE A-13 (continued)

INHALATION DOSE FACTORS FOR CHILD[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Cs-134m	6.33E-08	8.92E-08	6.12E-08	No Data	4.94E-08	8.35E-09	7.92E-08
Cs-134	1.76E-04	2.74E-04	6.07E-05	No Data	8.93E-05	3.27E-05	1.04E-06
Cs-135	6.23E-05	4.13E-05	4.45E-06	No Data	1.53E-05	5.22E-06	2.17E-07
Cs-136	1.76E-05	4.62E-05	3.14E-05	No Data	2.58E-05	3.93E-06	1.13E-06
Cs-137	2.45E-04	2.23E-04	3.47E-05	No Data	7.63E-05	2.81E-05	9.78E-07
Cs-138	1.71E-07	2.27E-07	1.50E-07	No Data	1.68E-07	1.84E-08	7.29E-08
Cs-139	1.09E-07	1.15E-07	5.80E-08	No Data	9.08E-08	9.36E-09	7.23E-12
Ba-139	4.98E-10	2.66E-13	1.45E-11	No Data	2.33E-13	1.56E-06	1.56E-05
Ba-140	2.00E-05	1.75E-08	1.17E-06	No Data	5.71E-09	4.71E-04	2.75E-05
Ba-141	5.29E-11	2.95E-14	1.72E-12	No Data	2.56E-14	7.89E-07	7.44E-08
Ba-142	1.35E-11	9.73E-15	7.54E-13	No Data	7.87E-15	4.44E-07	7.41E-10
La-140	1.74E-07	6.08E-08	2.04E-08	No Data	No Data	4.94E-05	6.10E-05
La-141	2.28E-09	5.31E-10	1.15E-10	No Data	No Data	4.48E-06	4.37E-05
La-142	3.50E-10	1.11E-10	3.49E-11	No Data	No Data	2.35E-06	2.05E-05
Ce-141	1.06E-05	5.28E-06	7.83E-07	No Data	2.31E-06	1.47E-04	1.53E-05
Ce-143	9.89E-08	5.37E-08	7.77E-09	No Data	2.26E-08	3.12E-05	3.44E-05
Ce-144	1.83E-03	5.72E-04	9.77E-05	No Data	3.17E-04	3.23E-03	1.05E-04
Pr-143	4.99E-06	1.50E-06	2.47E-07	No Data	8.11E-07	1.17E-04	2.63E-05
Pr-144	1.61E-11	4.99E-12	8.10E-13	No Data	2.64E-12	4.23E-07	5.32E-08
Nd-147	2.92E-06	2.36E-06	1.84E-07	No Data	1.30E-06	8.87E-05	2.22E-05
Pm-147	3.52E-04	2.52E-05	1.36E-05	No Data	4.45E-05	2.20E-04	5.70E-06
Pm-148m	3.31E-05	6.55E-06	6.55E-06	No Data	9.74E-06	5.72E-04	3.58E-05
Pm-148	1.61E-06	1.94E-07	1.25E-07	No Data	3.30E-07	1.24E-04	6.01E-05
Pm-149	1.47E-07	1.56E-08	8.45E-09	No Data	2.75E-08	2.40E-05	2.92E-05
Pm-151	3.57E-08	4.33E-09	2.82E-09	No Data	7.35E-09	1.24E-05	2.50E-05
Sm-151	3.14E-04	4.75E-05	1.49E-05	No Data	4.89E-05	1.48E-04	3.43E-06
Sm-153	7.24E-08	4.51E-08	4.35E-09	No Data	1.37E-08	1.37E-05	1.87E-05
Eu-152	7.42E-04	1.37E-04	1.61E-04	No Data	5.73E-04	9.00E-04	1.14E-05
Eu-154	2.74E-03	2.49E-04	2.27E-04	No Data	1.09E-03	1.66E-03	2.98E-05
Eu-155	5.60E-04	4.05E-05	3.18E-05	No Data	1.51E-04	2.79E-04	5.39E-05
Eu-156	7.89E-06	4.23E-06	8.75E-07	No Data	2.72E-06	2.54E-04	4.24E-05
Tb-160	7.79E-05	No Data	9.67E-06	No Data	2.32E-05	5.34E-04	2.28E-05
Ho-166m	1.34E-03	2.81E-04	2.37E-04	No Data	4.01E-04	1.13E-03	1.63E-05
W-181	2.66E-08	6.52E-09	8.99E-10	No Data	No Data	5.71E-06	2.61E-07
W-185	8.31E-07	2.08E-07	2.91E-08	No Data	No Data	1.86E-04	1.11E-05
W-187	4.41E-09	2.61E-09	1.17E-09	No Data	No Data	1.11E-05	2.46E-05
Pb-210	8.03E-02	1.85E-02	3.18E-03	No Data	6.31E-02	8.74E-02	1.55E-06
Bi-210	9.85E-07	5.11E-06	5.65E-07	No Data	5.76E-05	3.70E-03	3.21E-05
Po-210	1.70E-03	2.76E-03	4.09E-04	No Data	8.85E-03	1.05E-01	4.32E-05
Ra-223	7.69E-04	8.89E-07	1.54E-04	No Data	2.36E-05	8.48E-02	3.00E-04
Ra-224	8.44E-05	1.53E-07	1.69E-05	No Data	4.06E-06	2.92E-02	3.34E-04
Ra-225	1.28E-03	1.14E-06	2.56E-04	No Data	3.02E-05	9.74E-02	2.84E-04
Ra-226	2.34E-01	7.66E-06	1.92E-01	No Data	2.03E-04	3.90E-01	3.02E-04
Ra-228	1.49E-01	3.94E-06	1.68E-01	No Data	1.04E-04	5.37E-01	5.14E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-13 (continued)

INHALATION DOSE FACTORS FOR CHILD[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Ac-225	1.81E-03	1.87E-03	1.21E-04	No Data	1.99E-04	7.37E-02	2.67E-04
Ac-227	4.96E+00	8.05E-01	3.07E-01	No Data	1.77E-01	8.04E-01	5.22E-05
Th-227	9.24E-04	1.26E-05	2.67E-05	No Data	6.67E-05	1.26E-01	3.49E-04
Th-228	8.06E-01	1.04E-02	2.72E-02	No Data	5.41E-02	3.34E+00	3.59E-04
Th-229	2.18E+01	5.74E-01	3.63E-01	No Data	2.83E+00	1.08E+01	4.99E-05
Th-230	3.30E+00	1.73E-01	9.20E-02	No Data	8.52E-01	1.85E+00	3.84E-05
Th-232	3.68E+00	1.47E-01	1.28E-03	No Data	7.28E-01	1.77E+00	3.27E-05
Th-234	6.94E-06	3.07E-07	2.00E-07	No Data	1.62E-06	6.31E-04	7.32E-05
Pa-231	8.62E+00	2.86E-01	3.43E-01	No Data	1.56E+00	1.92E-01	4.57E-05
Pa-233	4.14E-06	6.48E-07	7.25E-07	No Data	2.38E-06	9.77E-05	8.95E-06
U-232	2.19E-01	No Data	1.56E-02	No Data	1.67E-02	7.42E-01	4.33E-05
U-233	4.64E-02	No Data	2.82E-03	No Data	7.62E-03	1.77E-01	4.00E-05
U-234	4.46E-02	No Data	2.76E-03	No Data	7.47E-03	1.74E-01	3.92E-05
U-235	4.27E-02	No Data	2.59E-03	No Data	7.01E-03	1.63E-01	4.98E-05
U-236	4.27E-02	No Data	2.65E-03	No Data	7.16E-03	1.67E-01	3.67E-05
U-237	1.57E-07	No Data	4.17E-08	No Data	4.53E-07	3.40E-05	1.29E-05
U-238	4.09E-02	No Data	2.42E-03	No Data	6.55E-03	1.53E-01	3.51E-05
Np-237	2.72E+00	1.62E+00	1.19E-01	No Data	7.41E-01	1.74E-01	5.06E-05
Np-238	1.26E-06	2.30E-07	1.97E-08	No Data	8.16E-08	3.39E-05	2.50E-05
Np-239	1.26E-07	8.14E-08	6.35E-09	No Data	2.63E-08	1.57E-05	1.73E-05
Pu-238	2.55E+00	1.60E+00	1.21E-01	No Data	4.47E-01	6.08E-01	4.65E-05
Pu-239	2.79E+00	1.68E+00	1.28E-01	No Data	4.78E-01	5.72E-01	4.24E-05
Pu-240	2.79E+00	1.68E+00	1.27E-01	No Data	4.77E-01	5.71E-01	4.33E-05
Pu-241	7.94E-02	1.75E-02	2.93E-03	No Data	1.10E-02	5.06E-04	8.90E-07
Pu-242	2.59E+00	1.62E+00	1.23E-01	No Data	4.60E-01	5.50E-01	4.16E-05
Pu-244	3.02E+00	1.85E+00	1.41E-01	No Data	5.27E-01	6.30E-01	6.20E-05
Am-241	2.97E+00	1.84E+00	1.24E-01	No Data	7.63E-01	2.02E-01	4.73E-05
Am-242m	3.07E+00	1.76E+00	1.27E-01	No Data	7.71E-01	8.14E-02	5.96E-05
Am-243	2.94E+00	1.78E+00	1.20E-01	No Data	7.42E-01	1.92E-01	5.55E-05
Cm-242	9.48E-02	5.68E-02	4.20E-03	No Data	1.34E-02	1.31E-01	5.06E-05
Cm-243	2.32E+00	1.42E+00	9.95E-02	No Data	3.74E-01	2.10E-01	4.98E-05
Cm-244	1.94E+00	1.18E+00	8.31E-02	No Data	3.06E-01	2.02E-01	4.82E-05
Cm-245	3.05E+00	1.84E+00	1.28E-01	No Data	5.03E-01	1.95E-01	4.49E-05
Cm-246	3.02E+00	1.84E+00	1.28E-01	No Data	5.03E-01	1.99E-01	4.41E-05
Cm-247	2.94E+00	1.82E+00	1.26E-01	No Data	4.95E-01	1.95E-01	5.80E-05
Cm-248	2.45E+01	1.50E+01	1.04E+00	No Data	4.08E+00	1.61E+00	9.35E-04
Cf-252	2.18E+00	No Data	9.33E-02	No Data	No Data	6.62E-01	1.84E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-14

INHALATION DOSE FACTORS FOR INFANT[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	No Data	2.63E-07	2.63E-07	2.63E-07	2.63E-07	2.63E-07	2.63E-07
Be-10	9.49E-04	1.25E-04	2.65E-05	No Data	No Data	1.49E-03	1.73E-05
C-14	1.89E-05	3.79E-06	3.79E-06	3.79E-06	3.79E-06	3.79E-06	3.79E-06
N-13	4.39E-08	4.39E-08	4.39E-08	4.39E-08	4.39E-08	4.39E-08	4.39E-08
F-18	3.92E-06	No Data	3.33E-07	No Data	No Data	No Data	6.10E-07
Na-22	7.37E-05	7.37E-05	7.37E-05	7.37E-05	7.37E-05	7.37E-05	7.37E-05
Na-24	7.54E-06	7.54E-06	7.54E-06	7.54E-06	7.54E-06	7.54E-06	7.54E-06
P-32	1.45E-03	8.03E-05	5.53E-05	No Data	No Data	No Data	1.15E-05
Ca-41	7.48E-05	No Data	8.16E-06	No Data	No Data	6.94E-02	2.96E-07
Sc-46	3.75E-04	5.41E-04	1.69E-04	No Data	3.56E-04	No Data	2.19E-05
Cr-51	No Data	No Data	6.39E-08	4.11E-08	9.45E-09	9.17E-06	2.55E-07
Mn-54	No Data	1.81E-05	3.56E-06	No Data	3.56E-06	7.14E-04	5.04E-06
Mn-56	No Data	1.10E-09	1.58E-10	No Data	7.86E-10	8.95E-06	5.12E-05
Fe-55	1.41E-05	8.39E-06	2.38E-06	No Data	No Data	6.21E-05	7.82E-07
Fe-59	9.69E-06	1.68E-05	6.77E-06	No Data	No Data	7.25E-04	1.77E-05
Co-57	No Data	4.65E-07	4.58E-07	No Data	No Data	2.71E-04	3.47E-06
Co-58	No Data	8.71E-07	1.30E-06	No Data	No Data	5.55E-04	7.95E-06
Co-60	No Data	5.73E-06	8.41E-06	No Data	No Data	3.22E-03	2.28E-05
Ni-59	1.81E-05	5.44E-06	3.10E-06	No Data	No Data	5.48E-05	6.34E-07
Ni-63	2.42E-04	1.46E-05	8.29E-06	No Data	No Data	1.49E-04	1.73E-06
Ni-65	1.71E-09	2.03E-10	8.79E-11	No Data	No Data	5.80E-06	3.58E-05
Cu-64	No Data	1.34E-09	5.53E-10	No Data	2.84E-09	6.64E-06	1.07E-05
Zn-65	1.38E-05	4.47E-05	2.22E-05	No Data	2.32E-05	4.62E-04	3.67E-05
Zn-69m	8.98E-09	1.84E-08	1.67E-09	No Data	7.45E-09	1.91E-05	2.92E-05
Zn-69	3.85E-11	6.91E-11	5.13E-12	No Data	2.87E-11	1.05E-06	9.44E-06
Se-79	No Data	2.25E-06	4.20E-07	No Data	2.47E-06	2.99E-04	3.46E-06
Br-82	No Data	No Data	9.49E-06	No Data	No Data	No Data	No Data
Br-83	No Data	No Data	2.72E-07	No Data	No Data	No Data	No Data
Br-84	No Data	No Data	2.86E-07	No Data	No Data	No Data	No Data
Br-85	No Data	No Data	1.46E-08	No Data	No Data	No Data	No Data
Rb-86	No Data	1.36E-04	6.30E-05	No Data	No Data	No Data	2.17E-06
Rb-87	No Data	7.11E-05	2.64E-05	No Data	No Data	No Data	2.99E-07
Rb-88	No Data	3.98E-07	2.05E-07	No Data	No Data	No Data	2.42E-07
Rb-89	No Data	2.29E-07	1.47E-07	No Data	No Data	No Data	4.87E-08
Sr-89	2.84E-04	No Data	8.15E-06	No Data	No Data	1.45E-03	4.57E-05
Sr-90	1.11E-02	No Data	2.23E-04	No Data	No Data	8.03E-03	9.36E-05
Sr-91	6.83E-08	No Data	2.47E-09	No Data	No Data	3.76E-05	5.24E-05
Sr-92	7.50E-09	No Data	2.79E-10	No Data	No Data	1.70E-05	1.00E-04
Y-90	2.35E-06	No Data	6.30E-08	No Data	No Data	1.92E-04	7.43E-05
Y-91m	2.91E-10	No Data	9.90E-12	No Data	No Data	1.99E-06	1.68E-06
Y-91	4.20E-04	No Data	1.12E-05	No Data	No Data	1.75E-03	5.02E-05
Y-92	1.17E-08	No Data	3.29E-10	No Data	No Data	1.75E-05	9.04E-05
Y-93	1.07E-07	No Data	2.91E-09	No Data	No Data	5.46E-05	1.19E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-14 (continued)

INHALATION DOSE FACTORS FOR INFANT[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Zr-93	2.24E-04	9.51E-06	6.18E-06	No Data	3.19E-05	1.37E-04	1.48E-06
Zr-95	8.24E-05	1.99E-05	1.45E-05	No Data	2.22E-05	1.25E-03	1.55E-05
Zr-97	1.07E-07	1.83E-08	8.36E-09	No Data	1.85E-08	7.88E-05	1.00E-04
Nb-93m	1.38E-04	3.59E-05	1.15E-05	No Data	3.68E-05	2.09E-04	2.47E-06
Nb-95	1.12E-05	4.59E-06	2.70E-06	No Data	3.37E-06	3.42E-04	9.05E-06
Nb-97	2.44E-10	5.21E-11	1.88E-11	No Data	4.07E-11	2.37E-06	1.92E-05
Mo-93	No Data	6.46E-06	2.22E-07	No Data	1.54E-06	3.40E-04	3.76E-06
Mo-99	No Data	1.18E-07	2.31E-08	No Data	1.89E-07	9.63E-05	3.48E-05
Tc-99m	9.98E-13	2.06E-12	2.66E-11	No Data	2.22E-11	5.79E-07	1.45E-06
Tc-99	2.09E-07	2.68E-07	8.85E-08	No Data	2.49E-06	6.77E-04	7.82E-06
Tc-101	4.65E-14	5.88E-14	5.80E-13	No Data	6.99E-13	4.17E-07	6.03E-07
Ru-103	1.44E-06	No Data	4.85E-07	No Data	3.03E-06	3.94E-04	1.15E-05
Ru-105	8.74E-10	No Data	2.93E-10	No Data	6.42E-10	1.12E-05	3.46E-05
Ru-106	6.20E-05	No Data	7.77E-06	No Data	7.61E-05	8.26E-03	1.17E-04
Rh-105	8.26E-09	5.41E-09	3.63E-09	No Data	1.50E-08	2.08E-05	1.37E-05
Pd-107	No Data	4.92E-07	4.11E-08	No Data	2.75E-06	6.34E-05	7.33E-07
Pd-109	No Data	3.92E-09	1.05E-09	No Data	1.28E-08	1.68E-05	2.85E-05
Ag-110m	7.13E-06	5.16E-06	3.57E-06	No Data	7.80E-06	2.62E-03	2.36E-05
Ag-111	3.75E-07	1.45E-07	7.75E-08	No Data	3.05E-07	2.06E-04	3.02E-05
Cd-113m	No Data	6.67E-04	2.64E-05	No Data	5.80E-04	1.40E-03	1.65E-05
Cd-115m	No Data	1.73E-04	6.19E-06	No Data	9.41E-05	1.47E-03	5.02E-05
Sn-123	2.09E-04	4.21E-06	7.28E-06	4.27E-06	No Data	2.22E-03	4.08E-05
Sn-125	1.01E-05	2.51E-07	6.00E-07	2.47E-07	No Data	6.43E-04	7.26E-05
Sn-126	8.30E-04	1.44E-05	3.52E-05	3.84E-06	No Data	4.93E-03	1.65E-05
Sb-124	2.71E-05	3.97E-07	8.56E-06	7.18E-08	No Data	1.89E-03	4.22E-05
Sb-125	3.69E-05	3.41E-07	7.78E-06	4.45E-08	No Data	1.17E-03	1.05E-05
Sb-126	3.08E-06	6.01E-08	1.11E-06	2.35E-08	No Data	6.88E-04	5.33E-05
Sb-127	2.82E-07	5.04E-09	8.76E-08	3.60E-09	No Data	1.54E-04	3.78E-05
Te-125m	3.40E-06	1.42E-06	4.70E-07	1.16E-06	No Data	3.19E-04	9.22E-06
Te-127m	1.19E-05	4.93E-06	1.48E-06	3.48E-06	2.68E-05	9.37E-04	1.95E-05
Te-127	1.59E-09	6.81E-10	3.49E-10	1.32E-09	3.47E-09	7.39E-06	1.74E-05
Te-129m	1.01E-05	4.35E-06	1.59E-06	3.91E-06	2.27E-05	1.20E-03	4.93E-05
Te-129	5.63E-11	2.48E-11	1.34E-11	4.82E-11	1.25E-10	2.14E-06	1.88E-05
Te-131m	7.62E-08	3.93E-08	2.59E-08	6.38E-08	1.89E-07	1.42E-04	8.51E-05
Te-131	1.24E-11	5.87E-12	3.57E-12	1.13E-11	2.85E-11	1.47E-06	5.87E-06
Te-132	2.66E-07	1.69E-07	1.26E-07	1.99E-07	7.39E-07	2.43E-04	3.15E-05
Te-133m	6.13E-11	3.59E-11	2.74E-11	5.52E-11	1.72E-10	3.92E-06	1.59E-05
Te-134	3.18E-11	2.04E-11	1.68E-11	2.91E-11	9.59E-11	2.93E-06	2.53E-06

[1] Data presented in this Table are from Reference 9.

TABLE A-14 (continued)

INHALATION DOSE FACTORS FOR INFANT[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Cs-134m	1.32E-07	2.10E-07	1.11E-07	No Data	8.50E-08	2.00E-08	1.16E-07
Cs-134	2.83E-04	5.02E-04	5.32E-05	No Data	1.36E-04	5.69E-05	9.53E-07
Cs-135	1.00E-04	8.66E-05	4.73E-06	No Data	2.58E-05	1.01E-05	2.18E-07
Cs-136	3.45E-05	9.61E-05	3.78E-05	No Data	4.03E-05	8.40E-06	1.02E-06
Cs-137	3.92E-04	4.37E-04	3.25E-05	No Data	1.23E-04	5.09E-05	9.53E-07
Cs-138	3.61E-07	5.58E-07	2.84E-07	No Data	2.93E-07	4.67E-08	6.26E-07
Cs-139	2.32E-07	3.03E-07	1.22E-07	No Data	1.65E-07	2.53E-08	1.33E-08
Ba-139	1.06E-09	7.03E-13	3.07E-11	No Data	4.23E-13	4.25E-06	3.64E-05
Ba-140	4.00E-05	4.00E-08	2.07E-06	No Data	9.59E-09	1.14E-03	2.74E-05
Ba-141	1.12E-10	7.70E-14	3.55E-12	No Data	4.64E-14	2.12E-06	3.39E-06
Ba-142	2.84E-11	2.36E-14	1.40E-12	No Data	1.36E-14	1.11E-06	4.95E-07
La-140	3.61E-07	1.43E-07	3.68E-08	No Data	No Data	1.20E-04	6.06E-05
La-141	4.85E-09	1.40E-09	2.45E-10	No Data	No Data	1.22E-05	5.96E-05
La-142	7.36E-10	2.69E-10	6.46E-11	No Data	No Data	5.87E-06	4.25E-05
Ce-141	1.98E-05	1.19E-05	1.42E-06	No Data	3.75E-06	3.69E-04	1.54E-05
Ce-143	2.09E-07	1.38E-07	1.58E-08	No Data	4.03E-08	8.30E-05	3.55E-05
Ce-144	2.28E-03	8.65E-04	1.26E-04	No Data	3.84E-04	7.03E-03	1.06E-04
Pr-143	1.00E-05	3.74E-06	4.99E-07	No Data	1.41E-06	3.09E-04	2.66E-05
Pr-144	3.42E-11	1.32E-11	1.72E-12	No Data	4.80E-12	1.15E-06	3.06E-06
Nd-147	5.67E-06	5.81E-06	3.57E-07	No Data	2.25E-06	2.30E-04	2.23E-05
Pm-147	3.91E-04	3.07E-05	1.56E-05	No Data	4.93E-05	4.55E-04	5.75E-06
Pm-148m	5.00E-05	1.24E-05	9.94E-06	No Data	1.45E-05	1.22E-03	3.37E-05
Pm-148	3.34E-06	4.82E-07	2.44E-07	No Data	5.76E-07	3.20E-04	6.04E-05
Pm-149	3.10E-07	4.08E-08	1.78E-08	No Data	4.96E-08	6.50E-05	3.01E-05
Pm-151	7.52E-08	1.10E-08	5.55E-09	No Data	1.30E-08	3.25E-05	2.58E-05
Sm-151	3.38E-04	6.45E-05	1.63E-05	No Data	5.24E-05	2.98E-04	3.46E-06
Sm-153	1.53E-07	1.18E-07	9.06E-09	No Data	2.47E-08	3.70E-05	1.93E-05
Eu-152	7.83E-04	1.77E-04	1.72E-04	No Data	5.94E-04	1.48E-03	9.88E-06
Eu-154	2.96E-03	3.46E-04	2.45E-04	No Data	1.14E-03	3.05E-03	2.84E-05
Eu-155	5.97E-04	5.72E-05	3.46E-05	No Data	1.58E-04	5.20E-04	5.19E-05
Eu-156	1.56E-05	9.59E-06	1.54E-06	No Data	4.48E-06	6.12E-04	4.14E-05
Tb-160	1.12E-04	No Data	1.40E-05	No Data	3.20E-05	1.11E-03	2.14E-05
Ho-166m	1.45E-03	3.07E-04	2.51E-04	No Data	4.22E-04	2.05E-03	1.65E-05
W-181	4.86E-08	1.46E-08	1.67E-09	No Data	No Data	1.33E-05	2.63E-07
W-185	1.57E-06	4.83E-07	5.58E-08	No Data	No Data	4.48E-04	1.12E-05
W-187	9.26E-09	6.44E-09	2.23E-09	No Data	No Data	2.83E-05	2.54E-05
Pb-210	8.62E-02	2.02E-02	3.43E-03	No Data	6.85E-02	1.76E-01	1.57E-06
Bi-210	2.06E-06	1.33E-05	1.18E-06	No Data	1.03E-04	9.96E-03	3.27E-05
Po-210	2.98E-03	5.63E-03	7.12E-04	No Data	1.30E-02	2.40E-01	4.36E-05
Ra-223	1.56E-03	2.26E-06	3.12E-04	No Data	4.16E-05	2.25E-01	3.04E-04
Ra-224	1.77E-04	4.00E-07	3.54E-05	No Data	7.30E-06	7.91E-02	3.42E-04
Ra-225	2.57E-03	2.88E-06	5.13E-04	No Data	5.31E-05	2.57E-01	2.87E-04
Ra-226	2.48E-01	1.46E-05	2.05E-01	No Data	2.94E-04	7.83E-01	3.05E-04
Ra-228	1.60E-01	7.61E-06	1.80E-01	No Data	1.53E-04	1.09E+00	5.19E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-14 (continued)

INHALATION DOSE FACTORS FOR INFANT[1]

mrem/pCi Inhaled

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Ac-225	3.69E-03	4.72E-03	2.48E-04	No Data	3.49E-04	1.96E-01	2.71E-04
Ac-227	5.29E+00	8.76E-01	3.28E-01	No Data	1.86E-01	1.62E+00	5.27E-05
Th-227	1.82E-03	3.03E-05	5.24E-05	No Data	1.13E-04	3.27E-01	3.53E-04
Th-228	8.46E-01	1.10E-02	2.86E-02	No Data	5.61E-02	4.65E+00	3.62E-04
Th-229	2.28E+01	5.94E-01	3.81E-01	No Data	9.32E-01	1.27E+01	5.02E-05
Th-230	3.46E+00	1.79E-01	9.65E-02	No Data	8.82E-01	2.18E+00	3.87E-05
Th-232	3.86E+00	1.53E-01	2.29E-03	No Data	7.54E-01	2.09E+00	3.29E-05
Th-234	1.33E-05	7.17E-07	3.84E-07	No Data	2.70E-06	1.62E-03	7.40E-05
Pa-231	9.10E+00	3.00E-01	3.62E-01	No Data	1.62E+00	3.85E-01	4.61E-05
Pa-233	6.84E-06	1.32E-06	1.19E-06	No Data	3.68E-06	2.19E-04	9.04E-06
U-232	2.57E-01	No Data	2.13E-02	No Data	2.40E-02	1.49E+00	4.36E-05
U-233	5.44E-02	No Data	3.83E-03	No Data	1.09E-02	3.56E-01	4.03E-05
U-234	5.22E-02	No Data	3.75E-03	No Data	1.07E-02	3.49E-01	3.95E-05
U-235	5.01E-02	No Data	3.52E-03	No Data	1.01E-02	3.28E-01	5.02E-05
U-236	5.01E-02	No Data	3.60E-03	No Data	1.03E-02	3.35E-01	3.71E-05
U-237	3.25E-07	No Data	8.65E-08	No Data	8.08E-07	9.13E-05	1.31E-05
U-238	4.79E-02	No Data	3.29E-03	No Data	9.40E-03	3.06E-01	3.54E-05
Np-237	2.88E+00	1.71E+00	1.26E-01	No Data	7.69E-01	3.49E-01	5.10E-05
Np-238	2.67E-06	6.05E-07	4.16E-08	No Data	1.47E-07	9.19E-05	2.58E-05
Np-239	2.65E-07	2.13E-07	1.34E-08	No Data	4.73E-08	4.25E-05	1.78E-05
Pu-238	2.69E+00	1.68E+00	1.27E-01	No Data	4.64E-01	9.03E-01	4.69E-05
Pu-239	2.93E+00	1.76E+00	1.34E-01	No Data	4.95E-01	8.47E-01	4.28E-05
Pu-240	2.93E+00	1.75E+00	1.34E-01	No Data	4.94E-01	8.47E-01	4.36E-05
Pu-241	8.43E-02	1.85E-02	3.11E-03	No Data	1.15E-02	7.62E-04	8.97E-07
Pu-242	2.72E+00	1.69E+00	1.29E-01	No Data	4.77E-01	8.15E-01	4.20E-05
Pu-244	3.17E+00	1.94E+00	1.48E-01	No Data	5.46E-01	9.33E-01	6.26E-05
Am-241	3.15E+00	1.95E+00	1.31E-01	No Data	7.94E-01	4.06E-01	4.78E-05
Am-242m	3.25E+00	1.86E+00	1.35E-01	No Data	8.03E-01	1.64E-01	6.01E-05
Am-243	3.10E+00	1.88E+00	1.27E-01	No Data	7.72E-01	3.85E-01	5.60E-05
Cm-242	1.28E-01	8.65E-02	5.70E-03	No Data	1.69E-02	2.97E-01	5.10E-05
Cm-243	2.47E+00	1.52E+00	1.06E-01	No Data	3.91E-01	4.24E-01	5.02E-05
Cm-244	2.07E+00	1.27E+00	8.89E-02	No Data	3.21E-01	4.08E-01	4.86E-05
Cm-245	3.22E+00	1.96E+00	1.36E-01	No Data	5.23E-01	3.92E-01	4.53E-05
Cm-246	3.20E+00	1.96E+00	1.36E-01	No Data	5.23E-01	3.99E-01	4.45E-05
Cm-247	3.11E+00	1.93E+00	1.33E-01	No Data	5.15E-01	3.92E-01	5.85E-05
Cm-248	2.58E+01	1.59E+01	1.10E+00	No Data	4.24E+00	3.23E+00	9.43E-04
Cf-252	2.37E+00	No Data	1.01E-01	No Data	No Data	1.37E+00	1.85E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-15

INGESTION DOSE FACTORS FOR ADULT[1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	No Data	5.99E-08	5.99E-08	5.99E-08	5.99E-08	5.99E-08	5.99E-08
Be-10	3.18E-06	4.91E-07	7.94E-08	No Data	3.71E-07	No Data	2.68E-05
C-14	2.84E-06	5.68E-07	5.68E-07	5.68E-07	5.68E-07	5.68E-07	5.68E-07
N-13	8.36E-09	8.36E-09	8.36E-09	8.36E-09	8.36E-09	8.36E-09	8.36E-09
F-18	6.24E-07	No Data	6.92E-08	No Data	No Data	No Data	1.85E-08
Na-22	1.74E-05	1.74E-05	1.74E-05	1.74E-05	1.74E-05	1.74E-05	1.74E-05
Na-24	1.70E-06	1.70E-06	1.70E-06	1.70E-06	1.70E-06	1.70E-06	1.70E-06
P-32	1.93E-04	1.20E-05	7.46E-06	No Data	No Data	No Data	2.17E-05
Ca-41	1.85E-04	No Data	2.00E-05	No Data	No Data	No Data	1.84E-07
Sc-46	5.51E-09	1.07E-08	3.11E-09	No Data	9.99E-09	No Data	5.21E-05
Cr-51	No Data	No Data	2.66E-09	1.59E-09	5.86E-10	3.53E-09	6.69E-07
Mn-54	No Data	4.57E-06	8.72E-07	No Data	1.36E-06	No Data	1.40E-05
Mn-56	No Data	1.15E-07	2.04E-08	No Data	1.46E-07	No Data	3.67E-06
Fe-55	2.75E-06	1.90E-06	4.43E-07	No Data	No Data	1.06E-06	1.09E-06
Fe-59	4.34E-06	1.02E-05	3.91E-06	No Data	No Data	2.85E-06	3.40E-05
Co-57	No Data	1.75E-07	2.91E-07	No Data	No Data	No Data	4.44E-06
Co-58	No Data	7.45E-07	1.67E-06	No Data	No Data	No Data	1.51E-05
Co-60	No Data	2.14E-06	4.72E-06	No Data	No Data	No Data	4.02E-05
Ni-59	9.76E-06	3.35E-06	1.63E-06	No Data	No Data	No Data	6.90E-07
Ni-63	1.30E-04	9.01E-06	4.36E-06	No Data	No Data	No Data	1.88E-06
Ni-65	5.28E-07	6.86E-08	3.13E-08	No Data	No Data	No Data	1.74E-06
Cu-64	No Data	8.33E-08	3.91E-08	No Data	2.10E-07	No Data	7.10E-06
Zn-65	4.84E-06	1.54E-05	6.96E-06	No Data	1.03E-05	No Data	9.70E-06
Zn-69m	1.70E-07	4.08E-07	3.73E-08	No Data	2.47E-07	No Data	2.49E-05
Zn-69	1.03E-08	1.97E-08	1.37E-09	No Data	1.28E-08	No Data	2.96E-09
Se-79	No Data	2.63E-06	4.39E-07	No Data	4.55E-06	No Data	5.38E-07
Br-82	No Data	No Data	2.26E-06	No Data	No Data	No Data	2.59E-06
Br-83	No Data	No Data	4.02E-08	No Data	No Data	No Data	5.79E-08
Br-84	No Data	No Data	5.21E-08	No Data	No Data	No Data	4.09E-13
Br-85	No Data	No Data	2.14E-09	No Data	No Data	No Data	No Data
Rb-86	No Data	2.11E-05	9.83E-06	No Data	No Data	No Data	4.16E-06
Rb-87	No Data	1.23E-05	4.28E-06	No Data	No Data	No Data	5.76E-07
Rb-88	No Data	6.05E-08	3.21E-08	No Data	No Data	No Data	8.36E-19
Rb-89	No Data	4.01E-08	2.82E-08	No Data	No Data	No Data	2.33E-21
Sr-89	3.08E-04	No Data	8.84E-06	No Data	No Data	No Data	4.94E-05
Sr-90	8.71E-03	No Data	1.75E-04	No Data	No Data	No Data	2.19E-04
Sr-91	5.67E-06	No Data	2.29E-07	No Data	No Data	No Data	2.70E-05
Sr-92	2.15E-06	No Data	9.30E-08	No Data	No Data	No Data	4.26E-05
Y-90	9.62E-09	No Data	2.58E-10	No Data	No Data	No Data	1.02E-04
Y-91m	9.09E-11	No Data	3.52E-12	No Data	No Data	No Data	2.67E-10
Y-91	1.41E-07	No Data	3.77E-09	No Data	No Data	No Data	7.76E-05
Y-92	8.45E-10	No Data	2.47E-11	No Data	No Data	No Data	1.48E-05
Y-93	2.68E-09	No Data	7.40E-11	No Data	No Data	No Data	8.50E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-15 (continued)

INGESTION DOSE FACTORS FOR ADULT[1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Zr-93	4.18E-08	2.34E-09	1.09E-09	No Data	8.87E-09	No Data	2.43E-06
Zr-95	3.04E-08	9.75E-09	6.60E-09	No Data	1.53E-08	No Data	3.09E-05
Zr-97	1.68E-09	3.39E-10	1.55E-10	No Data	5.12E-10	No Data	1.05E-04
Nb-93m	2.55E-08	8.32E-09	2.05E-09	No Data	9.57E-09	No Data	3.84E-06
Nb-95	6.22E-09	3.46E-09	1.86E-09	No Data	3.42E-09	No Data	2.10E-05
Nb-97	5.22E-11	1.32E-11	4.82E-12	No Data	1.54E-11	No Data	4.87E-08
Mo-93	No Data	7.51E-06	2.03E-07	No Data	2.13E-06	No Data	1.22E-06
Mo-99	No Data	4.31E-06	8.20E-07	No Data	9.76E-06	No Data	9.99E-06
Tc-99m	2.47E-10	6.98E-10	8.89E-09	No Data	1.06E-08	3.42E-10	4.13E-07
Tc-99	1.25E-07	1.86E-07	5.02E-08	No Data	2.34E-06	1.58E-08	6.08E-06
Tc-101	2.54E-10	3.66E-10	3.59E-09	No Data	6.59E-09	1.87E-10	1.10E-21
Ru-103	1.85E-07	No Data	7.97E-08	No Data	7.06E-07	No Data	2.16E-05
Ru-105	1.54E-08	No Data	6.08E-09	No Data	1.99E-07	No Data	9.42E-06
Ru-106	2.75E-06	No Data	3.48E-07	No Data	5.31E-06	No Data	1.78E-04
Rh-105	1.21E-07	8.85E-08	5.83E-08	No Data	3.76E-07	No Data	1.41E-05
Pd-107	No Data	1.47E-07	9.40E-09	No Data	1.32E-06	No Data	9.11E-07
Pd-109	No Data	1.77E-07	3.99E-08	No Data	1.01E-06	No Data	1.96E-05
Ag-110m	1.60E-07	1.48E-07	8.79E-08	No Data	2.91E-07	No Data	6.04E-05
Ag-111	5.81E-08	2.43E-08	1.21E-08	No Data	7.84E-08	No Data	4.46E-05
Cd-113m	No Data	3.18E-06	1.02E-07	No Data	3.50E-06	No Data	2.56E-05
Cd-115m	No Data	1.84E-06	5.87E-08	No Data	1.46E-06	No Data	7.74E-05
Sn-123	3.11E-05	5.15E-07	7.59E-07	4.38E-07	No Data	No Data	6.33E-05
Sn-125	8.33E-06	1.68E-07	3.78E-07	1.39E-07	No Data	No Data	1.04E-04
Sn-126	8.45E-05	1.67E-06	2.40E-06	4.92E-07	No Data	No Data	2.43E-05
Sb-124	2.80E-06	5.29E-08	1.11E-06	6.79E-09	No Data	2.18E-06	7.95E-05
Sb-125	1.79E-06	2.00E-08	4.26E-07	1.82E-09	No Data	1.38E-06	1.97E-05
Sb-126	1.15E-06	2.34E-08	4.15E-07	7.04E-09	No Data	7.05E-07	9.40E-05
Sb-127	2.58E-07	5.65E-09	9.90E-08	3.10E-09	No Data	1.53E-07	5.90E-05
Te-125m	2.68E-06	9.71E-07	3.59E-07	8.06E-07	1.09E-05	No Data	1.07E-05
Te-127m	6.77E-06	2.42E-06	8.25E-07	1.73E-06	2.75E-05	No Data	2.27E-05
Te-127	1.10E-07	3.95E-08	2.38E-08	8.15E-08	4.48E-07	No Data	8.68E-06
Te-129m	1.15E-05	4.29E-06	1.82E-06	3.95E-06	4.80E-05	No Data	5.79E-05
Te-129	3.14E-08	1.18E-08	7.65E-09	2.41E-08	1.32E-07	No Data	2.37E-08
Te-131m	1.73E-06	8.46E-07	7.05E-07	1.34E-06	8.57E-06	No Data	8.40E-05
Te-131	1.97E-08	8.23E-09	6.22E-09	1.62E-08	8.63E-08	No Data	2.79E-09
Te-132	2.52E-06	1.63E-06	1.53E-06	1.80E-06	1.57E-05	No Data	7.71E-05
Te-133m	4.62E-08	2.70E-08	2.60E-08	3.91E-08	2.67E-07	No Data	9.26E-09
Te-134	3.24E-08	2.12E-08	1.30E-08	2.83E-08	2.05E-07	No Data	3.59E-11

[1] Data presented in this Table are from Reference 9.

TABLE A-15 (continued)

INGESTION DOSE FACTORS FOR ADULT[1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Cs-134m	2.13E-08	4.48E-08	2.29E-08	No Data	2.43E-08	3.83E-09	1.58E-08
Cs-134	6.22E-05	1.48E-04	1.21E-04	No Data	4.79E-05	1.59E-05	2.59E-06
Cs-135	1.95E-05	1.80E-05	7.99E-06	No Data	6.81E-06	2.04E-06	4.21E-07
Cs-136	6.51E-06	2.57E-05	1.85E-05	No Data	1.43E-05	1.96E-06	2.92E-06
Cs-137	7.97E-05	1.09E-04	7.14E-05	No Data	3.70E-05	1.23E-05	2.11E-06
Cs-138	5.52E-08	1.09E-07	5.40E-08	No Data	8.01E-08	7.91E-09	4.65E-13
Cs-139	3.41E-08	5.08E-08	1.85E-08	No Data	4.07E-08	3.70E-09	1.10e-30
Ba-139	9.70E-08	6.91E-11	2.84E-09	No Data	6.46E-11	3.92E-11	1.72E-07
Ba-140	2.03E-05	2.55E-08	1.33E-06	No Data	8.67E-09	1.46E-08	4.18E-05
Ba-141	4.71E-08	3.56E-11	1.59E-09	No Data	3.31E-11	2.02E-11	2.22E-17
Ba-142	2.13E-08	2.19E-11	1.34E-09	No Data	1.85E-11	1.24E-11	3.00e-26
La-140	2.50E-09	1.26E-09	3.33E-10	No Data	No Data	No Data	9.25E-05
La-141	3.19E-10	9.90E-11	1.62E-11	No Data	No Data	No Data	1.18E-05
La-142	1.28E-10	5.82E-11	1.45E-11	No Data	No Data	No Data	4.25E-07
Ce-141	9.36E-09	6.33E-09	7.18E-10	No Data	2.94E-09	No Data	2.42E-05
Ce-143	1.65E-09	1.22E-06	1.35E-10	No Data	5.37E-10	No Data	4.56E-05
Ce-144	4.88E-07	2.04E-07	2.62E-08	No Data	1.21E-07	No Data	1.65E-04
Pr-143	9.20E-09	3.69E-09	4.56E-10	No Data	2.13E-09	No Data	4.03E-05
Pr-144	3.01E-11	1.25E-11	1.53E-12	No Data	7.05E-12	No Data	4.33E-18
Nd-147	6.29E-09	7.27E-09	4.35E-10	No Data	4.25E-09	No Data	3.49E-05
Pm-147	7.54E-08	7.09E-09	2.87E-09	No Data	1.34E-08	No Data	8.93E-06
Pm-148m	3.07E-08	7.95E-09	6.08E-09	No Data	1.20E-08	No Data	6.74E-05
Pm-148	7.17E-09	1.19E-09	5.99E-10	No Data	2.25E-09	No Data	9.35E-05
Pm-149	1.52E-09	2.15E-10	8.78E-11	No Data	4.06E-10	No Data	4.03E-05
Pm-151	6.97E-10	1.17E-10	5.91E-11	No Data	2.09E-10	No Data	3.22E-05
Sm-151	6.90E-08	1.19E-08	2.85E-09	No Data	1.33E-08	No Data	5.25E-06
Sm-153	8.57E-10	7.15E-10	5.22E-11	No Data	2.31E-10	No Data	2.55E-05
Eu-152	1.95E-07	4.44E-08	3.90E-08	No Data	2.75E-07	No Data	2.56E-05
Eu-154	6.15E-07	7.56E-08	5.38E-08	No Data	3.62E-07	No Data	5.48E-05
Eu-155	8.60E-08	1.22E-08	7.87E-09	No Data	5.63E-08	No Data	9.60E-06
Eu-156	1.37E-08	1.06E-08	1.71E-09	No Data	7.08E-09	No Data	7.26E-05
Tb-160	4.70E-08	No Data	5.86E-09	No Data	1.94E-08	No Data	4.33E-05
Ho-166m	2.70E-07	8.43E-08	6.40E-08	No Data	1.26E-07	No Data	2.56E-05
W-181	9.91E-09	3.23E-09	3.46E-10	No Data	No Data	No Data	3.68E-07
W-185	4.05E-07	1.35E-07	1.42E-08	No Data	No Data	No Data	1.56E-05
W-187	1.03E-07	8.61E-08	3.01E-08	No Data	No Data	No Data	2.82E-05
Pb-210	1.53E-02	4.37E-03	5.44E-04	No Data	1.23E-02	No Data	2.24E-06
Bi-210	4.61E-07	3.18E-06	2.64E-07	No Data	3.83E-05	No Data	4.75E-05
Po-210	3.56E-04	7.56E-04	8.59E-05	No Data	2.52E-03	No Data	6.36E-05
Ra-223	4.97E-03	7.65E-06	9.94E-04	No Data	2.17E-04	No Data	3.21E-04
Ra-224	1.61E-03	3.90E-06	3.23E-04	No Data	1.10E-04	No Data	3.40E-04
Ra-225	6.56E-03	7.78E-06	1.31E-03	No Data	2.21E-04	No Data	3.06E-04
Ra-226	3.02E-01	5.74E-06	2.20E-01	No Data	1.63E-04	No Data	3.32E-04
Ra-228	1.12E-01	3.12E-06	1.21E-01	No Data	8.83E-05	No Data	5.64E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-15 (continued)

INGESTION DOSE FACTORS FOR ADULT[1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Ac-225	4.40E-06	6.06E-06	2.96E-07	No Data	6.90E-07	No Data	4.07E-04
Ac-227	1.87E-03	2.48E-04	1.11E-04	No Data	8.00E-05	No Data	8.19E-05
Th-227	1.37E-05	2.48E-07	3.95E-07	No Data	1.41E-06	No Data	5.40E-04
Th-228	4.96E-04	8.40E-06	1.68E-05	No Data	4.67E-05	No Data	5.63E-04
Th-229	1.36E-02	3.89E-04	2.25E-04	No Data	1.88E-03	No Data	7.81E-05
Th-230	2.06E-03	1.17E-04	5.70E-05	No Data	5.65E-04	No Data	6.02E-05
Th-232	2.30E-03	1.00E-04	1.50E-06	No Data	4.82E-04	No Data	5.12E-05
Th-234	8.01E-08	4.71E-09	2.31E-09	No Data	2.67E-08	No Data	1.13E-04
Pa-231	4.10E-03	1.54E-04	1.59E-04	No Data	8.64E-04	No Data	7.17E-05
Pa-233	5.26E-09	1.06E-09	9.12E-10	No Data	3.99E-09	No Data	1.64E-05
U-232	4.13E-03	No Data	2.95E-04	No Data	4.47E-04	No Data	6.78E-05
U-233	8.71E-04	No Data	5.28E-05	No Data	2.03E-04	No Data	6.27E-05
U-234	8.36E-04	No Data	5.17E-05	No Data	1.99E-04	No Data	6.14E-05
U-235	8.01E-04	No Data	4.86E-05	No Data	1.87E-04	No Data	7.81E-05
U-236	8.01E-04	No Data	4.96E-05	No Data	1.91E-04	No Data	5.76E-05
U-237	5.52E-08	No Data	1.47E-08	No Data	2.27E-07	No Data	1.94E-05
U-238	7.67E-04	No Data	4.54E-05	No Data	1.75E-04	No Data	5.50E-05
Np-237	1.26E-03	8.96E-05	5.54E-05	No Data	4.12E-04	No Data	7.94E-05
Np-238	1.37E-08	3.69E-10	2.13E-10	No Data	1.25E-09	No Data	3.43E-05
Np-239	1.19E-09	1.17E-10	6.45E-11	No Data	3.65E-10	No Data	2.40E-05
Pu-238	6.30E-04	7.98E-05	1.71E-05	No Data	7.32E-05	No Data	7.30E-05
Pu-239	7.25E-04	8.71E-05	1.91E-05	No Data	8.11E-05	No Data	6.66E-05
Pu-240	7.24E-04	8.70E-05	1.91E-05	No Data	8.10E-05	No Data	6.78E-05
Pu-241	1.57E-05	7.45E-07	3.32E-07	No Data	1.53E-06	No Data	1.40E-06
Pu-242	6.72E-04	8.39E-05	1.84E-05	No Data	7.81E-05	No Data	6.53E-05
Pu-244	7.84E-04	9.61E-05	2.11E-05	No Data	8.95E-05	No Data	9.73E-05
Am-241	7.55E-04	7.05E-04	5.41E-05	No Data	4.07E-04	No Data	7.42E-05
Am-242m	7.61E-04	6.63E-04	5.43E-05	No Data	4.05E-04	No Data	9.34E-05
Am-243	7.54E-04	6.90E-04	5.30E-05	No Data	3.99E-04	No Data	8.70E-05
Cm-242	2.06E-05	2.19E-05	1.37E-06	No Data	6.22E-06	No Data	7.92E-05
Cm-243	5.99E-04	5.49E-04	3.75E-05	No Data	1.75E-04	No Data	7.81E-05
Cm-244	4.56E-04	4.27E-04	2.87E-05	No Data	1.34E-04	No Data	7.55E-05
Cm-245	9.38E-04	8.17E-04	5.76E-05	No Data	2.69E-04	No Data	7.04E-05
Cm-246	9.30E-04	8.16E-04	5.75E-05	No Data	2.68E-04	No Data	6.91E-05
Cm-247	9.07E-04	8.04E-04	5.67E-05	No Data	2.64E-04	No Data	9.09E-05
Cm-248	7.54E-03	6.63E-03	4.67E-04	No Data	2.18E-03	No Data	1.47E-03
Cf-252	2.61E-04	No Data	6.29E-06	No Data	No Data	No Data	2.88E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-16

INGESTION DOSE FACTORS FOR TEEN[1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	No Data	6.04E-08	6.04E-08	6.04E-08	6.04E-08	6.04E-08	6.04E-08
Be-10	4.48E-06	6.94E-07	1.13E-07	No Data	5.30E-07	No Data	2.84E-05
C-14	4.06E-06	8.12E-07	8.12E-07	8.12E-07	8.12E-07	8.12E-07	8.12E-07
N-13	1.15E-08	1.15E-08	1.15E-08	1.15E-08	1.15E-08	1.15E-08	1.15E-08
F-18	8.64E-07	No Data	9.47E-08	No Data	No Data	No Data	7.78E-08
Na-22	2.34E-05	2.34E-05	2.34E-05	2.34E-05	2.34E-05	2.34E-05	2.34E-05
Na-24	2.30E-06	2.30E-06	2.30E-06	2.30E-06	2.30E-06	2.30E-06	2.30E-06
P-32	2.76E-04	1.71E-05	1.07E-05	No Data	No Data	No Data	2.32E-05
Ca-41	1.97E-04	No Data	2.13E-05	No Data	No Data	No Data	1.95E-07
Sc-46	7.24E-09	1.41E-08	4.18E-09	No Data	1.35E-08	No Data	4.80E-05
Cr-51	No Data	No Data	3.60E-09	2.00E-09	7.89E-10	5.14E-09	6.05E-07
Mn-54	No Data	5.90E-06	1.17E-06	No Data	1.76E-06	No Data	1.21E-05
Mn-56	No Data	1.58E-07	2.81E-08	No Data	2.00E-07	No Data	1.04E-05
Fe-55	3.78E-06	2.68E-06	6.25E-07	No Data	No Data	1.70E-06	1.16E-06
Fe-59	5.87E-06	1.37E-05	5.29E-06	No Data	No Data	4.32E-06	3.24E-05
Co-57	No Data	2.38E-07	3.99E-07	No Data	No Data	No Data	4.44E-06
Co-58	No Data	9.72E-07	2.24E-06	No Data	No Data	No Data	1.34E-05
Co-60	No Data	2.81E-06	6.33E-06	No Data	No Data	No Data	3.66E-05
Ni-59	1.32E-05	4.66E-06	2.24E-06	No Data	No Data	No Data	7.31E-07
Ni-63	1.77E-04	1.25E-05	6.00E-06	No Data	No Data	No Data	1.99E-06
Ni-65	7.49E-07	9.57E-08	4.36E-08	No Data	No Data	No Data	5.19E-06
Cu-64	No Data	1.15E-07	5.41E-08	No Data	2.91E-07	No Data	8.92E-06
Zn-65	5.76E-06	2.00E-05	9.33E-06	No Data	1.28E-05	No Data	8.47E-06
Zn-69m	2.40E-07	5.66E-07	5.19E-08	No Data	3.44E-07	No Data	3.11E-05
Zn-69	1.47E-08	2.80E-08	1.96E-09	No Data	1.83E-08	No Data	5.16E-08
Se-79	No Data	3.73E-06	6.27E-07	No Data	6.50E-06	No Data	5.70E-07
Br-82	No Data	No Data	3.04E-06	No Data	No Data	No Data	No Data
Br-83	No Data	No Data	5.74E-08	No Data	No Data	No Data	No Data
Br-84	No Data	No Data	7.22E-08	No Data	No Data	No Data	No Data
Br-85	No Data	No Data	3.05E-09	No Data	No Data	No Data	No Data
Rb-86	No Data	2.98E-05	1.40E-05	No Data	No Data	No Data	4.41E-06
Rb-87	No Data	1.75E-05	6.11E-06	No Data	No Data	No Data	6.11E-07
Rb-88	No Data	8.52E-08	4.54E-08	No Data	No Data	No Data	7.30E-15
Rb-89	No Data	5.50E-08	3.89E-08	No Data	No Data	No Data	8.43E-17
Sr-89	4.40E-04	No Data	1.26E-05	No Data	No Data	No Data	5.24E-05
Sr-90	1.02E-02	No Data	2.04E-04	No Data	No Data	No Data	2.33E-04
Sr-91	8.07E-06	No Data	3.21E-07	No Data	No Data	No Data	3.66E-05
Sr-92	3.05E-06	No Data	1.30E-07	No Data	No Data	No Data	7.77E-05
Y-90	1.37E-08	No Data	3.69E-10	No Data	No Data	No Data	1.13E-04
Y-91m	1.29E-10	No Data	4.93E-12	No Data	No Data	No Data	6.09E-09
Y-91	2.01E-07	No Data	5.39E-09	No Data	No Data	No Data	8.24E-05
Y-92	1.21E-09	No Data	3.50E-11	No Data	No Data	No Data	3.32E-05
Y-93	3.83E-09	No Data	1.05E-10	No Data	No Data	No Data	1.17E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-16 (continued)

INGESTION DOSE FACTORS FOR TEEN[1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Zr-93	5.53E-08	2.73E-09	1.49E-09	No Data	9.65E-09	No Data	2.58E-06
Zr-95	4.12E-08	1.30E-08	8.94E-09	No Data	1.91E-08	No Data	3.00E-05
Zr-97	2.37E-09	4.69E-10	2.16E-10	No Data	7.11E-10	No Data	1.27E-04
Nb-93m	3.44E-08	1.13E-08	2.83E-09	No Data	1.32E-08	No Data	4.07E-06
Nb-95	8.22E-09	4.56E-09	2.51E-09	No Data	4.42E-09	No Data	1.95E-05
Nb-97	7.37E-11	1.83E-11	6.68E-12	No Data	2.14E-11	No Data	4.37E-07
Mo-93	No Data	1.06E-05	2.90E-07	No Data	3.04E-06	No Data	1.29E-06
Mo-99	No Data	6.03E-06	1.15E-06	No Data	1.38E-05	No Data	1.08E-05
Tc-99m	3.32E-10	9.26E-10	1.20E-08	No Data	1.38E-08	5.14E-10	6.08E-07
Tc-99	1.79E-07	2.63E-07	7.17E-08	No Data	3.34E-06	2.72E-08	6.44E-06
Tc-101	3.60E-10	5.12E-10	5.03E-09	No Data	9.26E-09	3.12E-10	8.75E-17
Ru-103	2.55E-07	No Data	1.09E-07	No Data	8.99E-07	No Data	2.13E-05
Ru-105	2.18E-08	No Data	8.46E-09	No Data	2.75E-07	No Data	1.76E-05
Ru-106	3.92E-06	No Data	4.94E-07	No Data	7.56E-06	No Data	1.88E-04
Rh-105	1.73E-07	1.25E-07	8.20E-08	No Data	5.31E-07	No Data	1.59E-05
Pd-107	No Data	2.08E-07	1.34E-08	No Data	1.88E-06	No Data	9.66E-07
Pd-109	No Data	2.51E-07	5.70E-08	No Data	1.45E-06	No Data	2.53E-05
Ag-110m	2.05E-07	1.94E-07	1.18E-07	No Data	3.70E-07	No Data	5.45E-05
Ag-111	8.29E-08	3.44E-08	1.73E-08	No Data	1.12E-07	No Data	4.80E-05
Cd-113m	No Data	4.51E-06	1.45E-07	No Data	4.99E-06	No Data	2.71E-05
Cd-115m	No Data	2.60E-06	8.39E-08	No Data	2.08E-06	No Data	8.23E-05
Sn-123	4.44E-05	7.29E-07	1.08E-06	5.84E-07	No Data	No Data	6.71E-05
Sn-125	1.19E-05	2.37E-07	5.37E-07	1.86E-07	No Data	No Data	1.12E-04
Sn-126	1.16E-04	2.16E-06	3.30E-06	5.69E-07	No Data	No Data	2.58E-05
Sb-124	3.87E-06	7.13E-08	1.51E-06	8.78E-09	No Data	3.38E-06	7.80E-05
Sb-125	2.48E-06	2.71E-08	5.80E-07	2.37E-09	No Data	2.18E-06	1.93E-05
Sb-126	1.59E-06	3.25E-08	5.71E-07	8.99E-09	No Data	1.14E-06	9.41E-05
Sb-127	3.63E-07	7.76E-09	1.37E-07	4.08E-09	No Data	2.47E-07	6.16E-05
Te-125m	3.83E-06	1.38E-06	5.12E-07	1.07E-06	No Data	No Data	1.13E-05
Te-127m	9.67E-06	3.43E-06	1.15E-06	2.30E-06	3.92E-05	No Data	2.41E-05
Te-127	1.58E-07	5.60E-08	3.40E-08	1.09E-07	6.40E-07	No Data	1.22E-05
Te-129m	1.63E-05	6.05E-06	2.58E-06	5.26E-06	6.82E-05	No Data	6.12E-05
Te-129	4.48E-08	1.67E-08	1.09E-08	3.20E-08	1.88E-07	No Data	2.45E-07
Te-131m	2.44E-06	1.17E-06	9.76E-07	1.76E-06	1.22E-05	No Data	9.39E-05
Te-131	2.79E-08	1.15E-08	8.72E-09	2.15E-08	1.22E-07	No Data	2.29E-09
Te-132	3.49E-06	2.21E-06	2.08E-06	2.33E-06	2.12E-05	No Data	7.00E-05
Te-133m	6.44E-08	3.66E-08	3.56E-08	5.11E-08	3.62E-07	No Data	1.48E-07
Te-134	4.47E-08	2.87E-08	3.00E-08	3.67E-08	2.74E-07	No Data	1.66E-09

[1] Data presented in this Table are from Reference 9.

TABLE A-16 (continued)

INGESTION DOSE FACTORS FOR TEEN[1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Cs-134m	2.94E-08	6.09E-08	3.13E-08	No Data	3.39E-08	5.95E-09	4.05E-08
Cs-134	8.37E-05	1.97E-04	9.14E-05	No Data	6.26E-05	2.39E-05	2.45E-06
Cs-135	2.78E-05	2.55E-05	5.96E-06	No Data	9.73E-06	3.52E-06	4.46E-07
Cs-136	8.59E-06	3.38E-05	2.27E-05	No Data	1.84E-05	2.90E-06	2.72E-06
Cs-137	1.12E-04	1.49E-04	5.19E-05	No Data	5.07E-05	1.97E-05	2.12E-06
Cs-138	7.76E-08	1.49E-07	7.45E-08	No Data	1.10E-07	1.28E-08	6.76E-11
Cs-139	4.87E-08	7.17E-08	2.63E-08	No Data	5.79E-08	6.34E-09	3.33E-23
Ba-139	1.39E-07	9.78E-11	4.05E-09	No Data	9.22E-11	6.74E-11	1.24E-06
Ba-140	2.84E-05	3.48E-08	1.83E-06	No Data	1.18E-08	2.34E-08	4.38E-05
Ba-141	6.71E-08	5.01E-11	2.24E-09	No Data	4.65E-11	3.43E-11	1.43E-13
Ba-142	2.99E-08	2.99E-11	1.84E-09	No Data	2.53E-11	1.99E-11	9.18E-20
La-140	3.48E-09	1.71E-09	4.55E-10	No Data	No Data	No Data	9.82E-05
La-141	4.55E-10	1.40E-10	2.31E-11	No Data	No Data	No Data	2.48E-05
La-142	1.79E-10	7.95E-11	1.98E-11	No Data	No Data	No Data	2.42E-06
Ce-141	1.33E-08	8.88E-09	1.02E-09	No Data	4.18E-09	No Data	2.54E-05
Ce-143	2.35E-09	1.71E-06	1.91E-10	No Data	7.67E-10	No Data	5.14E-05
Ce-144	6.96E-07	2.88E-07	3.74E-08	No Data	1.72E-07	No Data	1.75E-04
Pr-143	1.31E-08	5.23E-09	6.52E-10	No Data	3.04E-09	No Data	4.31E-05
Pr-144	4.30E-11	1.76E-11	2.18E-12	No Data	1.01E-11	No Data	4.74E-14
Nd-147	9.38E-09	1.02E-08	6.11E-10	No Data	5.99E-09	No Data	3.68E-05
Pm-147	1.05E-07	9.96E-09	4.06E-09	No Data	1.90E-08	No Data	9.47E-06
Pm-148m	4.14E-08	1.05E-08	8.21E-09	No Data	1.59E-08	No Data	6.61E-05
Pm-148	1.02E-08	1.66E-09	8.36E-10	No Data	3.00E-09	No Data	9.90E-05
Pm-149	2.17E-09	3.05E-10	1.25E-10	No Data	5.81E-10	No Data	4.49E-05
Pm-151	9.87E-10	1.63E-10	8.25E-11	No Data	2.93E-10	No Data	3.66E-05
Sm-151	8.73E-08	1.68E-08	3.94E-09	No Data	1.84E-08	No Data	5.70E-06
Sm-153	1.22E-09	1.01E-09	7.43E-11	No Data	3.30E-10	No Data	2.85E-05
Eu-152	2.45E-07	5.90E-08	5.20E-08	No Data	2.74E-07	No Data	2.17E-05
Eu-154	7.91E-07	1.02E-07	7.19E-08	No Data	4.56E-07	No Data	5.39E-05
Eu-155	1.74E-07	1.68E-08	1.04E-08	No Data	6.57E-08	No Data	9.63E-05
Eu-156	1.92E-08	1.44E-08	2.35E-09	No Data	9.69E-09	No Data	7.36E-05
Tb-160	6.47E-08	No Data	8.07E-09	No Data	2.56E-08	No Data	4.19E-05
Ho-166m	3.57E-07	1.10E-07	7.96E-08	No Data	1.61E-07	No Data	2.71E-05
W-181	1.42E-08	4.58E-09	4.79E-10	No Data	No Data	No Data	3.90E-07
W-185	5.79E-07	1.91E-07	2.02E-08	No Data	No Data	No Data	1.65E-05
W-187	1.46E-07	1.19E-07	4.17E-08	No Data	No Data	No Data	3.22E-05
Pb-210	1.81E-02	5.44E-03	7.01E-04	No Data	1.72E-02	No Data	2.37E-06
Bi-210	6.59E-07	4.51E-06	3.77E-07	No Data	5.48E-05	No Data	5.15E-05
Po-210	5.09E-04	1.07E-03	1.23E-04	No Data	3.60E-03	No Data	6.75E-05
Ra-223	7.11E-03	1.08E-05	1.42E-03	No Data	3.10E-04	No Data	3.43E-04
Ra-224	2.31E-03	5.52E-06	4.61E-04	No Data	1.58E-04	No Data	3.71E-04
Ra-225	9.37E-03	1.10E-05	1.87E-03	No Data	3.15E-04	No Data	3.27E-04
Ra-226	3.22E-01	8.13E-06	2.39E-01	No Data	2.32E-04	No Data	3.51E-04
Ra-228	1.37E-01	4.41E-06	1.51E-01	No Data	1.26E-04	No Data	5.98E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-16 (continued)

INGESTION DOSE FACTORS FOR TEEN [1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Ac-225	6.29E-06	8.59E-06	4.22E-07	No Data	9.85E-07	No Data	4.36E-04
Ac-227	2.05E-03	3.03E-04	1.22E-04	No Data	8.81E-05	No Data	8.68E-05
Th-227	1.96E-05	3.52E-07	5.65E-07	No Data	2.01E-06	No Data	5.75E-04
Th-228	6.80E-04	1.14E-05	2.30E-05	No Data	6.41E-05	No Data	5.97E-04
Th-229	1.43E-02	4.11E-04	2.37E-04	No Data	1.99E-03	No Data	8.28E-05
Th-230	2.16E-03	1.23E-04	6.00E-05	No Data	5.99E-04	No Data	6.38E-05
Th-232	2.42E-03	1.05E-04	1.63E-06	No Data	5.11E-04	No Data	5.43E-05
Th-234	1.14E-07	6.68E-09	3.31E-09	No Data	3.81E-08	No Data	1.21E-04
Pa-231	4.31E-03	1.62E-04	1.68E-04	No Data	9.10E-04	No Data	7.60E-05
Pa-233	7.33E-09	1.41E-09	1.26E-09	No Data	5.32E-09	No Data	1.61E-05
U-232	5.89E-03	No Data	4.21E-04	No Data	6.38E-04	No Data	7.19E-05
U-233	1.24E-03	No Data	7.54E-05	No Data	2.90E-04	No Data	6.65E-05
U-234	1.19E-03	No Data	7.39E-05	No Data	2.85E-04	No Data	6.51E-05
U-235	1.14E-03	No Data	6.94E-05	No Data	2.67E-04	No Data	8.28E-05
U-236	1.14E-03	No Data	7.09E-05	No Data	2.73E-04	No Data	6.11E-05
U-237	7.89E-08	No Data	2.10E-08	No Data	3.24E-07	No Data	2.09E-05
U-238	1.09E-03	No Data	6.49E-05	No Data	2.50E-04	No Data	5.83E-05
Np-237	1.33E-03	9.55E-05	5.85E-05	No Data	4.33E-04	No Data	8.41E-05
Np-238	1.95E-08	5.22E-10	3.04E-10	No Data	1.79E-09	No Data	3.83E-05
Np-239	1.76E-09	1.66E-10	9.22E-11	No Data	5.21E-10	No Data	2.67E-05
Pu-238	6.70E-04	8.58E-05	1.82E-05	No Data	7.80E-05	No Data	7.73E-05
Pu-239	7.65E-04	9.29E-05	2.01E-05	No Data	8.57E-05	No Data	7.06E-05
Pu-240	7.64E-04	9.27E-05	2.01E-05	No Data	8.56E-05	No Data	7.19E-05
Pu-241	1.75E-05	8.40E-07	3.69E-07	No Data	1.71E-06	No Data	1.48E-06
Pu-242	7.09E-04	8.94E-05	1.94E-05	No Data	8.25E-05	No Data	6.92E-05
Pu-244	8.28E-04	1.02E-04	2.22E-05	No Data	9.45E-05	No Data	1.03E-04
Am-241	7.98E-04	7.53E-04	5.75E-05	No Data	4.31E-04	No Data	7.87E-05
Am-242m	8.07E-04	7.11E-04	5.80E-05	No Data	4.30E-04	No Data	9.90E-05
Am-243	7.96E-04	7.35E-04	5.62E-05	No Data	4.22E-04	No Data	9.23E-05
Cm-242	2.94E-05	3.10E-05	1.95E-06	No Data	8.89E-06	No Data	8.40E-05
Cm-243	6.50E-04	6.03E-04	4.09E-05	No Data	1.91E-04	No Data	8.28E-05
Cm-244	5.04E-04	4.77E-04	3.19E-05	No Data	1.49E-04	No Data	8.00E-05
Cm-245	9.90E-04	8.71E-04	6.10E-05	No Data	2.85E-04	No Data	7.46E-05
Cm-246	9.82E-04	8.70E-04	6.09E-05	No Data	2.84E-04	No Data	7.33E-05
Cm-247	9.57E-04	8.57E-04	6.00E-05	No Data	2.80E-04	No Data	9.63E-05
Cm-248	7.95E-03	7.06E-03	4.95E-04	No Data	2.31E-03	No Data	1.55E-03
Cf-252	3.47E-04	No Data	8.37E-06	No Data	No Data	No Data	3.05E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-17

INGESTION DOSE FACTORS FOR CHILD [1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	No Data	1.16E-07	1.16E-07	1.16E-07	1.16E-07	1.16E-07	1.16E-07
Be-10	1.35E-05	1.57E-06	3.39E-07	No Data	1.11E-06	No Data	2.75E-05
C-14	1.21E-05	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06
N-13	3.10E-08	3.10E-08	3.10E-08	3.10E-08	3.10E-08	3.10E-08	3.10E-08
F-18	2.49E-06	No Data	2.47E-07	No Data	No Data	No Data	6.74E-07
Na-22	5.88E-05	5.88E-05	5.88E-05	5.88E-05	5.88E-05	5.88E-05	5.88E-05
Na-24	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06
P-32	8.25E-04	3.86E-05	3.18E-05	No Data	No Data	No Data	2.28E-05
Ca-41	3.47E-04	No Data	3.79E-05	No Data	No Data	No Data	1.90E-07
Sc-46	1.97E-08	2.70E-08	1.04E-08	No Data	2.39E-08	No Data	3.95E-05
Cr-51	No Data	No Data	8.90E-09	4.94E-09	1.35E-09	9.02E-09	4.72E-07
Mn-54	No Data	1.07E-05	2.85E-06	No Data	3.00E-06	No Data	8.98E-06
Mn-56	No Data	3.34E-07	7.54E-08	No Data	4.04E-07	No Data	4.84E-05
Fe-55	1.15E-05	6.10E-06	1.89E-06	No Data	No Data	3.45E-06	1.13E-06
Fe-59	1.65E-05	2.67E-05	1.33E-05	No Data	No Data	7.74E-06	2.78E-05
Co-57	No Data	4.93E-07	9.98E-07	No Data	No Data	No Data	4.04E-06
Co-58	No Data	1.80E-06	5.51E-06	No Data	No Data	No Data	1.05E-05
Co-60	No Data	5.29E-06	1.56E-05	No Data	No Data	No Data	2.93E-05
Ni-59	4.02E-05	1.07E-05	6.82E-06	No Data	No Data	No Data	7.10E-07
Ni-63	5.38E-04	2.88E-05	1.83E-05	No Data	No Data	No Data	1.94E-06
Ni-65	2.22E-06	2.09E-07	1.22E-07	No Data	No Data	No Data	2.56E-05
Cu-64	No Data	2.45E-07	1.48E-07	No Data	5.92E-07	No Data	1.15E-05
Zn-65	1.37E-05	3.65E-05	2.27E-05	No Data	2.30E-05	No Data	6.41E-06
Zn-69m	7.10E-07	1.21E-06	1.43E-07	No Data	7.03E-07	No Data	3.94E-05
Zn-69	4.38E-08	6.33E-08	5.85E-09	No Data	3.84E-08	No Data	3.99E-06
Se-79	No Data	8.43E-06	1.87E-06	No Data	1.37E-05	No Data	5.53E-07
Br-82	No Data	No Data	7.55E-06	No Data	No Data	No Data	No Data
Br-83	No Data	No Data	1.71E-07	No Data	No Data	No Data	No Data
Br-84	No Data	No Data	1.98E-07	No Data	No Data	No Data	No Data
Br-85	No Data	No Data	9.12E-09	No Data	No Data	No Data	No Data
Rb-86	No Data	6.70E-05	4.12E-05	No Data	No Data	No Data	4.31E-06
Rb-87	No Data	3.95E-05	1.83E-05	No Data	No Data	No Data	5.92E-07
Rb-88	No Data	1.90E-07	1.32E-07	No Data	No Data	No Data	9.32E-09
Rb-89	No Data	1.17E-07	1.04E-07	No Data	No Data	No Data	1.02E-09
Sr-89	1.32E-03	No Data	3.77E-05	No Data	No Data	No Data	5.11E-05
Sr-90	2.56E-02	No Data	5.15E-04	No Data	No Data	No Data	2.29E-04
Sr-91	2.40E-05	No Data	9.06E-07	No Data	No Data	No Data	5.30E-05
Sr-92	9.03E-06	No Data	3.62E-07	No Data	No Data	No Data	1.71E-04
Y-90	4.11E-08	No Data	1.10E-09	No Data	No Data	No Data	1.17E-04
Y-91m	3.82E-10	No Data	1.39E-11	No Data	No Data	No Data	7.48E-07
Y-91	6.02E-07	No Data	1.61E-08	No Data	No Data	No Data	8.02E-05
Y-92	3.60E-09	No Data	1.03E-10	No Data	No Data	No Data	1.04E-04
Y-93	1.14E-08	No Data	3.13E-10	No Data	No Data	No Data	1.70E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-17 (continued)

INGESTION DOSE FACTORS FOR CHILD [1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Zr-93	1.67E-07	6.25E-09	4.45E-09	No Data	2.42E-08	No Data	2.37E-06
Zr-95	1.16E-07	2.55E-08	2.27E-08	No Data	3.65E-08	No Data	2.66E-05
Zr-97	6.99E-09	1.01E-09	5.96E-10	No Data	1.45E-09	No Data	1.53E-04
Nb-93m	1.05E-07	2.62E-08	8.61E-09	No Data	2.83E-08	No Data	3.95E-06
Nb-95	2.25E-08	8.76E-09	6.26E-09	No Data	8.23E-09	No Data	1.62E-05
Nb-97	2.17E-10	3.92E-11	1.83E-11	No Data	4.35E-11	No Data	1.21E-05
Mo-93	No Data	2.41E-05	8.65E-07	No Data	6.35E-06	No Data	1.22E-06
Mo-99	No Data	1.33E-05	3.29E-06	No Data	2.84E-05	No Data	1.10E-05
Tc-99m	9.23E-10	1.81E-09	3.00E-08	No Data	2.63E-08	9.19E-10	1.03E-06
Tc-99	5.35E-07	5.96E-07	2.14E-07	No Data	7.02E-06	5.27E-08	6.25E-06
Tc-101	1.07E-09	1.12E-09	1.42E-08	No Data	1.91E-08	5.92E-10	3.56E-09
Ru-103	7.31E-07	No Data	2.81E-07	No Data	1.84E-06	No Data	1.89E-05
Ru-105	6.45E-08	No Data	2.34E-08	No Data	5.67E-07	No Data	4.21E-05
Ru-106	1.17E-05	No Data	1.46E-06	No Data	1.58E-05	No Data	1.82E-04
Rh-105	5.14E-07	2.76E-07	2.36E-07	No Data	1.10E-06	No Data	1.71E-05
Pd-107	No Data	4.72E-07	4.01E-08	No Data	3.95E-06	No Data	9.37E-07
Pd-109	No Data	5.67E-07	1.70E-07	No Data	3.04E-06	No Data	3.35E-05
Ag-110m	5.39E-07	3.64E-07	2.91E-07	No Data	6.78E-07	No Data	4.33E-05
Ag-111	2.48E-07	7.76E-08	5.12E-08	No Data	2.34E-07	No Data	4.75E-05
Cd-113m	No Data	1.02E-05	4.34E-07	No Data	1.05E-05	No Data	2.63E-05
Cd-115m	No Data	5.89E-06	2.51E-07	No Data	4.38E-06	No Data	8.01E-05
Sn-123	1.33E-04	1.65E-06	3.24E-06	1.75E-06	No Data	No Data	6.52E-05
Sn-125	3.55E-05	5.35E-07	1.59E-06	5.55E-07	No Data	No Data	1.10E-04
Sn-126	3.33E-04	4.15E-06	9.46E-06	1.14E-06	No Data	No Data	2.50E-05
Sb-124	1.11E-05	1.44E-07	3.89E-06	2.45E-08	No Data	6.16E-06	6.94E-05
Sb-125	7.16E-06	5.52E-08	1.50E-06	6.63E-09	No Data	3.99E-06	1.71E-05
Sb-126	4.40E-06	6.73E-08	1.58E-06	2.58E-08	No Data	2.10E-06	8.87E-05
Sb-127	1.06E-06	1.64E-08	3.68E-07	1.18E-08	No Data	4.60E-07	5.97E-05
Te-125m	1.14E-05	3.09E-06	1.52E-06	3.20E-06	No Data	No Data	1.10E-05
Te-127m	2.89E-05	7.78E-06	3.43E-06	6.91E-06	8.24E-05	No Data	2.34E-05
Te-127	4.71E-07	1.27E-07	1.01E-07	3.26E-07	1.34E-06	No Data	1.84E-05
Te-129m	4.87E-05	1.36E-05	7.56E-06	1.57E-05	1.43E-04	No Data	5.94E-05
Te-129	1.34E-07	3.74E-08	3.18E-08	9.56E-08	3.92E-07	No Data	8.34E-06
Te-131m	7.20E-06	2.49E-06	2.65E-06	5.12E-06	2.41E-05	No Data	1.01E-04
Te-131	8.30E-08	2.53E-08	2.47E-08	6.35E-08	2.51E-07	No Data	4.36E-07
Te-132	1.01E-05	4.47E-06	5.40E-06	6.51E-06	4.15E-05	No Data	4.50E-05
Te-133m	1.87E-07	7.56E-08	9.37E-08	1.45E-07	7.18E-07	No Data	5.77E-06
Te-134	1.29E-07	5.80E-08	7.74E-08	1.02E-07	5.37E-07	No Data	5.89E-07

[1] Data presented in this Table are from Reference 9.

TABLE A-17 (continued)

INGESTION DOSE FACTORS FOR CHILD [1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Cs-134m	8.44E-08	1.25E-07	8.16E-08	No Data	6.59E-08	1.09E-08	1.58E-07
Cs-134	2.34E-04	3.84E-04	8.10E-05	No Data	1.19E-04	4.27E-05	2.07E-06
Cs-135	8.30E-05	5.78E-05	5.93E-06	No Data	2.04E-05	6.81E-06	4.33E-07
Cs-136	2.35E-05	6.46E-05	4.18E-05	No Data	3.44E-05	5.13E-06	2.27E-06
Cs-137	3.27E-04	3.13E-04	4.62E-05	No Data	1.02E-04	3.67E-05	1.96E-06
Cs-138	2.28E-07	3.17E-07	2.01E-07	No Data	2.23E-07	2.40E-08	1.46E-07
Cs-139	1.45E-07	1.61E-07	7.74E-08	No Data	1.21E-07	1.22E-08	1.45E-11
Ba-139	4.14E-07	2.21E-10	1.20E-08	No Data	1.93E-10	1.30E-10	2.39E-05
Ba-140	8.31E-05	7.28E-08	4.85E-06	No Data	2.37E-08	4.34E-08	4.21E-05
Ba-141	2.00E-07	1.12E-10	6.51E-09	No Data	9.69E-11	6.58E-10	1.14E-07
Ba-142	8.74E-08	6.29E-11	4.88E-09	No Data	5.09E-11	3.70E-11	1.14E-09
La-140	1.01E-08	3.53E-09	1.19E-09	No Data	No Data	No Data	9.84E-05
La-141	1.36E-09	3.17E-10	6.88E-11	No Data	No Data	No Data	7.05E-05
La-142	5.24E-10	1.67E-10	5.23E-11	No Data	No Data	No Data	3.31E-05
Ce-141	3.97E-08	1.98E-08	2.94E-09	No Data	8.68E-09	No Data	2.47E-05
Ce-143	6.99E-09	3.79E-06	5.49E-10	No Data	1.59E-09	No Data	5.55E-05
Ce-144	2.08E-06	6.52E-07	1.11E-07	No Data	3.61E-07	No Data	1.70E-04
Pr-143	3.93E-08	1.18E-08	1.95E-09	No Data	6.39E-09	No Data	4.24E-05
Pr-144	1.29E-10	3.99E-11	6.49E-12	No Data	2.11E-11	No Data	8.59E-08
Nd-147	2.79E-08	2.26E-08	1.75E-09	No Data	1.24E-08	No Data	3.58E-05
Pm-147	3.18E-07	2.27E-08	1.22E-08	No Data	4.01E-08	No Data	9.19E-06
Pm-148m	1.03E-07	2.05E-08	2.05E-08	No Data	3.04E-08	No Data	5.78E-05
Pm-148	3.02E-08	3.63E-09	2.35E-09	No Data	6.17E-09	No Data	9.70E-05
Pm-149	6.49E-09	6.90E-10	3.74E-10	No Data	1.22E-09	No Data	4.71E-05
Pm-151	2.92E-09	3.55E-10	2.31E-10	No Data	6.02E-10	No Data	4.03E-05
Sm-151	2.56E-07	3.81E-08	1.20E-08	No Data	3.94E-08	No Data	5.53E-06
Sm-153	3.65E-09	2.27E-09	2.19E-10	No Data	6.91E-10	No Data	3.02E-05
Eu-152	6.15E-07	1.12E-07	1.33E-07	No Data	4.73E-07	No Data	1.84E-05
Eu-154	2.30E-06	2.07E-07	1.89E-07	No Data	9.09E-07	No Data	4.81E-05
Eu-155	4.82E-07	3.47E-08	2.72E-08	No Data	1.30E-07	No Data	8.69E-05
Eu-156	5.62E-08	3.01E-08	6.23E-09	No Data	1.94E-08	No Data	6.83E-05
Tb-160	1.66E-07	No Data	2.06E-08	No Data	4.94E-08	No Data	3.68E-05
Ho-166m	1.08E-06	2.26E-07	1.91E-07	No Data	3.22E-07	No Data	2.63E-05
W-181	4.23E-08	1.04E-08	1.43E-09	No Data	No Data	No Data	3.79E-07
W-185	1.73E-06	4.32E-07	6.05E-08	No Data	No Data	No Data	1.61E-05
W-187	4.29E-07	2.54E-07	1.14E-07	No Data	No Data	No Data	3.57E-05
Pb-210	4.75E-02	1.22E-02	2.09E-03	No Data	3.67E-02	No Data	2.30E-06
Bi-210	1.97E-06	1.02E-05	1.13E-06	No Data	1.15E-04	No Data	5.17E-05
Po-210	1.52E-03	2.43E-03	3.67E-04	No Data	7.56E-03	No Data	6.55E-05
Ra-223	2.12E-02	2.45E-05	4.24E-03	No Data	6.50E-04	No Data	3.38E-04
Ra-224	6.89E-03	1.25E-05	1.38E-03	No Data	3.31E-04	No Data	3.78E-04
Ra-225	2.80E-02	2.50E-05	5.59E-03	No Data	6.62E-04	No Data	3.21E-04
Ra-226	5.75E-01	1.84E-05	4.72E-01	No Data	4.88E-04	No Data	3.41E-04
Ra-228	3.85E-01	9.99E-06	4.32E-01	No Data	2.65E-04	No Data	5.81E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-17 (continued)

INGESTION DOSE FACTORS FOR CHILD [1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Ac-225	1.88E-05	1.94E-05	1.26E-06	No Data	2.07E-06	No Data	4.31E-04
Ac-227	4.12E-03	6.63E-04	2.55E-04	No Data	1.46E-04	No Data	8.43E-05
Th-227	5.85E-05	7.96E-07	1.69E-06	No Data	4.22E-06	No Data	5.63E-04
Th-228	2.07E-03	2.65E-05	7.00E-05	No Data	1.38E-04	No Data	5.79E-04
Th-229	2.35E-02	5.91E-04	3.92E-04	No Data	2.89E-03	No Data	8.04E-05
Th-230	3.55E-03	1.78E-04	9.91E-05	No Data	8.67E-04	No Data	6.19E-05
Th-232	3.96E-03	1.52E-04	3.01E-06	No Data	7.41E-04	No Data	5.27E-05
Th-234	3.42E-07	1.51E-08	9.88E-09	No Data	8.01E-08	No Data	1.18E-04
Pa-231	7.07E-03	2.34E-04	2.81E-04	No Data	1.28E-03	No Data	7.37E-05
Pa-233	1.81E-08	2.82E-09	3.16E-09	No Data	1.04E-08	No Data	1.44E-05
U-232	1.76E-02	No Data	1.26E-03	No Data	1.34E-03	No Data	6.98E-05
U-233	3.72E-03	No Data	2.25E-04	No Data	6.10E-04	No Data	6.45E-05
U-234	3.57E-03	No Data	2.21E-04	No Data	5.98E-04	No Data	6.32E-05
U-235	3.42E-03	No Data	2.07E-04	No Data	5.61E-04	No Data	8.03E-05
U-236	3.42E-03	No Data	2.12E-04	No Data	5.73E-04	No Data	5.92E-05
U-237	2.36E-07	No Data	6.27E-08	No Data	6.81E-07	No Data	2.08E-05
U-238	3.27E-03	No Data	1.94E-04	No Data	5.24E-04	No Data	5.66E-05
Np-237	2.23E-03	1.47E-04	9.79E-05	No Data	6.05E-04	No Data	8.16E-05
Np-238	5.83E-08	1.18E-09	9.08E-10	No Data	3.76E-09	No Data	4.04E-05
Np-239	5.25E-09	3.77E-10	2.65E-10	No Data	1.09E-09	No Data	2.79E-05
Pu-238	1.19E-03	1.38E-04	3.16E-05	No Data	1.15E-04	No Data	7.50E-05
Pu-239	1.29E-03	1.38E-04	3.31E-05	No Data	1.22E-04	No Data	6.85E-05
Pu-240	1.28E-03	1.43E-04	3.31E-05	No Data	1.22E-04	No Data	6.98E-05
Pu-241	3.87E-05	1.58E-06	8.04E-07	No Data	2.96E-06	No Data	1.44E-06
Pu-242	1.19E-03	1.38E-04	3.19E-05	No Data	1.17E-04	No Data	6.71E-05
Pu-244	1.39E-03	1.58E-03	3.65E-05	No Data	1.35E-04	No Data	1.00E-04
Am-241	1.36E-03	1.17E-03	1.02E-04	No Data	6.23E-04	No Data	7.64E-05
Am-242m	1.40E-03	1.12E-03	1.04E-04	No Data	6.30E-04	No Data	9.61E-05
Am-243	1.34E-03	1.13E-03	9.83E-05	No Data	6.06E-04	No Data	8.95E-05
Cm-242	8.78E-05	7.01E-05	5.84E-06	No Data	1.87E-05	No Data	8.16E-05
Cm-243	1.28E-03	1.04E-03	8.24E-05	No Data	3.08E-04	No Data	8.03E-05
Cm-244	1.08E-03	8.74E-04	6.93E-05	No Data	2.54E-04	No Data	7.77E-05
Cm-245	1.67E-03	1.34E-03	1.05E-04	No Data	4.11E-04	No Data	7.24E-05
Cm-246	1.65E-03	1.34E-03	1.05E-04	No Data	4.10E-04	No Data	7.11E-05
Cm-247	1.61E-03	1.32E-03	1.03E-04	No Data	4.04E-04	No Data	9.35E-05
Cm-248	1.34E-02	1.09E-02	8.52E-04	No Data	3.33E-03	No Data	1.51E-03
Cf-252	1.05E-03	No Data	2.54E-05	No Data	No Data	No Data	2.96E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-18

INGESTION DOSE FACTORS FOR INFANT [1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	No Data	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07
Be-10	1.71E-05	2.49E-06	5.16E-07	No Data	1.64E-06	No Data	2.78E-05
C-14	2.37E-05	5.06E-06	5.06E-06	5.06E-06	5.06E-06	5.06E-06	5.06E-06
N-13	5.85E-08	5.85E-08	5.85E-08	5.85E-08	5.85E-08	5.85E-08	5.85E-08
F-18	5.19E-06	No Data	4.43E-07	No Data	No Data	No Data	1.22E-06
Na-22	9.83E-05	9.83E-05	9.83E-05	9.83E-05	9.83E-05	9.83E-05	9.83E-05
Na-24	1.01E-05	1.01E-05	1.01E-05	1.01E-05	1.01E-05	1.01E-05	1.01E-05
P-32	1.70E-03	1.00E-04	6.59E-05	No Data	No Data	No Data	2.30E-05
Ca-41	3.74E-04	No Data	4.08E-05	No Data	No Data	No Data	1.91E-07
Sc-46	3.75E-08	5.41E-08	1.69E-08	No Data	3.56E-08	No Data	3.53E-05
Cr-51	No Data	No Data	1.41E-08	9.20E-09	2.01E-09	1.79E-08	4.11E-07
Mn-54	No Data	1.99E-05	4.51E-06	No Data	4.41E-06	No Data	7.31E-06
Mn-56	No Data	8.18E-07	1.41E-07	No Data	7.03E-07	No Data	7.43E-05
Fe-55	1.39E-05	8.98E-06	2.40E-06	No Data	No Data	4.39E-06	1.14E-06
Fe-59	3.08E-05	5.38E-05	2.12E-05	No Data	No Data	1.59E-05	2.57E-05
Co-57	No Data	1.15E-06	1.87E-06	No Data	No Data	No Data	3.92E-06
Co-58	No Data	3.60E-06	8.98E-06	No Data	No Data	No Data	8.97E-06
Co-60	No Data	1.08E-05	2.55E-05	No Data	No Data	No Data	2.57E-05
Ni-59	4.73E-05	1.45E-05	8.17E-06	No Data	No Data	No Data	7.16E-07
Ni-63	6.34E-04	3.92E-05	2.20E-05	No Data	No Data	No Data	1.95E-06
Ni-65	4.70E-06	5.32E-07	2.42E-07	No Data	No Data	No Data	4.05E-05
Cu-64	No Data	6.09E-07	2.82E-07	No Data	1.03E-06	No Data	1.25E-05
Zn-65	1.84E-05	6.31E-05	2.91E-05	No Data	3.06E-05	No Data	5.33E-05
Zn-69m	1.50E-06	3.06E-06	2.79E-07	No Data	1.24E-06	No Data	4.24E-05
Zn-69	9.33E-08	1.68E-07	1.25E-08	No Data	6.98E-08	No Data	1.37E-05
Se-79	No Data	2.10E-05	3.90E-06	No Data	2.43E-05	No Data	5.58E-07
Br-82	No Data	No Data	1.27E-05	No Data	No Data	No Data	No Data
Br-83	No Data	No Data	3.63E-07	No Data	No Data	No Data	No Data
Br-84	No Data	No Data	3.82E-07	No Data	No Data	No Data	No Data
Br-85	No Data	No Data	1.94E-08	No Data	No Data	No Data	No Data
Rb-86	No Data	1.70E-04	8.40E-05	No Data	No Data	No Data	4.35E-06
Rb-87	No Data	8.88E-05	3.52E-05	No Data	No Data	No Data	5.98E-07
Rb-88	No Data	4.98E-07	2.73E-07	No Data	No Data	No Data	4.85E-07
Rb-89	No Data	2.86E-07	1.97E-07	No Data	No Data	No Data	9.74E-08
Sr-89	2.51E-03	No Data	7.20E-05	No Data	No Data	No Data	5.16E-05
Sr-90	2.83E-02	No Data	5.74E-04	No Data	No Data	No Data	2.31E-04
Sr-91	5.00E-05	No Data	1.81E-06	No Data	No Data	No Data	5.92E-05
Sr-92	1.92E-05	No Data	7.13E-07	No Data	No Data	No Data	2.07E-04
Y-90	8.69E-08	No Data	2.33E-09	No Data	No Data	No Data	1.20E-04
Y-91m	8.10E-10	No Data	2.76E-11	No Data	No Data	No Data	2.70E-06
Y-91	1.13E-06	No Data	3.01E-08	No Data	No Data	No Data	8.10E-05
Y-92	7.65E-09	No Data	2.15E-10	No Data	No Data	No Data	1.46E-04
Y-93	2.43E-08	No Data	6.62E-10	No Data	No Data	No Data	1.92E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-18 (continued)

INGESTION DOSE FACTORS FOR INFANT [1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Zr-93	1.93E-07	9.19E-09	5.54E-09	No Data	2.71E-08	No Data	2.39E-06
Zr-95	2.06E-07	5.02E-08	3.56E-08	No Data	5.41E-08	No Data	2.50E-05
Zr-97	1.48E-08	2.54E-09	1.16E-09	No Data	2.56E-09	No Data	1.62E-04
Nb-93m	1.23E-07	3.33E-08	1.04E-08	No Data	3.25E-08	No Data	3.98E-06
Nb-95	4.20E-08	1.73E-08	1.00E-08	No Data	1.24E-08	No Data	1.46E-05
Nb-97	4.59E-10	9.79E-11	3.53E-11	No Data	7.65E-11	No Data	3.09E-05
Mo-93	No Data	5.65E-05	1.82E-06	No Data	1.13E-05	No Data	1.21E-06
Mo-99	No Data	3.40E-05	6.63E-06	No Data	5.08E-05	No Data	1.12E-05
Tc-99m	1.92E-09	3.96E-09	5.10E-08	No Data	4.26E-08	2.07E-09	1.15E-06
Tc-99	1.08E-06	1.46E-06	4.55E-07	No Data	1.23E-05	1.42E-07	6.31E-06
Tc-101	2.27E-09	2.86E-09	2.83E-08	No Data	3.40E-08	1.56E-09	4.86E-07
Ru-103	1.48E-06	No Data	4.95E-07	No Data	3.08E-06	No Data	1.80E-05
Ru-105	1.36E-07	No Data	4.58E-08	No Data	1.00E-06	No Data	5.41E-05
Ru-106	2.41E-05	No Data	3.01E-06	No Data	2.85E-05	No Data	1.83E-04
Rh-105	1.09E-06	7.13E-07	4.79E-07	No Data	1.98E-06	No Data	1.77E-05
Pd-107	No Data	1.19E-06	8.45E-08	No Data	6.79E-06	No Data	9.46E-07
Pd-109	No Data	1.50E-06	3.62E-07	No Data	5.51E-06	No Data	3.68E-05
Ag-110m	9.96E-07	7.27E-07	4.81E-07	No Data	1.04E-06	No Data	3.77E-05
Ag-111	5.20E-07	2.02E-07	1.07E-07	No Data	4.22E-07	No Data	4.82E-05
Cd-113m	No Data	1.77E-05	6.52E-07	No Data	1.34E-05	No Data	2.66E-05
Cd-115m	No Data	1.42E-05	4.93E-07	No Data	7.41E-06	No Data	8.09E-05
Sn-123	2.49E-04	3.89E-06	6.50E-06	3.91E-06	No Data	No Data	6.58E-05
Sn-125	7.41E-05	1.38E-06	3.29E-06	1.36E-06	No Data	No Data	1.11E-04
Sn-126	5.53E-04	7.26E-06	1.80E-05	1.91E-06	No Data	No Data	2.52E-05
Sb-124	2.14E-05	3.15E-07	6.63E-06	5.68E-08	No Data	1.34E-05	6.60E-05
Sb-125	1.23E-05	1.19E-07	2.53E-06	1.54E-08	No Data	7.12E-06	1.64E-05
Sb-126	8.06E-06	1.58E-07	2.91E-06	6.19E-08	No Data	5.07E-06	8.35E-05
Sb-127	2.23E-06	3.98E-08	6.90E-07	2.84E-08	No Data	1.15E-06	5.91E-05
Te-125m	2.33E-05	7.79E-06	3.15E-06	7.84E-06	No Data	No Data	1.11E-05
Te-127m	5.85E-05	1.94E-05	7.08E-06	1.69E-05	1.44E-04	No Data	2.36E-05
Te-127	1.00E-06	3.35E-07	2.15E-07	8.14E-07	2.44E-06	No Data	2.10E-05
Te-129m	1.00E-04	3.43E-05	1.54E-05	3.84E-05	2.50E-04	No Data	5.97E-05
Te-129	2.84E-07	9.79E-08	6.63E-08	2.38E-07	7.07E-07	No Data	2.27E-05
Te-131m	1.52E-05	6.12E-06	5.05E-06	1.24E-05	4.21E-05	No Data	1.03E-04
Te-131	1.76E-07	6.50E-08	4.94E-08	1.57E-07	4.50E-07	No Data	7.11E-06
Te-132	2.08E-05	1.03E-05	9.61E-06	1.52E-05	6.44E-05	No Data	3.81E-05
Te-133m	3.91E-07	1.79E-07	1.71E-07	3.45E-07	1.22E-06	No Data	1.93E-05
Te-134	2.67E-07	1.34E-07	1.38E-07	2.39E-07	9.03E-07	No Data	3.06E-06

[1] Data presented in this Table are from Reference 9.

TABLE A-18 (continued)

INGESTION DOSE FACTORS FOR INFANT [1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Cs-134m	1.76E-07	2.93E-07	1.48E-07	No Data	1.13E-07	2.60E-08	2.32E-07
Cs-134	3.77E-04	7.03E-04	7.10E-05	No Data	1.81E-04	7.42E-05	1.91E-06
Cs-135	1.33E-04	1.21E-04	6.30E-06	No Data	3.44E-05	1.31E-05	4.37E-07
Cs-136	4.59E-05	1.35E-04	5.04E-05	No Data	5.38E-05	1.10E-05	2.05E-06
Cs-137	5.22E-04	6.11E-04	4.33E-05	No Data	1.64E-04	6.64E-05	1.91E-06
Cs-138	4.81E-07	7.82E-07	3.79E-07	No Data	3.90E-07	6.09E-08	1.25E-06
Cs-139	3.10E-07	4.24E-07	1.62E-07	No Data	2.19E-07	3.30E-08	2.66E-08
Ba-139	8.81E-07	5.84E-10	2.55E-08	No Data	3.51E-10	3.54E-10	5.58E-05
Ba-140	1.71E-04	1.71E-07	8.81E-06	No Data	4.06E-08	1.05E-07	4.20E-05
Ba-141	4.25E-07	2.91E-10	1.34E-08	No Data	1.75E-10	1.77E-10	5.19E-06
Ba-142	1.84E-07	1.53E-10	9.06E-09	No Data	8.81E-11	9.26E-11	7.59E-07
La-140	2.11E-08	8.32E-09	2.14E-09	No Data	No Data	No Data	9.77E-05
La-141	2.89E-09	8.38E-10	1.46E-10	No Data	No Data	No Data	9.61E-05
La-142	1.10E-09	4.04E-10	9.67E-11	No Data	No Data	No Data	6.86E-05
Ce-141	7.87E-08	4.80E-08	5.65E-09	No Data	1.48E-08	No Data	2.48E-05
Ce-143	1.48E-08	9.82E-06	1.12E-09	No Data	2.86E-09	No Data	5.73E-05
Ce-144	2.98E-06	1.22E-06	1.67E-07	No Data	4.93E-07	No Data	1.71E-04
Pr-143	8.13E-08	3.04E-08	4.03E-09	No Data	1.13E-08	No Data	4.29E-05
Pr-144	2.74E-10	1.06E-10	1.38E-11	No Data	3.84E-11	No Data	4.93E-06
Nd-147	5.53E-08	5.68E-08	3.48E-09	No Data	2.19E-08	No Data	3.60E-05
Pm-147	3.88E-07	3.27E-08	1.59E-08	No Data	4.88E-08	No Data	9.27E-06
Pm-148m	1.65E-07	4.18E-08	3.28E-08	No Data	4.80E-08	No Data	5.44E-05
Pm-148	6.32E-08	9.13E-09	4.60E-09	No Data	1.09E-08	No Data	9.74E-05
Pm-149	1.38E-08	1.81E-09	7.90E-10	No Data	2.20E-09	No Data	4.86E-05
Pm-151	6.18E-09	9.01E-10	4.56E-10	No Data	1.07E-09	No Data	4.17E-05
Sm-151	2.90E-07	6.67E-08	1.44E-08	No Data	4.53E-08	No Data	5.58E-06
Sm-153	7.72E-09	5.97E-09	4.58E-10	No Data	1.25E-09	No Data	3.12E-05
Eu-152	6.74E-07	1.79E-07	1.51E-07	No Data	5.02E-07	No Data	1.59E-05
Eu-154	2.64E-06	3.67E-07	2.20E-07	No Data	9.95E-07	No Data	4.58E-05
Eu-155	5.42E-07	6.25E-08	3.23E-08	No Data	1.40E-07	No Data	8.37E-05
Eu-156	1.14E-07	7.06E-08	1.12E-08	No Data	3.26E-08	No Data	6.67E-05
Tb-160	2.59E-07	No Data	3.24E-08	No Data	7.37E-08	No Data	3.45E-05
Ho-166m	1.25E-06	2.69E-07	2.13E-07	No Data	3.57E-07	No Data	2.66E-05
W-181	8.85E-08	2.72E-08	3.04E-09	No Data	No Data	No Data	3.82E-07
W-185	3.62E-06	1.13E-06	1.29E-07	No Data	No Data	No Data	1.62E-05
W-187	9.03E-07	6.28E-07	2.17E-07	No Data	No Data	No Data	3.69E-05
Pb-210	5.28E-02	1.42E-02	2.38E-03	No Data	4.33E-02	No Data	2.32E-06
Bi-210	4.16E-06	2.68E-05	2.39E-06	No Data	2.08E-04	No Data	5.27E-05
Po-210	3.10E-03	5.93E-03	7.41E-04	No Data	1.26E-02	No Data	6.61E-05
Ra-223	4.41E-02	6.42E-05	8.82E-03	No Data	1.17E-03	No Data	3.43E-04
Ra-224	1.46E-02	3.29E-05	2.91E-03	No Data	6.00E-04	No Data	3.86E-04
Ra-225	5.78E-02	6.52E-05	1.15E-02	No Data	1.19E-03	No Data	3.24E-04
Ra-226	6.20E-01	4.76E-05	5.14E-01	No Data	8.71E-04	No Data	3.44E-04
Ra-228	4.32E-01	2.58E-05	4.86E-01	No Data	4.73E-04	No Data	5.86E-05

[1] Data presented in this Table are from Reference 9.

TABLE A-18 (continued)

INGESTION DOSE FACTORS FOR INFANT [1]

mrem/pCi Ingested

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Ac-225	3.92E-05	5.03E-05	2.63E-06	No Data	3.69E-06	No Data	4.36E-04
Ac-227	4.49E-03	7.67E-04	2.79E-04	No Data	1.56E-04	No Data	8.50E-05
Th-227	1.20E-04	2.01E-06	3.45E-06	No Data	7.41E-06	No Data	5.70E-04
Th-228	2.47E-03	3.38E-05	8.36E-05	No Data	1.58E-04	No Data	5.84E-04
Th-229	2.52E-02	6.33E-04	4.20E-04	No Data	3.03E-03	No Data	8.10E-05
Th-230	3.80E-03	1.90E-04	1.06E-04	No Data	9.12E-04	No Data	6.24E-05
Th-232	4.24E-03	1.63E-04	1.65E-06	No Data	7.79E-04	No Data	5.31E-05
Th-234	6.92E-07	3.77E-08	2.00E-08	No Data	1.39E-07	No Data	1.19E-04
Pa-231	7.57E-03	2.50E-04	3.02E-04	No Data	1.34E-03	No Data	7.44E-05
Pa-233	3.11E-08	6.09E-09	5.43E-09	No Data	1.67E-08	No Data	1.46E-05
U-232	2.42E-02	No Data	2.16E-03	No Data	2.37E-03	No Data	7.04E-05
U-233	5.08E-03	No Data	3.87E-04	No Data	1.08E-03	No Data	6.51E-05
U-234	4.88E-03	No Data	3.80E-04	No Data	1.06E-03	No Data	6.37E-05
U-235	4.67E-03	No Data	3.56E-04	No Data	9.93E-04	No Data	8.10E-05
U-236	4.67E-03	No Data	3.64E-04	No Data	1.01E-03	No Data	5.98E-05
U-237	4.95E-07	No Data	1.32E-07	No Data	1.23E-06	No Data	2.11E-05
U-238	4.47E-03	No Data	3.33E-04	No Data	9.28E-04	No Data	5.71E-05
Np-237	2.40E-03	1.59E-04	1.05E-04	No Data	6.34E-04	No Data	8.23E-05
Np-238	1.24E-07	3.12E-09	1.92E-09	No Data	6.81E-09	No Data	4.17E-05
Np-239	1.11E-08	9.93E-10	5.61E-10	No Data	1.98E-09	No Data	2.87E-05
Pu-238	1.28E-03	1.50E-04	3.40E-05	No Data	1.21E-04	No Data	7.57E-05
Pu-239	1.38E-03	1.55E-04	3.54E-05	No Data	1.28E-04	No Data	6.91E-05
Pu-240	1.38E-03	1.55E-04	3.54E-05	No Data	1.28E-04	No Data	7.04E-05
Pu-241	4.25E-05	1.76E-06	8.82E-07	No Data	3.17E-06	No Data	1.45E-06
Pu-242	1.28E-03	1.49E-04	3.41E-05	No Data	1.23E-04	No Data	6.77E-05
Pu-244	1.49E-03	1.71E-04	3.91E-05	No Data	1.41E-04	No Data	1.01E-04
Am-241	1.46E-03	1.27E-03	1.09E-04	No Data	6.55E-04	No Data	7.70E-05
Am-242m	1.51E-03	1.22E-03	1.13E-04	No Data	6.64E-04	No Data	9.69E-05
Am-243	1.44E-03	1.23E-03	1.06E-04	No Data	6.36E-04	No Data	9.03E-05
Cm-242	1.37E-04	1.27E-04	9.10E-06	No Data	2.62E-05	No Data	8.23E-05
Cm-243	1.40E-03	1.15E-03	8.98E-05	No Data	3.27E-04	No Data	8.10E-05
Cm-244	1.18E-03	9.70E-04	7.59E-05	No Data	2.71E-04	No Data	7.84E-05
Cm-245	1.79E-03	1.45E-03	1.13E-04	No Data	4.32E-04	No Data	7.30E-05
Cm-246	1.77E-03	1.45E-03	1.13E-04	No Data	4.31E-04	No Data	7.17E-05
Cm-247	1.73E-03	1.43E-03	1.11E-04	No Data	4.24E-04	No Data	9.43E-05
Cm-248	1.43E-02	1.18E-02	9.16E-04	No Data	3.50E-03	No Data	1.52E-03
Cf-252	1.22E-03	No Data	2.95E-05	No Data	No Data	No Data	2.99E-04

[1] Data presented in this Table are from Reference 9.

TABLE A-19

RECOMMENDED VALUES FOR GASEOUS EFFLUENTS [1]

Parameter Symbol	Parameter Description	Values
S	Attenuation factor that accounts for the shielding provided by residential structures	0.7 (maximum individual) 0.5 (average individual.)
t_e	Time period that crops are exposed to contamination during growing season	
	i) for crops ingested by man	1440 hrs (60 days)
t_h	Time delay between harvest of vegetation or crops and ingestion	
	i) for crops ingested by man	24 hr (1 day, for leafy vegetables & max. individual) 1440 hr (60 days, for produce & max. individual) 336 hr (14 days, for average individual)
Y_v	Agricultural productivity by unit area (measured in wet weight)	
	i) for crops ingested by man	2.0 kg/m^2

[1] All data presented in this table are from Reference 8, unless otherwise indicated.

[2] From Reference 12.

APPENDIX B

DEFINITION OF THE LOWER LIMIT OF DETECTION

For purposes of analyzing effluents and environmental samples for radioactivity, the lower limit of detection (LLD) is defined as the smallest concentration of radioactive material in a sample that will yield a net count, above system background, that will be detected with 95% probability, with only 5% probability of falsely concluding that a blank observation represents a "real" signal.

It should be recognized that the listed LLD is defined as an ***a priori*** (before the fact) limit representing the capability of the measurement system or analytical process, and not as an ***a posteriori*** (after the fact) limit for a particular measurement. Analyses should be performed in such a manner that the stated LLDs will be achieved under routine conditions. Usually, samples are counted for a period of time sufficient to ensure that the listed LLDs, based on normal analytical and counting parameters, are achieved.

Printouts of analytical results typically list the ***a posteriori*** minimum detectable concentration (MDC) which was actually achieved on a particular measurement. In those cases where a given sample MDC is less than or equal to the listed ***a priori*** LLD, the required LLD has been achieved. Occasionally background fluctuations, unavoidable small sample sizes, the presence of interfering radionuclides, or other uncontrollable circumstances may result in the MDC for a particular measurement not meeting the listed LLD. In such cases, the contributing factors shall be identified and described in the Semiannual Radioactive Effluent and Waste Disposal Report (for effluents) or the Annual Radiological Environmental Monitoring Report (for environmental samples).

The value of the counting standard deviation (s_b) used in the calculation of the LLD for a particular measurement system should be based on the actual observed standard deviation of the background counting rate or of the counting rate of an appropriate blank sample, rather than on an unverified, theoretically-predicted variance. One acceptable method for deriving s_b is as follows:

$$s_b = \sqrt{B/T}$$

where:

s_b = standard deviation of the background counting rate or of the counting rate of an appropriate blank sample (counts/minute);

B = background counting rate or counting rate of an appropriate blank sample (counts/minute);

T = counting time interval for sample analysis (minutes).

Lower Limit of Detection For Effluent Samples

For a particular measurement system or analytical process which may include radiochemical separation used to analyze effluent samples, the lower limit of detection is calculated as follows:

$$LLD_i = \frac{4.66\ s_b}{E\ V\ 2.22E6\ Y\ e^{-\lambda_i t}}$$

where:

LLD$_i$ = *a priori* lower limit of detection for radionuclide i, (μCi/mL or μCi/g);

4.66 = combined numerical constant corresponding to 95% probability of detection, with 5% probability of falsely identifying background as a "real" signal;

s_b = standard deviation of the background counting rate or of the counting rate of an appropriate blank sample, (counts/minute);

E = counting efficiency, (counts/disintegration);

V = sample size, (milliliters or grams);

2.22E6 = conversion factor for disintegrations/minute per μCi;

Y = fractional radiochemical yield, when applicable;

λ_i = radioactive decay constant for radionuclide i, (hr^{-1});

t = elapsed time between the midpoint of sample collection and time of counting, (hr).

Typical values of E, V, Y, and t used for normal effluent sample analyses should be used in this calculation.

Lower Limit of Detection For Environmental Samples

For a particular measurement system or analytical process which may include radiochemical separation used to analyze effluent samples, the lower limit of detection is calculated as follows:

$$LLD_i = \frac{4.66\ s_b}{E\ V\ 2.22\ Y\ e^{-\lambda_i t}}$$

where:

LLD_i = *a priori* lower limit of detection for radionuclide i, (pCi/liter, pCi/m^3, or pCi/kg);

4.66 = combined numerical constant corresponding to 95% probability of detection, with 5% probability of falsely identifying background as a "real" signal;

s_b = standard deviation of the background counting rate or of the counting rate of an appropriate blank sample, (counts/minute);

E = counting efficiency, (counts/disintegration);

V = sample size, (liters, cubic meters, or kilograms);

2.22 = conversion factor for disintegrations/minute per pCi;

Y = fractional radiochemical yield, when applicable;

λ_i = radioactive decay constant for radionuclide i, (hr^{-1});

t = elapsed time between environmental sample collection or end of the sample collection period, and time of counting, (hr).

Typical values of E, V, Y, and t used for normal effluent sample analyses should be used in this calculation.

APPENDIX C

NRC SAFETY EVALUATION FOR ONSITE DISPOSAL OF SLIGHTLY CONTAMINATED CONSTRUCTION SOIL

In May 1993, the NRC approved a permit under 10CFR20.302 to allow Pilgrim Station to dispose of construction soil containing small amounts of cobalt-60 and cesium-137. This soil was disposed of via onsite burial at a location on company property adjacent to the Pilgrim Station meteorological tower. Dose calculations performed as part of the permit application and within the NRC Safety Evaluation concluded that the maximum dose from the disposal area would be less than 0.1 mrem/year during the year of disposal. Doses during subsequent years through the time of site decommissioning would be less than 0.01 mrem/year. Such exposure levels are considered insignificant relative to radiation dose arising from naturally-occurring sources of radiation and radioactivity, and other exposure pathways arising from operation of Pilgrim Nuclear Power Station.

Complete details regarding the NRC permit for disposal, and the accompanying NRC Safety Evaluation, can be found in NRC Docket No. 50-293, “APPROVAL UNDER 10CFR20.302(a) RELOCATION AND PLACEMENT OF CONSTRUCTION SOIL WITH TRACES OF RESIDUAL RADIOACTIVITY ON SITE AT PILGRIM NUCLEAR POWER STATION (TAC NO. M85501)”, dated May 4, 1993.