ODCM

OFFSITE DOSE CALCULATION MANUAL

DOCUMENT TYPE: Controlled Reference

CLASSIFICATION: N/A

REVISION: 16

EFFECTIVE DATE: October 29, 2004

REVIEWER: Plant Operations Review Committee (PORC)

APPROVAL AUTHORITY: Plant Manager

PROCEDURE OWNER (title): Group Head

OWNER GROUP: Chemistry

Verified Current Copy: _____ _____ _____
Signature Date Time

List pages used for Partial Performance | Controlling Work Document Numbers

_____ _____ _____
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TABLE OF CONTENTS

SECTION	TITLE	PAGE
1.0	OFFSITE DOSE CALCULATION MANUAL ADMINISTRATION	7
1.1	Purpose	7
1.2	General Responsibilities	7
1.3	Manual Revisions	8
1.4	Audits	8
2.0	RADIATION MONITORING SYSTEM AND RELEASE ACCOUNTING	8
3.0	METHODOLOGY FOR DETERMINING ALARM SET POINTS	13
3.1	Introduction	13
3.2	Objective	13
3.3	Alert Set Point Guidelines	13
3.4	Alarm or Trip Set Point Guidelines	13
3.5	Monitor Calibration and Calibration Constant Determination	14
3.6	Determination of the Effective Maximum Effluent Concentration (EMEC) for Liquid Releases	15
3.7	Determination of Liquid Effluent Monitor Alarm Set Point	17
3.8	Determination of EMEC for Atmospheric Releases	21
3.9	Determination of Gaseous Effluent Monitor Alarm Set points	22
3.10	Determination of Maximum Release Rates	24
4.0	DEMONSTRATING COMPLIANCE WITH 10 CFR 50, APPENDIX I	28
4.1	Introduction	28
4.2	Dose Limits	28
4.3	Release Limits	29
4.4	EPA Regulations	30
5.0	CALCULATION AND COMPARISON OF EFFLUENT RELEASES TO RELEASE LIMITS	30
5.1	Appendix I Dose Calculations	30
5.1.1	Liquid Release Mode	30
5.1.2	Atmospheric Release Mode: Radioiodine, Tritium, and Particulates	50
5.1.3	Atmospheric Release Mode: Noble Gases	68
6.0	RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM	70

TABLE OF CONTENTS

SECTION	TITLE	PAGE
7.0	RADIOLOGICAL EFFLUENT CONTROLS PROGRAM	70
8.0	RADIOLOGICAL IMPACT EVALUATION OF SEWAGE TREATMENT SLUDGE DISPOSAL	70
8.1	Basis, Commitments, and Actions	70
8.1.1	Basis	70
8.1.2	Basis for NRC Commitment Modification	70
8.1.3	Modification	71
8.1.4	Exposure Evaluations	71
8.2	Procedure	72
8.3	Administrative Requirements	73
8.3.1	Complete records of each contaminated disposal shall be kept as follows:	73
APPENDIX A,	DERIVATION OF LIQUID RELEASE PATHWAY EFFECTIVE MAXIMUM EFFLUENT CONCENTRATION	75
A.1.0	Derivation of Liquid Release Effective Maximum Effluent Concentration	75
A.1.1	Source Term	75
A.1.2	Effective Maximum Effluent Concentration	75
APPENDIX B	DERIVATION OF ATMOSPHERIC RELEASE MODE EFFECTIVE MAXIMUM EFFLUENT CONCENTRATION	80
B.1.0	Derivation of Atmospheric Release Effective Maximum Effluent Concentration	80
B1.1	Source Term	80
B1.2	Effective Maximum Effluent Concentration	80

TABLE OF CONTENTS

SECTION TITLE PAGE

APPENDIX C CALCULATION OF TOTAL DOSE FACTORS USING REGULATORY GUIDE 1.109, REV. 1 85

C.1.0 Calculation of Total Dose Factors Using Regulatory Guide 1.109 Methodology 85
C.1.1 Liquid Release Dose Factors 85
C1.1.1 Aquatic Foods 85
C1.1.2 Irrigated Foods (Meat From Watered Cattle) 87
C1.1.3 Irrigated Foods (Milk From Watered Cattle) 89
C1.1.4 Potable Water 91
C1.1.5 Shoreline Deposits 92

C1.2 Atmospheric Release Dose Factors: Non-Gaseous 95
C1.2.1 Inhalation of Nuclides In Air 95
C1.2.2 Annual Organ Dose From External Irradiation From Nuclides Deposited On the Ground 96
C1.2.3 Annual Organ Dose From Atmospherically Released Nuclides In Milk 98
C1.2.4 Annual Organ Dose From Atmospherically Released Nuclides In Meat 101
C1.2.5 Annual Organ Dose From Atmospherically Released Nuclides In Produce 104
C1.2.6 Annual Organ Dose From Atmospherically Released Nuclides In Leafy Vegetables 107
C1.2.7 Doses from Airborne Tritium other than Inhalation 109
C1.2.8 Annual Organ Dose from Atmospherically Released Tritium in Produce 110
C1.2.9 Annual Organ Dose from Atmospherically Released Tritium in Milk 111
C1.2.10 Annual Organ Dose from Atmospherically Released Tritium in Meat 112

C1.3 Atmospheric Release Dose Factors: Noble Gases 114
C1.3.1 Annual Gamma and Beta Air Dose From All Noble Gas Releases 114
C1.3.2 Annual Skin Dose From All Noble Gas Releases 115
C1.3.3 Annual Total Body Dose From All Noble Gas Releases 116

TABLE OF CONTENTS

SECTION TITLE PAGE

APPENDIX D DERIVATION OF DILUTION FACTORS USING REGULATORY GUIDE 1.113 118

D1.0 Liquid Effluent Dilution Factor Calculations 118
D1.1 Methodology 118
D1.2 Dilution Factor Twelve Miles Downstream: Two Rivers Water Intake 121

LIST OF TABLES AND FIGURES

SECTION TITLE **PAGE**

SECTION 2.0

TABLE 2-1 RADIOACTIVE LIQUID WASTE EFFLUENT MONITORS 9
TABLE 2-2 RADIOACTIVE GASEOUS WASTE EFFLUENT MONITORS 10
FIGURE 2-2 RADIOACTIVE GASEOUS WASTE EFFLUENT MONITORS 12

SECTION 3.0

TABLE 3.7-1 SUMMARY OF LIQUID DILUTION AND EFFLUENT PATHWAY FLOW RATES 18
TABLE 3.7-2 LIQUID PATHWAY MONITOR CALCULATED DEFAULT SET POINTS 20
TABLE 3.9-1 SUMMARY OF GASEOUS EFFLUENT PATHWAY DISCHARGE DEFAULT 22
TABLE 3.9-2 ATMOSPHERIC PATHWAY MONITOR DEFAULT RMS SET POINTS 23
Table 3.10-1 mrem from all radionuclides (1985 - 1991 average) 25
Table 3.10-2 mrem from I-131 and I-133 (2.42E-03 Ci) 25
Table 3.10-3 mrem from H-3 (116.3 Ci) 25
Table 3.10-4 mrem from all radionuclides except H-3 and radioiodines (2.15E-03 Ci) 26
Table 3.10-5 mrem from Cs-134 and Cs-137 (1.84E-03 Ci) 26
Table 3.10-6 mrem from Co-57, Co-58, and Co-60 (1.93E-04 Ci) 26

SECTION 5.0

TABLE 5.1-1 LIQUID EFFLUENT DOSE FACTOR 32
TABLE 5.1-2 ..... AIRBORNE EFFLUENT DOSE FACTOR 51
TABLE 5.1-3 ACTIVITY TO DOSE CONVERSION FACTORS FOR NOBLE GASES. 69

APPENDIX A

TABLE A-1 CURIES RELEASED IN LIQUIDS 77
TABLE A-2 FRACTIONAL MEC IN LIQUID EFFLUENT 78

APPENDIX B

TABLE B-1 CURIES IN ATMOSPHERIC EFFLUENT 81
TABLE B-2 FRACTIONAL MEC FOR ATMOSPHERIC EFFLUENT 83

APPENDIX D

TABLE D-1 SURFACE DILUTION FACTORS LIQUID EFFLUENTS IN A LARGE LAKE 119
FIGURE D-1 DILUTION FACTOR AT SURFACE 120

1.0 OFFSITE DOSE CALCULATION MANUAL ADMINISTRATION

1.1 Purpose

The PBNP Offsite Dose Calculation Manual contains the current methodology and parameters for the calculation of offsite doses due to radioactive gaseous and liquid effluents. This manual describes a methodology for demonstrating compliance with 10 CFR 50, Appendix I dose limits. Compliance with Appendix I is demonstrated by periodic calculation of offsite doses based on actual plant releases and comparison to Appendix I dose limits.

The manual also details the methodology for the determination of gaseous and liquid effluent monitor alarm set points. The PBNP Radiation Monitoring System (RMS) effluent monitor alarm set points are established to ensure that controlled releases of liquid and gaseous radioactive effluents are maintained as low as is reasonably achievable. The setpoints also are established to ensure that concentrations of radioactive material released in effluents to the atmosphere do not exceed the values of Table 2, Column 1, of Appendix B to 10 CFR 20.1001-20.2402 at or beyond the site boundary and to ensure that the concentrations of radioactive materials released in liquid effluents to the unrestricted area conform to (do not exceed) 10 times the concentration values in Table 2, Column 2 of Appendix B to 10 CFR 20.1001-20.2402.

The manual also details the methodology for evaluating the radiological impact of sewage treatment sludge disposal. This methodology addresses the commitments made to the United States Nuclear Regulatory Commission in our application dated October 8, 1987 (NRC-87-104) and accepted by the USNRC in a letter dated January 13, 1988. This application was submitted in accordance with the provisions of 10 CFR 20.302(a). Dose limits are established in the application to ensure the health and safety of the maximally exposed member of the general public and the inadvertent intruder. 10 CFR 50, Appendix I dose limits do not apply to sewage treatment sludge disposal.

1.2 General Responsibilities

The primary responsibility for the implementation of the PBNP offsite dose calculation program and for any actions required by the program resides with Chemistry. Chemistry will provide the technical, regulatory, licensing, and administrative support necessary to fulfill the requirements of this manual. The calculation of offsite doses and analysis of data are Chemistry responsibilities.

The Manager, PBNP is responsible for assuring that Radiation Monitoring System alarm set points are established and maintained in accordance with the methodologies outlined in this manual. The Manager, PBNP is also responsible for assuring the performance of periodic release summaries for the purpose of demonstrating compliance with PBNP effluent release limits.

1.3 Manual Revisions

Per TS 5.5.1.C, licensee initiated changes to the Offsite Dose Calculation Manual (ODCM) shall be documented and records of reviews performed shall be retained. This documentation shall contain sufficient information to support the changes(s) together with the appropriate analyses or evaluations justifying the changes(s), and a determination that the change(s) maintain the levels of radioactive effluent control required by 10 CFR 20.1302, 40 CFR 190, 10 CFR 50.36a, and 10 CFR 50, Appendix I, and do not adversely impact the accuracy or reliability of effluent, dose, or setpoint calculations. These changes shall become effective after receiving concurrence from the Plant Operations Review Committee (PORC) and approval of the Plant Manager, and shall be submitted to the NRC in the form of a complete, legible copy of the entire ODCM as a part of or concurrent with the Annual Monitoring Report for the period of the report in which any change in the ODCM was made. Each change shall be identified by markings in the affected pages, clearly indicating the area of the page that was changed, and shall indicate the date (i.e. month and year) the change was implemented.

1.4 Audits

An audit of the activities encompassed by the ODCM, the Radiological Effluent Control Program, and the Radiological Environmental Monitoring Program and its implementing procedures shall be performed. Planning and scheduling of audits of the ODCM shall be performed in accordance with site Quality Assurance Program procedures. The results of the audit shall be transmitted to the Chief Nuclear Officer and the Chairman of the Offsite Review Committee.

2.0 RADIATION MONITORING SYSTEM AND RELEASE ACCOUNTING

A computerized Radiation Monitoring System (RMS) is installed at Point Beach Nuclear Plant (PBNP). The RMS includes area, process, and effluent monitors. A description of those monitors used for liquid and gaseous effluents is presented in Tables 2-1 and 2-2. The liquid and gaseous waste processing flow paths, equipment, and monitoring systems are depicted in Figures 2-1 and 2-2. Calibration of the RMS detectors is accomplished in accordance with procedures contained in the PBNP Health Physics Calibration Manual. The set point methodology is described in Section 3 of this manual.

The RMS is designed to detect and measure liquid and gaseous releases from the plant effluent pathways. The RMS will initiate isolation and control functions on certain effluent streams identified in Tables 2-1 and 2-2. Complete monitoring and accounting of nuclides released in liquid and gaseous effluents is accomplished with the RMS together with the characterization of nuclide distributions by laboratory analysis of grab samples. Sampling frequencies and analysis requirements are described in Tables 6-1 and 6-2 of the Radiological Effluent Control Manual. The various aspects of grab sampling and release accountability are described in the PBNP Release Accountability Manual.

TABLE 2-1
RADIOACTIVE LIQUID WASTE EFFLUENT MONITORS

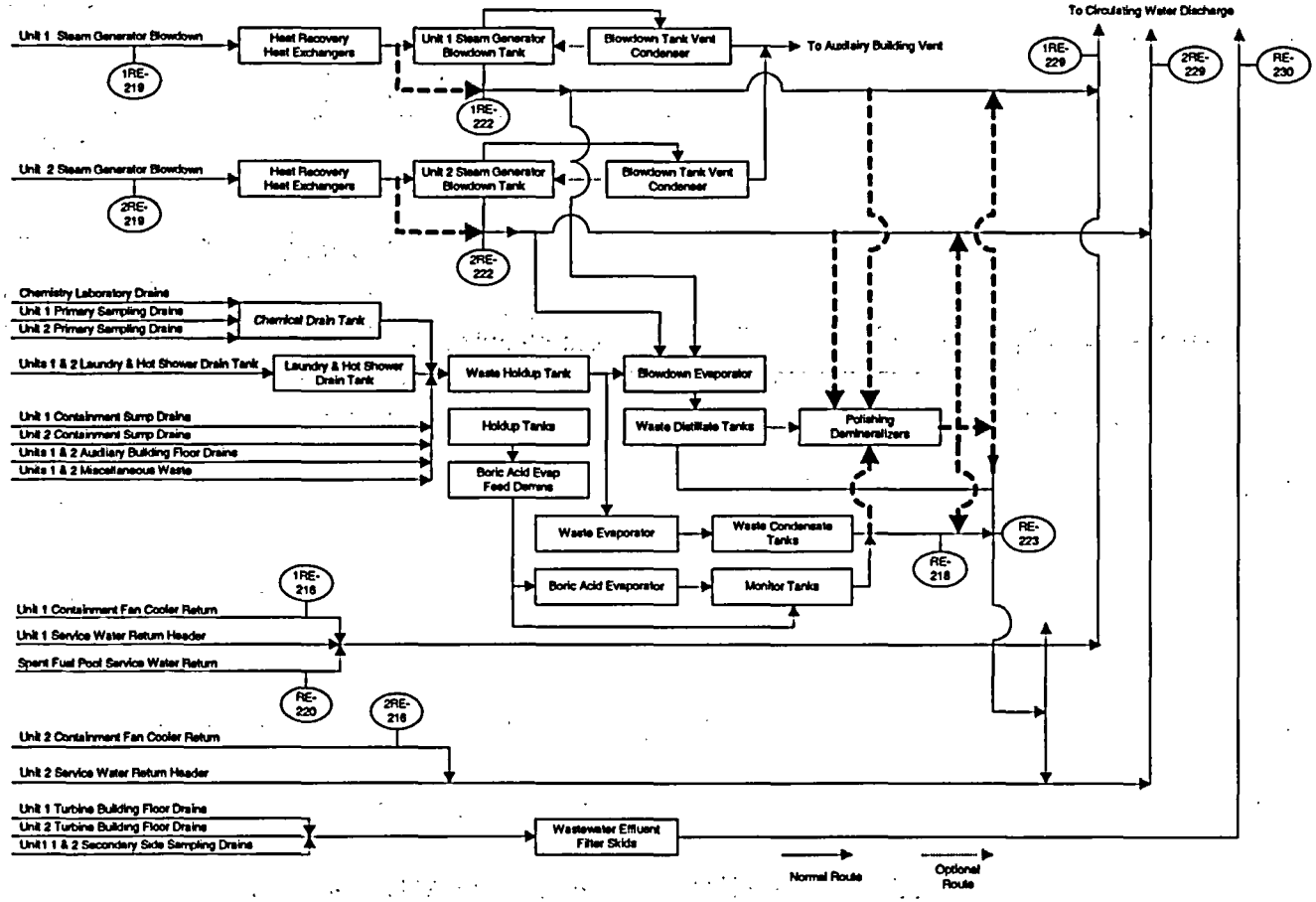
CHANNEL NUMBER	NAME	CONTROL FUNCTION	DETECTOR TYPE
1 (2) RE-216	Containment Fan Coolers Liquid Monitors	None	Scintillation
RE-218	Waste Disposal System Liquid Monitor	Shuts waste liquid overboard	Scintillation
1 (2) RE-219	Steam Generator Blowdown Liquid Monitors	Shuts steam generator blowdown isolation valves, blowdown tank outlet valves and steam generator sample valves	Scintillation
RE-220	Spent Fuel Pool Liquid Monitor	None	Scintillation
RE-223	Waste Distillate Overboard Liquid Monitor	Shuts waste distillate overboard isolation valve	Scintillation
1 (2) RE-229	Service Water Discharge Monitors	None	Scintillation
RE-230	Waste Water Effluent Monitor	None	Scintillation
1 (2) RE-222	Steam Generator Blowdown Tank Outlet Monitor	Shuts steam generator blowdown isolation valves and blowdown tank outlet valves	GM Tube

TABLE 2-2
RADIOACTIVE GASEOUS WASTE EFFLUENT MONITORS

CHANNEL NUMBER	NAME	CONTROL FUNCTION	DETECTOR TYPE
1 (2) RE-212	Containment Noble Gas Monitor	Actuates containment ventilation isolation	Scintillation
RE-214	Auxiliary Building Exhaust Ventilation Noble Gas Monitor	Shuts gas release valve and shifts auxiliary building exhaust through carbon filters	Scintillation
1 (2) RE-215	Condenser Air Ejector Noble Gas Monitors	None	Scintillation
RE-225	Combined Air Ejector Low-Range Noble Gas Monitor	None	Scintillation
RE-221	Drumming Area Vent Noble Gas Monitor	None	Scintillation
RE-224	Gas Stripper Building Exhaust Noble Gas Monitor	None	Scintillation
1 (2) RE-305	Unit 1 and 2 Purge Exhaust Noble Gas Monitors (Channel 5 on SPING Units No. 21 and No. 22)	Containment ventilation isolation	Scintillation
RE-315	Auxiliary Building Exhaust Ventilation Noble Gas Monitor (Channel 5 on SPING Unit No. 23)	None	Scintillation
RE-325	Drumming Area Ventilation Noble Gas Monitor (Channel 5 on SPING Unit No. 24)	None	Scintillation

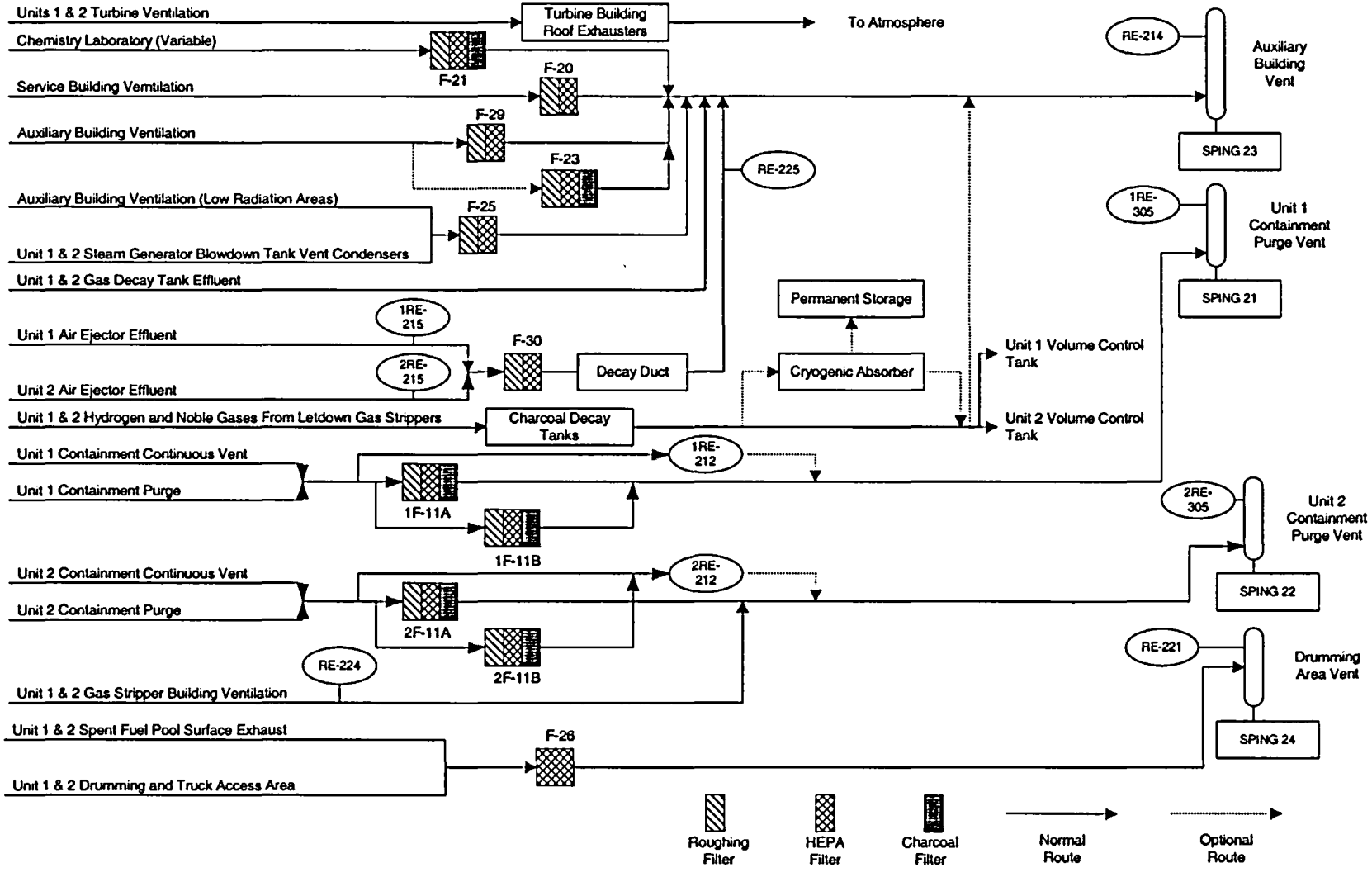
OFFSITE DOSE CALCULATION MANUAL

FIGURE 2-1
RADIOACTIVE LIQUID WASTE EFFLUENT MONITORS



Radioactive Liquid Waste
Effluent Monitors

FIGURE 2-2
RADIOACTIVE GASEOUS WASTE EFFLUENT MONITORS



3.0 METHODOLOGY FOR DETERMINING ALARM SET POINTS

3.1 Introduction

The selection and maintenance of alert and alarm set points for each effluent monitor of the PBNP radiation monitoring system will be accomplished within the guidelines of this section. The computerized PBNP radiation monitoring system permits each effluent radiation monitor to be programmed to alarm at two distinct set-points. The alert set point, typically twice the steady-state reading, is intended to delineate a changing plant condition which may warrant corrective action. The high alarm or trip set point either will actuate a control function as applicable or will require corrective action to be initiated.

3.2 Objective

The effluent monitor set points are established to ensure that controlled releases of liquid and gaseous radioactive effluents are maintained as low as is reasonably achievable, to ensure releases result in concentrations to unrestricted areas within specified limits and to ensure that the dose limits of 10 CFR 50, Appendix I are not exceeded.

3.3 Alert Set Point Guidelines

The alert set point of each effluent monitor generally will be set to alarm at two times the established steady-state reading. The alert set point is normally set at concentrations well below the alarm set point value and is never to be set in excess of the alarm set point. In the course of plant operations, certain situations may require a deviation from the two times steady-state guideline. The intent of the alert set point is to warn of changing plant conditions which may warrant an evaluation of the cause of the increased radiation. If the increased reading is actually due to an increased radiation inventory within the system being monitored, as opposed to an increased background radiation field in the vicinity of the detector, an evaluation should be made to determine the impact of the release. The alert set point may be adjusted with the approval of the Duty Shift Superintendent. Alert set point adjustments are to be made in accordance with the PBNP RMS Alarm Set Point and Response Book.

3.4 Alarm or Trip Set Point Guidelines

Pursuant to regulatory and TS requirements as stated in Section 5 of the Radiological Effluent Control Manual, the alarm or trip set point for effluent monitors shall be established to annunciate at radiation levels which would result in an unrestricted area concentration equal to or less than the applicable maximum effluent concentration (MEC) for a single radionuclide. However, for a mixture of radionuclides, the set point shall be established so that the summation of fractions, as defined in Appendix B of 10 CFR 20 (see Section 3.6), is less than or equal to one (1). If the calculated setpoint is above the saturation level of the monitor, a setpoint value below the saturation level (70% or lower) may be used. The appropriate detailed response to an effluent alarm is described in the PBNP RMS Alarm Set Point and Response Book

3.5 Monitor Calibration and Calibration Constant Determination

Calibration of the RMS effluent detectors is accomplished in accordance with procedures contained in the PBNP Health Physics Calibration Manual. Noble gas effluent monitors apply the calibration constant to standardize all gaseous releases to the 1985-1991 average isotopic noble gas distribution. The calibration constants are based on the calculated monitor response to the beta energy distribution in the 1985-1991 average isotopic noble gas distribution.

Noble gas effluent monitor calibration constants are derived from the following formulae:

$$\text{Cal. Constant} = \frac{1}{\text{Sensitivity}}$$

and

$$\text{Sensitivity} = \frac{\text{Monitor Response}}{\Sigma(\text{microCi/cc}_i)}$$

where:

Monitor response = the calculated counts per minute registered by monitor exposed to the 1985-1991 average noble gas isotopic distribution

$\Sigma(\mu Ci/cc_i)$ = total concentration of isotopes in the 1985-1991 average noble gas isotopic distribution

The liquid effluent monitors apply the derived calibration constant to standardize all liquid releases to the total concentration in the release path. The calibration constants are based on the monitor response to the 1985-1991 average liquid isotopic distribution. Each liquid monitor channel displays the effluent concentration in terms of a total release concentration.

Liquid effluent monitor calibration constants are derived from the following formulae:

$$\text{Cal. Constant} = \frac{1}{\text{Sensitivity}}$$

and

$$\text{Sensitivity} = \frac{\textit{Monitor}\,\text{Re}\,\textit{sponse}}{\Sigma(\mu Ci/cc_i)}$$

where:

Monitor Response = the counts per minute registered by monitor exposed to calibration source

$\Sigma(\mu Ci/cc_i)$ = total concentration on radionuclides in the 1985-1991 average liquid effluent isotopic distribution

The QAD computer program may be utilized to predict or determine monitor calibration constants. Application of the QAD program may be appropriate for determining monitor response for accident source terms or other instances when the use of a calibration source is impracticable. The methodology for determination of calibration constants using the QAD program is maintained by Radiation Protection.

3.6 Determination of the Effective Maximum Effluent Concentration (EMEC) for Liquid Releases

Pursuant to PBNP TS, the concentration of radioactive materials in liquid effluent may not exceed 10 times the values of Column 2, Table 2, of Appendix B to 10 CFR 20.1001-20.2402. However, as a conservative measure, the following determination of the EMEC and the subsequent setpoint determination for liquid effluent (Section 3.7) do not employ the augmented concentration values.

In order to fulfill the requirements of 10 CFR 20, the RMS set point must be a value which will alarm when a liquid effluent would contain enough radionuclides to cause the effluent concentration limit of 10 CFR 20, Appendix B, Table 2, Column 2 for a single radionuclide to be exceeded, or for a mixture of radionuclides, the summation of fractions (SOF), as defined in Appendix B, to exceed one (1). Dividing the average isotopic concentrations for the years 1985-1991 by the SOF scales the total of individual concentrations up to the value where the SOF equals one. This total concentration is called the effective maximum effluent concentration (EMEC) and its calculation is described below. (For a complete discussion of the EMEC derivation, see Appendix A.)

The SOF is calculated using the formula found in the revised 10 CFR 20, Appendix B, Note 4:

$$SOF = \Sigma C_i/MEC_i$$

where:

C_i = concentration of radionuclide "i" (μCi/ml) in effluent (annual discharge/total volume of discharge)

MEC_i = maximum effluent concentration for unrestricted areas from Appendix B, Table 2, Column 2 of the revised 10 CFR 20.

The SOF for radionuclides in liquid effluent for the years 1985 through 1991 were averaged and applied to the average of the isotopic concentrations for the same years. Na-24 and H-3 were not used in the calculations (see Appendix A for details).

Next, the "effective MEC" or EMEC is calculated using the formula:

$$EMEC = \Sigma C_i / \Sigma (C_i/MEC_i) \text{ or } \Sigma C_i * 1/SOF$$

where the variables are the same as defined above.

The average EMEC, based on 1985-1991 data is 4.29E-06 µCi/cc. This is the maximum non H-3 radionuclide mixture concentration that could be released in liquid effluent without the SOF exceeding one (1).

However, the 10 CFR 20, Appendix B criterion is that the SOF for all radionuclides, including H-3 which cannot be measured by the liquid effluent NaI RMS monitors, be less than or equal to one (1). Therefore, the above equation modified by a factor of 0.70 (see Appendix A) to account for H-3 becomes

$EMEC = 0.70 \Sigma C_i / \Sigma (C_i/MEC_i)$ or $\Sigma C_i * 0.70/SOF$.

The EMEC becomes

EMEC = 0.70 * 4.29E-06 = 3.00E-06 µCi/cc.

Only three radionuclides identified in PBNP liquid effluent have a lower MEC (10 CFR 20, Appendix B, Table 2). They are I-131 (1E-06), Cs-134 (9E-07), and Cs-137 (1E-06).

Note that the use of the 0.7 modifying factor sets the SOF for non-tritium radionuclides to 0.7 and allows an SOF of 0.3 for H-3. A SOF of 0.3 limits the discharge concentration of H-3 to 0.3 MEC or 3E-04 µCi/cc. The factor of 0.3 may be changed as needed for releases for which the isotopic mixture and concentrations are known as long as the total SOF ≤1.

3.7 Determination of Liquid Effluent Monitor Alarm Set Point

The alarm set point for each liquid monitor is based upon the 1985-1991 average radionuclide concentration in the effluent discharged to the unrestricted area. The radionuclide concentration in the release is calculated assuming a minimum circulating water flow rate of 206,000 gpm and the maximum flow rate of the individual liquid effluent waste stream. The isotopic distribution of the waste stream is obtained from the historical PBNP release data for the seven years mentioned above. Set points are determined such that the sum of all radionuclides in the mixture, when released into the circulating water system, will be maintained at or below the unrestricted area EMEC.

Set points are calculated using the formula

$$SP = EMEC * \frac{\text{Circ water flow rate (gpm)}}{\text{Waste Discharge Flow Rate (gpm)}}$$

where

SP = RMS alarm set point in µCi/cc

EMEC = effective maximum effluent concentration

Circ water flow rate = total flow from Unit 1 + Unit 2

Waste discharge flow rate = flow rate for effluent line on which the monitor is located

Maximum waste discharge flow rates and monitors associated with each liquid effluent pathway are described in Table 3.7-1.

Default alarm set points normally are established based upon the maximum waste discharge flow rate and the minimum circulation water flow rate. The liquid release monitor default set points are listed in Table 3.7-2. Alarm set points may be adjusted for batch releases, when actual flow rates are known. Alarm set point adjustments which are higher than default values, are to be made in accordance with the provisions and methodologies of this section and requires approval of the PORC . Lower alarm set point values maybe used without PORC approval if the default values lie outside the upper range of the monitor or if compliance with applicable limits will not be compromised.

TABLE 3.7-1
SUMMARY OF LIQUID DILUTION AND EFFLUENT PATHWAY FLOW RATES

LIQUID EFFLUENT PATHWAY	DISCHARGE FLOW RATE (GPM)	PATHWAY MONITOR
RECIRCULATION WATER		
1 pump, either unit	206,000	None
2 pumps, either unit	350,000	
1 pump, each unit	392,000	
1 pump, one unit & 2 pumps, other unit	530,000	
2 pumps, each unit	680,000	
SERVICE WATER RETURN (normal cooldown per pump		1 (2) RE-229
2 pumps @ 7500 gpm	15,000	
3 pumps @ 6300 gpm	18,900	
4 pumps @ 5100 gpm	20,400	
5 pumps @ 4300 gpm	21,500	
6 pumps @ 3700 gpm	22,200	
STEAM GENERATOR BLOWDOWN		1 (2) RE-219 & 1 (2) RE-222
Max flow	200	
WASTE WATER EFFLUENT		RE-230
Max Flow Rate (both filter skids running in parallel)	600	

TABLE 3.7-1, cont
SUMMARY OF LIQUID DILUTION AND EFFLUENT PATHWAY FLOW RATES

LIQUID EFFLUENT PATHWAY	DISCHARGE FLOW RATE (GPM)	PATHWAY MONITOR
SPENT FUEL POOL		RE-220
Max Flow Rate	700	
WASTE DISTILLATE & CONDENSATE TANK DISCHARGE		RE-218 & RE-223
Max Flow Rate	100	
CONTAINMENT FAN COOLER RETURN		1 (2) RE-216
Max Flow Rate per Containment	4000	

TABLE 3.7-2
LIQUID PATHWAY MONITOR
CALCULATED DEFAULT SET POINTS

MONITOR	FLOWRATE (gpm)	SET POINT (μCi/cc)
1 (2) RE-229	6 @ 3700[1]	2.78E-05
1 (2) RE-219 & 1 (2) RE-222	200	3.09E-03
RE-230	600	1.03E-03
RE-220	700	8.83E-04
RE-218 & RE-223	100	6.18E-03
1 (2) RE-216	4000	1.55E-04

[1] six service water pumps at normal cooldown flow rates

3.8 Determination of EMEC for Atmospheric Releases

The maximum concentration of the mixture of radionuclides that is allowable at the site boundary is called the effective maximum effluent concentration (EMEC). The EMEC for an effluent mixture is defined by the equation

$$EMEC = \Sigma C_i / \Sigma(C_i / MEC_i)$$

where

C_i = concentration of radionuclide "i"

MEC_i = maximum effluent concentration for radionuclide i from 10 CFR 20, Appendix B, Table 2

$\Sigma (C_i / MEC_i)$ = summation of fractions (SOF), as discussed in Section 3.6, applied to atmospheric releases

The EMEC is calculated from the reference radionuclide mixture. This mixture is obtained from the 1985 - 1991 average annual atmospheric releases and the corresponding concentrations determined from the highest annual average χ/Q. (Details of the EMEC calculation are found in Appendix B.)

The calculated EMEC, corrected for H-3, of 1.92E-08 µCi/cc was obtained to be used in the set point calculations.

3.9 Determination of Gaseous Effluent Monitor Alarm Set points

The alarm set point for each monitor is based upon maintaining the concentration of the reference radionuclide mixture at or below the EMEC. The set point is calculated using the formula

$$SP = 2.12E+03 * EMEC / (\chi/Q * FR)$$

where

SP = set point in μCi/cc

2.12E + 03 = conversion factor for ft^3/min to m^3/sec

EMEC = 1.92E-08 μCi/cc

χ/Q = highest site boundary annual average 1.5E-06 sec/m^3

FR = the flow rate in ft^3/min of the effluent pathway being monitored.

Combining the above numerical values yields

$$SP(\mu Ci/cc) = 2.71E + 01 / FR$$

Gaseous effluent pathway discharge flow rates and monitors associated with each pathway are summarized in Table 3.9-1.

TABLE 3.9-1
SUMMARY OF GASEOUS EFFLUENT PATHWAY DISCHARGE FLOW RATES

GASEOUS EFFLUENT PATHWAY		DISCHARGE FLOW RATE CFM	MONITOR(S) IN EFFLUENT PATHWAY
a.	Auxiliary Building Vent	66,400	RE-214 & SPING 23
b.	Combined Air Ejector	20	RE-225
c.	Unit Air Ejector	10	1 (2) RE-215
d.	Containment Purge Vent		
	1) 1 fan operating	12,500	1 (2) RE-212 &
	2) 2 fans operating	25,000	SPINGS 21 & 22
e.	Gas Stripper Building	13,000	RE-224
f.	Drumming Area Vent	43,100	RE-221 & SPING 24

Alarm set points are to be normally established based upon maximum waste discharge flow rates and the highest annual average χ/Q value at the site boundary. The alarm set points may be adjusted for release periods if actual flow rates are reduced to less than maximum values or actual χ/Q values are calculated. Alarm set point adjustments to higher values are to be made in accordance with the provisions and methodologies of this section and require PORC approval. Default set point values obtained using the flow rates in Table 3.9-1 are presented in Table 3.9-2. An additional reduction factor of 1/4 has been applied to the four release point monitors so that the maximum allowable site boundary concentrations will not be exceeded in the event simultaneous releases from these points occur. Lower set point values may be used for any of the monitors without PORC approval if the default value is outside the upper range of the monitor or if compliance with applicable release limits will not be compromised. The set point values for the SPINGs will be the same as the corresponding release point monitor; RE-214 (SPING 23), 1(2)RE-212 (SPINGS 21 and 22) or RE-221 (SPING 24).

TABLE 3.9-2
ATMOSPHERIC PATHWAY MONITOR
DEFAULT RMS SET POINTS

MONITOR	FLOW RATE (ft^3/min)	SET POINT (µCi/cc)
RE-214	66,400	1.02E-04
RE-225	20	1.36E+00
1RE-215	10	2.71E+00
2RE-215	10	2.71E+00
1RE-212	25,000[1]	2.73E-04
2RE-212	38,000[2]	1.78E-04
1/2RE-212[3]	30	2.26E-01
RE-224	13,000	2.09E-03
RE-221	43,000	1.58E-04

[1] 2 fans (with 1 fan the flow rate is 12,500 cubic feet/minute)

[2] 2 fans + 13,000 cfm from the gas stripper building [3] Forced vent with nominal 30 cfm flow rate

The individual 1/2RE-212 setpoints are based on purge flow rates. During operational modes 1-4, the purge valves are locked shut. Therefore, forced vent alarm setpoints are calculated based on the nominal 30 cfm flow rate. This yields, upon applying the 1/4 reduction factor, a setpoint of 2.26E-01 µCi/cc. Because this is an order of magnitude above the monitors' saturation or fail high levels, the MSS approved (MSSM No. 93-01) the use of a setpoint which is higher than the individual RE-212 Table 3.9-2 values and set at $\leq$70% of the monitor's fail high level. This approval applies to those monitors for which the calculated setpoint falls above the fail high level. The current alarm setpoint levels are recorded in the RMS Alarm Set Point and Response Book.

3.10 Determination of Maximum Release Rates

Technical specifications restrict the rate of release of radionuclides to the atmosphere to that value, which if continued for one year, would result in the following annual dose rates at or beyond the site boundary: 500 mrem/yr to the whole body and 3000 mrem/yr to the skin from noble gases; and, 1500 mrem/yr to any organ from I-131, I-133, H-3, and particulates with a half-life >8 days.

3.10.1 Noble gas release rate

The release rate for noble gases are calculated using the Reg. Guide 1.109 dose factors and the annual average isotopic noble gas release for the years 1985 - 1991 as shown in Table B-1. Following the methodology in Section 5.1.3, the calculated annual skin dose from the average 1985 - 1991 isotopic mixture with a total of 4.51E+01 curies is 1.03E-02 mrem. Therefore the maximum release rate is calculated from the formula

Ci/sec = total Ci * dose limit / (sec/yr * dose from total Ci).

Based on skin dose, the release rate formula

Ci/sec = 4.51E+01 Ci * 3000 mrem/yr/ (3.15E+07 sec/yr * 1.03E-02 mrem) yields a release rate of 4.17E-01 Ci/sec.

Using the same total curies with the same isotopic mixture but with the whole body dose of 5.89E-03 mrem/yr and the whole body dose limit of 500 mrem/yr, the release rate becomes 1.22E-01 Ci/sec.

Therefore the whole body dose rate is limiting and the maximum allowable PBNP noble gas release rate is 1.22E-01 Ci/sec. This rate is higher than any PBNP noble gas release rate from 1985 - 1991 based on the highest reported hourly average release rates of approximately 4.3E-02 Ci/sec.

3.10.2 Release rate for I-131, I-133, H-3, and particulates released to the atmosphere with half-lives >8 days

During the time period of 1985 - 1991, PBNP released an annual average of 116.30457 Ci to the atmosphere consisting of I-131, I-133, H-3, and particulates whole half-life >8 days. Of this quantity, 116.30 was H-3 and 4.57E-03 was I-131, I-133, and particulates whose half-life was >8 days. The doses from this mixture, calculated using ODCM methodology are shown in Table 3.10.1.

Table 3.10-1 mrem from all radionuclides (1985 - 1991 average)

mrem from all radionuclides (1985 - 1991 average)

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
ADULT	1.66E-02	3.68E-02	5.74E-02	5.44E-02	2.01E-02	1.42E-02	1.23E-02	3.27E-02
TEEN	2.69E-02	5.25E-02	5.57E-02	4.64E-02	2.56E-02	1.72E-02	1.29E-02	3.27E-02
CHILD	6.31E-02	8.30E-02	5.48E-02	7.70E-02	3.73E-02	2.31E-02	1.60E-02	3.27E-02
INFANT	5.04E-02	6.77E-02	3.58E-02	1.04E-01	2.00E-02	9.39E-03	2.59E-03	3.27E-02

If the 1985 - 1991 average isotopic effluent mixture released to the atmosphere is broken down into the following grouping: H-3, I-131 and I-133, and the remaining radionuclides, the groups contribution to the various organ doses are revealed (Tables 3.10-2 - 3.10-4).

Table 3.10-2 mrem from I-131 and I-133 (2.42E-03 Ci)

mrem from I-131 AND I-133

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
ADULT	9.26E-05	1.32E-04	1.10E-04	4.31E-02	2.29E-04	0.00E+00	3.66E-05	4.20E-05
TEEN	8.52E-05	1.20E-04	9.82E-05	3.44E-02	2.06E-04	0.00E+00	2.50E-05	4.20E-05
CHILD	1.86E-04	1.88E-04	1.41E-04	6.17E-02	3.09E-04	0.00E+00	1.79E-05	4.20E-05
INFANT	2.63E-04	3.10E-04	1.71E-04	1.01E-01	3.62E-04	0.00E+00	1.17E-05	4.20E-05

Table 3.10-3 mrem from H-3 (116.3 Ci)

mrem from H-3

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
ADULT	0.00E+00	1.13E-02	1.13E-02	1.13E-02	1.13E-02	1.13E-02	1.13E-02	0.00E+00
TEEN	0.00E+00	1.19E-02	1.19E-02	1.19E-02	1.19E-02	1.19E-02	1.19E-02	0.00E+00
CHILD	0.00E+00	1.53E-02	1.53E-02	1.53E-02	1.53E-02	1.53E-02	1.53E-02	0.00E+00
INFANT	0.00E+00	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	0.00E+00

Table 3.10-4 mrem from all radionuclides except H-3 and radioiodines (2.15E-03 Ci)

	mrem from all radionuclides except H-3 and radioiodines							
	Bone	**Liver**	**T. Body**	**Thyroid**	**Kidney**	**Lungs**	**GI-LLI**	**Skin**
ADULT	1.65E-02	2.53E-02	4.59E-02	2.08E-09	8.49E-03	2.84E-03	9.41E-04	3.27E-02
TEEN	2.68E-02	4.04E-02	4.37E-02	2.64E-09	1.35E-02	5.25E-03	9.76E-04	3.27E-02
CHILD	6.29E-02	6.75E-02	3.94E-02	4.94E-09	2.16E-02	7.81E-03	6.72E-04	3.27E-02
INFANT	5.01E-02	6.51E-02	3.32E-02	1.88E-09	1.73E-02	7.04E-03	2.27E-04	3.27E-02

As evident from Tables 3.10-1 through 3.10-4, H-3 contributes a significant portion of the thyroid dose for all age groups for the 1985 - 1991 mixture of radionuclides released to the atmosphere. Comparison of Tables 3.10-5 and 3.10-6 to Table 3.10-4 reveals that the major portion of the organ doses from radionuclides other than H-3 and radioiodines results from cobalt and cesium. Cs-134 and Cs-137 are the major dose contributors to the bone, liver, skin and kidneys whereas cobalt is the major contributor to the GI-LLI dose. Therefore, the dose results obtained from the 1985 - 1991 radionuclide mixture is consistent with the dose results from current effluents.

Table 3.10-5 mrem from Cs-134 and Cs-137 (1.84E-03 Ci)

	mrem from Cs-134 and Cs-137							
	Bone	**Liver**	**T. Body**	**Thyroid**	**Kidney**	**Lungs**	**GI-LLI**	**Skin**
ADULT	1.62E-02	2.53E-02	4.21E-02	0.00E+00	8.48E-03	2.82E-03	4.76E-04	2.84E-02
TEEN	2.64E-02	4.04E-02	3.98E-02	0.00E+00	1.35E-02	5.22E-03	5.52E-04	2.84E-02
CHILD	6.22E-02	6.74E-02	3.54E-02	0.00E+00	2.16E-02	7.78E-03	4.05E-04	2.84E-02
INFANT	5.01E-02	6.50E-02	2.95E-02	0.00E+00	1.73E-02	7.02E-03	1.96E-04	2.84E-02

Table 3.10-6 mrem from Co-57, Co-58, and Co-60 (1.93E-04 Ci)

	mrem from cobalts							
	Bone	**Liver**	**T. Body**	**Thyroid**	**Kidney**	**Lungs**	**GI-LLI**	**Skin**
ADULT	0.00E+00	2.24E-05	3.72E-03	0.00E+00	0.00E+00	2.32E-05	4.26E-04	4.32E-03
TEEN	0.00E+00	2.97E-05	3.73E-03	0.00E+00	0.00E+00	3.40E-05	3.88E-04	4.32E-03
CHILD	0.00E+00	4.35E-05	3.80E-03	0.00E+00	0.00E+00	2.76E-05	2.43E-04	4.32E-03
INFANT	0.00E+00	7.75E-06	3.69E-03	0.00E+00	0.00E+00	1.78E-05	1.86E-05	4.32E-03

Based on these results, the release rates for various radionuclide mixture can be determined using the methodology in Section 3.10.1.

For the total radionuclide mixture, the maximum release rate is

Ci/sec =1.16E+02 Ci *1500 mrem/yr/ (1.04E-01 mrem * 3.15E+07 sec/yr)

or 5.33E-02 Ci/sec,

OFFSITE DOSE CALCULATION MANUAL

For radioiodines (I-131 and I-133), the maximum release rate is

Ci/sec =2.42E-03 Ci *1500 mrem/yr/ (1.01E-01 mrem * 3.15E+07 sec/yr)

or 1.14E-06 Ci/sec,

For H-3, the maximum release rate is

Ci/sec =1.16E+02 Ci *1500 mrem/yr/ (1.53E-02 mrem * 3.15E+07 sec/yr)

or 3.62E-01 Ci/sec,

For all radionuclides (other than H-3 and radioiodines) with a half-life > 8 days, the maximum release rate is

Ci/sec =2.15E-03 Ci *1500 mrem/yr/ (6.75E-02 mrem * 3.15E+07 sec/yr)

or 1.52E-06 Ci/sec,

For cesium (Cs-134, -137), the maximum release rate is

Ci/sec =1.84E-03 Ci *1500 mrem/yr/ (6.74E-02 mrem * 3.15E+07 sec/yr)

or 1.30E-06 Ci/sec,

For cobalt (Co-57, -58, -60), the maximum release rate is

Ci/sec =1.93E-04 Ci *1500 mrem/yr/ (4.26E-02 mrem * 3.15E+07 sec/yr)

or 2.16E-05 Ci/sec,

Finally, for the total of all radionuclides in the mixture except H-3, the maximum release rate is

Ci/sec =4.57E-03 Ci *1500 mrem/yr/ (1.01E-01 mrem * 3.15E+07 sec/yr)

or 2.15E-06 Ci/sec.

Because the limiting release rate is that of the radioiodines, a mixture of radionuclides whose half-lives is >8 days should be restricted to 1.14E-06 Ci/sec. However, if there is no I-131 and I-133, the cesium doses become limiting and the release rate limit may be raised to 1.30E-06 Ci/sec.

4.0 DEMONSTRATING COMPLIANCE WITH 10 CFR 50, APPENDIX I

4.1 Introduction

Maintaining effluents within the dose objectives of Appendix I is demonstrated at PBNP by periodic calculations. Compliance with Appendix I limits is demonstrated by periodically calculating doses to the maximum exposed individual using the methodology set forth in Regulatory Guide 1.109, Rev. 1, October 1977 and in other recognized sources such as ICRP publications.

In order to aid in the dose calculations, the formulae in Reg Guide 1.109 were rearranged to calculate the dose per curie released (mrem/Ci) to the environment. For each pathway given in Reg Guide 1.109, a radionuclide's mrem/Ci values for the whole body and the organs were calculated for each of the two release modes, liquid and atmospheric. All of the pathway doses for a radionuclide via the release mode under consideration were summed to obtain the radionuclide's total mrem/Ci released. These values, called total dose factors (TDFs), are listed in Tables 5.1.1 and 5.1.2. The application of TDFs are given in Section 5; the calculations used to obtain them, in Appendix C.

4.2 Dose Limits

To define the limits and conditions for the controlled release of radioactive materials in liquid and gaseous effluents to the environment, to ensure that these releases are as low as is reasonably achievable in conformance with 10 CFR Parts 50.34a and 50.36a, to ensure that these releases result in concentrations of radioactive materials in liquid and gaseous effluents released to unrestricted areas that are within the limits specified in 10 CFR 20, and to ensure that the releases of radioactive material above background to unrestricted areas are as low as is reasonably achievable, the following design release limits as defined in Appendix I to 10 CFR 50 apply:

A. The calculated annual total quantity of all radioactive material above background that may be released from each light-water-cooled nuclear power reactor to unrestricted areas should not result in an annual dose or dose commitment from liquid effluents for any individual in an unrestricted area from all pathways of exposure in excess of 3 millirems to the total body or 10 millirems to any organ.

B. The calculated annual total quantity of all radioactive material above background that may be released from each light-water-cooled nuclear power reactor to the atmosphere should not result in an annual air dose from gaseous effluents at any location near ground level which could be occupied by individuals in unrestricted areas in excess of 10 millirads for gamma radiation or 20 millirads for beta radiation, or that this quantity should not result in an annual external dose from gaseous effluents to any individual in unrestricted areas in excess of 5 millirems to the total body or 15 millirems to the skin.

C. The calculated annual total quantity of all radioactive iodine and radioactive material in particulate form above background that may be released from each light-water-cooled nuclear power reactor in effluents to the atmosphere should not result in an annual dose or dose commitment from such radioactive iodine and radioactive material in particulate form for any individual in an unrestricted area from all pathways of exposure in excess of 15 millirems to any organ.

D. Pursuant to NRC interpretation as stated in PBNP TS 5.5.4.i, the dose guideline of Section 4.2.C, above, applies only to I-131, I-133, H-3, and all particulate material released to the atmosphere which has a half-life >8 days. Particulates with shorter half-lives are not considered because of their negligible dose contribution.

4.3 Release Limits

Based on the Appendix I dose limits, Point Beach, being a two (2) unit nuclear plant, may release into the environment the quantities of radionuclides above background that fulfill the criteria listed below.

A. Pursuant to Section 4.2.A, the doses from radionuclides in the unrestricted area in liquids shall not exceed

1. Six (6) millirem to the whole body, or

2. Twenty (20) millirem to any organ.

B. Pursuant to Section 4.2.B, the doses from gaseous radionuclides in the unrestricted area shall not exceed

1. Twenty (20) millirads to the air from gamma radiation,

2. Forty (40) millirads to the air from beta radiation,

3. Ten (10) millirem to the whole body, or

4. Thirty (30) millirem to the skin.

C. Pursuant to Section 4.2.C, the dose from radioiodine and radioactive material in particulate form released to the atmosphere in the unrestricted area shall not exceed thirty (30) millirem to any organ.

D. Quarterly release limits are defined as ½ the annual limits.

4.4 EPA Regulations

Compliance with the provisions of Appendix I to 10 CFR 50 is adequate demonstration of conformance to the standards set forth in 40 CFR 190 regarding the dose commitment to individuals from the uranium fuel cycle. For 40 CFR 190 compliance, quarterly dose calculations shall include exposures from effluent pathways and direct radiation contributions from the reactor units and from any outside storage tanks.

The above calculations do not include contributions from the Kewaunee Nuclear Power Plant (KNPP) which is some four miles north of PBNP. Under normal operations using the PBNP annual average χ/Q and assuming that the KNPP source term is identical to either PBNP unit, the greatest KNPP dose contribution occurs at the north sector PBNP boundary. However, the total KNPP-PBNP dose at that point is less than the dose in the highest sector (south boundary) from PBNP alone. The KNPP contribution in this sector adds only 1 percent to 8 percent to the total dose depending upon the release mode. Even in the highly unlikely event that PBNP and KNPP operated for an entire year at twice the Appendix I levels, the small percentage contribution from KNPP would be insufficient to yield doses exceeding 40 CFR 190 limits.

5.0 CALCULATION AND COMPARISON OF EFFLUENT RELEASES TO RELEASE LIMITS

Technical Specification 5.5.4.e requires that an effluent release summary and dose calculations be performed periodically. This section describes the methodology for the calculation of doses for comparison to the corresponding dose limits. For Appendix I compliance, the organ and whole body doses shall be calculated for the maximally exposed individual in each age group using the appropriate total dose factors in mrem/Ci released which were obtained using Regulatory Guide 1.109 and other documented methodologies.

5.1 Appendix I Dose Calculations

5.1.1 Liquid Release Mode

The dose calculations for demonstration of compliance with the 10 CFR 50, Appendix I dose limits will be accomplished by Chemistry. Doses will be calculated for each month to track compliance with effluent and dose goals. The doses from each radionuclide will be calculated for each age group and for each organ, including the whole body, and summed over all the identified radionuclides released. The total dose is compared to the corresponding liquid release mode Appendix I dose limit for the organ in question. Noble gases released in liquids are added to the atmospherically released noble gases for Appendix I dose compliance calculations.

The doses are calculated using the following formula:

$$API = \Sigma Dose_{aomi} = \Sigma (TDF_{aomi} \times C_i) \leq K_{om} \text{ mrem}$$

OFFSITE DOSE CALCULATION MANUAL

where

API = the Appendix I dose for compliance evaluation in mrem

$Dose_{aomi}$ = the dose to the specific age group (a) and organ (o) via release mode (m) from radionuclide (i)

TDF_{aomi} = total dose factor for the specific age group (a) and organ (o) via release mode (m) from radionuclide (i) from Table 5.1-1 in mrem/Ci

C_i = curies of radionuclide (i) released

K_{om} = the Appendix I dose limit for organ (o) and release mode (m) for which the calculation is being made.

The methodology and the values used to obtain the TDF_{aomi} values are given in Appendix C.

It is recognized that some of the release quantities may not be available at the end of the month because the samples from these release paths are sent to a vendor for analysis. Usually, the only radionuclides affected by these delays are Sr-89 and Sr-90. Because the quantities of these two radionuclides are but a small fraction of the total release, the absence of their dose contributions from the initial monthly dose calculation will not significantly affect the total dose obtained from the remaining radionuclides. The dose for the month will be updated upon the receipt of the vendor isotopic results and upon the receipt of any corrections to previous release quantities.

Note that all of the liquid release dose calculations assume that the discharge rate is 677,000 gpm. Whenever the average discharge rate for the month or year differs, the final dose calculated must be multiplied by the correction factor CF where:

CF = 677,000 gpm / actual average discharge gpm

This correction will produce a greater change during the winter months when the circ water flow rates are lower.

TABLE 5.1-1
LIQUID EFFLUENT DOSE FACTOR

Summation of dose per curie released factor calculations over the pathways: potable water, aquatic food, shoreline deposit, irrigated foods (milk), and irrigated foods (meat).

Dose factor - liquid release pathway (mrem/Ci released)							
H-3							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	4.46E-06	4.46E-06	4.46E-06	4.46E-06	4.46E-06	4.46E-06
Teen	0.00E+00	4.04E-06	4.04E-06	4.04E-06	4.04E-06	4.04E-06	4.04E-06
Child	0.00E+00	6.67E-06	6.67E-06	6.67E-06	6.67E-06	6.67E-06	6.67E-06
Infant	0.00E+00	7.79E-06	7.79E-06	7.79E-06	7.79E-06	7.79E-06	7.79E-06

Dose factor - liquid release pathway (mrem/Ci released)							
F-18							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.15E-07	9.12E-89	1.28E-08	0.00E+00	5.14E-89	0.00E+00	3.40E-09
Teen	1.21E-07	7.59E-89	1.35E-08	0.00E+00	4.35E-89	0.00E+00	1.09E-08
Child	1.51E-07	1.08E-88	1.50E-08	0.00E+00	5.74E-89	0.00E+00	4.08E-08
Infant	2.05E-12	0.00E+00	1.75E-13	0.00E+00	0.00E+00	0.00E+00	4.83E-13

Dose factor - liquid release pathway (mrem/Ci released)							
Na-22							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	4.71E-03	4.71E-03	4.82E-03	4.71E-03	4.71E-03	4.71E-03	4.71E-03
Teen	5.48E-03	5.48E-03	6.07E-03	5.48E-03	5.48E-03	5.48E-03	5.48E-03
Child	8.32E-03	8.32E-03	8.45E-03	8.32E-03	8.32E-03	8.32E-03	8.32E-03
Infant	7.21E-03	7.21E-03	7.21E-03	7.21E-03	7.21E-03	7.21E-03	7.21E-03

Dose factor - liquid release pathway (mrem/Ci released)							
Na-24							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.85E-04	1.85E-04	1.85E-04	1.85E-04	1.85E-04	1.85E-04	1.85E-04
Teen	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04
Child	2.40E-04	2.40E-04	2.40E-04	2.40E-04	2.40E-04	2.40E-04	2.40E-04
Infant	8.06E-05	8.06E-05	8.06E-05	8.06E-05	8.06E-05	8.06E-05	8.06E-05

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Sc-46							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.70E-07	3.31E-07	8.92E-06	0.00E+00	3.09E-07	0.00E+00	1.61E-03
Teen	1.52E-07	2.97E-07	4.94E-05	0.00E+00	2.84E-07	0.00E+00	1.01E-03
Child	3.54E-07	4.85E-07	1.05E-05	0.00E+00	4.29E-07	0.00E+00	7.09E-04
Infant	3.42E-07	4.94E-07	1.54E-07	0.00E+00	3.25E-07	0.00E+00	3.22E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Mn-54							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	3.28E-03	6.34E-04	0.00E+00	9.75E-04	0.00E+00	1.00E-02
Teen	0.00E+00	3.22E-03	6.86E-04	0.00E+00	9.59E-04	0.00E+00	6.60E-03
Child	0.00E+00	2.60E-03	7.04E-04	0.00E+00	7.30E-04	0.00E+00	2.19E-03
Infant	0.00E+00	1.92E-04	4.34E-05	0.00E+00	4.25E-05	0.00E+00	7.04E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Cr-51							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	0.00E+00	1.01E-06	5.84E-07	2.15E-07	1.30E-06	2.46E-04
Teen	0.00E+00	0.00E+00	1.17E-06	5.60E-07	2.21E-07	1.44E-06	1.70E-04
Child	0.00E+00	0.00E+00	1.19E-06	6.44E-07	1.76E-07	1.18E-06	6.15E-05
Infant	0.00E+00	0.00E+00	1.72E-07	1.12E-07	2.45E-08	2.18E-07	5.01E-06

Dose factor - liquid release pathway (mrem/Ci released)							
Mn-56							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	3.18E-06	5.65E-07	0.00E+00	4.04E-06	0.00E+00	1.02E-04
Teen	0.00E+00	3.33E-06	5.94E-07	0.00E+00	4.22E-06	0.00E+00	2.19E-04
Child	0.00E+00	3.04E-06	6.86E-07	0.00E+00	3.67E-06	0.00E+00	4.40E-04
Infant	0.00E+00	1.97E-11	3.39E-12	0.00E+00	1.69E-11	0.00E+00	1.79E-09

Dose factor - liquid release pathway (mrem/Ci released)							
Fe-55							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.98E-04	4.13E-04	9.63E-05	0.00E+00	0.00E+00	2.31E-04	2.37E-04
Teen	6.11E-04	4.33E-04	1.01E-04	0.00E+00	0.00E+00	2.75E-04	1.88E-04
Child	9.35E-04	4.96E-04	1.54E-04	0.00E+00	0.00E+00	2.80E-04	9.19E-05
Infant	1.55E-04	1.00E-04	2.68E-05	0.00E+00	0.00E+00	4.91E-05	1.28E-05

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Fe-59							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	9.12E-04	2.14E-03	8.23E-04	0.00E+00	0.00E+00	5.99E-04	7.14E-03
Teen	9.22E-04	2.15E-03	8.40E-04	0.00E+00	0.00E+00	6.79E-04	5.09E-03
Child	1.29E-03	2.09E-03	1.04E-03	0.00E+00	0.00E+00	6.07E-04	2.18E-03
Infant	3.34E-04	5.84E-04	2.30E-04	0.00E+00	0.00E+00	1.73E-04	2.79E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Co-57							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	2.02E-05	3.57E-05	0.00E+00	0.00E+00	0.00E+00	5.13E-04
Teen	0.00E+00	2.06E-05	4.62E-05	0.00E+00	0.00E+00	0.00E+00	3.83E-04
Child	0.00E+00	2.31E-05	4.93E-05	0.00E+00	0.00E+00	0.00E+00	1.89E-04
Infant	0.00E+00	1.24E-05	2.02E-05	0.00E+00	0.00E+00	0.00E+00	4.24E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Co-58							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	8.49E-05	1.93E-04	0.00E+00	0.00E+00	0.00E+00	1.72E-03
Teen	0.00E+00	8.30E-05	2.04E-04	0.00E+00	0.00E+00	0.00E+00	1.14E-03
Child	0.00E+00	8.32E-05	2.57E-04	0.00E+00	0.00E+00	0.00E+00	4.85E-04
Infant	0.00E+00	3.84E-05	9.58E-05	0.00E+00	0.00E+00	0.00E+00	9.57E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Co-60							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	2.48E-04	6.82E-04	0.00E+00	0.00E+00	0.00E+00	4.66E-03
Teen	0.00E+00	2.44E-04	1.30E-03	0.00E+00	0.00E+00	0.00E+00	3.17E-03
Child	0.00E+00	2.49E-04	8.92E-04	0.00E+00	0.00E+00	0.00E+00	1.38E-03
Infant	0.00E+00	1.17E-04	2.77E-04	0.00E+00	0.00E+00	0.00E+00	2.79E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Ni-63							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.03E-02	2.10E-03	1.02E-03	0.00E+00	0.00E+00	0.00E+00	4.38E-04
Teen	3.13E-02	2.21E-03	1.06E-03	0.00E+00	0.00E+00	0.00E+00	3.52E-04
Child	5.00E-02	2.67E-03	1.70E-03	0.00E+00	0.00E+00	0.00E+00	1.80E-04
Infant	1.27E-02	7.85E-04	4.41E-04	0.00E+00	0.00E+00	0.00E+00	3.91E-05

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Ni-65							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.39E-06	4.40E-07	2.01E-07	0.00E+00	0.00E+00	0.00E+00	1.12E-05
Teen	3.66E-06	4.68E-07	2.13E-07	0.00E+00	0.00E+00	0.00E+00	2.54E-05
Child	4.68E-06	4.41E-07	2.57E-07	0.00E+00	0.00E+00	0.00E+00	5.40E-05
Infant	1.74E-10	1.97E-11	8.95E-12	0.00E+00	0.00E+00	0.00E+00	1.50E-09

Dose factor - liquid release pathway (mrem/Ci released)							
Cu-64							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	4.02E-06	1.89E-06	0.00E+00	1.01E-05	0.00E+00	3.43E-04
Teen	0.00E+00	4.31E-06	2.04E-06	0.00E+00	1.09E-05	0.00E+00	3.34E-04
Child	0.00E+00	4.30E-06	2.60E-06	0.00E+00	1.04E-05	0.00E+00	2.02E-04
Infant	0.00E+00	1.41E-06	6.52E-07	0.00E+00	2.38E-06	0.00E+00	2.89E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Zn-65							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.73E-02	5.50E-02	2.49E-02	0.00E+00	3.68E-02	0.00E+00	3.46E-02
Teen	1.58E-02	5.50E-02	2.57E-02	0.00E+00	3.52E-02	0.00E+00	2.33E-02
Child	1.68E-02	4.47E-02	2.78E-02	0.00E+00	2.82E-02	0.00E+00	7.85E-03
Infant	1.32E-03	4.51E-03	2.08E-03	0.00E+00	2.19E-03	0.00E+00	3.81E-03

Dose factor - liquid release pathway (mrem/Ci released)							
Zn-69							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.97E-05	3.76E-05	2.62E-06	0.00E+00	2.44E-05	0.00E+00	5.65E-06
Teen	2.14E-05	4.08E-05	2.86E-06	0.00E+00	2.67E-05	0.00E+00	7.52E-05
Child	2.77E-05	4.00E-05	3.70E-06	0.00E+00	2.43E-05	0.00E+00	2.52E-03
Infant	5.98E-07	1.08E-06	8.01E-08	0.00E+00	4.47E-07	0.00E+00	8.78E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Zn-69m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.25E-04	7.79E-04	7.12E-05	0.00E+00	4.72E-04	0.00E+00	4.76E-02
Teen	3.50E-04	8.25E-04	7.57E-05	0.00E+00	5.01E-04	0.00E+00	4.53E-02
Child	4.49E-04	7.65E-04	9.04E-05	0.00E+00	4.44E-04	0.00E+00	2.49E-02
Infant	9.61E-06	1.96E-05	1.79E-06	0.00E+00	7.94E-06	0.00E+00	2.72E-04

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Br-82							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	0.00E+00	1.39E-03	0.00E+00	0.00E+00	0.00E+00	1.59E-03
Teen	0.00E+00	0.00E+00	1.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Child	0.00E+00	0.00E+00	1.71E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Infant	0.00E+00	0.00E+00	4.43E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Dose factor - liquid release pathway (mrem/Ci released)							
Br-83							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	0.00E+00	9.06E-07	0.00E+00	0.00E+00	0.00E+00	1.30E-06
Teen	0.00E+00	0.00E+00	9.85E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Child	0.00E+00	0.00E+00	1.27E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Infant	0.00E+00	0.00E+00	2.93E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Dose factor - liquid release pathway (mrem/Ci released)							
Br-84							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	0.00E+00	3.12E-05	0.00E+00	0.00E+00	0.00E+00	2.44E-10
Teen	0.00E+00	0.00E+00	3.43E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Child	0.00E+00	0.00E+00	4.33E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Infant	0.00E+00	0.00E+00	1.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Dose factor - liquid release pathway (mrem/Ci released)							
Br-85							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	0.00E+00	4.24E-82	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Teen	0.00E+00	0.00E+00	4.60E-82	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Child	0.00E+00	0.00E+00	5.94E-82	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Infant	0.00E+00	0.00E+00	9.35E-309	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Dose factor - liquid release pathway (mrem/Ci released)							
Rb-86							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	7.36E-02	3.43E-02	0.00E+00	0.00E+00	0.00E+00	1.45E-02
Teen	0.00E+00	7.98E-02	3.75E-02	0.00E+00	0.00E+00	0.00E+00	1.18E-02
Child	0.00E+00	7.93E-02	4.88E-02	0.00E+00	0.00E+00	0.00E+00	5.10E-03
Infant	0.00E+00	9.07E-03	4.48E-03	0.00E+00	0.00E+00	0.00E+00	2.32E-04

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Rb-88							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	1.41E-16	7.46E-17	0.00E+00	0.00E+00	0.00E+00	1.94E-27
Teen	0.00E+00	1.51E-16	8.04E-17	0.00E+00	0.00E+00	0.00E+00	1.29E-23
Child	0.00E+00	1.45E-16	1.01E-16	0.00E+00	0.00E+00	0.00E+00	7.12E-18
Infant	0.00E+00	5.68E-54	3.12E-54	0.00E+00	0.00E+00	0.00E+00	5.54E-54

Dose factor - liquid release pathway (mrem/Ci released)							
Rb-89							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	1.28E-18	8.99E-19	0.00E+00	0.00E+00	0.00E+00	7.42E-32
Teen	0.00E+00	1.34E-18	9.45E-19	0.00E+00	0.00E+00	0.00E+00	2.05E-27
Child	0.00E+00	1.23E-18	1.09E-18	0.00E+00	0.00E+00	0.00E+00	1.07E-20
Infant	0.00E+00	1.15E-61	7.93E-62	0.00E+00	0.00E+00	0.00E+00	3.92E-62

Dose factor - liquid release pathway (mrem/Ci released)							
Sr-89							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.26E-02	0.00E+00	6.48E-04	0.00E+00	0.00E+00	0.00E+00	3.62E-03
Teen	2.43E-02	0.00E+00	6.95E-04	0.00E+00	0.00E+00	0.00E+00	2.89E-03
Child	4.27E-02	0.00E+00	1.22E-03	0.00E+00	0.00E+00	0.00E+00	1.65E-03
Infant	2.58E-02	0.00E+00	7.40E-04	0.00E+00	0.00E+00	0.00E+00	5.30E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Sr-90							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.63E-01	0.00E+00	1.38E-01	0.00E+00	0.00E+00	0.00E+00	1.63E-02
Teen	4.64E-01	0.00E+00	1.15E-01	0.00E+00	0.00E+00	0.00E+00	1.30E-02
Child	5.59E-01	0.00E+00	1.42E-01	0.00E+00	0.00E+00	0.00E+00	7.53E-03
Infant	1.95E-01	0.00E+00	4.97E-02	0.00E+00	0.00E+00	0.00E+00	2.44E-03

Dose factor - liquid release pathway (mrem/Ci released)							
Sr-91							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.27E-04	0.00E+00	5.14E-06	0.00E+00	0.00E+00	0.00E+00	6.05E-04
Teen	1.38E-04	0.00E+00	5.51E-06	0.00E+00	0.00E+00	0.00E+00	6.24E-04
Child	1.83E-04	0.00E+00	6.91E-06	0.00E+00	0.00E+00	0.00E+00	4.04E-04
Infant	1.59E-05	0.00E+00	5.76E-07	0.00E+00	0.00E+00	0.00E+00	1.88E-05

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Sr-92							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.21E-06	0.00E+00	2.26E-07	0.00E+00	0.00E+00	0.00E+00	1.03E-04
Teen	5.64E-06	0.00E+00	2.42E-07	0.00E+00	0.00E+00	0.00E+00	1.44E-04
Child	7.20E-06	0.00E+00	2.89E-07	0.00E+00	0.00E+00	0.00E+00	1.36E-04
Infant	9.41E-10	0.00E+00	3.50E-11	0.00E+00	0.00E+00	0.00E+00	1.01E-08

Dose factor - liquid release pathway (mrem/Ci released)							
Y-90							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	4.85E-07	0.00E+00	1.30E-08	0.00E+00	0.00E+00	0.00E+00	5.15E-03
Teen	5.16E-07	0.00E+00	1.40E-08	0.00E+00	0.00E+00	0.00E+00	4.26E-03
Child	8.67E-07	0.00E+00	2.32E-08	0.00E+00	0.00E+00	0.00E+00	2.47E-03
Infant	4.80E-07	0.00E+00	1.29E-08	0.00E+00	0.00E+00	0.00E+00	6.63E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Y-91							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	9.20E-06	0.00E+00	2.53E-07	0.00E+00	0.00E+00	0.00E+00	5.06E-03
Teen	9.68E-06	0.00E+00	2.97E-07	0.00E+00	0.00E+00	0.00E+00	3.97E-03
Child	1.74E-05	0.00E+00	4.74E-07	0.00E+00	0.00E+00	0.00E+00	2.32E-03
Infant	1.03E-05	0.00E+00	2.73E-07	0.00E+00	0.00E+00	0.00E+00	7.35E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Y-91m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.71E-13	0.00E+00	5.10E-14	0.00E+00	0.00E+00	0.00E+00	5.02E-13
Teen	1.85E-13	0.00E+00	2.55E-13	0.00E+00	0.00E+00	0.00E+00	8.72E-12
Child	2.36E-13	0.00E+00	6.04E-14	0.00E+00	0.00E+00	0.00E+00	4.62E-10
Infant	2.62E-26	0.00E+00	8.92E-28	0.00E+00	0.00E+00	0.00E+00	8.72E-23

Dose factor - liquid release pathway (mrem/Ci released)							
Y-92							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.51E-09	0.00E+00	2.88E-10	0.00E+00	0.00E+00	0.00E+00	6.15E-05
Teen	3.83E-09	0.00E+00	1.15E-09	0.00E+00	0.00E+00	0.00E+00	1.05E-04
Child	4.92E-09	0.00E+00	3.57E-10	0.00E+00	0.00E+00	0.00E+00	1.42E-04
Infant	5.88E-12	0.00E+00	1.65E-13	0.00E+00	0.00E+00	0.00E+00	1.12E-07

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Y-93							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.32E-08	0.00E+00	2.33E-09	0.00E+00	0.00E+00	0.00E+00	1.69E-03
Teen	5.77E-08	0.00E+00	6.38E-09	0.00E+00	0.00E+00	0.00E+00	1.76E-03
Child	7.75E-08	0.00E+00	3.13E-09	0.00E+00	0.00E+00	0.00E+00	1.16E-03
Infant	8.33E-09	0.00E+00	2.27E-10	0.00E+00	0.00E+00	0.00E+00	6.58E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Zr-95							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.23E-06	3.94E-07	1.79E-06	0.00E+00	6.19E-07	0.00E+00	1.25E-03
Teen	1.11E-06	3.52E-07	8.74E-06	0.00E+00	5.17E-07	0.00E+00	8.11E-04
Child	2.48E-06	5.45E-07	2.26E-06	0.00E+00	7.80E-07	0.00E+00	5.69E-04
Infant	1.87E-06	4.56E-07	3.23E-07	0.00E+00	4.91E-07	0.00E+00	2.27E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Zr-97							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.07E-08	2.16E-09	1.23E-08	0.00E+00	3.27E-09	0.00E+00	6.70E-04
Teen	1.11E-08	2.19E-09	6.42E-08	0.00E+00	3.33E-09	0.00E+00	5.94E-04
Child	2.21E-08	3.19E-09	1.51E-08	0.00E+00	4.58E-09	0.00E+00	4.83E-04
Infant	1.92E-08	3.29E-09	1.50E-09	0.00E+00	3.32E-09	0.00E+00	2.10E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Nb-95							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.23E-04	1.79E-04	9.73E-05	0.00E+00	1.77E-04	0.00E+00	1.09E+00
Teen	3.25E-04	1.80E-04	1.04E-04	0.00E+00	1.75E-04	0.00E+00	7.70E-01
Child	3.84E-04	1.49E-04	1.08E-04	0.00E+00	1.40E-04	0.00E+00	2.76E-01
Infant	5.36E-07	2.21E-07	1.28E-07	0.00E+00	1.58E-07	0.00E+00	1.86E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Nb-97							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.69E-09	6.81E-10	2.51E-10	0.00E+00	7.95E-10	0.00E+00	2.51E-06
Teen	2.90E-09	7.20E-10	2.73E-10	0.00E+00	8.41E-10	0.00E+00	1.72E-05
Child	3.68E-09	6.65E-10	3.12E-10	0.00E+00	7.38E-10	0.00E+00	2.05E-04
Infant	5.81E-21	1.24E-10	4.47E-22	0.00E+00	9.68E-22	0.00E+00	3.91E-16

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Mo-99							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	1.49E-04	2.84E-05	0.00E+00	3.38E-04	0.00E+00	3.46E-04
Teen	0.00E+00	1.76E-04	3.36E-05	0.00E+00	4.03E-04	0.00E+00	3.15E-04
Child	0.00E+00	2.79E-04	6.91E-05	0.00E+00	5.96E-04	0.00E+00	2.31E-04
Infant	0.00E+00	4.38E-04	8.54E-05	0.00E+00	6.54E-04	0.00E+00	1.44E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Tc-99m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.68E-09	4.74E-09	6.07E-08	0.00E+00	7.20E-08	2.32E-09	2.81E-06
Teen	1.74E-09	4.86E-09	6.46E-08	0.00E+00	7.24E-08	2.70E-09	3.19E-06
Child	2.19E-09	4.29E-09	7.15E-08	0.00E+00	6.24E-08	2.18E-09	2.44E-06
Infant	3.78E-10	7.79E-10	1.00E-08	0.00E+00	8.38E-09	4.07E-10	2.26E-07

Dose factor - liquid release pathway (mrem/Ci released)							
Tc-101							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.60E-24	5.19E-24	5.10E-23	0.00E+00	9.34E-23	2.65E-24	1.56E-35
Teen	3.89E-24	5.53E-24	5.49E-23	0.00E+00	1.00E-22	3.37E-24	9.45E-31
Child	4.98E-24	5.22E-24	6.63E-23	0.00E+00	8.90E-23	2.76E-24	1.66E-23
Infant	9.73E-69	1.23E-68	1.21E-67	0.00E+00	1.46E-67	6.69E-69	2.08E-66

Dose factor - liquid release pathway (mrem/Ci released)							
Ru-103							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.47E-05	0.00E+00	1.56E-05	0.00E+00	1.32E-04	0.00E+00	4.05E-03
Teen	2.96E-05	0.00E+00	1.64E-05	0.00E+00	1.04E-04	0.00E+00	2.47E-03
Child	5.53E-05	0.00E+00	2.20E-05	0.00E+00	1.39E-04	0.00E+00	1.43E-03
Infant	1.33E-05	0.00E+00	4.43E-06	0.00E+00	2.76E-05	0.00E+00	1.61E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Ru-105							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	4.13E-08	0.00E+00	1.75E-08	0.00E+00	5.34E-07	0.00E+00	2.53E-05
Teen	4.45E-08	0.00E+00	2.42E-08	0.00E+00	5.62E-07	0.00E+00	3.59E-05
Child	5.71E-08	0.00E+00	2.22E-08	0.00E+00	5.02E-07	0.00E+00	3.73E-05
Infant	6.98E-10	0.00E+00	2.35E-10	0.00E+00	5.13E-09	0.00E+00	2.78E-07

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Ru-106							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	6.71E-04	0.00E+00	8.76E-05	0.00E+00	1.30E-03	0.00E+00	4.34E-02
Teen	5.86E-04	0.00E+00	8.85E-05	0.00E+00	1.13E-03	0.00E+00	2.81E-02
Child	1.13E-03	0.00E+00	1.44E-04	0.00E+00	1.53E-03	0.00E+00	1.76E-02
Infant	2.23E-04	0.00E+00	2.78E-05	0.00E+00	2.63E-04	0.00E+00	1.69E-03

Dose factor - liquid release pathway (mrem/Ci released)							
Rh-105							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.35E-06	2.45E-06	1.62E-06	0.00E+00	1.04E-05	0.00E+00	3.90E-04
Teen	4.10E-06	2.96E-06	1.97E-06	0.00E+00	1.26E-05	0.00E+00	3.77E-04
Child	8.43E-06	4.52E-06	3.88E-06	0.00E+00	1.80E-05	0.00E+00	2.80E-04
Infant	1.08E-05	7.05E-06	4.74E-06	0.00E+00	1.96E-05	0.00E+00	1.75E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Ag-110m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.06E-05	2.83E-05	3.83E-05	0.00E+00	5.56E-05	0.00E+00	1.15E-02
Teen	3.74E-05	3.54E-05	1.41E-04	0.00E+00	6.75E-05	0.00E+00	9.94E-03
Child	6.78E-05	4.58E-05	6.17E-05	0.00E+00	8.53E-05	0.00E+00	5.45E-03
Infant	8.87E-05	6.47E-05	4.28E-05	0.00E+00	9.26E-05	0.00E+00	3.36E-03

Sn-113 and Sn-117m - liquid release pathway (mrem/Ci released)							
	Bone	Liver	W. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	6.40E-03	2.17E-04	6.78E-04	1.26E-04	0.00E+00	0.00E+00	1.32E-01
Teen	6.96E-03	2.33E-04	7.33E-04	1.28E-04	0.00E+00	0.00E+00	1.08E-01
Child	9.03E-03	2.28E-04	9.44E-04	1.66E-04	0.00E+00	0.00E+00	4.61E-02
Infant	1.42E-04	4.43E-06	1.47E-05	3.07E-06	0.00E+00	0.00E+00	3.50E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Sb-124							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.42E-04	1.02E-05	2.21E-04	1.32E-06	0.00E+00	4.22E-04	1.54E-02
Teen	5.66E-04	1.04E-05	2.53E-04	1.28E-06	0.00E+00	4.94E-04	1.14E-02
Child	7.89E-04	1.02E-05	2.83E-04	1.74E-06	0.00E+00	4.38E-04	4.94E-03
Infant	1.95E-04	2.86E-06	6.03E-05	5.17E-07	0.00E+00	1.22E-04	6.00E-04

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Sb-125							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.49E-04	3.90E-06	1.07E-04	3.55E-07	0.00E+00	2.69E-04	3.85E-03
Teen	3.65E-04	3.99E-06	2.19E-04	3.49E-07	0.00E+00	3.21E-04	2.84E-03
Child	5.14E-04	3.96E-06	1.35E-04	4.76E-07	0.00E+00	2.86E-04	1.23E-03
Infant	1.14E-04	1.11E-06	2.35E-05	1.43E-07	0.00E+00	7.17E-05	1.52E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Te-125m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.30E-04	1.20E-04	4.43E-05	9.93E-05	1.34E-03	0.00E+00	1.32E-03
Teen	3.36E-04	1.21E-04	4.53E-05	9.39E-05	0.00E+00	0.00E+00	9.92E-04
Child	5.74E-04	1.56E-04	7.67E-05	1.61E-04	0.00E+00	0.00E+00	5.54E-04
Infant	2.47E-04	8.27E-05	3.35E-05	8.33E-05	0.00E+00	0.00E+00	1.18E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Te-127							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.15E-05	1.13E-05	6.83E-06	2.34E-05	1.28E-04	0.00E+00	2.49E-03
Teen	3.45E-05	1.22E-05	7.43E-06	2.38E-05	1.40E-04	0.00E+00	2.67E-03
Child	4.45E-05	1.20E-05	9.54E-06	3.08E-05	1.27E-04	0.00E+00	1.74E-03
Infant	3.10E-07	1.04E-07	6.67E-08	2.52E-07	7.56E-07	0.00E+00	6.51E-06

Dose factor - liquid release pathway (mrem/Ci released)							
Te-127m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	8.63E-04	3.08E-04	1.05E-04	2.21E-04	3.51E-03	0.00E+00	2.89E-03
Teen	8.74E-04	3.10E-04	1.04E-04	2.08E-04	3.54E-03	0.00E+00	2.18E-03
Child	1.50E-03	4.05E-04	1.79E-04	3.60E-04	4.29E-03	0.00E+00	1.22E-03
Infant	6.28E-04	2.08E-04	7.61E-05	1.82E-04	1.55E-03	0.00E+00	2.54E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Te-129							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.68E-08	6.32E-09	4.10E-09	1.29E-08	7.07E-08	0.00E+00	1.27E-08
Teen	1.83E-08	6.82E-09	4.45E-09	1.31E-08	7.68E-08	0.00E+00	1.00E-07
Child	2.36E-08	6.58E-09	5.60E-09	1.68E-08	6.90E-08	0.00E+00	1.47E-06
Infant	1.08E-18	3.73E-19	2.53E-19	9.07E-19	2.69E-18	0.00E+00	8.65E-17

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Te-129m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.35E-03	5.04E-04	2.14E-04	4.64E-04	5.63E-03	0.00E+00	6.80E-03
Teen	1.37E-03	5.10E-04	2.18E-04	4.43E-04	5.75E-03	0.00E+00	5.16E-03
Child	2.34E-03	6.54E-04	3.64E-04	7.55E-04	6.88E-03	0.00E+00	2.86E-03
Infant	1.04E-03	3.58E-04	1.61E-04	4.01E-04	2.61E-03	0.00E+00	6.23E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Te-131m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.04E-04	5.08E-05	4.24E-05	8.05E-05	5.15E-04	0.00E+00	5.05E-03
Teen	1.11E-04	5.34E-05	4.49E-05	8.03E-05	5.56E-04	0.00E+00	4.28E-03
Child	1.63E-04	5.63E-05	6.00E-05	1.16E-04	5.45E-04	0.00E+00	2.28E-03
Infant	5.46E-05	2.20E-05	1.81E-05	4.45E-05	1.51E-04	0.00E+00	3.70E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Te-131							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.97E-15	1.24E-15	9.40E-16	2.44E-15	1.30E-14	0.00E+00	4.21E-16
Teen	3.21E-15	1.32E-15	1.01E-15	2.47E-15	1.40E-14	0.00E+00	2.63E-16
Child	4.12E-15	1.25E-15	1.23E-15	3.15E-15	1.24E-14	0.00E+00	2.16E-14
Infant	4.22E-41	1.56E-41	1.18E-41	3.77E-41	1.08E-40	0.00E+00	1.71E-39

Dose factor - liquid release pathway (mrem/Ci released)							
Te-132							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.96E-04	1.26E-04	1.19E-04	1.40E-04	1.22E-03	0.00E+00	5.98E-03
Teen	2.05E-04	1.30E-04	1.22E-04	1.37E-04	1.24E-03	0.00E+00	4.11E-03
Child	3.15E-04	1.39E-04	1.69E-04	2.03E-04	1.29E-03	0.00E+00	1.40E-03
Infant	1.48E-04	7.32E-05	6.83E-05	1.08E-04	4.58E-04	0.00E+00	2.71E-04

Dose factor - liquid release pathway (mrem/Ci released)							
I-131							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.09E-04	2.99E-04	1.71E-04	9.78E-02	5.12E-04	0.00E+00	7.88E-05
Teen	2.41E-04	3.37E-04	1.81E-04	9.83E-02	5.80E-04	0.00E+00	6.66E-05
Child	4.90E-04	4.93E-04	2.80E-04	1.63E-01	8.09E-04	0.00E+00	4.39E-05
Infant	5.71E-04	6.73E-04	2.96E-04	2.21E-01	7.86E-04	0.00E+00	2.40E-05

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
I-132							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.43E-07	3.81E-07	1.34E-07	1.33E-05	6.07E-07	0.00E+00	7.16E-08
Teen	1.49E-07	3.90E-07	1.41E-07	1.32E-05	6.15E-07	0.00E+00	1.70E-07
Child	1.85E-07	3.39E-07	1.56E-07	1.57E-05	5.19E-07	0.00E+00	3.99E-07
Infant	1.64E-11	3.32E-11	1.18E-11	1.56E-09	3.71E-11	0.00E+00	2.69E-11

Dose factor - liquid release pathway (mrem/Ci released)							
I-133							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.33E-05	5.80E-05	1.77E-05	8.52E-03	1.01E-04	0.00E+00	5.21E-05
Teen	3.74E-05	6.34E-05	1.94E-05	8.85E-03	1.11E-04	0.00E+00	4.80E-05
Child	6.27E-05	7.75E-05	2.94E-05	1.44E-02	1.29E-04	0.00E+00	3.13E-05
Infant	4.77E-05	6.95E-05	2.04E-05	1.26E-02	8.17E-05	0.00E+00	1.18E-05

Dose factor - liquid release pathway (mrem/Ci released)							
I-134							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.09E-10	5.69E-10	2.04E-10	9.85E-09	9.04E-10	0.00E+00	4.96E-13
Teen	2.20E-10	5.82E-10	2.10E-10	9.70E-09	9.18E-10	0.00E+00	7.67E-12
Child	2.72E-10	5.05E-10	2.33E-10	1.16E-08	7.72E-10	0.00E+00	3.35E-10
Infant	5.37E-22	1.10E-21	3.91E-22	2.56E-20	1.23E-21	0.00E+00	1.14E-21

Dose factor - liquid release pathway (mrem/Ci released)							
I-135							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.37E-06	8.83E-06	3.26E-06	5.82E-04	1.42E-05	0.00E+00	9.97E-06
Teen	3.55E-06	9.14E-06	3.41E-06	5.88E-04	1.44E-05	0.00E+00	1.01E-05
Child	4.54E-06	8.17E-06	3.87E-06	7.24E-04	1.25E-05	0.00E+00	6.23E-06
Infant	4.48E-07	8.92E-07	3.25E-07	7.99E-05	9.94E-07	0.00E+00	3.23E-07

Dose factor - liquid release pathway (mrem/Ci released)							
Cs-134							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.19E-01	5.21E-01	4.26E-01	0.00E+00	1.69E-01	5.60E-02	9.12E-03
Teen	2.25E-01	5.30E-01	2.46E-01	0.00E+00	1.68E-01	6.43E-02	6.59E-03
Child	2.76E-01	4.52E-01	9.55E-02	0.00E+00	1.40E-01	5.03E-02	2.44E-03
Infant	1.07E-02	2.00E-02	2.02E-03	0.00E+00	5.16E-03	2.11E-03	5.44E-05

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Cs-134m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	4.21E-06	8.85E-06	4.52E-06	0.00E+00	4.80E-06	7.56E-07	3.12E-06
Teen	4.42E-06	9.16E-06	4.71E-06	0.00E+00	5.10E-06	8.95E-07	6.0E-06
Child	5.48E-06	8.11E-06	5.29E-06	0.00E+00	4.28E-06	7.07E-07	1.03E-05
Infant	5.19E-11	8.64E-11	4.37E-11	0.00E+00	3.33E-11	7.67E-12	6.84E-11

Dose factor - liquid release pathway (mrem/Ci released)							
Cs-136							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.23E-02	8.81E-02	6.34E-02	0.00E+00	4.90E-02	6.72E-03	1.00E-02
Teen	2.25E-02	8.85E-02	5.95E-02	0.00E+00	4.82E-02	7.59E-03	7.12E-03
Child	2.69E-02	7.40E-02	4.79E-02	0.00E+00	3.94E-02	5.87E-03	2.60E-03
Infant	1.18E-03	3.47E-03	1.29E-03	0.00E+00	1.38E-03	2.83E-04	5.27E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Cs-137							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.81E-01	3.84E-01	2.52E-01	0.00E+00	1.30E-01	4.33E-02	7.43E-03
Teen	3.02E-01	4.01E-01	1.40E-01	0.00E+00	1.36E-01	5.30E-02	5.71E-03
Child	3.85E-01	3.69E-01	5.45E-02	0.00E+00	1.20E-01	4.33E-02	2.31E-03
Infant	1.49E-02	1.74E-02	1.24E-03	0.00E+00	4.68E-03	1.89E-03	5.45E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Cs-138							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.57E-11	7.04E-11	3.49E-11	0.00E+00	5.18E-11	5.11E-12	3.00E-16
Teen	3.82E-11	7.34E-11	3.67E-11	0.00E+00	5.42E-11	6.30E-12	3.33E-14
Child	4.84E-11	6.73E-11	4.27E-11	0.00E+00	4.73E-11	5.10E-12	3.10E-11
Infant	1.63E-32	2.65E-32	1.28E-32	0.00E+00	1.32E-32	2.06E-33	4.23E-32

Dose factor - liquid release pathway (mrem/Ci released)							
Ba-139							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.67E-09	1.19E-12	4.93E-11	0.00E+00	1.12E-12	6.77E-13	2.97E-09
Teen	1.83E-09	1.29E-12	5.50E-11	0.00E+00	1.21E-12	8.87E-13	1.63E-08
Child	2.35E-09	1.25E-12	6.84E-11	0.00E+00	1.09E-12	7.37E-13	1.36E-07
Infant	3.30E-16	2.19E-19	9.55E-18	0.00E+00	1.31E-19	1.33E-19	2.09E-14

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Ba-140							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.34E-04	6.71E-07	3.51E-05	0.00E+00	2.28E-07	3.84E-07	1.10E-03
Teen	5.41E-04	6.63E-07	3.56E-05	0.00E+00	2.25E-07	4.46E-07	8.35E-04
Child	1.32E-03	1.16E-06	7.72E-05	0.00E+00	3.76E-07	6.89E-07	6.69E-04
Infant	1.52E-03	1.52E-06	7.84E-05	0.00E+00	3.61E-07	9.34E-07	3.74E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Ba-141							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	4.57E-19	3.45E-22	1.63E-20	0.00E+00	3.21E-22	1.96E-22	2.15E-28
Teen	4.96E-19	3.70E-22	2.14E-20	0.00E+00	3.44E-22	2.53E-22	1.06E-24
Child	6.37E-19	3.57E-22	2.18E-20	0.00E+00	3.09E-22	2.10E-21	3.63E-19
Infant	1.58E-53	1.08E-56	4.99E-55	0.00E+00	6.52E-57	6.60E-57	1.93E-52

Dose factor - liquid release pathway (mrem/Ci released)							
La-140							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.66E-08	1.84E-08	1.03E-07	0.00E+00	0.00E+00	0.00E+00	1.35E-03
Teen	3.68E-08	1.81E-08	5.51E-07	0.00E+00	0.00E+00	0.00E+00	1.04E-03
Child	8.21E-08	2.87E-08	1.24E-07	0.00E+00	0.00E+00	0.00E+00	8.00E-04
Infant	8.56E-08	3.38E-08	8.69E-09	0.00E+00	0.00E+00	0.00E+00	3.97E-04

Dose factor - liquid release pathway (mrem/Ci released)							
La-142							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.92E-11	1.33E-11	4.94E-11	0.00E+00	0.00E+00	0.00E+00	9.71E-08
Teen	3.12E-11	1.38E-11	2.61E-10	0.00E+00	0.00E+00	0.00E+00	4.21E-07
Child	3.93E-11	1.25E-11	5.77E-11	0.00E+00	0.00E+00	0.00E+00	2.48E-06
Infant	7.74E-18	2.84E-18	6.81E-19	0.00E+00	0.00E+00	0.00E+00	4.83E-13

Dose factor - liquid release pathway (mrem/Ci released)							
Ce-141							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.05E-07	1.39E-07	2.42E-07	0.00E+00	6.45E-08	0.00E+00	5.31E-04
Teen	2.06E-07	1.37E-07	4.88E-07	0.00E+00	6.47E-08	0.00E+00	3.93E-04
Child	5.80E-07	2.89E-07	1.42E-07	0.00E+00	1.27E-07	0.00E+00	3.61E-04
Infant	7.11E-07	4.34E-07	5.11E-08	0.00E+00	1.34E-07	0.00E+00	2.24E-04

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Ce-143							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.47E-08	1.09E-05	1.78E-08	0.00E+00	4.78E-09	0.00E+00	4.06E-04
Teen	1.49E-08	1.08E-05	9.40E-08	0.00E+00	4.86E-09	0.00E+00	3.26E-04
Child	4.01E-08	2.17E-05	2.25E-08	0.00E+00	9.12E-09	0.00E+00	3.18E-04
Infant	5.10E-08	3.38E-05	3.86E-09	0.00E+00	9.85E-09	0.00E+00	1.97E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Ce-144							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.12E-05	4.67E-06	1.04E-06	0.00E+00	2.77E-06	0.00E+00	3.78E-03
Teen	1.12E-05	4.65E-06	3.03E-06	0.00E+00	2.78E-06	0.00E+00	2.82E-03
Child	3.17E-05	9.92E-06	2.20E-06	0.00E+00	5.50E-06	0.00E+00	2.59E-03
Infant	2.80E-05	1.15E-05	1.57E-06	0.00E+00	4.63E-06	0.00E+00	1.61E-03

Dose factor - liquid release pathway (mrem/Ci released)							
Pr-143							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.69E-07	2.28E-07	2.82E-08	0.00E+00	1.32E-07	0.00E+00	2.49E-03
Teen	6.00E-07	2.40E-07	2.99E-08	0.00E+00	1.39E-07	0.00E+00	1.97E-03
Child	1.07E-06	3.21E-07	5.31E-08	0.00E+00	1.74E-07	0.00E+00	1.15E-03
Infant	6.81E-07	2.55E-07	3.38E-08	0.00E+00	9.47E-08	0.00E+00	3.60E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Pr-144							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.76E-22	1.56E-22	2.24E-23	0.00E+00	8.80E-23	0.00E+00	5.41E-29
Teen	4.09E-22	1.67E-22	3.91E-23	0.00E+00	9.61E-23	0.00E+00	4.51E-25
Child	5.29E-22	1.64E-22	3.05E-23	0.00E+00	8.66E-23	0.00E+00	3.52E-19
Infant	1.72E-59	6.66E-60	8.67E-61	0.00E+00	2.41E-60	0.00E+00	3.10E-55

Dose factor - liquid release pathway (mrem/Ci released)							
Nd-147							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.82E-07	4.42E-07	1.13E-07	0.00E+00	2.58E-07	0.00E+00	2.12E-03
Teen	4.23E-07	4.60E-07	5.09E-07	0.00E+00	2.70E-07	0.00E+00	1.66E-03
Child	7.45E-07	6.03E-07	1.47E-07	0.00E+00	3.31E-07	0.00E+00	9.55E-04
Infant	4.53E-07	4.65E-07	2.85E-08	0.00E+00	1.79E-07	0.00E+00	2.95E-04

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Eu-152							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.31E-05	2.99E-04	1.63E-04	0.00E+00	1.85E-05	0.00E+00	1.72E-03
Teen	1.21E-05	2.92E-06	9.00E-04	0.00E+00	1.35E-05	0.00E+00	1.07E-03
Child	1.84E-05	3.34E-06	1.91E-04	0.00E+00	1.41E-05	0.00E+00	5.49E-04
Infant	6.27E-06	1.67E-06	1.40E-06	0.00E+00	4.67E-06	0.00E+00	1.48E-04

Dose factor - liquid release pathway (mrem/Ci released)							
W-187							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.52E-04	1.27E-04	4.45E-05	0.00E+00	0.00E+00	0.00E+00	4.17E-02
Teen	1.65E-04	1.34E-04	4.71E-05	0.00E+00	0.00E+00	0.00E+00	3.63E-02
Child	2.09E-04	1.24E-04	5.57E-05	0.00E+00	0.00E+00	0.00E+00	1.74E-02
Infant	2.25E-06	1.57E-06	5.41E-07	0.00E+00	0.00E+00	0.00E+00	9.21E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Np-239							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.15E-08	3.09E-09	2.30E-08	0.00E+00	9.65E-09	0.00E+00	6.34E-04
Teen	3.42E-08	3.22E-09	1.21E-07	0.00E+00	1.01E-08	0.00E+00	5.19E-04
Child	6.77E-08	4.86E-09	2.83E-08	0.00E+00	1.41E-08	0.00E+00	3.60E-04
Infant	5.72E-08	5.12E-09	2.89E-09	0.00E+00	1.02E-08	0.00E+00	1.48E-04

Dose factor - liquid release pathway (mrem/Ci released)							
U-235							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.05E-02	0.00E+00	1.89E-03	0.00E+00	7.13E-03	0.00E+00	2.98E-03
Teen	3.17E-02	0.00E+00	2.13E-03	0.00E+00	7.43E-03	0.00E+00	2.30E-03
Child	6.92E-02	0.00E+00	4.23E-03	0.00E+00	1.14E-02	0.00E+00	1.63E-03
Infant	4.42E-02	0.00E+00	3.37E-03	0.00E+00	9.40E-03	0.00E+00	7.67E-04

Dose factor - liquid release pathway (mrem/Ci released)							
U-238							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.92E-02	0.00E+00	1.73E-03	0.00E+00	6.67E-03	0.00E+00	2.10E-03
Teen	3.03E-02	0.00E+00	1.81E-03	0.00E+00	6.96E-03	0.00E+00	1.62E-03
Child	6.62E-02	0.00E+00	3.93E-03	0.00E+00	1.06E-02	0.00E+00	1.15E-03
Infant	4.23E-02	0.00E+00	3.15E-03	0.00E+00	8.78E-03	0.00E+00	5.41E-04

Table 5.1-1

Dose factor - liquid release pathway (mrem/Ci released)							
Am-241							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.25E-02	1.85E-02	3.47E-03	0.00E+00	2.61E-02	0.00E+00	4.75E-03
Teen	4.10E-02	1.56E-02	2.77E-03	0.00E+00	2.05E-02	0.00E+00	3.74E-03
Child	4.10E-02	1.83E-02	2.93E-03	0.00E+00	1.79E-02	0.00E+00	2.19E-03
Infant	1.42E-02	6.68E-03	1.01E-03	0.00E+00	6.10E-03	0.00E+00	7.17E-04

Table 5.1-2

5.1.2 Atmospheric Release Mode: Radioiodine, Tritium, and Particulates

The dose calculations for demonstration of compliance with the 10 CFR 50, Appendix I dose limits for radioiodines, tritium, and particulate radionuclides released to the atmosphere will be done in the manner similar to the liquid release dose calculations described in Section 5.1.1. The total dose is compared to the corresponding atmospheric release mode Appendix I dose limit for the organ in question.

The doses are calculated using the following formula:

$$API = \Sigma\ Dose_{aomi} = \Sigma\ (TDF_{aomi} \times C_i) \leq K_{om}\ mrem$$

Where

API = the Appendix I dose for compliance evaluations in mrem

$Dose_{aomi}$ = the dose to the specific age group (a) and organ (o) via release mode (m) from radionuclide (i)

TDF_{aomi} = total dose factor for the specific age group (a) and organ (o) via release mode (m) from radionuclide (i) from Table 5.1-2 in mrem/Ci

C_i = curies of radionuclide (i) released

K_{om} = the Appendix I dose limit for organ (o) and release mode (m) for which the calculation is being made.

The methodology and the values used to obtain the TDF_{aomi} values are given in Appendix C.

It is recognized that some of the release quantities may not be available at the end of the month because the samples from these release paths are sent to a vendor for analysis. Usually, the only radionuclides affected by these delays are Sr-89 and Sr-90. Because the quantities of these two radionuclides are but a small fraction of the total release, the absence of their dose contributions from the initial monthly dose calculation will not significantly affect the total dose obtained from the remaining radionuclides. The dose for the month will be updated upon the receipt of the vendor isotopic results and upon the receipt of any corrections to previous release quantities.

Instead of using the precalculated total dose factors, the Appendix I dose calculation may be modified to reflect the actual χ/Q during the release period using the methodology of Appendix C.

TABLE 5.1-2
AIRBORNE EFFLUENT DOSE FACTOR

Summations of dose per curie released were made for calculations over the pathways: ingestion of produce, leafy vegetables, milk, meat; inhalation of airborne radionuclides, and direct exposure to deposited radioactivity.

Dose factor - airborne release pathway (mrem/Ci released)								
H-3								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	0.00E+00
Teen	0.00E+00	2.69E-04	2.69E-04	2.69E-04	2.69E-04	2.69E-04	2.69E-04	0.00E+00
Child	0.00E+00	3.93E-04	3.93E-04	3.93E-04	3.93E-04	3.93E-04	3.93E-04	0.00E+00
Infant	0.00E+00	1.73E-04	1.73E-04	1.73E-04	1.73E-04	1.73E-04	1.73E-04	0.00E+00

Dose factor - airborne release pathway (mrem/Ci released)								
F-18								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.12E-04	0.00E+00	9.61E-04	0.00E+00	0.00E+00	0.00E+00	2.19E-06	2.23E-03
Teen	1.55E-04	0.00E+00	9.65E-04	0.00E+00	0.00E+00	0.00E+00	9.23E-06	2.23E-03
Child	2.06E-04	0.00E+00	9.69E-04	0.00E+00	0.00E+00	0.00E+00	3.70E-05	2.23E-03
Infant	1.63E-04	0.00E+00	9.62E-04	0.00E+00	0.00E+00	0.00E+00	2.53E-05	2.23E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Na-22								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.83E+00	4.83E+00	2.89E+01	4.83E+00	4.83E+00	4.83E+00	4.83E+00	3.79E+01
Teen	7.41E+00	7.41E+00	3.15E+01	7.41E+00	7.41E+00	7.41E+00	7.41E+00	3.79E+01
Child	1.50E+01	1.50E+01	3.90E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	3.79E+01
Infant	1.81E+01	1.81E+01	4.21E+01	1.81E+01	1.81E+01	1.81E+01	1.81E+01	3.79E+01

Dose factor - airborne release pathway (mrem/Ci released)								
Na-24								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	9.48E-04	9.48E-04	1.77E-02	9.48E-04	9.48E-04	9.48E-04	9.48E-04	7.64E-02
Teen	1.36E-03	1.36E-03	1.81E-02	1.36E-03	1.36E-03	1.36E-03	1.36E-03	7.64E-02
Child	2.37E-03	2.37E-03	1.91E-02	2.37E-03	2.37E-03	2.37E-03	2.37E-03	7.64E-02
Infant	3.14E-03	3.14E-03	1.99E-02	3.14E-03	3.14E-03	3.14E-03	3.14E-03	7.64E-02

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Sc-46								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.33E-02	2.59E-02	2.00E+00	0.00E+00	2.42E-02	0.00E+00	2.40E+00	2.69E+00
Teen	1.75E-02	3.41E-02	2.00E+00	0.00E+00	3.26E-02	0.00E+00	2.09E+00	2.69E+00
Child	2.23E-02	3.05E-02	2.00E+00	0.00E+00	2.70E-02	0.00E+00	1.32E+00	2.69E+00
Infant	1.56E-02	2.25E-02	2.00E+00	0.00E+00	1.48E-02	0.00E+00	1.35E-03	2.69E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Mn-54								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	2.32E-01	1.99E+00	0.00E+00	6.89E-02	4.15E-02	7.08E-01	2.28E+00
Teen	0.00E+00	3.34E-01	2.01E+00	0.00E+00	9.95E-02	5.89E-02	6.83E-01	2.28E+00
Child	0.00E+00	4.86E-01	2.07E+00	0.00E+00	1.36E-01	4.68E-02	4.08E-01	2.28E+00
Infant	0.00E+00	2.03E-02	1.95E+00	0.00E+00	4.47E-03	2.97E-02	7.38E-03	2.28E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Cr-51								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	0.00E+00	6.59E-03	2.68E-05	9.86E-06	4.83E-04	1.07E-02	7.73E-03
Teen	0.00E+00	0.00E+00	6.60E-03	3.39E-05	1.34E-05	7.03E-04	9.66E-03	7.73E-03
Child	0.00E+00	0.00E+00	6.66E-03	6.30E-05	1.72E-05	6.14E-04	5.81E-03	7.73E-03
Infant	0.00E+00	0.00E+00	6.58E-03	2.42E-05	5.31E-06	4.25E-04	1.02E-03	7.73E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Mn-56								
	Bone	Liver	T.Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	4.81E-08	1.27E-03	0.00E+00	5.31E-08	2.80E-04	6.01E-04	1.50E-03
Teen	0.00E+00	6.05E-08	1.27E-03	0.00E+00	6.61E-08	4.51E-04	1.70E-03	1.50E-03
Child	0.00E+00	6.26E-08	1.27E-03	0.00E+00	6.58E-08	3.90E-04	3.66E-03	1.50E-03
Infant	0.00E+00	4.57E-08	1.27E-03	0.00E+00	3.27E-08	3.72E-04	2.13E-03	1.50E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Fe-55								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.20E-01	2.21E-01	5.15E-02	0.00E+00	0.00E+00	1.25E-01	1.27E-01	0.00E+00
Teen	3.80E-01	2.70E-01	6.29E-02	0.00E+00	0.00E+00	1.74E-01	1.17E-01	0.00E+00
Child	8.65E-01	4.59E-01	1.42E-01	0.00E+00	0.00E+00	2.62E-01	8.49E-02	0.00E+00
Infant	7.36E-02	4.75E-02	1.27E-02	0.00E+00	0.00E+00	2.56E-02	6.02E-03	0.00E+00

OFFSITE DOSE CALCULATION MANUAL

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Fe-59								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.01E-01	4.73E-01	5.65E-01	0.00E+00	0.00E+00	1.62E-01	1.58E+00	4.50E-01
Teen	2.25E-01	5.24E-01	5.86E-01	0.00E+00	0.00E+00	2.10E-01	1.24E+00	4.50E-01
Child	4.62E-01	7.48E-01	7.56E-01	0.00E+00	0.00E+00	2.54E-01	7.80E-01	4.50E-01
Infant	6.14E-02	1.07E-01	4.26E-01	0.00E+00	0.00E+00	6.16E-02	5.16E-02	4.50E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Co-57								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	1.17E-02	4.93E-01	0.00E+00	0.00E+00	1.10E-02	2.97E-01	6.13E-01
Teen	0.00E+00	1.59E-02	5.00E-01	0.00E+00	0.00E+00	1.74E-02	2.97E-01	6.13E-01
Child	0.00E+00	2.57E-02	5.26E-01	0.00E+00	0.00E+00	1.50E-02	2.11E-01	6.13E-01
Infant	0.00E+00	4.38E-03	4.81E-01	0.00E+00	0.00E+00	1.13E-02	1.50E-02	6.13E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Co-58								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	3.14E-02	6.02E-01	0.00E+00	0.00E+00	2.75E-02	6.38E-01	6.23E-01
Teen	0.00E+00	4.00E-02	6.24E-01	0.00E+00	0.00E+00	3.99E-02	5.53E-01	6.23E-01
Child	0.00E+00	5.73E-02	7.07E-01	0.00E+00	0.00E+00	3.28E-02	3.35E-01	6.23E-01
Infant	0.00E+00	9.90E-03	5.57E-01	0.00E+00	0.00E+00	2.31E-02	2.49E-02	6.23E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Co-60								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	1.68E-01	3.06E+01	0.00E+00	0.00E+00	1.77E-01	3.16E+00	3.56E+01
Teen	0.00E+00	2.23E-01	3.07E+01	0.00E+00	0.00E+00	2.59E-01	2.90E+00	3.56E+01
Child	0.00E+00	3.28E-01	3.12E+01	0.00E+00	0.00E+00	2.10E-01	1.82E+00	3.56E+01
Infant	0.00E+00	5.86E-02	3.04E+01	0.00E+00	0.00E+00	1.34E-01	1.40E-01	3.56E+01

Dose factor - airborne release pathway (mrem/Ci released)								
Ni-63								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.39E+01	1.65E+00	8.00E-01	0.00E+00	0.00E+00	5.29E-03	3.45E-01	0.00E+00
Teen	2.93E+01	2.07E+00	9.92E-01	0.00E+00	0.00E+00	9.11E-03	3.29E-01	0.00E+00
Child	6.73E+01	3.60E+00	2.29E+00	0.00E+00	0.00E+00	8.16E-03	2.43E-01	0.00E+00
Infant	2.11E+01	1.30E+00	7.32E-01	0.00E+00	0.00E+00	6.19E-03	6.49E-02	0.00E+00

REFERENCE USE

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Ni-65								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	8.95E-08	1.19E-08	4.17E-04	0.00E+00	0.00E+00	1.66E-04	3.66E-04	4.85E-04
Teen	1.06E-07	1.39E-08	4.17E-04	0.00E+00	0.00E+00	2.78E-04	1.09E-03	4.85E-04
Child	1.64E-07	1.58E-08	4.17E-04	0.00E+00	0.00E+00	2.43E-04	2.49E-03	4.85E-04
Infant	7.17E-08	8.51E-09	4.17E-04	0.00E+00	0.00E+00	2.41E-04	1.49E-03	4.85E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Cu-64								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	1.12E-05	8.57E-04	0.00E+00	2.82E-05	2.01E-04	2.40E-03	9.65E-04
Teen	0.00E+00	1.40E-05	8.58E-04	0.00E+00	3.54E-05	3.30E-04	2.90E-03	9.65E-04
Child	0.00E+00	2.19E-05	8.65E-04	0.00E+00	5.28E-05	2.84E-04	2.11E-03	9.65E-04
Infant	0.00E+00	3.42E-05	8.68E-04	0.00E+00	5.79E-05	2.76E-04	1.15E-03	9.65E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Zn-65								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.21E+00	3.85E+00	2.79E+00	0.00E+00	2.57E+00	2.56E-02	2.42E+00	1.21E+00
Teen	1.63E+00	5.67E+00	3.69E+00	0.00E+00	3.63E+00	3.68E-02	2.40E+00	1.21E+00
Child	3.12E+00	8.31E+00	6.22E+00	0.00E+00	5.24E+00	2.95E-02	1.46E+00	1.21E+00
Infant	2.95E+00	1.01E+01	5.71E+00	0.00E+00	4.91E+00	1.92E-02	8.54E+00	1.21E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Zn-69								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.01E-06	5.76E-06	4.01E-07	0.00E+00	3.74E-06	2.73E-05	1.35E-06	0.00E+00
Teen	4.64E-06	8.83E-06	6.18E-07	0.00E+00	5.77E-06	4.70E-05	2.47E-05	0.00E+00
Child	1.08E-05	1.56E-05	1.45E-06	0.00E+00	9.49E-06	4.22E-05	1.29E-03	0.00E+00
Infant	1.93E-05	3.48E-05	2.59E-06	0.00E+00	1.45E-05	4.36E-05	3.23E-03	0.00E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Zn-69m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.99E-05	1.20E-04	3.07E-03	0.00E+00	7.26E-05	5.65E-04	1.13E-02	5.74E-03
Teen	7.60E-05	1.79E-04	3.07E-03	0.00E+00	1.09E-04	9.30E-04	1.49E-02	5.74E-03
Child	1.76E-04	3.00E-04	3.09E-03	0.00E+00	1.74E-04	8.08E-04	1.27E-02	5.74E-03
Infant	3.11E-04	6.35E-04	3.12E-03	0.00E+00	2.57E-04	7.93E-04	1.00E-02	5.74E-03

OFFSITE DOSE CALCULATION MANUAL

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Br-82								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	0.00E+00	5.44E-02	0.00E+00	0.00E+00	0.00E+00	8.47E-03	6.41E-02
Teen	0.00E+00	0.00E+00	5.89E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.41E-02
Child	0.00E+00	0.00E+00	7.04E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.41E-02
Infant	0.00E+00	0.00E+00	8.32E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.41E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Br-83								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	0.00E+00	1.65E-05	0.00E+00	0.00E+00	0.00E+00	6.89E-06	2.84E-03
Teen	0.00E+00	0.00E+00	1.96E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.84E-03
Child	0.00E+00	0.00E+00	2.34E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.84E-03
Infant	0.00E+00	0.00E+00	2.07E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.84E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Br-84								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	0.00E+00	2.59E-02	0.00E+00	0.00E+00	0.00E+00	1.11E-09	2.49E-01
Teen	0.00E+00	0.00E+00	2.60E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E-01
Child	0.00E+00	0.00E+00	2.63E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E-01
Infant	0.00E+00	0.00E+00	2.66E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Br-85								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	0.00E+00	4.95E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E-04
Teen	0.00E+00	0.00E+00	7.06E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E-04
Child	0.00E+00	0.00E+00	2.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E-04
Infant	0.00E+00	0.00E+00	4.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Rb-86								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	8.21E-01	3.95E-01	0.00E+00	0.00E+00	0.00E+00	1.61E-01	1.44E-02
Teen	0.00E+00	1.23E+00	5.92E-01	0.00E+00	0.00E+00	0.00E+00	1.82E-01	1.44E-02
Child	0.00E+00	2.18E+00	1.35E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-01	1.44E-02
Infant	0.00E+00	4.17E+00	2.07E+00	0.00E+00	0.00E+00	0.00E+00	1.07E-01	1.44E-02

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Rb-88								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	1.15E-05	5.22E-05	0.00E+00	0.00E+00	0.00E+00	9.92E-17	5.31E-05
Teen	0.00E+00	1.62E-05	5.45E-05	0.00E+00	0.00E+00	0.00E+00	8.66E-13	5.31E-05
Child	0.00E+00	1.67E-05	5.73E-05	0.00E+00	0.00E+00	0.00E+00	5.12E-07	5.31E-05
Infant	0.00E+00	1.65E-05	5.50E-05	0.00E+00	0.00E+00	0.00E+00	1.01E-05	5.31E-05

Dose factor - airborne release pathway (mrem/Ci released)								
Rb-89								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	7.60E-06	1.78E-04	0.00E+00	0.00E+00	0.00E+00	2.75E-19	2.07E-04
Teen	0.00E+00	1.04E-05	1.80E-04	0.00E+00	0.00E+00	0.00E+00	1.00E-14	2.07E-04
Child	0.00E+00	1.02E-05	1.81E-04	0.00E+00	0.00E+00	0.00E+00	5.61E-08	2.07E-04
Infant	0.00E+00	9.51E-06	1.79E-04	0.00E+00	0.00E+00	0.00E+00	2.02E-06	2.07E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Sr-89								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	7.63E+00	0.00E+00	2.19E-01	0.00E+00	0.00E+00	4.15E-02	1.23E+00	3.53E-05
Teen	1.16E+01	0.00E+00	3.34E-01	0.00E+00	0.00E+00	7.17E-02	1.40E+00	3.53E-05
Child	2.77E+01	0.00E+00	7.90E-01	0.00E+00	0.00E+00	6.40E-02	1.08E+00	3.53E-05
Infant	3.66E+00	0.00E+00	1.05E-01	0.00E+00	0.00E+00	6.02E-02	7.69E-02	3.53E-05

Dose factor - airborne release pathway (mrem/Ci released)								
Sr-90								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	5.10E+02	0.00E+00	1.25E+02	0.00E+00	0.00E+00	2.85E-01	1.47E+01	0.00E+00
Teen	6.33E+02	0.00E+00	1.56E+02	0.00E+00	0.00E+00	4.89E-01	1.77E+01	0.00E+00
Child	1.05E+03	0.00E+00	2.65E+02	0.00E+00	0.00E+00	4.38E-01	1.41E+01	0.00E+00
Infant	7.33E+01	0.00E+00	1.84E+01	0.00E+00	0.00E+00	3.34E-01	9.04E-01	0.00E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Sr-91								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.29E-04	0.00E+00	3.03E-03	0.00E+00	0.00E+00	1.08E-03	6.76E-03	3.53E-03
Teen	2.20E-04	0.00E+00	3.03E-03	0.00E+00	0.00E+00	1.80E-03	8.68E-03	3.53E-03
Child	4.09E-04	0.00E+00	3.03E-03	0.00E+00	0.00E+00	1.58E-03	6.06E-03	3.53E-03
Infant	5.29E-05	0.00E+00	3.02E-03	0.00E+00	0.00E+00	1.56E-03	2.24E-03	3.53E-03

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Sr-92								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	5.04E-07	0.00E+00	1.65E-03	0.00E+00	0.00E+00	4.89E-04	1.28E-03	3.15E-03
Teen	5.66E-07	0.00E+00	1.65E-03	0.00E+00	0.00E+00	8.14E-04	3.54E-03	3.15E-03
Child	9.08E-07	0.00E+00	1.65E-03	0.00E+00	0.00E+00	7.12E-04	7.20E-03	3.15E-03
Infant	3.12E-07	0.00E+00	1.65E-03	0.00E+00	0.00E+00	7.06E-04	4.15E-03	3.15E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Y-90								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	7.17E-05	0.00E+00	8.23E-06	0.00E+00	0.00E+00	5.03E-03	1.19E-01	7.45E-06
Teen	9.77E-05	0.00E+00	8.93E-06	0.00E+00	0.00E+00	8.69E-03	9.20E-02	7.45E-06
Child	1.39E-04	0.00E+00	1.00E-05	0.00E+00	0.00E+00	7.76E-03	5.63E-02	7.45E-06
Infant	9.77E-05	0.00E+00	8.93E-06	0.00E+00	0.00E+00	7.98E-03	3.26E-03	7.45E-06

Dose factor - airborne release pathway (mrem/Ci released)								
Y-91								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.78E-02	0.00E+00	1.98E-03	0.00E+00	0.00E+00	5.06E-02	2.26E+00	1.70E-03
Teen	2.55E-02	0.00E+00	2.19E-03	0.00E+00	0.00E+00	8.71E-02	2.44E+00	1.70E-03
Child	4.10E-02	0.00E+00	2.60E-03	0.00E+00	0.00E+00	7.79E-02	1.86E+00	1.70E-03
Infant	1.75E-02	0.00E+00	1.97E-03	0.00E+00	0.00E+00	7.27E-02	3.72E-03	1.70E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Y-91m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.58E-06	0.00E+00	2.31E-04	0.00E+00	0.00E+00	5.70E-05	1.05E-05	4.33E-04
Teen	6.15E-06	0.00E+00	2.31E-04	0.00E+00	0.00E+00	9.49E-05	2.91E-04	4.33E-04
Child	1.50E-05	0.00E+00	2.31E-04	0.00E+00	0.00E+00	8.34E-05	2.94E-02	4.33E-04
Infant	1.21E-08	0.00E+00	2.31E-04	0.00E+00	0.00E+00	8.27E-05	6.98E-05	4.33E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Y-92								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.35E-05	0.00E+00	4.38E-04	0.00E+00	0.00E+00	4.65E-04	5.83E-01	2.90E-02
Teen	5.80E-05	0.00E+00	4.39E-04	0.00E+00	0.00E+00	7.95E-04	1.58E+00	2.90E-02
Child	1.42E-04	0.00E+00	4.41E-04	0.00E+00	0.00E+00	7.09E-04	4.09E+00	2.90E-02
Infant	4.86E-07	0.00E+00	4.37E-04	0.00E+00	0.00E+00	7.27E-04	3.76E-03	2.90E-02

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Y-93								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.08E-04	0.00E+00	4.43E-04	0.00E+00	0.00E+00	1.44E-03	3.35E+00	6.58E-02
Teen	1.86E-04	0.00E+00	4.45E-04	0.00E+00	0.00E+00	2.47E-03	5.59E+00	6.58E-02
Child	4.53E-04	0.00E+00	4.52E-04	0.00E+00	0.00E+00	2.21E-03	6.69E+00	6.58E-02
Infant	4.45E-06	0.00E+00	4.40E-04	0.00E+00	0.00E+00	2.27E-03	4.95E-03	6.58E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Zr-95								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.79E-03	1.54E-03	3.45E-01	0.00E+00	2.42E-03	5.25E-02	1.64E+00	3.98E-01
Teen	6.16E-03	1.94E-03	3.45E-01	0.00E+00	2.85E-03	7.98E-02	1.35E+00	3.98E-01
Child	9.47E-03	2.08E-03	3.45E-01	0.00E+00	2.97E-03	6.62E-02	8.81E-01	3.98E-01
Infant	3.43E-03	8.27E-04	3.44E-01	0.00E+00	9.23E-04	5.19E-02	9.12E-04	3.98E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Zr-97								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.12E-06	6.31E-07	4.16E-03	0.00E+00	9.56E-07	2.34E-03	3.09E-02	4.84E-03
Teen	4.31E-06	8.52E-07	4.16E-03	0.00E+00	1.29E-06	3.85E-03	3.09E-02	4.84E-03
Child	5.98E-06	8.66E-07	4.16E-03	0.00E+00	1.24E-06	3.36E-03	1.95E-02	4.84E-03
Infant	4.45E-06	7.60E-07	4.16E-03	0.00E+00	7.69E-07	3.27E-03	4.16E-03	4.84E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Nb-95								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.39E-03	7.75E-04	1.92E-01	0.00E+00	7.67E-04	1.50E-02	3.30E+00	2.26E-01
Teen	1.39E-03	7.72E-04	1.92E-01	0.00E+00	7.48E-04	2.23E-02	1.99E+00	2.26E-01
Child	2.22E-03	8.65E-04	1.93E-01	0.00E+00	8.13E-04	1.82E-02	1.10E+00	2.26E-01
Infant	6.08E-04	2.49E-04	1.92E-01	0.00E+00	1.82E-04	1.42E-02	4.99E-02	2.26E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Nb-97								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.05E-06	5.17E-07	4.17E-04	0.00E+00	6.03E-07	7.12E-05	1.91E-03	3.20E-03
Teen	3.50E-06	8.68E-07	4.17E-04	0.00E+00	1.02E-06	1.17E-04	2.07E-02	3.20E-03
Child	8.49E-06	1.53E-06	4.17E-04	0.00E+00	1.70E-06	1.01E-04	4.73E-01	3.20E-03
Infant	1.01E-08	2.16E-09	4.17E-04	0.00E+00	1.69E-09	9.84E-05	7.98E-04	3.20E-03

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Mo-99								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	9.10E-03	7.34E-03	0.00E+00	2.06E-02	2.71E-03	2.85E-02	6.50E-03
Teen	0.00E+00	1.24E-02	7.97E-03	0.00E+00	2.84E-02	4.56E-03	3.02E-02	6.50E-03
Child	0.00E+00	2.06E-02	1.07E-02	0.00E+00	4.41E-02	4.02E-03	2.08E-02	6.50E-03
Infant	0.00E+00	3.82E-02	1.31E-02	0.00E+00	5.70E-02	4.00E-03	1.40E-02	6.50E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Tc-99m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.92E-09	8.24E-09	2.59E-04	0.00E+00	1.25E-07	2.27E-05	1.28E-04	2.96E-04
Teen	3.11E-09	8.68E-09	2.59E-04	0.00E+00	1.29E-07	3.42E-05	1.87E-04	2.96E-04
Child	5.95E-09	1.17E-08	2.59E-04	0.00E+00	1.69E-07	2.82E-05	1.49E-04	2.96E-04
Infant	5.14E-09	1.06E-08	2.59E-04	0.00E+00	1.14E-07	2.41E-05	6.33E-05	2.96E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Tc-101								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.16E-05	1.67E-05	2.08E-04	0.00E+00	3.01E-04	2.04E-05	5.06E-17	5.80E-04
Teen	1.99E-05	2.83E-05	3.23E-04	0.00E+00	5.12E-04	3.71E-05	4.87E-12	5.80E-04
Child	4.89E-05	5.12E-05	6.93E-04	0.00E+00	8.72E-04	4.44E-05	1.63E-04	5.80E-04
Infant	1.93E-12	2.44E-12	4.44E-05	0.00E+00	2.90E-11	1.73E-05	2.50E-05	5.80E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Ru-103								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.36E-02	0.00E+00	1.71E-01	0.00E+00	1.66E-01	1.50E-02	5.08E+00	1.77E-01
Teen	3.76E-02	0.00E+00	1.68E-01	0.00E+00	1.33E-01	2.32E-02	3.14E+00	1.77E-01
Child	7.01E-02	0.00E+00	1.79E-01	0.00E+00	1.77E-01	1.97E-02	1.81E+00	1.77E-01
Infant	6.20E-05	0.00E+00	1.52E-01	0.00E+00	1.30E-04	1.64E-02	5.05E-04	1.77E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Ru-105								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	6.19E-04	0.00E+00	2.07E-03	0.00E+00	7.99E-03	3.25E-04	3.80E-01	1.02E-02
Teen	1.06E-03	0.00E+00	2.23E-03	0.00E+00	1.34E-02	5.39E-04	8.59E-01	1.02E-02
Child	2.59E-03	0.00E+00	2.76E-03	0.00E+00	2.28E-02	4.72E-04	1.69E+00	1.02E-02
Infant	3.63E-08	0.00E+00	1.82E-03	0.00E+00	2.67E-08	4.65E-04	1.44E-03	1.02E-02

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Ru-106								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.65E+00	0.00E+00	8.01E-01	0.00E+00	3.18E+00	2.78E-01	1.06E+02	7.11E-01
Teen	1.49E+00	0.00E+00	7.81E-01	0.00E+00	2.88E+00	4.77E-01	7.16E+01	7.11E-01
Child	2.93E+00	0.00E+00	9.58E-01	0.00E+00	3.96E+00	4.25E-01	4.55E+01	7.11E-01
Infant	2.67E-03	0.00E+00	5.93E-01	0.00E+00	3.28E-03	3.43E-01	5.60E-03	7.11E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Rh-105								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.81E-02	3.52E-02	2.47E-02	0.00E+00	1.50E-01	5.72E-04	5.61E+00	7.74E-03
Teen	8.33E-02	6.02E-02	4.10E-02	0.00E+00	2.56E-01	9.71E-04	7.66E+00	7.74E-03
Child	2.04E-01	1.10E-01	9.53E-02	0.00E+00	4.37E-01	8.59E-04	6.80E+00	7.74E-03
Infant	7.15E-04	4.68E-04	1.83E-03	0.00E+00	1.30E-03	8.64E-04	1.22E-02	7.74E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Ag-110m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.10E-02	3.80E-02	4.85E+00	0.00E+00	7.47E-02	1.37E-01	1.54E+01	5.63E+00
Teen	6.28E-02	5.94E-02	4.86E+00	0.00E+00	1.13E-01	2.00E-01	1.66E+01	5.63E+00
Child	1.34E-01	9.04E-02	4.90E+00	0.00E+00	1.68E-01	1.62E-01	1.07E+01	5.63E+00
Infant	1.93E-01	1.41E-01	4.92E+00	0.00E+00	2.02E-01	1.09E-01	7.31E+00	5.63E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Sb-124								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.44E-01	2.73E-03	1.36E+00	3.50E-04	0.00E+00	1.85E-01	4.09E+00	4.02E+00
Teen	2.22E-01	4.09E-03	1.39E+00	5.03E-04	0.00E+00	3.07E-01	4.46E+00	4.02E+00
Child	5.11E-01	6.63E-03	1.48E+00	1.13E-03	0.00E+00	3.79E-01	3.19E+00	4.02E+00
Infant	6.72E-02	9.90E-04	1.32E+00	1.78E-04	0.00E+00	1.20E-01	2.06E-01	4.02E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Sb-125								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.07E-01	1.20E-03	5.38E+00	1.09E-04	0.00E+00	1.33E-01	1.17E+00	9.11E+00
Teen	1.61E-01	1.76E-03	5.39E+00	1.54E-04	0.00E+00	2.21E-01	1.24E+00	9.11E+00
Child	3.69E-01	2.84E-03	5.43E+00	3.42E-04	0.00E+00	2.73E-01	8.75E-01	9.11E+00
Infant	8.33E-02	8.05E-04	5.37E+00	1.04E-04	0.00E+00	9.99E-02	1.09E-01	9.11E+00

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Te-125m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.87E-01	1.40E-01	6.67E-02	1.16E-01	1.57E+00	9.30E-03	1.55E+00	3.96E-02
Teen	5.11E-01	1.84E-01	8.32E-02	1.43E-01	0.00E+00	1.59E-02	1.51E+00	3.96E-02
Child	1.17E+00	3.16E-01	1.70E-01	3.27E-01	0.00E+00	1.42E-02	1.13E+00	3.96E-02
Infant	5.10E-02	1.71E-02	2.18E-02	1.72E-02	0.00E+00	1.33E-02	2.46E-02	3.96E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Te-127								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.47E-06	1.61E-06	5.15E-06	3.31E-06	1.82E-05	1.93E-04	2.05E-03	4.60E-06
Teen	4.34E-06	1.55E-06	5.12E-06	3.00E-06	1.76E-05	3.32E-04	2.73E-03	4.60E-06
Child	8.13E-06	2.20E-06	5.93E-06	5.63E-06	2.31E-05	2.98E-04	1.98E-03	4.60E-06
Infant	1.25E-06	4.25E-07	4.45E-06	1.02E-06	3.03E-06	3.07E-04	7.48E-04	4.60E-06

Dose factor - airborne release pathway (mrem/Ci released)								
Te-127m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.19E+00	4.26E-01	1.54E-01	3.05E-01	4.84E+00	2.85E-02	4.00E+00	6.16E-02
Teen	1.48E+00	5.26E-01	1.85E-01	3.52E-01	6.01E+00	4.91E-02	3.70E+00	6.16E-02
Child	3.32E+00	8.94E-01	4.03E-01	7.94E-01	9.47E+00	4.39E-02	2.69E+00	6.16E-02
Infant	1.96E-01	6.50E-02	3.26E-02	5.66E-02	4.82E-01	3.89E-02	7.96E-02	6.16E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Te-129								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.48E-09	7.10E-10	3.68E-05	1.16E-09	5.56E-09	5.74E-05	4.65E-06	4.36E-05
Teen	2.11E-09	1.00E-09	3.68E-05	1.54E-09	7.88E-09	9.78E-05	4.79E-05	4.36E-05
Child	2.90E-09	1.04E-09	3.68E-05	2.12E-09	7.62E-09	8.71E-05	7.56E-04	4.36E-05
Infant	2.34E-09	1.03E-09	3.68E-05	2.00E-09	5.19E-09	8.89E-05	7.81E-04	4.36E-05

Dose factor - airborne release pathway (mrem/Ci released)								
Te-129m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.39E+00	5.19E-01	2.35E-01	4.78E-01	5.80E+00	3.44E-02	7.01E+00	9.07E-01
Teen	1.94E+00	7.20E-01	3.22E-01	6.26E-01	8.12E+00	5.86E-02	7.30E+00	9.07E-01
Child	4.53E+00	1.26E+00	7.18E-01	1.46E+00	1.33E+01	5.23E-02	5.53E+00	9.07E-01
Infant	1.39E-01	4.77E-02	3.66E-02	5.34E-02	3.48E-01	4.98E-02	8.46E-02	9.07E-01

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Te-131								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.47E-03	6.14E-04	5.56E-04	1.21E-03	6.43E-03	4.13E-05	2.09E-04	1.63E-03
Teen	2.52E-03	1.04E-03	8.80E-04	1.94E-03	1.10E-02	6.93E-05	2.07E-04	1.63E-03
Child	6.19E-03	1.89E-03	1.93E-03	4.73E-03	1.87E-02	6.09E-05	3.25E-02	1.63E-03
Infant	5.15E-10	2.44E-10	9.27E-05	4.69E-10	1.18E-09	6.11E-05	2.44E-04	1.63E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Te-131m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.30E-01	6.34E-02	7.45E-02	1.00E-01	6.43E-01	4.32E-03	6.32E+00	3.77E-02
Teen	2.21E-01	1.06E-01	1.10E-01	1.60E-01	1.11E+00	7.05E-03	8.53E+00	3.77E-02
Child	5.38E-01	1.86E-01	2.20E-01	3.83E-01	1.80E+00	6.10E-03	7.56E+00	3.77E-02
Infant	6.34E-04	2.56E-04	2.18E-02	5.18E-04	1.76E-03	5.90E-03	7.81E-03	3.77E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Te-132								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.92E-01	1.24E-01	1.27E-01	1.37E-01	1.20E+00	8.55E-03	5.89E+00	1.32E-02
Teen	3.19E-01	2.02E-01	2.00E-01	2.13E-01	1.94E+00	1.33E-02	6.42E+00	1.32E-02
Child	7.61E-01	3.37E-01	4.17E-01	4.91E-01	3.13E+00	1.12E-02	3.39E+00	1.32E-02
Infant	3.94E-03	1.95E-03	1.17E-02	2.88E-03	1.22E-02	1.01E-02	8.50E-03	1.32E-02

Dose factor - airborne release pathway (mrem/Ci released)								
I-131								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	7.16E-02	1.02E-01	8.29E-02	3.36E+01	1.76E-01	0.00E+00	2.69E-02	2.93E-02
Teen	6.57E-02	9.19E-02	7.35E-02	2.68E+01	1.58E-01	0.00E+00	1.81E-02	2.93E-02
Child	1.44E-01	1.45E-01	1.07E-01	4.80E+01	2.38E-01	0.00E+00	1.29E-02	2.93E-02
Infant	2.04E-01	2.40E-01	1.30E-01	7.89E+01	2.80E-01	0.00E+00	8.56E-03	2.93E-02

Dose factor - airborne release pathway (mrem/Ci released)								
I-132								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.44E-05	9.67E-05	1.78E-03	3.40E-03	1.54E-04	0.00E+00	1.21E-05	2.06E-03
Teen	4.73E-05	1.30E-04	1.80E-03	4.49E-03	2.05E-04	0.00E+00	3.78E-05	2.06E-03
Child	6.28E-05	1.21E-04	1.80E-03	5.74E-03	1.86E-04	0.00E+00	9.50E-05	2.06E-03
Infant	5.03E-05	1.05E-04	1.79E-03	5.03E-03	1.17E-04	0.00E+00	5.65E-05	2.06E-03

OFFSITE DOSE CALCULATION MANUAL

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
I-133								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.46E-03	2.53E-03	4.21E-03	3.71E-01	4.41E-03	0.00E+00	2.14E-03	4.19E-03
Teen	1.49E-03	2.52E-03	4.21E-03	3.53E-01	4.42E-03	0.00E+00	1.75E-03	4.19E-03
Child	2.87E-03	3.55E-03	4.78E-03	6.61E-01	5.91E-03	0.00E+00	1.35E-03	4.19E-03
Infant	3.16E-03	4.59E-03	4.79E-03	8.37E-01	5.40E-03	0.00E+00	7.45E-04	4.19E-03

Dose factor - airborne release pathway (mrem/Ci released)								
I-134								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.91E-05	5.13E-05	6.45E-04	8.85E-04	8.17E-05	0.00E+00	2.99E-08	7.45E-04
Teen	2.63E-05	6.88E-05	6.52E-04	1.17E-03	1.09E-04	0.00E+00	6.05E-07	7.45E-04
Child	3.48E-05	6.41E-05	6.57E-04	1.50E-03	9.79E-05	0.00E+00	2.83E-05	7.45E-04
Infant	2.73E-05	5.57E-05	6.47E-04	1.32E-03	6.19E-05	0.00E+00	3.83E-05	7.45E-04

Dose factor - airborne release pathway (mrem/Ci released)								
I-135								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	9.31E-05	2.43E-04	3.64E-03	1.56E-02	3.87E-04	0.00E+00	1.96E-04	4.14E-03
Teen	1.22E-04	3.12E-04	3.66E-03	2.05E-02	4.92E-04	0.00E+00	2.41E-04	4.14E-03
Child	1.69E-04	3.00E-04	3.69E-03	2.72E-02	4.61E-04	0.00E+00	1.63E-04	4.14E-03
Infant	1.23E-04	2.43E-04	3.64E-03	2.22E-02	2.70E-04	0.00E+00	6.06E-05	4.14E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Cs-134								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	6.68E+00	1.59E+01	2.26E+01	0.00E+00	5.15E+00	1.71E+00	2.78E-01	1.12E+01
Teen	1.06E+01	2.49E+01	2.12E+01	0.00E+00	7.90E+00	3.02E+00	3.09E-01	1.12E+01
Child	2.39E+01	3.93E+01	1.79E+01	0.00E+00	1.22E+01	4.37E+00	2.12E-01	1.12E+01
Infant	1.96E+01	3.66E+01	1.33E+01	0.00E+00	9.42E+00	3.86E+00	9.94E-02	1.12E+01

Dose factor - airborne release pathway (mrem/Ci released)								
Cs-134m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	8.36E-04	1.76E-03	9.41E-04	0.00E+00	9.54E-04	1.50E-04	6.19E-04	6.90E-05
Teen	1.40E-03	2.89E-03	1.53E-03	0.00E+00	1.61E-03	2.83E-04	1.92E-03	6.90E-05
Child	3.30E-03	4.89E-03	3.24E-03	0.00E+00	2.58E-03	4.27E-04	6.18E-03	6.90E-05
Infant	5.48E-06	8.72E-06	4.70E-05	0.00E+00	3.53E-06	8.31E-07	4.82E-06	6.90E-05

REFERENCE USE

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Cs-136								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.31E-01	1.31E+00	1.28E+00	0.00E+00	7.27E-01	9.97E-02	1.48E-01	4.73E-01
Teen	5.12E-01	2.02E+00	1.70E+00	0.00E+00	1.10E+00	1.73E-01	1.62E-01	4.73E-01
Child	1.14E+00	3.14E+00	2.38E+00	0.00E+00	1.67E+00	2.49E-01	1.10E-01	4.73E-01
Infant	3.54E-01	1.04E+00	7.33E-01	0.00E+00	4.15E-01	8.48E-02	1.58E-02	4.73E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Cs-137								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	9.52E+00	1.30E+01	2.30E+01	0.00E+00	4.42E+00	1.47E+00	2.52E-01	1.69E+01
Teen	1.57E+01	2.09E+01	2.18E+01	0.00E+00	7.12E+00	2.77E+00	2.97E-01	1.69E+01
Child	3.73E+01	3.57E+01	1.97E+01	0.00E+00	1.16E+01	4.18E+00	2.23E-01	1.69E+01
Infant	2.99E+01	3.49E+01	1.70E+01	0.00E+00	9.38E+00	3.80E+00	1.09E-01	1.69E+01

Dose factor - airborne release pathway (mrem/Ci released)								
Cs-138								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.17E-03	4.28E-03	2.70E-03	0.00E+00	3.14E-03	3.10E-04	1.82E-08	4.39E-03
Teen	3.69E-03	7.08E-03	4.13E-03	0.00E+00	5.23E-03	6.08E-04	3.21E-06	4.39E-03
Child	8.93E-03	1.24E-02	8.46E-03	0.00E+00	8.73E-03	9.40E-04	5.71E-03	4.39E-03
Infant	1.50E-05	2.32E-05	5.97E-04	0.00E+00	1.22E-05	1.94E-06	2.60E-05	4.39E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Ba-139								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.78E-03	2.69E-06	1.38E-04	0.00E+00	2.52E-06	4.62E-05	6.71E-03	6.76E-03
Teen	6.56E-03	4.61E-06	2.18E-04	0.00E+00	4.35E-06	8.00E-05	5.86E-02	6.76E-03
Child	1.61E-02	8.60E-06	4.95E-04	0.00E+00	7.51E-06	7.37E-05	9.31E-01	6.76E-03
Infant	1.76E-08	1.17E-11	2.75E-05	0.00E+00	7.04E-12	7.07E-05	6.06E-04	6.76E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Ba-140								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.09E-01	1.37E-04	3.60E-02	0.00E+00	4.67E-05	3.78E-02	2.29E-01	3.29E-02
Teen	1.19E-01	1.46E-04	3.65E-02	0.00E+00	4.94E-05	6.04E-02	1.88E-01	3.29E-02
Child	2.39E-01	2.10E-04	4.28E-02	0.00E+00	6.83E-05	5.18E-02	1.23E-01	3.29E-02
Infant	4.46E-02	4.46E-05	3.11E-02	0.00E+00	1.06E-05	4.74E-02	1.17E-02	3.29E-02

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Ba-141								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.83E-03	1.39E-06	2.01E-04	0.00E+00	1.29E-06	2.38E-05	8.66E-13	1.55E-03
Teen	3.16E-03	2.36E-06	2.45E-04	0.00E+00	2.19E-06	4.07E-05	6.75E-09	1.55E-03
Child	7.79E-03	4.36E-06	3.92E-04	0.00E+00	3.77E-06	6.03E-05	4.44E-03	1.55E-03
Infant	1.86E-09	1.28E-12	1.39E-04	0.00E+00	7.72E-13	3.53E-05	5.64E-05	1.55E-03

Dose factor - airborne release pathway (mrem/Ci released)								
La-140								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.17E-05	5.91E-06	2.70E-02	0.00E+00	0.00E+00	4.04E-03	6.96E-02	3.06E-02
Teen	1.57E-05	7.71E-06	2.70E-02	0.00E+00	0.00E+00	6.36E-03	5.51E-02	3.06E-02
Child	2.18E-05	7.60E-06	2.70E-02	0.00E+00	0.00E+00	5.42E-03	3.26E-02	3.06E-02
Infant	1.56E-05	6.17E-06	2.70E-02	0.00E+00	0.00E+00	4.98E-03	5.27E-03	3.06E-02

Dose factor - airborne release pathway (mrem/Ci released)								
La-142								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.98E-06	2.27E-06	1.97E-03	0.00E+00	0.00E+00	7.52E-05	1.65E-02	9.71E-03
Teen	8.44E-06	3.75E-06	1.97E-03	0.00E+00	0.00E+00	1.21E-04	1.14E-01	9.71E-03
Child	2.04E-05	6.50E-06	1.97E-03	0.00E+00	0.00E+00	1.03E-04	1.29E+00	9.71E-03
Infant	1.22E-08	4.48E-09	1.97E-03	0.00E+00	0.00E+00	9.77E-05	7.07E-04	9.71E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Ce-141								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	7.38E-04	5.01E-04	1.93E-02	0.00E+00	2.32E-04	1.07E-02	3.84E-01	2.16E-02
Teen	1.05E-03	7.02E-04	1.93E-02	0.00E+00	3.29E-04	1.82E-02	4.02E-01	2.16E-02
Child	1.65E-03	8.20E-04	1.93E-02	0.00E+00	3.59E-04	1.61E-02	3.02E-01	2.16E-02
Infant	8.32E-04	5.00E-04	1.92E-02	0.00E+00	1.58E-04	1.53E-02	3.79E-03	2.16E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Ce-143								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	6.71E-05	4.80E-02	4.80E-03	0.00E+00	2.18E-05	9.48E-04	1.80E+00	6.60E-02
Teen	1.15E-04	8.10E-02	4.81E-03	0.00E+00	3.74E-05	1.55E-03	2.44E+00	6.60E-02
Child	2.77E-04	1.48E-01	4.82E-03	0.00E+00	6.31E-05	1.37E-03	2.17E+00	6.60E-02
Infant	3.55E-06	5.06E-05	4.80E-03	0.00E+00	6.85E-07	1.38E-03	8.73E-04	6.60E-02

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
Ce-144								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.26E-01	5.24E-02	1.04E-01	0.00E+00	3.10E-02	2.31E-01	8.05E+00	1.13E-01
Teen	1.83E-01	7.56E-02	1.07E-01	0.00E+00	4.51E-02	3.96E-01	9.46E+00	1.13E-01
Child	2.91E-01	9.10E-02	1.13E-01	0.00E+00	5.04E-02	3.55E-01	7.37E+00	1.13E-01
Infant	9.58E-02	3.64E-02	1.03E-01	0.00E+00	1.61E-02	2.92E-01	6.97E-02	1.13E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Pr-143								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	5.11E-04	2.05E-04	2.53E-05	0.00E+00	1.18E-04	3.34E-03	1.75E+00	3.77E-01
Teen	8.14E-04	3.25E-04	4.05E-05	0.00E+00	1.89E-04	5.74E-03	2.16E+00	3.77E-01
Child	1.82E-03	5.46E-04	9.02E-05	0.00E+00	2.96E-04	5.15E-03	1.73E+00	3.77E-01
Infant	1.67E-04	6.23E-05	8.32E-06	0.00E+00	2.35E-05	5.14E-03	5.83E-04	3.77E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Pr-144								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	8.93E-10	3.70E-10	2.58E-06	0.00E+00	2.09E-10	3.01E-05	6.39E-16	2.96E-06
Teen	1.27E-09	5.22E-10	2.58E-06	0.00E+00	2.99E-10	5.20E-05	6.98E-12	2.96E-06
Child	1.77E-09	5.48E-10	2.58E-06	0.00E+00	2.90E-10	4.64E-05	5.84E-06	2.96E-06
Infant	1.42E-09	5.48E-10	2.58E-06	0.00E+00	1.99E-10	4.78E-05	1.27E-04	2.96E-06

Dose factor - airborne release pathway (mrem/Ci released)								
Nd-147								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	8.95E-05	1.03E-04	2.00E-02	0.00E+00	6.04E-05	2.62E-03	1.51E-01	2.00E-01
Teen	1.22E-04	1.33E-04	2.00E-02	0.00E+00	7.80E-05	4.42E-03	1.15E-01	2.00E-01
Child	1.85E-04	1.49E-04	2.00E-02	0.00E+00	8.22E-05	3.90E-03	7.33E-02	2.00E-01
Infant	9.45E-05	9.69E-05	2.00E-02	0.00E+00	3.75E-05	3.83E-03	4.73E-04	2.00E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Eu-152								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.32E-02	2.45E-01	3.62E+01	0.00E+00	4.67E-02	3.26E-02	1.38E+00	6.86E+01
Teen	4.20E-02	1.02E-02	3.62E+01	0.00E+00	4.73E-02	4.76E-02	1.23E+00	6.86E+01
Child	6.02E-02	1.10E-02	3.62E+01	0.00E+00	4.64E-02	3.96E-02	8.25E-01	6.86E+01
Infant	1.30E-02	2.95E-03	3.62E+01	0.00E+00	9.90E-03	2.46E-02	5.31E-04	6.86E+01

Table 5.1-2

Dose factor - airborne release pathway (mrem/Ci released)								
W-187								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.08E-03	3.41E-03	7.22E-03	0.00E+00	0.00E+00	3.45E-04	1.12E+00	2.79E-02
Teen	6.98E-03	5.69E-03	8.03E-03	0.00E+00	0.00E+00	5.63E-04	1.54E+00	2.79E-02
Child	1.69E-02	1.00E-02	1.05E-02	0.00E+00	0.00E+00	4.88E-04	1.41E+00	2.79E-02
Infant	1.13E-05	7.88E-06	6.04E-03	0.00E+00	0.00E+00	4.71E-04	8.79E-04	2.79E-02

Dose factor - airborne release pathway (mrem/Ci released)								
U-235								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.06E+01	0.00E+00	1.04E+01	0.00E+00	9.47E+00	4.66E+00	3.87E+00	1.06E+01
Teen	6.45E+01	0.00E+00	1.19E+01	0.00E+00	1.51E+01	8.03E+00	4.59E+00	1.06E+01
Child	1.54E+02	0.00E+00	1.73E+01	0.00E+00	2.53E+01	7.17E+00	3.58E+00	1.06E+01
Infant	1.17E+01	0.00E+00	8.84E+00	0.00E+00	2.49E+00	5.46E+00	1.90E-01	1.06E+01

Dose factor - airborne release pathway (mrem/Ci released)								
U-238								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.88E+01	0.00E+00	2.33E+00	0.00E+00	8.86E+00	4.36E+00	2.72E+00	2.47E-01
Teen	6.17E+01	0.00E+00	3.70E+00	0.00E+00	1.41E+01	7.50E+00	3.23E+00	2.47E-01
Child	1.48E+02	0.00E+00	8.79E+00	0.00E+00	2.37E+01	6.73E+00	2.53E+00	2.47E-01
Infant	1.12E+01	0.00E+00	8.63E-01	0.00E+00	2.33E+00	5.09E+00	1.34E-01	2.47E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Np-239								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	5.00E-05	4.92E-06	5.54E-03	0.00E+00	1.53E-05	4.47E-04	9.55E-01	9.52E-03
Teen	8.79E-05	8.29E-06	5.55E-03	0.00E+00	2.60E-05	7.71E-04	1.27E+00	9.52E-03
Child	2.11E-04	1.52E-05	5.55E-03	0.00E+00	4.39E-05	6.91E-04	1.10E+00	9.52E-03
Infant	4.42E-06	3.95E-07	5.54E-03	0.00E+00	7.88E-07	7.07E-04	3.14E-04	9.52E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Am-241								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.34E+02	4.76E+01	1.03E+01	0.00E+00	6.70E+01	5.76E+00	3.48E+00	2.94E+00
Teen	1.46E+02	5.59E+01	1.11E+01	0.00E+00	7.31E+01	9.99E+00	4.12E+00	2.94E+00
Child	1.37E+02	6.14E+01	1.11E+01	0.00E+00	5.98E+01	8.88E+00	3.22E+00	2.94E+00
Infant	3.07E+01	1.41E+01	3.56E+00	0.00E+00	1.32E+01	6.76E+00	2.58E-03	2.94E+00

5.1.3 Atmospheric Release Mode: Noble Gases

The dose calculations for demonstration of compliance with the 10 CFR 50, Appendix I dose limits for noble gases released to the atmosphere will be done in the manner similar to the liquid release dose calculations described in Section 5.1.1. The total doses to the air, skin, and whole body resulting from the release of noble gases is compared to the corresponding Appendix limits. Noble gases released in liquids are to be added to the atmospherically released noble gases for Appendix I dose compliance calculations.

The doses are calculated using the following formula:

$$API = \Sigma\ Dose_{ti} = \Sigma\ (TDF_{ti} \times C_i) \leq K_t\ mrem$$

where

API = the Appendix I dose for compliance evaluation in mrem

$Dose_{ti}$ = the dose to the applicable target (t) from radionuclide (i)

TDF_{ti} = total dose factor from Table 5.1-3 in mrem/Ci for the specific target (t) from radionuclide (i) based on the maximum annual average χ/Q at the site boundary

C_i = curies of radionuclide (i) released

K_t = the noble gas Appendix I dose limit for target (t)

The methodology used to obtain the TDF values are given in Appendix C.

Instead of using the precalculated total dose factors, the Appendix I dose calculation may be modified to reflect actual χ/Q values during the release using the methodology of Appendix C.

TABLE 5.1-3
ACTIVITY TO DOSE CONVERSION FACTORS FOR NOBLE GASES

(Highest Annual Average χ/Q)				
Nuclide	Beta Air (mrad/Ci)	Gamma Air (mrad/Ci)	Skin (mrem/Ci)	Whole Body (mrem/Ci)
AR-41	1.56E-04	4.42E-04	6.19E-04	4.20E-04
KR-83M	1.37E-05	9.18E-07	1.02E-06	3.59E-09
KR-85M	9.37E-05	5.85E-05	1.34E-04	5.56E-05
KR-85	9.27E-05	8.18E-07	6.46E-05	7.66E-07
KR-87	4.90E-04	2.93E-04	7.88E-04	2.81E-04
KR-88	1.39E-04	7.23E-04	9.15E-04	6.99E-04
KR-89	5.04E-04	8.23E-04	1.39E-03	7.89E-04
KR-90	3.72E-04	7.75E-04	1.21E-03	7.42E-04
XE-131M	5.28E-05	7.42E-06	3.09E-05	4.35E-06
XE-133M	7.04E-05	1.55E-05	6.45E-05	1.19E-05
XE-133	4.99E-05	1.68E-05	3.32E-05	1.40E-05
XE-135M	3.51E-05	1.60E-04	2.11E-04	1.48E-04
XE-135	1.17E-04	9.13E-05	1.90E-04	8.61E-05
XE-137	6.04E-04	7.18E-05	6.60E-04	6.75E-05
XE-138	2.26E-04	4.38E-04	6.82E-04	4.20E-04

6.0 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Technical Specification 5.5.1.b requires the ODCM to contain the radiological environmental monitoring activities. A complete description of the PBNP radiological environmental monitoring program, including procedures and responsibilities, is contained in the PBNP Environmental Manual. The latter is hereby incorporated into the Offsite Dose Calculation Manual (ODCM) by reference.

7.0 RADIOLOGICAL EFFLUENT CONTROLS PROGRAM

Technical Specifications 5.5.1.b and 5.5.4 require the ODCM to contain the radiological effluent controls program. A complete description of the PBNP radiological effluent controls program is contained in the PBNP Radiological Effluent Control Manual. The latter is hereby incorporated in the ODCM by reference.

8.0 RADIOLOGICAL IMPACT EVALUATION OF SEWAGE TREATMENT SLUDGE DISPOSAL

The methodology for determining the radiological impact of contaminated sewage treatment sludge is presented in this section. The evaluation must be made prior to every land application of sewage treatment plant (STP) sludge that contains licensed material. Sludge and other STP material which does not contain licensed materials may be disposed of by any legal method without prior radiological analysis.

8.1 Basis, Commitments, and Actions

8.1.1 Basis

With the discovery that the PBNP STP sludge contained licensed material, Wisconsin Electric applied for NRC approval to dispose of the sludge by land application on land within the PBNP site boundary pursuant to 10 CFR 20.302(a). Wisconsin Electric committed to gamma isotopic analysis (GIA) of the sludge to measure the concentrations of licensed material in the STP sludge and to compare the results to concentration limits prior to each disposal [letter dated October 8, 1987 (VPNPD-87-430, NRC-87-104)]. In addition, the dose to the maximally exposed individual of the general public and to the inadvertent intruder would be evaluated for the appropriate exposure pathways.

8.1.2 Basis for NRC Commitment Modification

Pursuant to NRC guidance, the sludge is clean if no licensed materials are found when analyzed under conditions necessary to achieve the environmental LLDs (NRC HPPOS 221). Clean sludge is not under NRC jurisdiction and may be disposed of by any legal method without prior radioanalyses. Therefore, if the sludge is clean and there is no pathway to the STP from the RCA, or pathways are administratively controlled to prevent the transfer of licensed materials to the STP, there is no need to analyze the sludge prior to any disposal.

Since the 1987 commitment, engineering modifications and administrative controls have eliminated the pathways from the RCA to the STP. Three subsequent sludge GIAs (a total of eight STP samples) utilizing the analytical parameters required to achieve environmental lower limit of detection (LLD) found only naturally occurring radionuclides. In each analysis, the licensed materials were below the minimum detectable activity for the particular measurement and below the required LLDs. These results verify the efficiency of the modifications and administrative controls in eliminating pathways from the RCA to the STP. Therefore, because there is no longer any reason to believe that the PBNP STP sewage contains licensed material and there are no pathways from the RCA to the STP, the sewage may be disposed of by any legal method without GIA prior to each disposal.

8.1.3 Modification

Periodic gamma isotopic analyses (GIA) of the STP sludge shall occur at a frequency set forth in the Chemistry Analytical Methods & Procedures (CAMP). This may include analyses prior to disposal depending on the results from the periodic analyses. The GIA of the STP sludge shall meet the LLD criteria of normal liquid effluents. The detection of any licensed material in the sludge during the periodic GIA shall necessitate returning to the GIA prior to disposal in order to evaluate the radiological consequences of the disposal. The GIA prior to each disposal shall continue until such time that the sludge can be shown, using environmental LLD criteria, not to contain licensed material.

Also, re-initiation of the 1987 commitment to analyze the STP sludge prior to each disposal shall be required if plant conditions change in a manner which would lead one to believe that the STP sludge may be contaminated. An example of such a condition is the opening of valve STP-009 which is controlled by a danger tag. Again, reversion to a CAMP controlled frequency can occur only upon verification that no licensed material is in the sludge pursuant to the environmental LLD criteria.

8.1.4 Exposure Evaluations

If the sludge contains licensed material, the 1987 commitment requires that the appropriate exposure pathways be evaluated prior to each application of sludge to insure that the dose to the maximally exposed member of the general public is maintained at less than 1 mrem/year and that to the inadvertent intruder, at less than 5 mrem/year. Also, the measured concentration shall be compared to the liquid maximum effluent concentrations of Appendix B to 10 CFR 20.

The exposure pathways evaluated for the maximally exposed individual are the following:

1. External whole body exposure due to a ground plane source of radionuclides.
2. Milk ingestion pathway from cows fed alfalfa grown on plot.
3. Meat ingestion pathway from cows fed alfalfa grown on plot.

4. Vegetable ingestion pathway from vegetables grown on plot.

5. Inhalation of radioactivity resuspended in air above plot.

6. Pathways associated with a release to Lake Michigan. These pathways are ingestion of potable water at the Two Rivers, Wisconsin municipal water supply, ingestion of fish from edge of initial mixing zone of radionuclide release, ingestion of fresh and stored vegetables irrigated with water from Lake Michigan, ingestion of milk and meat from cows utilizing Lake Michigan as drinking water source, swimming and boating activities at the edge of the initial mixing zone, and shoreline deposits.

The exposure pathways evaluated for the inadvertent intruder are the same as items 1, 4, 5, and 6 identified above for the maximally exposed individual.

8.2 Procedure

The following steps are to be performed by the responsible Chemistry Specialist for each contaminated sewage treatment sludge disposal:

8.2.1 Determine the radionuclide concentrations in each representative sewage treatment sludge sample. The minimum number of representative samples required is three from each sludge storage tank. The average of all statistically valid concentration determinations will be utilized in determining the sludge storage tank concentration values.

8.2.2 Verify that the concentration of each radionuclide meets the concentration and activity limit criteria. The methodology for determining compliance with the concentration and activity limit criteria are contained in Wisconsin Electric letter VPNPD 87-430.

8.2.3 Verify that the proposed disposal of the sewage treatment sludge will maintain doses within the applicable limits. This calculation will include radionuclides disposed of in previous sludge applications. The activity from these prior disposals will be corrected for radiological decay prior to performing dose calculations for the meat, milk, and vegetable ingestion pathways, the inhalation of resuspended radionuclides, and all pathways associated with a potential release to Lake Michigan. The residual radioactivity will be corrected, if applicable, for the mixing of radionuclides in the soil prior to performing external exposure calculations.

QAD, a nationally recognized computer code, will be used to calculate the dose rate due to standing on a plot of land utilized for sludge disposal in which the radionuclides from prior disposals have been incorporated into the plot by plowing. This calculated dose rate will be used to assess the radiological consequences from prior disposals with the consequences of proposed future disposals. The total radiological dose consequence of the past and the proposed disposal will be compared to the applicable limits to insure the dose is maintained at or below the limits.

The methodology for calculating the radiological impact of the sewage treatment sludge disposal is contained in Wisconsin Electric letter VPNPD 87-430.

8.2.4 Inform the appropriate Chemistry Specialist that the sewage treatment sludge disposal may proceed after verifying that the sewage treatment sludge meets the concentration, activity, and dose limits.

8.2.5 All calculations shall be included with the sewage treatment sludge disposal record.

8.3 Administrative Requirements

8.3.1 Complete records of each contaminated disposal shall be kept as follows:

a. Radionuclide concentration of the sludge.

b. Total volume of sludge disposed.

c. The identity of the plot used for the disposal.

d. Dose calculation results.

e. Results of annual chemical composition determination.

8.3.2 Modifications to the WE application as documented in the October 8, 1987, letter shall be processed in accordance with NP 5.1.7, "Regulatory Commitment Management." (CCE 2001-013)

a. Commitment Change -1

Section 3.2 of Attachment II of the submittal states that physical and chemical properties of the sludge would be determined prior the each land application. Pursuant to a change in the PBNP WPDES Permit, non-radiological properties are now determined annually instead of per application. The frequency for radiological characterization did not change. (See CCE 2002-002)

b. Commitment Change -2

In Section 3.3 of Attachment II of the submittal letter, the annual disposal rate was..." limited to 4,000 gallons/acre, provided WDNR chemical composition, NRC dose guidelines and activity limits are maintained...." Modification 2 removes the 4,000 gallon limit and makes the application unlimited provided the WDNR and NRC constraints are met. (See CCE 2002-004)

c. Commitment Change -3

In Section 3.2 of Attachment II of NRC submittal letter dated October 8, 1987, Wisconsin Electric committed to gamma isotopic analysis (GIA) to determine the concentration of licensed material in sewage treatment plant (STP) sludge prior to each disposal. Pursuant to NRC HPPOS-221 guidance, the sludge has been shown to be clean on three different occasions after pathways from the RCA to the STP were eliminated by plant modifications and administrative controls. Pursuant to HPPOS, the sludge analyses were done under the conditions necessary to achieve the environmental LLDs. Only naturally occurring radionuclides were found and licensed material was below the minimum detectable concentration. This indicates that the former pathways from the RCA to the STP had been eliminated. Therefore, there is not need to continue the analyses because there is no RCA to STP pathway and there is no reason to believe that the sewage contains licensed material. Hence, the commitment to analyze STP sludge prior to every disposal is modified and replaced with periodic analyses at a frequency set by CAMP 914. However, if plant conditions change in a manner which places the STP sewage outside the guidance parameters which allowed for the discontinuance of analyses, the sewage must be analyzed prior to each disposal until it again is shown not to contain licensed material. (See CCE-2002-3)

APPENDIX A

DERIVATION OF LIQUID RELEASE PATHWAY

EFFECTIVE MAXIMUM EFFLUENT CONCENTRATION

A.1.0 Derivation of Liquid Release Effective Maximum Effluent Concentration

A.1.1 Source Term

The effective maximum effluent concentration is calculated from the annual releases via liquids for the years 1985-1991 (Table A-1). Although Na-24 was discharged in 1985, it was excluded from the isotopic mixture because it is not a radionuclide which would be normally found in PBNP effluent. Na-24 appears in the effluent because it was used for tests run on the steam system. Tritium also was omitted from the initial calculation because its production is largely independent from the appearance of the fission products in the effluent.

A.1.2 Effective Maximum Effluent Concentration

The effective maximum effluent concentration (EMEC) was calculated using the formula given in Section 3.6

$$EMEC = \Sigma C_i \; / \; \Sigma (C_i/MEC_i) \text{ or } \Sigma C_i * 1/SOF$$

where:

SOF = $\Sigma C_i/MEC_i$ is the summation of fractions for the annual effluent isotopic release

C_i = concentration of radionuclide "i" (μCi/ml) in effluent (annual discharge/total volume of discharge)

MEC_i = maximum effluent concentration for unrestricted areas from Appendix B, Table 2, Column 2 of the revised 10 CFR 20.

The SOF for radionuclides in liquid effluent for the years 1985 through 1991 were calculated with and without H-3 and used to calculate the EMEC for the same years (Table B-2). The average EMEC without H-3 is 4.29E-06 μCi/cc. This is the maximum concentration of non H-3 radionuclides in a mixture that could be released in liquid effluent without the SOF exceeding one (1).

However, the 10 CFR 20 Appendix B criterion is that the SOF for all radionuclides, including H-3 which can not be measured by the liquid effluent NaI RMS monitors, be less than or equal to one (1). Therefore, the above equation, modified by a factor of 0.70 to account for H-3, becomes

$$EMEC = 0.70\,\Sigma C_i \; / \; \Sigma (C_i/MEC_i) \text{ or } \Sigma C_i * 0.70/SOF.$$

The EMEC becomes

EMEC = 0.70 * 4.29E-06 = 3.00E-06 µCi/cc.

Only three radionuclides identified in PBNP liquid effluent have a lower MEC (10 CFR 20, Appendix B, Table 2). They are I-131 (1E-06), Cs-134 (9E-07), and Cs-137 (1E-06).

By restricting the non-tritium radionuclides to 70% of their calculated EMEC, the H-3 concentration can be discharged at 30% of its MEC or 3.00E-04 µCi/cc without exceeding the SOF criterion of 10 CFR 20, Appendix B for the total liquid effluent isotopic mixture.

TABLE A-1
CURIES RELEASED IN LIQUIDS

LIQUID RELEASES								
NUCLIDE	MEC uCi/cc	1985	1986	1987	1988	1989	1990	1991
H-3	1.00E-03	8.05E+02	8.11E+02	7.09E+02	3.57E+02	5.59E+02	8.72E+02	7.87E+02
I-131	1.00E-06	1.02E-01	3.74E-02	1.04E-02	1.40E-03	1.77E-03	1.53E-04	1.83E-03
I-132	1.00E-04	6.15E-02	7.25E-02	5.82E-02	1.03E-03	8.15E-04	4.45E-05	9.41E-03
I-133	7.00E-06	1.27E-01	1.49E-01	1.04E-01	1.21E-02	8.11E-03	3.01E-03	1.01E-02
I-134	4.00E-04	3.18E-02	4.39E-02	3.97E-02	2.29E-04	6.83E-04		
I-135	3.00E-05	1.04E-01	1.34E-01	1.23E-01	4.48E-04	8.21E-04		
AG-110M	6.00E-06	2.55E-05	2.84E-04	3.09E-03	9.85E-04	4.70E-04	1.71E-04	4.06E-04
BA-133	2.00E-05							
BA-139	2.00E-04			8.63E-06	2.47E-04			
BA-140	8.00E-06	6.90E-06		4.45E-05	6.13E-05			
CD-109	6.00E-06		6.33E-05	1.31E-04				
CE-139	7.00E-05							
CE-141	3.00E-05	1.31E-03		7.50E-04				
CE-144	3.00E-06		1.37E-03	2.08E-03	4.76E-04	1.59E-04	9.47E-06	9.64E-06
CO-56	6.00E-06							
CO-57	6.00E-05	2.52E-03	1.33E-04	3.21E-04	5.07E-05	6.90E-07	4.08E-06	
CO-58	2.00E-05	4.05E-01	9.02E-03	3.36E-02	6.81E-03	3.12E-03	3.25E-04	2.93E-03
CO-60	3.00E-06	2.88E-01	2.85E-02	6.34E-02	2.04E-02	1.54E-02	1.41E-03	5.53E-03
CR-51	5.00E-04	2.71E-02	3.16E-04	1.58E-02	5.31E-05	4.44E-04	8.71E-05	
CS-134	9.00E-07	4.76E-02	6.92E-03	1.18E-03	4.96E-04			1.49E-03
CS-134M	2.00E-03				3.59E-04	5.97E-06		4.67E-04
CS-136	6.00E-06							
CS-137	1.00E-06	9.60E-02	2.11E-02	7.54E-03	8.63E-03	2.80E-03	1.94E-03	8.93E-03
CS-138	4.00E-04	1.11E-03	5.48E-03	3.24E-03				
F-18	7.00E-04		1.00E-02	1.67E-02	7.56E-04	1.66E-03	2.26E-03	4.06E-04
FE-59	1.00E-05			2.76E-04				
LA-140	9.00E-06							
MN-54	3.00E-05	7.46E-03	1.18E-03	4.68E-03	1.54E-04	2.68E-04	3.10E-05	1.96E-04
M0-99	2.00E-05				3.70E-05			
NB-95	3.00E-05	6.28E-03	6.65E-04	3.21E-03	1.61E-04	2.33E-06	8.68E-05	
NB-97	3.00E-04	1.35E-03	5.22E-04	6.16E-05	1.06E-05	3.90E-06	8.80E-06	5.30E-06
RB-88	4.00E-04	8.46E-05	1.11E-02	3.33E-03				
RB-89	9.00E-04		7.98E-04	2.34E-04				
RU-103	3.00E-05	3.59E-03	1.68E-06	8.41E-04	5.86E-05			
RU-106	3.00E-06	8.07E-04	2.88E-03	7.33E-03	1.04E-04			
SB-124	7.00E-06	3.86E-02	2.96E-04	1.42E-04	2.34E-04			
SB-125	3.00E-05	1.12E-02	1.20E-03	1.95E-03	1.00E-03	2.12E-02	1.28E-05	1.08E-02
SN-113	3.00E-05	1.07E-03	4.20E-05	5.13E-04	3.21E-04			3.07E-06
SR-89	8.00E-06	2.27E-04	3.46E-05	3.89E-03	2.68E-03	8.69E-06		
SR-90	5.00E-07	1.29E-03	2.28E-04	2.80E-04	3.50E-04	2.55E-04		
TC-99M	1.00E-03	1.75E-05	3.75E-06		3.30E-05			
TC-101	2.00E-03			1.10E-05				
TE-131	8.00E-05				7.98E-05			
TE-132	9.00E-06	5.83E-07	6.94E-05	2.74E-05	7.19E-06			1.74E-04
W-187	3.00E-05				3.41E-05			
Y-91M	2.00E-03							
ZN-65	5.00E-06			5.15E-05				
ZR-95	2.00E-05	7.95E-05	2.61E-04	2.45E-03		1.58E-05		
ZR-97	9.00E-06	1.49E-06	3.09E-06		1.74E-05			
TOTAL CI		8.06E+02	8.12E+02	7.10E+02	3.57E+02	5.59E+02	8.72E+02	7.87E+02
TOTAL W/O H-3		1.37E+00	5.39E-01	5.12E-01	5.99E-02	5.65E-02	9.57E-03	5.42E-02

TABLE A-2
FRACTIONAL MEC IN LIQUID EFFLUENT

NUCLIDE	MEC uCi/cc	1985	1986	1987	1988	1989	1990	1991
H-3	1.00E-03	1.27E-03	1.25E-03	1.04E-03	5.17E-04	8.36E-04	1.26E-03	1.22E-03
I-131	1.00E-06	1.61E-04	5.75E-05	1.52E-05	2.03E-06	2.65E-06	2.21E-07	2.84E-06
I-132	1.00E-04	9.70E-07	1.12E-06	8.53E-07	1.49E-08	1.22E-08	6.43E-10	1.46E-07
I-133	7.00E-06	2.86E-05	3.27E-05	2.18E-05	2.51E-06	1.73E-06	6.21E-07	2.24E-06
I-134	4.00E-04	1.25E-07	1.69E-07	1.46E-07	8.30E-10			2.65E-09
I-135	3.00E-05	5.47E-06	6.87E-06	6.01E-06	2.16E-08			4.24E-08
AG-110M	6.00E-06	6.70E-09	7.28E-08	7.55E-07	2.38E-07	1.17E-07	4.12E-08	1.05E-07
BA-133	2.00E-05							
BA-139	2.00E-04			6.33E-11	1.79E-09			
BA-140	8.00E-06	1.36E-09	0.00E+00	8.16E-09	1.11E-08			
CD-109	6.00E-06		1.62E-08		3.16E-08			
CE-139	7.00E-05							
CE-141	3.00E-05	6.89E-08		3.67E-08				
CE-144	3.00E-06		7.03E-07	1.02E-06	2.30E-07	7.92E-08	4.56E-09	4.98E-09
CO-56	6.00E-06							
CO-57	6.00E-05	6.62E-08	3.41E-09	7.84E-09	1.22E-09	1.72E-11	9.83E-11	
CO-58	2.00E-05	3.19E-05	6.94E-07	2.46E-06	4.93E-07	2.33E-07	2.35E-08	2.27E-07
CO-60	3.00E-06	1.51E-04	1.46E-05	3.10E-05	9.86E-06	7.67E-06	6.79E-07	2.86E-06
CR-51	5.00E-04	8.55E-08	9.72E-10	4.63E-08	1.54E-10	1.33E-09	2.52E-10	
CS-134	9.00E-07	8.34E-05	1.18E-05	1.92E-06	7.99E-07			2.57E-06
CS-134M	2.00E-03				2.60E-10	4.46E-12		3.62E-10
CS-136	6.00E-06							
CS-137	1.00E-06	1.51E-04	3.25E-05	1.11E-05	1.25E-05	4.19E-06	2.80E-06	1.38E-05
CS-138	4.00E-04	4.38E-09	2.11E-08	1.19E-08				
F-18	7.00E-04		2.20E-08	3.50E-08	1.57E-09	3.54E-09	4.67E-09	8.99E-10
FE-59	1.00E-05			4.05E-08				
LA-140	9.00E-06							
MN-54	3.00E-05	3.92E-07	6.05E-08	2.29E-07	7.44E-09	1.34E-08	1.49E-09	1.01E-08
M0-99	2.00E-05				2.68E-09			
NB-95	3.00E-05	3.30E-07	3.41E-08	1.57E-07	7.78E-09	1.16E-10	4.18E-09	
NB-97	3.00E-04	7.10E-09	2.68E-09	3.01E-10	5.12E-11	1.94E-11	4.24E-11	2.74E-11
RB-88	4.00E-04	3.34E-10	4.27E-08	1.22E-08				
RB-89	9.00E-04		1.36E-09	3.81E-10				
RU-103	3.00E-05	1.89E-07	8.62E-11	4.11E-08	2.83E-09			
RU-106	3.00E-06	4.24E-07	1.48E-06	3.58E-06	5.02E-08			
SB-124	7.00E-06	8.70E-06	6.51E-08	2.97E-08	4.84E-08			
SB-125	3.00E-05	5.89E-07	6.15E-08	9.53E-08	4.83E-08	1.06E-06	6.17E-10	5.58E-07
SN-113	3.00E-05	5.63E-08	2.15E-09	2.51E-08	1.55E-08			1.59E-10
SR-89	8.00E-06	4.48E-08	6.65E-09	7.13E-07	4.86E-07	1.62E-09		
SR-90	5.00E-07	4.07E-06	7.02E-07	8.21E-07	1.01E-06	7.62E-07		
TC-99M	1.00E-03	2.76E-11	5.77E-12		4.78E-11			
TC-101	2.00E-03			8.06E-12				
TE-131	8.00E-05				1.45E-09			
TE-132	9.00E-06	1.02E-10	1.19E-08	4.46E-09	1.16E-09			3.00E-08
W-187	3.00E-05				1.65E-09			
Y-91M	2.00E-03							
ZN-65	5.00E-06			1.51E-08				
ZR-95	2.00E-05	6.27E-09	2.01E-08	1.80E-07			1.14E-09	
ZR-97	9.00E-06	2.61E-10	5.28E-10		2.80E-09			

TABLE A-2, (cont.)
FRACTIONAL MEC IN LIQUID EFFLUENT

	1985	1986	1987	1988	1989	1990	1991
ANNUAL VOL(CCs)	6.34E+14	6.50E+14	6.82E+14	6.90E+14	6.69E+14	6.92E+14	6.45E+14
TOT FRACTION	1.90E-03	1.41E-03	1.14E-03	5.48E-04	8.54E-04	1.26E-03	1.25E-03
FRACT W/O H-3	6.29E-04	1.61E-04	9.83E-05	3.04E-05	1.85E-05	4.41E-06	2.55E-05
TOTAL CI	8.06E+02	8.12E+02	7.10E+02	3.57E+02	5.59E+02	8.72E+02	7.87E+02
TOTAL W/O H-3	1.37E+00	5.39E-01	5.12E-01	5.99E-02	5.65E-02	9.57E-03	5.42E-02
TOT CONC(uCi/CC)	1.27E-06	1.25E-06	1.04E-06	5.17E-07	8.36E-07	1.26E-06	1.22E-06
TCON W/O H-3	2.16E-09	8.30E-10	7.51E-10	8.69E-11	8.44E-11	1.38E-11	8.40E-11
EMEC	6.70E-04	8.86E-04	9.14E-04	9.45E-04	9.78E-04	9.97E-04	9.80E-04
EMEC W/O H-3	3.43E-06	5.14E-06	7.64E-06	2.85E-06	4.56E-06	3.14E-06	3.30E-06

APPENDIX B

DERIVATION OF ATMOSPHERIC RELEASE MODE

EFFECTIVE MAXIMUM EFFLUENT CONCENTRATION

B.1.0 Derivation of Atmospheric Release Effective Maximum Effluent Concentration

B1.1 Source Term

The effective maximum effluent concentration (EMEC) for atmospheric effluents is calculated from the annual releases for the years 1985-1991 (Table B-1). Unlike liquid releases, tritium was not omitted from the EMEC calculation. Instead, the EMEC was calculated with H-3 and then modified by the fraction of non-tritium radionuclides in the effluent.

B1.2 Effective Maximum Effluent Concentration

The maximum concentration of a radionuclide mixture that is allowable at the site boundary is called the effective maximum effluent concentration (EMEC). The EMEC for an effluent mixture is defined by the equation

$$EMEC = \Sigma C_i \; / \; \Sigma(C_i \; / \; MEC_i)$$

where

C_i = concentration of radionuclide "i"

MEC_i = maximum effluent concentration for radionuclide "i" from 10 CFR 20, Appendix B, Table 2, Column 1

$\Sigma (C_i \; / \; MEC_i)$ = summation of fractions (SOF), as discussed in Section 3.6, applied to atmospheric releases

The EMEC is calculated from the reference radionuclide mixture which is the radionuclides released during the years 1985 - 1991. The average annual site boundary concentration for each year was calculated using the highest annual average χ/Q of 1.56E-06 sec/m^3. Then the total EMEC was calculated for each year (Table C-2). The average total EMEC is 8.04E-08±1.31E-08 µCi/cc with a range of 5.84E-08 to 9.50E-08 µCi/cc. Next, the annual EMEC was modified for the presence of H-3, which is not detected by the atmospheric RMS, by multiplying each EMEC by the ratio of the non H-3 concentration to the total concentration. The annual H-3 corrected EMECs were averaged to obtain a value of 1.92E-08±1.23E-08 µCi/cc with a range of 5.02E-09 to 3.70E-08 µCi/cc.

TABLE B-1
CURIES IN ATMOSPHERIC EFFLUENT

NUCLIDE	MEC uCi/ml	1985	1986	1987	1988	1989	1990	1991
H-3	1.00E-07	6.71E+01	1.20E+02	1.18E+02	1.26E+02	1.42E+02	1.28E+02	1.13E+02
AR-41	1.00E-08	1.27E+00	6.81E-01	2.17E+00	1.96E+00	1.57E+00	1.11E+00	1.07E+00
KR-85M	1.00E-07	1.84E+01	6.77E-01	1.18E+00	7.31E-01	2.24E-01	1.85E-01	1.03E-01
KR-85	7.00E-07	1.67E+01	1.32E+00	7.11E-01	9.84E-01	3.58E-01	1.78E-01	2.74E-01
KR-87	2.00E-08	4.78E+00	1.01E+00	2.37E+00	1.48E+00	4.94E-01	4.05E-01	2.31E-01
KR-88	9.00E-09	5.73E+00	1.30E+00	2.72E+00	1.69E+00	5.64E-01	4.49E-01	2.56E-01
XE-131M	2.00E-06	8.54E-02						
XE-133M	6.00E-07	3.30E-01	1.38E-01	2.12E-01	3.35E-01	4.94E-03	2.06E-02	3.97E-02
XE-133	5.00E-07	3.45E+01	1.53E+01	2.06E+01	6.04E+01	7.54E+00	1.96E+00	1.60E+01
XE-135M	4.00E-08	5.76E+00	1.27E+00	3.68E+00	2.54E+00	7.37E-01	6.49E-01	3.44E-01
XE-135	7.00E-08	1.19E+01	3.21E+00	5.64E+00	3.53E+00	1.08E+00	1.09E+00	6.03E-01
XE-138	2.00E-08	1.65E+01	2.91E+00	8.87E+00	7.19E+00	2.45E+00	1.99E+00	1.06E+00
AG-110M	1.00E-10				2.31E-07			
BA-133	9.00E-10							
BA-139	4.00E-08							1.17E-07
BA-140	2.00E-09			3.41E-07				
CD-109	2.00E-10	8.92E-06	1.26E-06	2.28E-04				
CE-139	9.00E-10							
CE-141	8.00E-10	8.48E-09						
CE-144	2.00E-11		2.04E-06			3.92E-07		3.94E-09
CO-57	9.00E-10	2.10E-07		2.52E-11	1.13E-08		1.23E-06	4.80E-07
CO-58	1.00E-09	1.57E-04	1.33E-05	1.01E-04	3.59E-05	1.69E-04	2.74E-05	3.85E-06
CO-60	5.00E-11	7.94E-05	1.11E-04	1.18E-05	3.64E-04	1.63E-04	3.56E-06	1.06E-04
CR-51	3.00E-08					5.28E-04		7.58E-09
CS-134	2.00E-10	1.18E-03	9.49E-04	5.86E-05	7.27E-05			1.10E-03
CS-136	9.00E-10							
CS-137	2.00E-10	4.02E-03	2.94E-04	3.08E-04	6.74E-04	2.10E-03	1.91E-04	1.90E-03
CS-138	8.00E-08	9.64E-07	1.92E-06	1.85E-03	1.26E-07	3.44E-06		1.92E-02
F-18	1.00E-07		1.08E-05	2.52E-04	3.87E-05	3.31E-04	1.10E-05	6.60E-04
FE-59	7.00E-10							4.87E-09
MN-54	1.00E-09	1.99E-06	1.70E-06		4.86E-05			
M0-99	2.00E-09			7.27E-09	2.71E-08			
NA-24	7.00E-09	1.39E-04		4.32E-04	4.29E-04			
NB-95	2.00E-09	2.52E-06	7.70E-07	5.97E-07	6.25E-08		9.56E-10	
NB-97	1.00E-07				1.60E-08			1.65E-09
RB-88	9.00E-08	4.63E-05	3.46E-05	1.03E-02	4.00E-06	1.81E-05		1.62E-01
RB-89	2.00E-07					4.30E-09		
RU-103	9.00E-10	1.91E-08	1.89E-05					
SB-125	7.00E-10	1.25E-07		3.68E-06	9.39E-08			
SN-113	8.00E-10	2.16E-08			4.80E-10			
SR-89	2.00E-10	4.87E-08	1.54E-06	7.70E-07	3.71E-06			
SR-90	6.00E-12			1.68E-10	4.30E-06			
SR-91	5.00E-09							
TC-99M	3.00E-07			6.43E-08	2.20E-07	9.24E-07		
TC-101	5.00E-07							
TE-132	9.00E-10				3.07E-06	7.33E-08		2.34E-06
Y-88	3.00E-10			1.28E-10				
ZN-65	4.00E-10				9.27E-06			
ZR-95	4.00E-10	1.31E-06			3.56E-09		7.43E-10	
ZR-97	2.00E-09	2.97E-10						

TABLE B-1, (cont.)
CURIES IN ATMOSPHERIC EFFLUENT

NUCLIDE	MEC uCi/ml	1985	1986	1987	1988	1989	1990	1991
I-131	2.00E-10	3.44E-03	1.11E-03	3.08E-03	5.43E-04	3.18E-04	7.85E-05	3.46E-04
I-132	2.00E-08	3.75E-03	1.79E-03	2.42E-03	4.78E-04	4.20E-05	1.09E-05	2.95E-05
I-133	1.00E-09	1.37E-03	6.80E-04	3.04E-03	1.53E-03	1.19E-03	1.13E-04	1.13E-04
I-134	6.00E-08	1.33E-05		9.32E-04				
I-135	6.00E-09	5.79E-04	1.09E-04	2.19E-03	9.18E-05	1.26E-05	3.15E-08	1.58E-05

TABLE B-2
FRACTIONAL MEC FOR ATMOSPHERIC EFFLUENT

NUCLIDE	1985	1986	1987	1988	1989	1990	1991
H-3	3.20E-05	5.71E-05	5.62E-05	6.00E-05	6.76E-05	6.10E-05	5.38E-05
AR-41	6.05E-06	3.24E-06	1.03E-05	9.33E-06	7.48E-06	5.29E-06	5.10E-06
KR-85M	8.76E-06	3.22E-07	5.62E-07	3.48E-07	1.07E-07	8.81E-08	4.90E-08
KR-85	1.14E-06	8.98E-08	4.84E-08	6.69E-08	2.44E-08	1.21E-08	1.86E-08
KR-87	1.14E-05	2.40E-06	5.64E-06	3.52E-06	1.18E-06	9.64E-07	5.50E-07
KR-88	3.03E-05	6.88E-06	1.44E-05	8.94E-06	2.98E-06	2.38E-06	1.35E-06
XE-131M	2.03E-09						
XE-133M	2.62E-08	1.10E-08	1.68E-08	2.66E-08	3.92E-10	1.63E-09	3.15E-09
XE-133	3.29E-06	1.46E-06	1.96E-06	5.75E-06	7.18E-07	1.87E-07	1.52E-06
XE-135M	6.86E-06	1.51E-06	4.38E-06	3.02E-06	8.77E-07	7.73E-07	4.10E-07
XE-135	8.10E-06	2.18E-06	3.84E-06	2.40E-06	7.35E-07	7.41E-07	4.10E-07
XE-138	3.93E-05	6.93E-06	2.11E-05	1.71E-05	5.83E-06	4.74E-06	2.52E-06
AG-110M				1.10E-10			
BA-139							1.39E-13
BA-140			8.12E-12				
CD-109	2.12E-09	3.00E-10	5.43E-08				
CE-141	5.05E-13						
CE-144		4.86E-09			9.33E-10		9.38E-12
CO-57	1.11E-11		1.33E-15	5.98E-13		6.51E-11	2.54E-11
CO-58	7.48E-09	6.33E-10	4.81E-09	1.71E-09	8.05E-09	1.30E-09	1.83E-10
CO-60	7.56E-08	1.06E-07	1.12E-08	3.47E-07	1.55E-07	3.39E-09	1.01E-07
CR-51					8.38E-10		1.20E-14
CS-134	2.81E-07	2.26E-07	1.40E-08	1.73E-08			2.62E-07
CS-136							
CS-137	9.57E-07	7.00E-08	7.33E-08	1.60E-07	5.00E-07	4.55E-08	4.52E-07
CS-138	5.74E-13	1.14E-12	1.10E-09	7.50E-14	2.05E-12		1.14E-08
F-18		5.14E-12	1.20E-10	1.84E-11	1.58E-10	5.24E-12	3.14E-10
FE-59							3.31E-13
MN-54	9.48E-11	8.10E-11		2.31E-09			
M0-99			1.73E-13	6.45E-13			
NA-24	9.46E-10		2.94E-09	2.92E-09			
NB-95	6.00E-11	1.83E-11	1.42E-11	1.49E-12		2.28E-14	
NB-97				7.62E-15			7.86E-16
RB-88	2.45E-11	1.83E-11	5.45E-09	2.12E-12	9.58E-12		8.57E-08
RB-89					1.02E-15		
RU-103	1.01E-12	1.00E-09					
SB-125	8.50E-12		2.50E-10	6.39E-12			
SN-113	1.29E-12			2.86E-14			
SR-89	1.16E-11	3.67E-10	1.83E-10	8.83E-10			
SR-90			1.33E-12	3.41E-08			
SR-91							
TC-99M			1.02E-14	3.49E-14	1.47E-13		
TC-101							
TE-132				1.62E-10	3.88E-12		1.24E-10
Y-88			2.03E-14				
ZN-65				1.10E-09			
ZR-95	1.56E-10			4.24E-13		8.85E-14	
ZR-97	7.07E-15						

TABLE B-2, (cont.)
FRACTIONAL MEC FOR ATMOSPHERIC EFFLUENT

NUCLIDE	1985	1986	1987	1988	1989	1990	1991
I-131	8.19E-07	2.64E-07	7.33E-07	1.29E-07	7.57E-08	1.87E-08	8.24E-08
I-132	8.93E-09	4.26E-09	5.76E-09	1.14E-09	1.00E-10	2.60E-11	7.02E-11
I-133	6.52E-08	3.24E-08	1.45E-07	7.29E-08	5.67E-08	5.38E-09	5.38E-09
I-134	1.06E-11		7.40E-10				
I-135	4.60E-09	8.65E-10	1.74E-08	7.29E-10	1.00E-10	2.50E-13	1.25E-10
TOTALFRAC	1.49E-04	8.29E-05	1.20E-04	1.11E-04	8.83E-05	7.62E-05	6.67E-05
TOTAL-H3	1.17E-04	2.57E-05	6.34E-05	5.13E-05	2.07E-05	1.52E-05	1.29E-05
EFF MEC	5.84E-08	8.49E-08	6.62E-08	8.85E-08	8.46E-08	8.50E-08	9.50E-08
W/O H-3	3.70E-08	1.60E-08	1.92E-08	3.46E-08	8.10E-09	5.02E-09	1.44E-08

APPENDIX C

CALCULATION OF TOTAL DOSE FACTORS

USING

REGULATORY GUIDE 1.109, REV. 1

C.1.0 Calculation of Total Dose Factors Using Regulatory Guide 1.109 Methodology

C.1.1 Liquid Release Dose Factors

The equations and values used to calculate the total dose to the maximum exposed individual for each of the liquid release mode pathways evaluated according to Regulatory Guide 1.109, Rev. 1, 1977 methodology is shown below. The total dose factor in mrem/Ci released is the sum of all pathway doses in mrem/Ci for the following pathways: milk, meat, fish, potable water, and shoreline deposits. The results for an organ is summed for each pathway and the total presented by age group and target organ in a matrix format for each radionuclide in Section 5, Table 5.1.1. The derivation of dilution factors used in the calculations is presented in Appendix D. The highest dose in each matrix is used as the dose tracking factor to be used for the monthly tracking of release doses. These values are found in Section 5, Table 5.2.

Note that all of the liquid release dose calculations assume that the discharge rate is 677,000 gpm. Whenever the average discharge rate for the month or year differs, the final dose calculated must be multiplied by the correction factor CF where:

CF = 677,000 gpm / actual average discharge gpm

This correction will produce a greater change during the winter months when the circ water flow rates are lower.

C1.1.1 Aquatic Foods

The dose from the eating of fresh fish caught at the edge of the initial mixing zone was calculated using the equation:

$$Dose_{apj} = 1100\frac{M_p U_{ap}}{F}\sum_i Q_i B_{ip} D_{aipj} e^{-\lambda_i t_p}$$

where:

$Dose_{apj}$ = the dose to the organ j of an individual of age group a from all of the nuclides i in pathway p, in mrem/year;

1100 = a factor to convert from Ci-sec/yr-ft^3 to pCi/liter;

M_p = the mixing ratio (reciprocal of the dilution factor) at the point of harvest of aquatic food, dimensionless;

U_{ap} = a usage factor that specifies the intake rate for an individual of age group a associated with pathway p, in kg/year;

F = the flow rate of the liquid effluent, in ft^3/sec;

Q_i = the release rate of nuclide i, in Ci/year;

B_{ip} = the equilibrium bioaccumulation factor for nuclide i in pathway p, expressed as the ratio of the concentration in biota (in pCi/kg) to the radionuclide concentration in water (in pCi/l), in liters/kg;

D_{aipj} = the dose factor, specific to a given age group a, nuclide i, pathway p, and organ j, which is used to calculate the radiation dose from an intake of a nuclide, in mrem/pCi;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_p = the average transit time required for nuclides to reach the point of exposure. For internal dose, t_p is the total time elapsed between release of the nuclides and the ingestion of the water, in days.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{aipj}}{Q_i} = 1100 \frac{M_p U_{ap}}{F} B_{ip} D_{aipj} e^{-\lambda_i t_p}$$

The values used in the equation above are:

M_p = 0.1136 (Point of harvest of the fresh fish is taken at a point 1000 m downstream. The plume centerline dilution factor at this location is 8.8 using RG 1.111 methodology. The dilution factor calculations are attached. The factor of 2 allowed for current reversals was not used.);

U_{ap} = Infant - 0, Child - 6.9, Teen - 16, and Adult - 21 kg/year;

F = 1507 ft^3/sec. (677000 gpm);

B_{ip} = Values used are taken from Table A-1 of RG 1.109;

D_{aipj} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_p = 0.5 days.

C1.1.2 Irrigated Foods (Meat From Watered Cattle)

The dose from the ingestion of meat from cattle which have been given contaminated water was calculated using the equation:

$$Dose_{apj} = 1100 \frac{M_p U_{ap} Q_{Aw}}{F} \sum_i Q_i F_{iA} D_{aipj} e^{-\lambda_i t_e}$$

where:

$Dose_{apj}$ = the dose to the organ j of an individual of age group a from all of the nuclides i in pathway p, in mrem/year;

1100 = factor to convert from Ci-sec/yr-ft^3 to pCi/liter;

U_{ap} = a usage factor that specifies the intake rate for an individual of age group a associated with pathway p, in kg/year;

M_p = the mixing ratio (reciprocal of the dilution factor) at the point of exposure, dimensionless;

Q_{Aw} = consumption rate of contaminated water by an animal, in liters/day;

F = the flow rate of the liquid effluent, in ft^3/sec;

Q_i = the release rate of nuclide i, in Ci/year;

F_{iA} = the stable element transfer coefficient that relates the daily intake rate by an animal to the concentration in an edible portion of animal product, in pCi/liter of meat per pCi/day;

D_{aipj} = the dose factor, specific to a given age group a, nuclide i, pathway p, and organ j, which is used to calculate the radiation dose from an intake of a nuclide, in mrem/pCi;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_s = the average time from slaughter to consumption, in days.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{aipj}}{Q_i} = 1100\frac{M_p U_{ap} Q_{Aw}}{F} F_{iA} D_{aipj} e^{-\lambda_i t_s}$$

The values used in the equation above are:

M_p = 0.1111 (Point at which water is taken from the lake is taken as plume centerline 1 mile downstream. The plume centerline dilution factor at this location is 9 using RG 1.111 methodology.);

U_{ap} = Infant - 0, Child - 41, Teen - 65, and Adult - 110 kg/year;

Q_{Aw} = 60 liters/day;

F = 1507 ft^3/sec. (677000 gpm);

F_{iA} = Values used are taken from Table E-1 of RG 1.109;

D_{aipj} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_s = 20 days.

C1.1.3 Irrigated Foods (Milk From Watered Cattle)

The dose from the ingestion of milk from cows which have been given contaminated water was calculated using the equation:

$$Dose_{apj} = 1100 \frac{M_p U_{ap} Q_{Aw}}{F} \sum_i Q_i F_{iA} D_{aipj} e^{-\lambda_i t_f}$$

where:

$Dose_{apj}$ = the dose to the organ j of an individual of age group a from all of the nuclides i in pathway p, in mrem/year;

1100 = factor to convert from Ci-sec/yr-ft^3 to pCi/liter;

M_p = the mixing ratio (reciprocal of the dilution factor) at the point of exposure, dimensionless;

U_{ap} = a usage factor that specifies the intake rate for an individual of age group a associated with pathway p, in liters/year;

Q_{Aw} = consumption rate of contaminated water by an animal, in liters/day;

F = the flow rate of the liquid effluent, in ft^3/sec;

Q_i = the release rate of nuclide i, in Ci/year;

F_{iA} = the stable element transfer coefficient that relates the daily intake rate by an animal to the concentration in an edible portion of animal product, in pCi/liter of milk per pCi/day;

D_{aipj} = the dose factor, specific to a given age group a, nuclide i, pathway p, and organ j, which is used to calculate the radiation dose from an intake of a nuclide, in mrem/pCi;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_f = the average transport time of the activity from the feed into the milk and to the receptor, in days.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{aipj}}{Q_i} = 1100\frac{M_p U_{ap} Q_{Aw}}{F} F_{iA} D_{aipj} e^{-\lambda_i t_f}$$

The values used in the equation above are:

M_p = 0.1111 (Point at which water is taken from the lake is taken as plume centerline 1 mile downstream. The plume centerline dilution factor at this location is 9 using RG 1.111 methodology. the dilution factor calculations are attached. The factor of 2 allowed for current reversals was not used. This is a conservative assumption.);

U_{ap} = Infant - 330, Child - 330, Teen - 400, and Adult - 310 liters/year;

Q_{Aw} = 60 liters/day;

F = 1507 ft^3/sec. (677000 gpm);

F_{iA} = Values used are taken from Table E-1 of RG 1.109;

D_{aipj} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_f = 2 days.

C1.1.4 Potable Water

The dose from ingestion of water was calculated using the equation:

$$Dose_{apj} = 1100 \frac{M_p U_{ap}}{F} \sum_i Q_i D_{aipj} e^{-\lambda_i t_p}$$

where:

$Dose_{apj}$ = the dose to the organ j of an individual of age group a from all of the nuclides i in pathway p, in mrem/year;

1100 = a factor to convert from Ci-sec/yr-ft^3 to pCi/liter;

M_p = the mixing ratio (reciprocal of the dilution factor) at the point of withdrawal of drinking water, dimensionless;

U_{ap} = a usage factor that specifies the intake rate for an individual of age group a associated with pathway p, in l/year;

F = the flow rate of the liquid effluent, in ft^3/sec;

Q_i = the release rate of nuclide i, in Ci/year;

D_{aipj} = the dose factor, specific to a given age group a, nuclide i, pathway p, and organ j, which is used to calculate the radiation dose from an intake of a nuclide, in mrem/pCi;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_p = the average transit time required for nuclides to reach the point of exposure. For internal dose, t_p is the total time elapsed between release of the nuclides and the ingestion of the water, in days.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{aipj}}{Q_i} = 1100 \frac{M_p U_{ap}}{F} D_{aipj} e^{-\lambda_i t_p}$$

The values used in the equation above are:

M_p = 0.0384 (Withdrawal point is taken as the Two Rivers municipal water intake located a distance of 12 miles downstream. The plume centerline dilution factor at this location is 26 using RG 1.111 methodology and the factor of 2 allowed for current reversals. The dilution factor calculations are attached.);

U_{ap} = Infant - 330, Child - 510, Teen - 510, and Adult - 730 liters/year;

F = 1507 ft^3/sec. (677000 gpm);

D_{aipj} = Values used are taken from Tables E-11 through E-14 of RG 1.109

t_p = 2 days (This was calculated using a current speed of 12.2 cm/s plus 12 hours to reflect the transport of the water through the water purification plant and distribution system.)

C1.1.5 Shoreline Deposits

The dose from exposure to radioactive materials deposited on the shoreline of the lake was calculated using the equation:

$$Dose_{apj} = 110000 \frac{M_p U_{ap} W}{F} \sum_i Q_i T_i D_{aipj} e^{-\lambda_i t_p} \left(1 - e^{-\lambda_i t_b}\right)$$

where:

$Dose_{apj}$ = the dose to the organ j of an individual of age group a from all of the nuclides i in pathway p, in mrem/year;

110000 = a factor to convert from Ci-sec/yr-ft^3 to pCi/liter and to account for the proportionality constant used in the sediment radioactivity model;

M_p = the mixing ratio (reciprocal of the dilution factor) at the point of exposure, dimensionless;

U_{ap} = a usage factor that specifies the exposure time for an individual of age group a associated with pathway p, in hours/year;

W = shoreline width factor, dimensionless;

F = the flow rate of the liquid effluent, in ft^3/sec;

Q_i = the release rate of nuclide i, in Ci/year;

T_i = the radioactive half life of nuclide i, in days;

D_{aipj} = the dose factor, specific to a given age group a, nuclide i, pathway p, and organ j, which is used to calculate the radiation dose from an intake of a nuclide, in mrem/pCi;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_p = the average transit time required for nuclides to reach the point of exposure. For internal dose, t_p is the total time elapsed between release of the nuclides and the ingestion of the water, in days;

t_b = the period of time for which the sediment or soil is exposed to the contaminated water, in days.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{aipj}}{Q_i} = 110000 \frac{M_p U_{ap} W}{F} T_i D_{aipj} e^{-\lambda_i t_p} \left(1 - e^{-\lambda_i t_b}\right)$$

The values used in the equation above are:

M_p = 0.01821 (Point of exposure is taken as the Point Beach State Park beach which is located 8000 meters downstream. The plume shoreline dilution factor at this location is 54.9 using RG 1.111 methodology. The dilution factor calculations are attached. The factor of 2 allowed for current reversals was not used.);

U_{ap} = Infant - 0, Child - 14, Teen - 67, and Adult - 12 hours/year;

W = 0.3;

F = 1507 ft^3/sec. (677000 gpm);

D_{aipj} = Values used are taken from Table E-6 of RG 1.109;

t_p = 0.5 day;

t_b = 5458 days.

C1.2 Atmospheric Release Dose Factors: Non-Gaseous

The equations and values used to calculate the total dose to the maximum exposed individual factors for non-gaseous radionuclides released to the atmosphere using Regulatory Guide 1.109, Rev. 1, 1977 is shown below. The total dose factor in mrem/Ci released is the sum of all airborne effluent doses in mrem/Ci for the following pathways: milk, meat, leafy vegetables, potable water, and shoreline deposits. A summary of totals is presented by age group and target organ in matrix format for each radionuclide in Section 5, Table 5-1. The highest dose in each matrix is used as the dose tracking factor to be used for the monthly tracking of release doses. These values are found in Section 5, Table 5-2.

Note that Section C1.2.1 applies to both tritium and particulates. Sections C1.2.2 through C1.2.6 apply only to particulates released to the atmosphere. Atmospheric tritium releases are treated differently. Sections C1.2.7 through C1.2.10 apply to tritium.

C1.2.1 Inhalation of Nuclides In Air

The dose from the inhalation of nuclides in the air was calculated using the equation:

$$Dose_{ja} = 3.17E+04 R_a \left(\frac{\chi}{Q}\right) \sum_i Q_i DFI_{ija}$$

where:

$Dose_{ja}$ = the annual dose to organ j of an individual of age group a due to inhalation, in mrem/year;

3.17E+04 = the number of pCi/Ci divided by the number of sec/year;

R_a = the annual air intake for individuals in the age group a, in m^3/year;

χ/Q = the annual average atmosphere dispersion factor, in sec/m^3 (The location at which the dose was calculated was the site boundary in the south sector - a distance of 1270 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

DFI_{ija} = the inhalation dose factor for radionuclide i, organ j, and age group a, mrem/pCi.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ija}}{Q_i} = 3.17\,E{+}04\,R_a\left(\frac{\chi}{Q}\right)DFI_{ija}$$

The values used in the equation above are:

R_a = Infant - 1400, Child - 3700, Teen - 8000, and Adult - 8000 m^3/year;

χ/Q = 9.36E-07 seconds/m^3 (This value taken from Table I.4-2 of the FSAR, release mode 1B, annual average, site boundary.);

DFI_{ija} = Values used are taken from Tables E-7 through E-10 of RG 1.109.

C1.2.2 Annual Organ Dose From External Irradiation From Nuclides Deposited On the Ground

The organ dose from external irradiation from nuclides deposited on the ground was calculated using the equation:

$$Dose_j = 1E{+}12\,(8760)\,\delta_i\,S_F\sum_i \frac{Q_i\left(1-e^{-\lambda_i t_b}\right)}{\lambda_i}DFG_{ij}$$

where:

$Dose_j$ = the annual dose to the organ j, in mrem/year;

1E+12 = the number of pCi per Ci;

8760 = the number of hours in a year;

δ_i = the annual average relative deposition of nuclide i, considering depletion of the plume during transport, in m^{-2}, (The location at which the dose is calculated is the site boundary in the south sector - a distance of 1300 meters.);

S_F = the attenuation factor that accounts for the dose reduction due to shielding provided by residential structures, dimensionless;

Q_i = the release rate of nuclide i, in Ci/year;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_b = the time period over which the accumulation is evaluated, in days;

DFG_{ij} = the open field ground plane dose conversion factor for organ j from nuclide i, in mrem-m^2/pCi-hour.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ij}}{Q_i} = 1E+12\,(8760)\,\delta_i\,S_F\,\frac{\left(1-e^{-\lambda_i t_b}\right)}{\lambda_i}\,DFG_{ij}$$

The values used in the equation above are:

δ_i = 31E-09 m^{-2} (This value taken from Table I.4-2 of the FSAR, release mode 1B, annual average, site boundary.);

S_F = 1 (No structural shielding is assumed.);

t_b = 5479 days (15 years);

DFG_{ij} = Values used are taken from Table E-6 of RG 1.109.

C1.2.3 Annual Organ Dose From Atmospherically Released Nuclides In Milk

The organ dose from atmospherically released nuclides in milk was calculated using the equation:

$$Dose_{ja} = 2.7E+09\, U_a Q_F \delta_i \sum_i Q_i F_{im} DFI_{ija} e^{-\lambda_i t_f} \left\{ f_p f_s + e^{-90\lambda_i}\left(1 - f_p f_s\right)\right\}$$

$$x \left\{ \frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_v \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P \lambda_i} \right\}$$

where:

$Dose_{ja}$ = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides, in mrem/year;

2.7E+09* = the number of pCi per Ci divided by the number of days per year;

U_a = the ingestion rate of milk for individuals in age group a, in liters/year;

Q_F = the amount of feed consumed by a cow per, in kg/day;

δ_i = the annual average relative deposition of nuclide i, considering depletion of the plume during transport, in m^{-2}, (The location at which the dose is calculated is the nearest animal location in the south-southeast sector - a distance of 1300 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_b = the time period over which the accumulation is evaluated, in days;

DFI_{ija} = the dose conversion factor for the ingestion of nuclide i, organ j, and age group a, in mrem/pCi;

F_{im} = the average fraction of the animal's daily intake of nuclide i which appears in each liter of milk, in days/liter;

t_f = the average transport time of the activity from the feed into the milk and to the receptor, in days;

f_p = the fraction of the year that the animals graze on pasture, dimensionless;

f_s = the fraction of the daily feed that is pasture grass when the animal grazes on pasture, dimensionless;

r = the fraction of the deposited activity retained on crops, dimensionless;

λ_{Ei} = the effective removal rate constant for nuclide i from crops, in $days^{-1}$, where $\lambda_{Ei} = \lambda_i + \lambda_w$, and λ_w is the removal rate constant for physical loss by weathering;

λ_w = 0.0504 day^{-1};

t_e = the time period that crops are exposed to contamination during the growing season, in days;

Y_V = the agricultural productivity, in kg (wet weight)/m^2;

B_{iv} = the concentration factor for the uptake of nuclide i in pathway p, expressed as the ratio of the concentration in biota (in pCi/kg) to the nuclide concentration in water (in pCi/liter), in liters/kg;

P = the effective surface density for soil, in kg (dry soil)/m^2.

* For iodines, this factor is changed to 1.4E+09.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ija}}{Q_i} = 2.7E+9\, U_a Q_F \delta_i \sum_i F_{im} DFI_{ija} e^{-\lambda_i t_f} \left\{ f_p f_s + e^{-90\lambda_i} \left(1 - f_p f_s\right) \right\} \times \left\{ \frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_V \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P \lambda_i} \right\}$$

The values used in the equation above are:

U_a = Infant - 330, Child - 330, Teen - 400, and Adult - 310 liters/year;

Q_F = 50 kg/day;

δ_i = 18.8E-09 m^{-2} (This value taken from Table I.4-2 of the FSAR, release mode 1B, grazing season, site boundary.);

F_{im} = Values used are taken from Table E-1 of RG 1.109;

DFI_{ija} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_f = 2 days;

f_p = 0.5;

f_s = 0.5;

r = 0.25, 1.0 for iodines, and 0.20 for noble gases, tritium, and carbon-14;

t_e = 30 days;

Y_V = 0.7 kg/m^2;

B_{iv} = Values used are taken from Table E-1 of RG 1.109;

P = 240 kg/m^2;

t_b = 5458 days (15 years).

C1.2.4 Annual Organ Dose From Atmospherically Released Nuclides In Meat

The organ dose from atmospherically released nuclides in meat was calculated using the equation:

$$Dose_{ja} = 2.7E+9\, U_a Q_F \delta_i \sum_i Q_i F_{if} DFI_{ija} e^{-\lambda_i t_e} \left\{ f_p f_s + e^{-90\lambda_i}\left(1 - f_p f_s\right)\right\} \times \left\{ \frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_v \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P \lambda_i} \right\}$$

where:

$Dose_{ja}$ = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides, in mrem/year;

2.7E+9* = the number of pCi per Ci divided by the number of days per year;

U_a = the ingestion rate of meat for individuals in age group a, in liters/year;

Q_F = the amount of feed consumed by a cow per, in kg/day;

δ_i = the annual average relative deposition of nuclide i, considering depletion of the plume during transport, in m^{-2}, (The location at which the dose is calculated is the nearest animal location in the south-southeast sector - a distance of 1300 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_b = the time period over which the accumulation is evaluated, in days;

DFI_{ija} = the dose conversion factor for the ingestion of nuclide i, organ j, and age group a, in mrem/pCi;

F_{if} = the average fraction of the animal's daily intake of nuclide i which appears in each kilogram of flesh, in days/kg;

t_s = the average time from slaughter to consumption, in days;

f_p = the fraction of the year that the animals graze on pasture, dimensionless;

f_s = the fraction of the daily feed that is pasture grass when the animal grazes on pasture, dimensionless;

r = the fraction of the deposited activity retained on crops, dimensionless;

λ_{Ei} = the effective removal rate constant for nuclide i from crops, in $days^{-1}$, where $\lambda_{Ei} = \lambda_i + \lambda_w$, and λ_w is the removal rate constant for physical loss by weathering;

t_e = the time period that crops are exposed to contamination during the growing season, in days;

Y_V = the agricultural productivity, in kg (wet weight)/m^2;

B_{iv} = the concentration factor for the uptake of nuclide i in pathway p, expressed as the ratio of the concentration in biota (in pCi/kg) to the nuclide concentration in water (in pCi/liter), in liters/kg;

P = the effective surface density for soil, in kg (dry soil)/m^2.

* For iodines, this factor is changed to 1.4E+09.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ija}}{Q_i} = 2.7E+9\, U_a Q_F \delta_i \sum_i F_{if}\, DFI_{ija}\, e^{-\lambda_i t_s}\left\{f_p f_s + e^{-90\lambda_i}\left(1 - f_p f_s\right)\right\} \times \left\{\frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_V \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P\lambda_i}\right\}$$

The values used in the equation above are:

U_a = Infant - 0, Child - 41, Teen - 65, and Adult - 110 kg/year;

Q_F = 50 kg/day;

δ_i = 18.8E-09 m^{-2} (This value taken from Table I.4-2 of the FSAR, release mode 1B, grazing season, site boundary.);

F_{if} = Values used are taken from Table E-1 of RG 1.109;

DFI_{ija} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_s = 20 days;

f_p = 0.5;

f_s = 1.0;

r = 0.25, 1.0 for iodines, and 0.20 for noble gases, tritium, and carbon-14;

t_e = 30 days;

B_{iv} = Values used are taken from Table E-1 of RG 1.109;

Y_V = 0.7 kg/m^2;

P = 240 kg/m^2;

λ_w = 0.0504 day^{-1};

t_b = 5458 days (15 years).

C1.2.5 Annual Organ Dose From Atmospherically Released Nuclides In Produce

The organ dose from atmospherically released nuclides in produce was calculated using the equation:

$$Dose_{ja} = 2.7E+9\, U_a f_g \delta_i \sum_i Q_i DFI_{ija} e^{-\lambda_i t_h} \left\{ \frac{r\left(1-e^{-\lambda_{Ei} t_e}\right)}{Y_v \lambda_{Ei}} + \frac{B_{iv}\left(1-e^{-\lambda_i t_b}\right)}{P \lambda_i} \right\}$$

where:

$Dose_{ja}$ = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides, in mrem/year;

2.7E+9* = the number of pCi per Ci divided by the number of days per year;

U_a = the ingestion rate of produce for individuals in age group a, in kg/year;

f_g = fraction of produce ingested grown in garden of interest, dimensionless;

δ_i = the annual average relative deposition of nuclide i, considering depletion of the plume during transport, in m^{-2}, (The location at which the dose is calculated is the nearest garden location in the south-southwest sector - a distance of 1460 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_b = the time period over which the accumulation is evaluated, in days;

DFI_{ija} = the dose conversion factor for the ingestion of nuclide i, organ j, and age group a, in mrem/pCi;

t_h = the holdup time that represents the time interval between harvest and consumption of the food, in days;

r = the fraction of the deposited activity retained on crops, dimensionless;

λ_{Ei} = the effective removal rate constant for nuclide i from crops, in $days^{-1}$, where $\lambda_{Ei} = \lambda_i + \lambda_w$, and λ_w is the removal rate constant for physical loss by weathering;

t_e = the time period that crops are exposed to contamination during the growing season, in days;

Y_V = the agricultural productivity, in kg (wet weight)/m^2;

B_{iv} = the concentration factor for the uptake of nuclide i in pathway p, expressed as the ratio of the concentration in biota (in pCi/kg) to the nuclide concentration in water (in pCi/liter), in liters/kg;

P = the effective surface density for soil, in kg (dry soil)/m^2.

* For iodines, this factor is changed to 1.4E+09.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ija}}{Q_i} = 2.7E+9\, U_a f_g \delta_i \sum_i DFI_{ija} e^{-\lambda_i t_h} \left\{ \frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_v \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P \lambda_i} \right\}$$

The values used in the equation above are:

U_a = Infant - 0, Child - 520, Teen - 630, and Adult - 520 kg/year;

f_g = 0.76;

δ_i = 18.8E-09 m^{-2} (This value taken from Table I.4-2 of the FSAR, release mode 1B, growing season, site boundary.);

DFI_{ija} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_h = 60 days;

r = 0.25, 1.0 for iodines, and 0.20 for noble gases, tritium, and carbon-14;

λ_w = 0.0504 day^{-1};

t_e = 60 days;

Y = 0.7 kg/m^2;

B_{iv} = Values used are taken from Table E-1 of RG 1.109;

P = 240 kg/m^2;

t_b = 5458 days (15 years).

C1.2.6 Annual Organ Dose From Atmospherically Released Nuclides In Leafy Vegetables

The organ dose from atmospherically released nuclides in leafy vegetables was calculated using the equation:

$$Dose_{ja} = 2.7E+9\, U_a f_l \delta_i \sum_i Q_i DFI_{ija}\, e^{-\lambda_i t_h} \left\{ \frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_v \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P \lambda_i} \right\}$$

where:

$Dose_{ja}$ = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides, in mrem/year;

2.7E+9* = the number of pCi per Ci divided by the number of days per year;

U_a = the ingestion rate of produce for individuals in age group a, in kg/year;

f_l = fraction of leafy vegetables ingested grown in garden of interest, dimensionless;

δ_i = the annual average relative deposition of nuclide i, considering depletion of the plume during transport, in m^{-2}, (The location at which the dose is calculated is the nearest garden location in the south-southwest sector - a distance of 1460 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_b = the time period over which the accumulation is evaluated, in days;

DFI_{ija} = the dose conversion factor for the ingestion of nuclide i, organ j, and age group a, in mrem/pCi;

t_h = the holdup time that represents the time interval between harvest and consumption of the food, in days;

r = the fraction of the deposited activity retained on crops, dimensionless;

λ_{Ei} = the effective removal rate constant for nuclide i from crops, in days^{-1}, where $\lambda_{Ei} = \lambda_i + \lambda_w$, and λ_w is the removal rate constant for physical loss by weathering;

t_e = the time period that crops are exposed to contamination during the growing season, in days;

Y_V = the agricultural productivity, in kg (wet weight)/m^2;

B_{iv} = the concentration factor for the uptake of nuclide i in pathway p, expressed as the ratio of the concentration in biota (in pCi/kg) to the nuclide concentration in water (in pCi/liter), in liters/kg;

P = the effective surface density for soil, in kg (dry soil)/m^2.

* For iodines, this factor is changed to 1.4E+09.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ija}}{Q_i} = 2.7E+9\, U_a f_1 \delta_i \sum_i DFI_{ija}\, e^{-\lambda_i t_h} \left\{ \frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_V \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P \lambda_i} \right\}$$

The values used in the equation above are:

U_a = Infant - 0, Child - 26, Teen - 42, and Adult - 64 kg/year;

f_1 = 1;

δ_i = 18.8E-09 m^{-2} (This value taken from Table I.4-2 of the FSAR, release mode 1B, growing season, site boundary.);

DFI_{ija} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_h = 1 day;

OFFSITE DOSE CALCULATION MANUAL

r = 0.25, 1.0 for iodines, and 0.20 for noble gases, tritium, and carbon-14;

λ_w = 0.0504 day^{-1};

t_e = 60 days;

Y_V = 0.7 kg/m^2;

B_{iv} = Values used are taken from Table E-1 of RG 1.109;

P = 240 kg/m^2;

t_b = 5458 days (15 years).

C1.2.7 Doses from Airborne Tritium other than Inhalation

The calculation methodology for doses from airborne H-3 via the meat, milk and vegetation pathways is different from that of particulates because tritium is a vapor and not a particle. The concentrations of tritium in vegetation are based on the concentrations found in the air surrounding the vegetation; and, all other vegetation based pathway doses are calculated from this quantity. The concentration in vegetation (forage, produce and leafy vegetables) is calculated from the formula (Reg. Guide 1.109, Rev. 1, p.1.109-27):

$$C_{tv} = 3.17E+07\ Q_T[\chi/Q](0.75)(0.5/H)$$

where:

Q_T = annual release rate of tritium in Ci/year;

$[\chi/Q]$ = annual average atmosphere dispersion factor, in sec/m^3 (The location at which the dose was calculated was the site boundary in the south sector, a distance of 1270m);

3.17E+07 = (1.0E+12 pCi/Ci) (1.0E+03 g/Kg) / (3.15E+07 sec/yr)

0.75 = fraction of plant mass which is water;

0.5 = fraction of concentration of tritium in plant water to concentration of tritium in atmospheric water;

H = absolute humidity of atmosphere in g/m^3

Inserting the following values into the formula:

$[\chi/Q]$ = 9.36E-07 sec/m^3 (from Table I.4-2 of the FSAR, release mode 1B, annual average site boundary);

H = 5.5 g/m^3 (from E. L. Entier (1980), Health Physics 39:318-320).

yields

$$C_{tv} = 2.0230\ Q_T$$

which then is used to calculate doses from leafy vegetables and produce as well as from milk and meat results for cattle ingestion of vegetation with the H-3 concentration.

C1.2.8 Annual Organ Dose from Atmospherically Released Tritium in Produce

Concentrations of tritium in vegetation are based on its concentration in the air surrounding the vegetation as defined above in C1.2.7. The doses are calculated using the equation:

$$Dose_{ja} = DFI_{ja} U_a f_g C_{tv}$$

where:

$Dose_{ja}$ = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides in mrem/yr;

DFI_{ja} = the dose conversion factor for the ingestion of tritium in organ j and age group a in mrem/yr;

U_a = ingestion rate for produce for individuals in age group a;

f_g = fraction of produce ingested;

C_{tv} = concentration of tritium in vegetation, defined as 2.023 Q_T.

To calculate the dose per curie released, the equation above is rearranged and the calculation performed. The rearranged equation is shown below:

$$\frac{Dose_{ja}}{Q_T} = 2.023\ DFI_{ja}U_a f_g$$

The values used in the equation above are:

DFI_{ja} = values taken from Tables E-11 through E-14 of RG 1.109;

U_a = Infant-0, Child-520, Teen-630, Adult-520;

f_g = 0.76;

C1.2.9 Annual Organ Dose from Atmospherically Released Tritium in Milk

The organ dose is calculated using the equation:

$$Dose_{ja} = DFI_{ja}U_aC_{tm}$$

where C_{tm} is the concentration of tritium in milk which is calculated using the formula:

$$C_{tm} = F_mC_{tv}Q_F\exp(-\lambda_t t_f).$$

Substituting C_{tm} into the dose formula, the following equation results:

$$Dose_{ja} = DFI_{ja}U_aF_mC_{tv}Q_F\exp(-\lambda_t t_f)$$

where:

$Dose_{ja}$ = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides in mrem/yr;

DFI_{ja} = the dose conversion factor for the ingestion of tritium in organ j and age group a in mrem/yr;

U_a = ingestion rate for produce for individuals in age group a;

F_m = average fraction of animal's daily intake of tritium which appears in milk (days/liter);

C_{tv} = concentration of tritium in animal's feed (since the formula for the concentration of tritium in vegetation does not depend on time, there is no distinction made between pasture grass and stored feeds);

Q_F = amount of feed consumed by animal per day;

t_f = average transport time from feed into milk and to receptor;

λ_t = radiological decay constant for tritium.

To calculate the dose per curie released, the equation above is rearranged and the calculation performed. The rearranged equation is shown below:

$$\frac{Dose_{ja}}{Q_T} = 2.023\ DFI_{ja}U_aF_mQ_F\exp(-\lambda_t t_f)$$

The values used in the above equation are:

DFI_{ja} = values taken from Tables E-11 through E-14 of RG 1.109;

U_a = Infant-330, Child-330, Teen-400, Adult-310;

F_m = 1.0E-02 days/liter (from RG 1.109 Table E-1);

C_{tv} = 2.0230 Q_T pCi/g;

Q_F = 50 kg/day;

t_f = 2 days;

λ_t = 0.000154 days^{-1}.

C1.2.10 Annual Organ Dose from Atmospherically Released Tritium in Meat

The organ dose is calculated using the equation:

$$Dose_{ja} = DFI_{ja}U_aC_{tf}$$

where C_{tf} is defined as the concentration of tritium in meat which is calculated using the formula:

$$C_{tf} = F_f C_{tv}Q_F\exp(-\lambda_t t_s)$$

When this is inserted into the dose formula, the following equation results:

$$Dose_{ja} = DFI_{ja}U_aF_f C_{tv}Q_F\exp(-\lambda_t t_s)$$

where:

$Dose_{ja}$ = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides in mrem/yr;

DFI_{ja} = the dose conversion factor for the ingestion of tritium in organ j and age group a in mrem/yr;

U_a = ingestion rate for produce for individuals in age group a;

F_f = fraction of animal's daily intake of tritium which appears in each kilogram of flesh (days/kg);

C_{tv} = concentration of tritium in animal's feed (since the formula for the concentration of tritium in vegetation does not depend on time, there is no distinction made between pasture grass and stored feeds);

Q_F = amount of feed consumed by animal per day;

t_s = average time from slaughter to consumption;

λ_t = radiological decay constant for tritium.

To calculate the dose per curie released, the equation above is rearranged and the calculation performed. The rearranged equation is shown below:

$$\frac{Dose_{ja}}{Q_T} = 2.023\ DFI_{ja}U_aF_fQ_F\exp(-\lambda_t t_s)$$

The values used in the equation above are:

DFI_{ja} = values taken from Tables E-11 through E-14 of RG 1.109;

U_a = Infant-0, Child-41, Teen-65, Adult-110;

F_f = 1.2E-02 days/kg;

C_{tv} = 2.0230 Q_T pCi/g;

Q_F = 50 kg/day;

t_s = 20 days;

λ_t = 0.000154 $days^{-1}$.

C1.3 Atmospheric Release Dose Factors: Noble Gases

The equations and values used to calculate the total dose factors for noble gases released to the atmosphere using Regulatory Guide 1.109, Rev. 1, 1977 is shown below. The dose factor in mrem/Ci and mrad/Ci released for each radionuclide is presented in Section 5, Table 5-1.

C1.3.1 Annual Gamma and Beta Air Dose From All Noble Gas Releases

The dose from the submersion of individuals in air containing noble gases was calculated using the equation:

$$\text{Dose}^{\gamma} \text{ or } \text{Dose}^{\beta} = 3.17\text{E+}04\left(\frac{\chi}{Q}\right)\sum_i Q_i\left(DF_i^{\gamma} \text{ or } DF_i^{\beta}\right)$$

where:

Dose^{γ} or Dose^{β}	=	the annual gamma and beta air dose, in mrad/year;
3.17E+04	=	the number of pCi/Ci divided by the number of sec/year;
χ/Q	=	the annual average atmosphere dispersion factor, in sec/m^3 (The location at which the dose was calculated was the site boundary in the south sector-a distance of 1270 meters.);
Q_i	=	the release rate of nuclide i, in Ci/year;
DF_i^{γ} or DF_i^{β}	=	the gamma and beta air dose factors for a uniform semi-infinite cloud of radionuclide i, in mrad-m^3/pCi-year.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_i^{\gamma} \text{ or } Dose_i^{\beta}}{Q_i} = 3.17E{+}04\left(\frac{\chi}{Q}\right)\left(DF_i^{\gamma} \text{ or } DF_i^{\beta}\right)$$

The values used in the equation above are:

χ/Q = 9.36E-07 seconds/m^3 (This value taken from Table I.4-2 of the FSAR, release mode 1B, intermittent, annual average, site boundary.);

$DE_i^{\gamma} \text{ or } DF_i^{B}$ = Values used are taken from Table B-1 of RG 1.109.

C1.3.2 Annual Skin Dose From All Noble Gas Releases

The skin dose from the submersion of individuals in air containing noble gases was calculated using the equation:

$$\text{Dose} = 3.17E{+}04\left(\frac{\chi}{Q}\right)\left(1.11 S_F \sum_i Q_i DF_i^{\gamma} + \sum_i Q_i DFS_i\right)$$

where:

Dose = the annual skin dose due to immersion in a semi-infinite cloud, in mrem/year;

3.17E+04 = the number of pCi/Ci divided by the number of sec/year;

1.11 = the average ratio of tissue to air energy absorption coefficients;

S_F = the attenuation factor that accounts for the dose reduction due to shielding provided by residential structures, dimensionless;

χ/Q = the annual average atmosphere dispersion factor, in sec/m^3 (The location at which the dose was calculated was the site boundary in the south sector - a distance of 1270 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

DF_i^γ = the annual gamma air dose factor for a uniform semi-infinite cloud of nuclide i, in mrad-m^3/pCi-year;

DFS_i = the beta skin dose factor for a semi-infinite cloud of nuclide i, which includes the attenuation by 7 mg/cm^2 of skin, in mrem-m^3/pCi-year.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_i}{Q_i} = 3.17E+04\left(\frac{\chi}{Q}\right)\left(1.11\,S_F DF_i^\gamma + DFS_i\right)$$

The values used in the equation above are:

S_F = 1 (No structural shielding is assumed.);

χ/Q = 9.36E-07 seconds/m^3 (This value taken from Table I.4-2 of the FSAR, release mode 1B, annual average, site boundary.);

DF_i^γ = Values used are taken from Table B-1 of RG 1.109;

DFS_i = Values used are taken from Table B-1 of RG 1.109.

C1.3.3 Annual Total Body Dose From All Noble Gas Releases

The total body dose from the submersion of individuals in air containing noble gases was calculated using the equation:

$$Dose = 3.17E+04\,S_F\left(\frac{\chi}{Q}\right)\sum_i Q_i DFB_i$$

where:

Dose = the annual total body dose due to immersion in a semi-infinite cloud, in mrem/year;

3.17E+04 = the number of pCi/Ci divided by the number of sec/year;

S_F = the attenuation factor that accounts for the dose reduction due to shielding provided by residential structures, dimensionless;

χ/Q = the annual average atmosphere dispersion factor, in sec/m^3 (The location at which the dose was calculated was the site boundary in the south sector - a distance of 1270 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

DFB_i = the total body dose factor for a uniform semi-infinite cloud of nuclide i, which includes the attenuation of 5 g/cm^2 of tissue, in mrem-m^3/pCi-year.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_i}{Q_i} = 3.17\,E{+}04\,S_F\left(\frac{\chi}{Q}\right)DFB_i$$

The values used in the equation above are:

S_F = 1 (No structural shielding is assumed.);

χ/Q = 9.36E-07 seconds/m^3 (This value taken from Table I.4-2 of the FSAR, release mode 1B, annual average, site boundary.);

DFB_i = Values used are taken from Table B-1 of RG 1.109.

APPENDIX D

DERIVATION OF DILUTION FACTORS

USING

REGULATORY GUIDE 1.113

D1.0 Liquid Effluent Dilution Factor Calculations

D1.1 Methodology

The dilution factors used for calculating the doses from liquid effluent released to Lake Michigan were calculated using the methodology of Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I." The parameters used in the calculation and the results of the calculation are given in Table D-1. The results are presented graphically in Figure D-1.

The centerline and shoreline values were calculated using Reg Guide 1.113 formulae 17 and 18 which apply to discharges to the Great Lakes. (The formulae are not presented here. See Section 5 of the PBNP FSAR for the formulae and origin of values used.) These results are applied as calculated for fish caught near PBNP. But for other pathways, an extra factor of two (2) is applied to account for current reversals which occur in Lake Michigan as described in the Appendix I, Section 5, of the PBNP FSAR.

TABLE D-1
SURFACE DILUTION FACTORS
LIQUID EFFLUENTS IN A LARGE LAKE

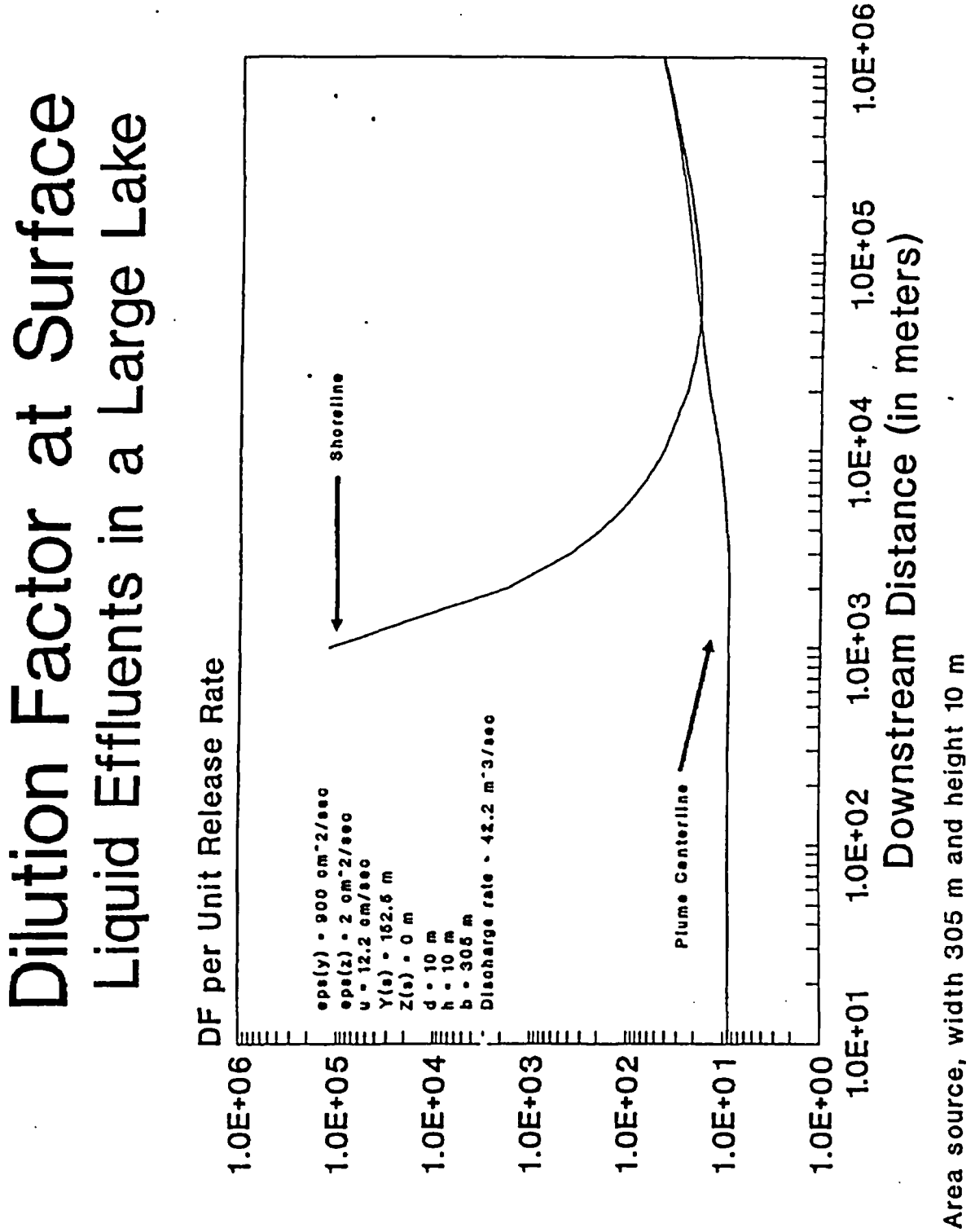
Downstream Distance (meters)	Plume Centerline	Shoreline
10	8.81	
20	8.81	
30	8.81	
40	8.81	
50	8.81	
60	8.81	
70	8.81	
80	8.81	
90	8.81	
100	8.81	
200	8.81	
300	8.81	
400	8.81	
500	8.81	
600	8.81	
700	8.81	
800	8.81	
900	8.81	
1000	8.81	122000
2000	8.86	1758
3000	9.01	401
4000	9.25	186
5000	9.53	116
6000	9.85	83.8
7000	10.2	65.9
8000	10.5	54.9
9000	10.8	47.4
10000	11.1	42.1
20000	14.0	24
30000	16.1	20.1
40000	17.7	18.7
50000	18.8	18.3
60000	19.6	18.2
70000	20.3	18.3
80000	20.9	18.6
90000	21.4	18.9
100000	21.9	19.2
200000	25.9	23.2
300000	29.2	26.9
400000	32.3	30.3
500000	35.2	33.3
600000	37.8	36.0
700000	40.2	38.6
800000	42.6	41.0
900000	44.8	43.3
1000000	46.9	45.5

NOTE: **These values were calculated using the equation described in Section 5.2 of the PBNP FSAR and the following values:**

ϵ_y	=	*900 cm²/sec*	z_s	=	*0 meters*
ϵ_z	=	*2 cm²/sec*	d	=	*10 meters*
u	=	*12.2 cm/sec*	h	=	*10 meters*
y_s	=	*152.5 meters*	b	=	*305 meters*

and a discharge rate of 42.2 m³/sec.

FIGURE D-1
DILUTION FACTOR AT SURFACE



D1.2 Dilution Factor Twelve Miles Downstream: Two Rivers Water Intake

The dilution factor used at the Two Rivers water intake twelve miles downstream from PBNP included the factor of two described in Section D1.1. However, instead of using the straight centerline dilution factor shown in Table 1, the weighted average dilution factor calculated over the width of the plume was used.

This approach was used for the following reasons. First, the path that the current takes to reach the Two Rivers water intake is not straight. In order to reach Two Rivers, the water must flow southeast around Point Beach State Park, which juts into Lake Michigan, and then curves back 90 degrees towards Two Rivers. As a result of this deviation from straight line flow, any part of the plume or possibly none of the plume would impinge upon the intake structure.

Second, there is a difference in the distance offshore of the PBNP discharge and the Two Rivers water intake. The Two Rivers water intake is located 5080 feet offshore. By contrast, PBNP discharges close to the shoreline through two flumes, one directed north and one directed south, and is modeled as a source that extends 1000 feet out into the lake from the shoreline.

Based on these two considerations, it was concluded that the weighted average dilution across the width of the plume as it diverges while flowing south would constitute a better estimate of the dilution factor instead of the calculated for the centerline of an area source as is assumed for the FSAR calculation. The calculation and the values used are shown below.

The average dilution factor at 12 miles downstream was calculated in the following manner:

1. The standard deviation of the radionuclide concentration in the y direction at 12 miles downstream on the surface of the lake was calculated. This calculation used the following formula:

$$\sigma_y = \sqrt{\frac{2 \times \epsilon_y \times x}{u}}$$

where

ϵ_y = lateral turbulent diffusion coefficient in cm^2/sec

x = the downstream distance in cm

u = current in cm/sec

Substituting the values for ϵ_y, x, and u of 900 cm^2/sec, 19308 m, and 12.2 cm/sec, respectively, into the equation yields

$$\sigma_y = \frac{\sqrt{\frac{2 \times 900 \frac{cm^2}{sec} \times 19308\ m \times 100 \frac{cm}{m}}{12.2 \frac{cm}{sec}}}}{100 \frac{cm}{m}} = 168.8 \text{ meters}$$

2. At distances of 0.1σ, 0.2σ, etc., off the plume centerline, the dilution factor was calculated using the equation shown in Section 5.2 of the PBNP FSAR. The distances off the plume centerline, the calculated dilution factor, and the fraction of the area under the normal distribution curve is listed below.

Distance Off Plume Centerline

Fraction of Standard Deviation	Equivalent Distance (m)	Fraction of Total Area Under the Curve for Interval	Dilution Factor
0.1σ	16.9	0.080	13.8
0.2σ	33.8	0.080	14.0
0.3σ	50.6	0.078	14.3
0.4σ	67.5	0.075	14.7
0.5σ	84.4	0.072	15.2
0.6σ	101.3	0.068	15.8
0.7σ	118.1	0.065	16.6
0.8σ	135.0	0.060	17.6
0.9σ	151.9	0.056	18.8
1.0σ	168.8	0.051	20.2
1.1σ	185.6	0.046	21.9
1.2σ	202.5	0.042	23.9
1.3σ	219.4	0.037	26.3
1.4σ	236.3	0.032	29.2
1.5σ	253.2	0.028	32.6
1.75σ	295.4	0.053	44.7
2.0σ	337.6	0.035	64.7
2.25σ	379.8	0.021	98.4
2.5σ	421.9	0.012	158.4
3.0σ	506.3	0.010	482
Totals		1.00	

* It is assumed that the standard deviation of the radionuclide concentrations across the plume can be represented by a normal distribution curve. The fraction of the total area under the curve is that fraction of the area under the curve that lies between, for example, the interval 0.1σ and 0.2σ which also includes the area of the curve in the interval -0.1σ and -0.2σ.

The average dilution factor over the width of the plume was calculated by multiplying the dilution factor at each of the locations off of the plume centerline by the fraction of the total area of the curve occupied by that interval and then summing over all the intervals. An average dilution actor of 29 was calculated.