APPENDIX C

DOSE ANALYSIS REFERENCE 1

Sargent & Lundy LLC

ISSUE SUMMARY
Form SOP-0402-07. Revision 12

DESIGN CONTROL SUMMARY			
CLIENT:	Northern States Power Company	UNIT NO.: 1 & 2	PAGE NO.: 1
PROJECT NAME:	**Prairie Island Nuclear Generating Plant**		TOTAL PGS.: 51
PROJECT NO.:	13385-051	S&L NUCLEAR QA PROGRAM	
CALC. NO.:	2018-04151	APPLICABLE ☒ YES ☐ NO	
TITLE:	Dose Rate Analysis for Prairie Island ISFSI Expansion		
EQUIPMENT NO.:	N/A		

IDENTIFICATION OF PAGES ADDED/REVISED/SUPERSEDED/VOIDED & REVIEW METHOD

Initial Issue.
Pages 1 – 49 (calculation body) and Attachment A (page A1) and Attachment B (page B1). Total 51 pages.

INPUTS/ ASSUMPTIONS
☒ VERIFIED
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IDENTIFICATION OF PAGES ADDED/REVISED/SUPERSEDED/VOIDED & REVIEW METHOD

Revision 1 incorporates changes made to Revision 1 of Calculation TN40HT.0512 (Reference 7.7), which was revised to update the berm geometry by reducing the height of the berm by 3.5 feet with respect to the Independent Spent Fuel Storage Installation (ISFSI) pad elevation. Calculation TN40HT.0512 provides dose rates as a function of distance from the Prairie Island (PI) ISFSI.

Changes to the calculation body made between Revision 0 and Revision 1 are denoted with revision bars along the right margin. All page headers in the main body of the calculation are replaced to reflect the new revision.

Pages 1 – 49 (calculation body) and Attachment A (page A1) and Attachment B (page B1). Total 51 pages.

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NOTE: PRINT AND SIGN IN THE SIGNATURE AREAS

TABLE OF CONTENTS

1.0 Purpose and Scope

Prairie Island Nuclear Generating Plant (PINGP) has a site specific license under 10 CFR Part 72 for independent storage of spent nuclear fuel and high-level radioactive waste storage. This license is specific to the PINGP site, the AREVA TN-40 and TN-40HT metal cask storage technology and to the amount of spent fuel assemblies that may be possessed. Addendum A to the Independent Spent Fuel Storage Installation (ISFSI) Safety Analysis Report (SAR) provides for an ISFSI designed to accommodate a total of 48 TN-40/TN-40HT storage casks [Reference 7.1]. The Minnesota Public Utilities Commission has issued a Certificate of Need (CON) for the storage of up to 64 TN-40/TN-40HT casks to support continued operation of the PINGP site until the end of current plant operating license in 2033/2034 [Reference 7.2]. As part of the ISFSI expansion project per EC 601000000444, the station is installing a new ISFSI pad to accommodate a minimum of 16 additional TN-40/TN-40HT casks to allow continued operation through the current plant license [Reference 7.3]. With the addition of 16 casks, the ISFSI capacity will be 64 casks.

The purpose and scope of this calculation is to determine the total normal operation radiation dose values at the nearest site boundary and at the nearest resident when including the dose contribution due to the 16 additional casks for the expansion ISFSI pad design (i.e., total of 64 TN-40/TN-40HT casks on existing and expansion ISFSI). The total normal operation radiation dose consists of the dose from the existing 48 cask ISFSI, the dose from the 16 cask expansion ISFSI, and the dose due to non-ISFSI related operation of the PINGP. Note: for the purpose of this evaluation, the existing ISFSI refers to the two existing ISFSI concrete pads that are designed to store 48 fuel-loaded casks and the expansion ISFSI refers to the new ISFSI concrete pad for storage of 16 fuel-loaded casks.

The objective of this calculation is to demonstrate that the total normal operation radiation doses will be in accordance with the requirements of 10 CFR 72.104(a) [Reference 7.4], 40 CFR 190.10(a) [Reference 7.5], and 10 CFR 20.1301(a) [Reference 7.6].

In addition, for information purposes, this calculation determines the additional dose rates and collective doses to station personnel and the offsite population due to the 16 additional casks for the expansion ISFSI pad design.

This dose analysis does not consider dose contributions due to radioactivity releases from the fuel-loaded and sealed casks during normal, off-normal, or accident situations. This dose analysis also does not determine a direct shine dose due to accident conditions (Assumption 3.1).

Limitation

Doses calculated in this analysis are based on the assumption that no more than 4 casks are loaded onto the new expansion ISFSI pad every 2 years (Assumption 3.3). This is the same limitation that is applied to the dose analysis used for the existing ISFSI pads [i.e., Calculation TN40HT.0512, Reference 7.7].

2.0 Design Inputs

2.1 48 TN-40HT Cask Loaded ISFSI Dose Rates

The dose rates at different distances from a 48 TN-40HT cask loaded ISFSI are listed in Tables 2.1-1 through 2.1-6. These values are obtained from Calculation TN40HT.0512 [Tables 14 through 19 of Reference 7.7]. The arrangement of the casks and the directions of the "detectors" used in the Monte Carlo N-Particle (MCNP) model in Calculation TN40HT.0512 is shown in Figure 2.1-1 of this calculation (Figure 1 of Calculation TN40HT.0512). The ISFSI layout as illustrated in Figure 2.1-1 is explicitly modeled in MCNP using advanced MCNP geometry. Note that Section 3.1 of Calculation TN40HT.0512 states that no control components like Burnable Poison Rod Assemblies (BPRAs) are included in the MCNP model explicitly. However, Section 6 of Calculation TN40HT.0512 states that using design basis spectral distribution in the MCNP model for the primary gamma radiation sources in all the casks overwhelms the nonconservatism due to not including BPRAs sources.

2.2 Nearest Site Boundary Distance

The nearest site boundary from the existing ISFSI is located 110 meters from the western edge of the ISFSI concrete pads. This value is obtained from Table 8.2-1 of the ISFSI SAR [Reference 7.1].

2.3 Nearest Resident Distance

The nearest residence from the existing ISFSI is located 0.45 miles (i.e., 724 meters) northwest from the ISFSI site. This value is obtained from Section 2.1.4 of the ISFSI SAR [Reference 7.1].

2.4 Existing ISFSI Dose for 40 CFR 190 Compliance

The nearest resident neutron skyshine dose that is used to demonstrate 40 CFR 190 compliance for the existing ISFSI with the 2017 cask loading condition (i.e., 40 casks) is 7.10E-01 mrem/yr. This value is obtained from Page 4 of the 2017 Annual Radioactive Effluent Report [Reference 7.8]. There were no spent fuel storage casks loaded in 2017 and so the 2017 neutron skyshine dose represents a full year of exposure to the 40 casks. There is no nearest resident measured gamma dose contribution from the existing ISFSI with the 2017 cask loading condition (i.e., 40 casks). Section 4.4 of the 2017 Annual Radiological Environmental Monitoring Program Report states that no spent fuel storage effect on offsite ambient gamma radiation was indicated [Reference 7.13]. Note that the 2016 and 2015 Annual Radiological Environmental Monitoring Program Reports were also reviewed [References 7.16 and 7.17]. These reports also state that no spent fuel storage effect on offsite ambient gamma radiation was indicated. Even though the nearest resident gamma dose was found to be not detectable in the 2017 report, the calculated gamma dose discussed in Section 2.1 of this calculation is conservatively used in this analysis. For consistency, the calculated nearest resident neutron dose discussed in Section 2.1 of this calculation is also used in this analysis instead of the measured value in the 2017 report.

2.5 Plant Direct and Gaseous Effluent Dose for 40 CFR 190 Compliance

The nearest resident total plant direct and gaseous effluent dose that is used for 40 CFR 190 compliance is 1.50E-02 mrem/yr (i.e., 3.44E-05 mrem/yr gamma dose + 1.53E-04 mrem/yr beta dose + 1.48E-02 mrem/yr iodine, particulate, H-3 and C-14 dose). These values are obtained from Page 4 of the 2017 Annual Radioactive Effluent Report [Reference 7.8]. Note that the 2016 and 2015 Annual Radioactive Effluent Reports were also reviewed [References 7.14 and 7.15]. These reports indicate that the 2017 values are bounding.

2.6 Radiation Source Term Decay Constant

The decay constant used to calculate the 48 TN-40HT cask loaded ISFSI gamma and neutron radiation source strength due to the assembly in-core region is 0.025 $years^{-1}$ (corresponds to approximately 27.7 years half-life) and 0.0358 $years^{-1}$ (corresponds to approximately 19.4 years half-life), respectively. The decay constant due to the end fittings regions is 0.1315 $years^{-1}$ (corresponds to 5.27 years half-life which is the Co-60 half-life). These values are obtained from Section 4.1 of Calculation TN40HT.0512 [Reference 7.7].

2.7 48 TN-40HT Cask Loaded ISFSI Station Personnel Dose Rates and Collective Doses

The station personnel dose rates and collective doses at specific distances (i.e., locations) from a 48 TN-40HT cask loaded ISFSI are listed in Tables 2.7-1 and 2.7-2, respectively. These values are obtained from Calculation TN40HT.0512 [Tables 7 and 8 of Reference 7.7]. The locations designated in Tables 2.7-1 and 2.7-2 are shown on Figure A7.4-A of the ISFSI SAR (included as Attachment B to this calculation).

2.8 48 TN-40HT Cask Loaded ISFSI Offsite Population Dose Rates and Collective Doses

The offsite population dose rates and collective doses at different distances (i.e., locations) from a 48 TN-40HT cask loaded ISFSI are listed in Table 2.8-1. The offsite population dose rates are obtained from Table 11 of Calculation TN40HT.0512 [Reference 7.7]. Note that the offsite population numbers are taken from Table A7.5-2 of the ISFSI SAR [Reference 7.1] versus Table 11 of Calculation TN40HT.0512 because the ISFSI SAR uses more recent population data (i.e., from 2012) [Reference 6 listed in Section A7.8 of the ISFSI SAR].

Table 2.1-1
48 TN-40HT Cask Loaded ISFSI Dose Rates from North/South Faces
Total Dose Rates (Direct plus Skyshine)

Distance from the ISFSI Face (m)	Distance from the ISFSI Center (m)	Gamma Radiation		Neutron Radiation		Total	
		Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error
0	4.03	5.59E+00	0.014	6.65E+00	0.018	1.22E+01	0.012
10	14.03	3.76E+00	0.010	4.77E+00	0.011	8.52E+00	0.008
45	49.03	1.14E+00	0.006	1.54E+00	0.007	2.68E+00	0.005
100	104.03	8.04E-02	0.005	2.32E-01	0.006	3.13E-01	0.005
200	204.03	1.99E-02	0.006	4.46E-02	0.008	6.44E-02	0.006
300	304.03	6.02E-03	0.020	1.14E-02	0.015	1.74E-02	0.012
400	404.03	2.02E-03	0.011	3.30E-03	0.020	5.33E-03	0.013
500	504.03	7.62E-04	0.016	1.06E-03	0.025	1.82E-03	0.016
600	604.03	3.17E-04	0.019	4.06E-04	0.055	7.24E-04	0.032
700	704.03	1.43E-04	0.023	1.52E-04	0.075	2.95E-04	0.040
800	804.03	7.01E-05	0.041	5.79E-05	0.093	1.28E-04	0.048
900	904.03	3.49E-05	0.037	2.89E-05	0.182	6.38E-05	0.085
1000	1004.03	1.76E-05	0.017	9.95E-06	0.102	2.75E-05	0.039

Table 2.1-2
48 TN-40HT Cask Loaded ISFSI Dose Rates from East/West Faces
Total Dose Rates (Direct plus Skyshine)

Distance from the ISFSI Face (m)	Distance from the ISFSI Center (m)	Gamma Radiation		Neutron Radiation		Total	
		Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error
0	70.47	3.46E+01	0.021	2.91E+01	0.018	6.36E+01	0.014
10	80.47	2.85E+00	0.023	4.49E+00	0.020	7.35E+00	0.015
45	115.47	6.56E-02	0.005	2.79E-01	0.018	3.45E-01	0.014
100	170.47	3.24E-02	0.007	1.06E-01	0.009	1.39E-01	0.007
200	270.47	8.01E-03	0.007	2.06E-02	0.011	2.86E-02	0.008
300	370.47	2.48E-03	0.014	5.33E-03	0.013	7.81E-03	0.010
400	470.47	8.53E-04	0.015	1.85E-03	0.098	2.70E-03	0.067
500	570.47	3.31E-04	0.024	5.66E-04	0.037	8.97E-04	0.025
600	670.47	1.58E-04	0.111	2.23E-04	0.087	3.81E-04	0.068
700	770.47	6.38E-05	0.037	8.03E-05	0.084	1.44E-04	0.049
800	870.47	2.96E-05	0.023	4.06E-05	0.160	7.02E-05	0.093
900	970.47	1.55E-05	0.034	1.55E-05	0.247	3.10E-05	0.125
1000	1070.47	8.53E-06	0.023	7.70E-06	0.207	1.62E-05	0.099

Table 2.1-3
48 TN-40HT Cask Loaded ISFSI Dose Rates from ISFSI Corners(1)
Total Dose Rates (Direct plus Skyshine)

Distance from the ISFSI Face (m)	Distance from the ISFSI Center (m)	Gamma Radiation		Neutron Radiation		Total	
		Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error
10	77.91	3.74E+00	0.011	4.97E+00	0.012	8.71E+00	0.008
45	107.91	5.10E-01	0.007	7.88E-01	0.008	1.30E+00	0.005
100	159.24	4.19E-02	0.005	1.23E-01	0.007	1.65E-01	0.005
200	256.49	1.15E-02	0.007	2.52E-02	0.008	3.67E-02	0.006
300	355.27	3.67E-03	0.009	6.75E-03	0.014	1.04E-02	0.010
400	454.58	1.40E-03	0.065	1.97E-03	0.015	3.37E-03	0.028
500	554.14	5.34E-04	0.013	7.20E-04	0.029	1.25E-03	0.018
600	653.84	2.27E-04	0.017	2.64E-04	0.063	4.91E-04	0.035
700	753.61	1.03E-04	0.015	1.04E-04	0.055	2.07E-04	0.029
800	853.44	5.21E-05	0.020	3.64E-05	0.041	8.84E-05	0.020
900	953.31	2.68E-05	0.016	1.78E-05	0.107	4.46E-05	0.044
1000	1053.20	1.49E-05	0.021	7.47E-06	0.144	2.24E-05	0.050

Note:
(1) Distances are measured along an imaginary line drawn from the corners of the ISFSI at 45 degrees.

Table 2.1-4
48 TN-40HT Cask Loaded ISFSI Skyshine Radiation Dose Rates from North/South Faces

Distance from the ISFSI Face (m)	Distance from the ISFSI Center (m)	Gamma Skyshine Radiation		Neutron Skyshine Radiation		Total Skyshine	
		Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error
0	4.03	4.85E+00	0.016	6.65E+00	0.018	1.15E+01	0.012
10	14.03	3.27E+00	0.011	4.76E+00	0.012	8.03E+00	0.008
45	49.03	9.88E-01	0.007	1.54E+00	0.008	2.53E+00	0.005
100	104.03	7.42E-02	0.006	2.32E-01	0.006	3.06E-01	0.005
200	204.03	1.85E-02	0.007	4.46E-02	0.008	6.31E-02	0.006
300	304.03	5.63E-03	0.022	1.14E-02	0.015	1.70E-02	0.012
400	404.03	1.89E-03	0.011	3.30E-03	0.020	5.19E-03	0.014
500	504.03	7.08E-04	0.017	1.06E-03	0.025	1.77E-03	0.016
600	604.03	2.93E-04	0.021	4.06E-04	0.055	7.00E-04	0.033
700	704.03	1.30E-04	0.025	1.52E-04	0.075	2.82E-04	0.042
800	804.03	6.36E-05	0.046	5.79E-05	0.093	1.21E-04	0.050
900	904.03	3.15E-05	0.041	2.89E-05	0.182	6.04E-05	0.090
1000	1004.03	1.56E-05	0.019	9.95E-06	0.102	2.56E-05	0.041

Table 2.1-5
48 TN-40HT Cask Loaded ISFSI Skyshine Radiation Dose Rates from East/West Faces

Distance from the ISFSI Face (m)	Distance from the ISFSI Center (m)	Gamma Skyshine Radiation		Neutron Skyshine Radiation		Total Skyshine	
		Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error
0	70.47	2.95E+01	0.024	2.90E+01	0.018	5.85E+01	0.015
10	80.47	2.46E+00	0.027	4.49E+00	0.020	6.95E+00	0.016
45	115.47	5.75E-02	0.005	2.79E-01	0.018	3.37E-01	0.015
100	170.47	2.93E-02	0.008	1.06E-01	0.009	1.35E-01	0.007
200	270.47	7.31E-03	0.008	2.06E-02	0.011	2.79E-02	0.008
300	370.47	2.26E-03	0.016	5.33E-03	0.013	7.59E-03	0.011
400	470.47	7.70E-04	0.017	1.85E-03	0.098	2.62E-03	0.069
500	570.47	2.98E-04	0.027	5.66E-04	0.037	8.65E-04	0.026
600	670.47	1.42E-04	0.123	2.23E-04	0.087	3.65E-04	0.071
700	770.47	5.60E-05	0.042	8.03E-05	0.084	1.36E-04	0.052
800	870.47	2.54E-05	0.028	4.06E-05	0.160	6.60E-05	0.099
900	970.47	1.31E-05	0.040	1.55E-05	0.247	2.87E-05	0.135
1000	1070.47	7.04E-06	0.028	7.70E-06	0.207	1.47E-05	0.109

Table 2.1-6
48 TN-40HT Cask Loaded ISFSI Skyshine Radiation Dose Rates from ISFSI Corners(1)

Distance from the ISFSI Face (m)	Distance from the ISFSI Center (m)	Gamma Skyshine Radiation		Neutron Skyshine Radiation		Total Skyshine	
		Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error	Dose Rate (mrem/hr)	Dose Rate Relative Error
10	77.91	3.22E+00	0.012	4.96E+00	0.012	8.18E+00	0.009
45	107.91	4.40E-01	0.008	7.88E-01	0.008	1.23E+00	0.006
100	159.24	3.84E-02	0.006	1.23E-01	0.007	1.61E-01	0.005
200	256.49	1.07E-02	0.008	2.52E-02	0.008	3.59E-02	0.006
300	355.27	3.43E-03	0.010	6.75E-03	0.014	1.02E-02	0.010
400	454.58	1.31E-03	0.069	1.97E-03	0.015	3.27E-03	0.029
500	554.14	4.96E-04	0.014	7.20E-04	0.029	1.22E-03	0.018
600	653.84	2.09E-04	0.019	2.64E-04	0.063	4.73E-04	0.036
700	753.61	9.38E-05	0.017	1.04E-04	0.055	1.98E-04	0.030
800	853.44	4.70E-05	0.023	3.64E-05	0.041	8.34E-05	0.022
900	953.31	2.39E-05	0.018	1.78E-05	0.107	4.17E-05	0.047
1000	1053.20	1.33E-05	0.024	7.47E-06	0.144	2.08E-05	0.054

Note:
(1) Distances are measured along an imaginary line drawn from the corners of the ISFSI at 45 degrees.

[NOT-PUBLIC DATA BEGINS

Table 2.7-1
48 TN-40HT Cask Loaded ISFSI Station Personnel Dose Rates

Location #	Location	Distance (Feet From Center ISFSI)	Full Time (Personnel)	Outage (Personnel)	Dose Rate (mrem/hr)
1	34 OCA Gatehouse (D-2)	[redacted]	2	0	2.57E-02
2	22 Receiving Warehouse (D-5) 55 13 P1ex Project Office (D-5) A 4 P1ex Project Office (D-5)		30	0	2.77E-02
3	24 NPD Building (E-6) 33 NPD Annex Building (E-5) Quality Assurance Modular Office (E-5)		60	1	2.26E-02
4	42 Fabrication Shop (C-5) 25 Steam Generator Mock up Building (C-5) 48 Fabrication Shop (D-5)		2	45	5.76E-03
5	30 Warehouse (C-5) 31 Multiuse Warehouse (C-5) 21 Warehouse -8 (C-6)		0	2	2.34E-03
6	12 Substation, SBO Structures (B-6)		0	2	4.12E-04
7	23 New Administration Building (D-6) 6 Security Building (D-6)		287	25	3.34E-03
8	4 Turbine Building (D-7) 28 Warehouse -2 (E-7) 3 Auxiliary Building (E-7) 13 New Service Building (D-8) 11 D5/D6 DG Building (D-7) 79 Security DG Building (D-7)		180	192	2.34E-03
9	Outage Trailers (E-7)		5	40	7.04E-03
10	60 Fabrication Shop (E-7) 29 Main Plant Warehouse (E-7) 66 Maintenance Storage Building (E-7)		23	45	2.94E-03
11	20 Environmental Lab (B-9)		2	0	1.85E-04
12	Training Center		49	0	3.16E-02
13	38 Old Administration Building (D-7) 71 Administration Building Addition (D-7)		68	0	1.73E-03
14	13 New Service Building (D-8)		9	0	1.05E-03

NOT-PUBLIC DATA ENDS]

[NOT-PUBLIC DATA BEGINS

Table 2.7-2
48 TN-40HT Cask Loaded ISFSI Station Personnel Collective Doses

Location #	Location	Distance (Feet From Center ISFSI)	Full Time (person-rem)	Outage (person-rem)	Total Exposure (person-rem)
1	34 OCA Gatehouse (D-2)	[redacted]	0.13	0	0.13
2	22 Receiving Warehouse (D-5) 55 13 P1ex Project Office (D-5) A 4 P1ex Project Office (D-5)		2.08	0	2.08
3	24 NPD Building (E-6) 33 NPD Annex Building (E-5) Quality Assurance Modular Office (E-5)		3.39	1.22E-02	3.40
4	42 Fabrication Shop (C-5) 25 Steam Generator Mock up Building (C-5) 48 Fabrication Shop (D-5)		0.03	0.14	0.17
5	30 Warehouse (C-5) 31 Multiuse Warehouse (C-5) 21 Warehouse -8 (C-6)		0	2.53E-03(1)	2.53E-03
6	12 Substation, SBO Structures (B-6)		0	4.45E-04	4.45E-04
7	23 New Administration Building (D-6) 6 Security Building (D-6)		2.39	0.05	2.44
8	4 Turbine Building (D-7) 28 Warehouse -2 (E-7) 3 Auxiliary Building (E-7) 13 New Service Building (D-8) 11 D5/D6 DG Building (D-7) 79 Security DG Building (D-7)		1.05	0.24	1.30
9	Outage Trailers (E-7)		0.09	0.15	0.24
10	60 Fabrication Shop (E-7) 29 Main Plant Warehouse (E-7) 66 Maintenance Storage Building (E-7)		0.17	0.07	0.24
11	20 Environmental Lab (B-9)		9.24E-04(1)	0	9.24E-04
12	Training Center		3.87	0	3.87
13	38 Old Administration Building (D-7) 71 Administration Building Addition (D-7)		0.29	0	0.29
14	13 New Service Building (D-8)		0.02	0	0.02
Total			13.51	0.67	14.18

Note:
1) The values in this table are from Table 8 of Calculation TN40HT.0512 [Reference 7.7] (Design Input 2.7). Table 8 of Calculation TN40HT.0512 lists a collective dose of "0.00" for this location. However, the total exposure column shows a non-zero value. Therefore; since Table 2.7-1 shows that personnel are located at this location, this value is made equal to the total exposure. It is assumed that the "0.00" value is due to round-off.

NOT-PUBLIC DATA ENDS]

Table 2.8-1
48 TN-40HT Cask Loaded ISFSI Offsite Population Dose Rates and Collective Doses

Offsite Population	Description	Distance	Occupancy Times	Population	Dose Rate (mrem/hr)	Collective Exposure (person-rem)(1)
Permanent Population Within 2 Mile Radius	2 mile - radius	> 0.45 mile	8760	398	2.91E-04	1.01
Transient Employee Population	2 mile - PI community center, government center, and clinic	0.8 mile	2000	80	3.33E-05	5.33E-03
	2 mile - Employees at Treasure Island Casino	0.8 mile	8760	435	3.33E-05	0.13
Transient Recreational Population	2 mile - Treasure Island Casino	0.8 mile	8760	5400	3.33E-05	1.58
Marina and RV Park(2)	2 mile - PI community center, government center, and clinic(2)	0.8 mile(2)	1160(2)	450	3.33E-05	1.74E-02
	Total Collective Within 2 Mile					**2.74**

Note:
(1) Collective exposures are determined by multiplying the dose rate (column 6) by the population (column 5) and by the occupancy time (column 4). The product is divided by 1000 mrem/rem to obtain collective exposures in person-rem.
(2) This location is obtained from Table A7.5-2 of the ISFSI SAR [Reference 7.1].

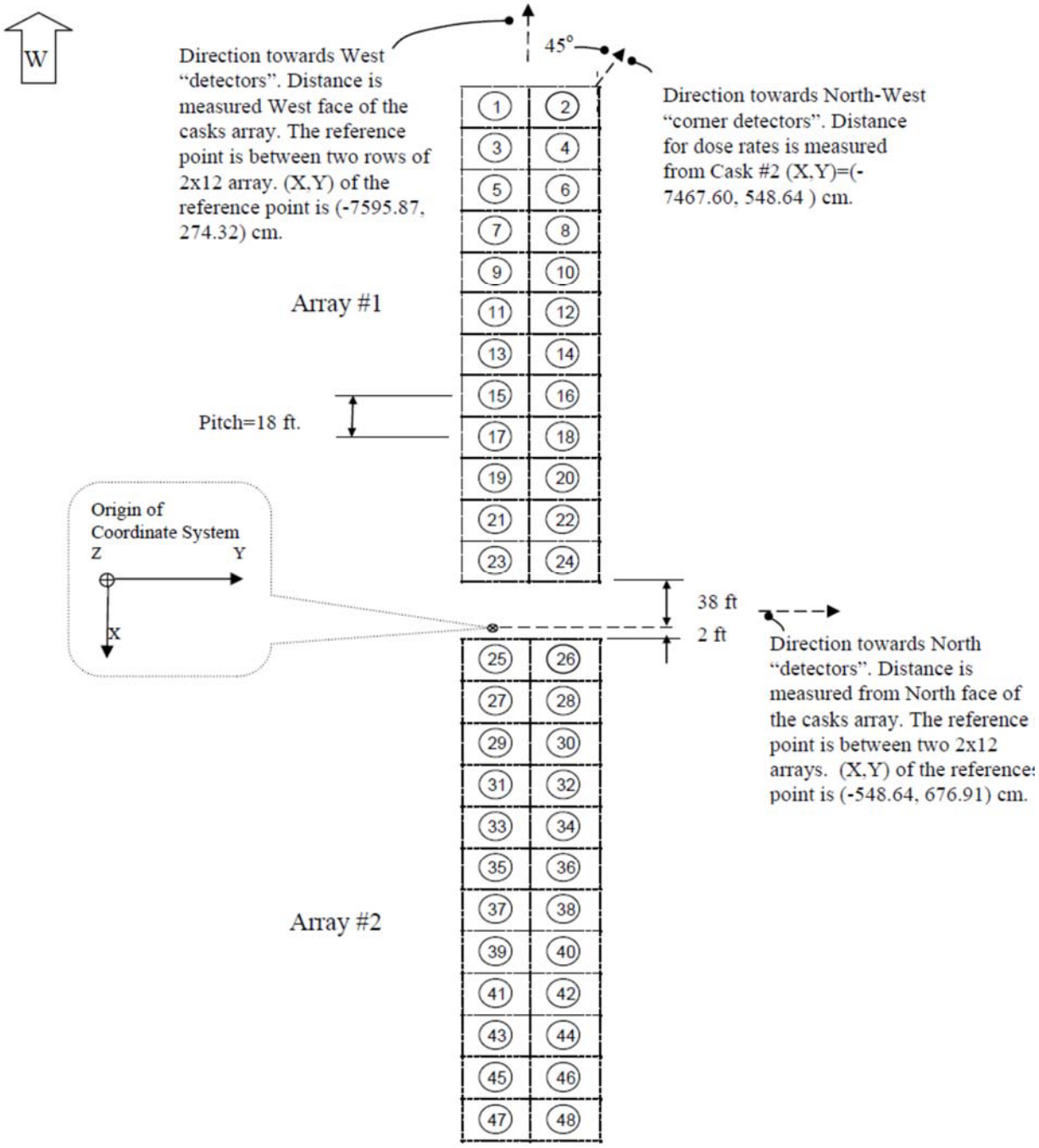

Figure 2.1-1

Arrangement of Casks and "Detectors" in MCNP Calculation Model for ISFSI Dose Rate Estimates (Not to Scale Sketch)

3.0 Assumptions

3.1 As indicated in Section A3.3.5.3 of the ISFSI SAR [Reference 7.1], there are no credible events associated with use of the TN-40HT casks which could result in releases of radioactive products or unacceptable increases in direct radiation. It is assumed that this remains true for the ISFSI expansion design. Therefore, this dose analysis does not consider dose contributions due to radioactivity releases from the fuel-loaded and sealed casks during normal, off-normal, or accident situations. This dose analysis also does not determine a direct shine dose due to accident conditions. In addition, the confinement analysis which uses design basis source terms in Calculation TN40HT-0503 assumes only one cask is in the off-normal or accident condition [Reference 7.9]. Since the TN-40HT cask with the design basis source term is also used for the expansion ISFSI pad, the confinement analysis performed in Calculation TN40HT-0503 remains applicable and so the confinement analysis is not redone in this calculation for the storage of spent fuel in TN-40HT casks on the expansion ISFSI pad.

3.2 Other sources of radiation located on the PINGP site which could add to the radiation level at the ISFSI controlled area boundary are considered to be insignificant when compared to the radiation level associated with the spent fuel storage casks. This assumption is consistent with Assumption #2 of Calculation 12911.54-UR(D)-003 [Reference 7.10], which compares the ISFSI controlled area boundary dose to the 10 CFR 20.1301(a)(2) unrestricted area dose rate requirement not to exceed 2 mrem/hr.

3.3 The dose rate estimates at different distances from a 48 TN-40HT cask loaded ISFSI as determined in Assumption 3.1.3 of Calculation TN40HT.0512 use a cask loading schedule of 4 storage casks every 2 years. This cask loading schedule (i.e., 4 storage casks every 2 years) is assumed to remain the same for the expansion ISFSI pad.

3.4 As described in Section 4.0, the dose contribution due to fuel-loaded casks stored on the expansion ISFSI pad is determined by applying the ISFSI dose versus distance information for the existing ISFSI pads to the expansion ISFSI pad by using Equations 2 through 5. These equations are based on given dose rates at particular distances from the ISFSI, i.e., dose rates from Tables 2.1-1 through 2.1-3, which are calculated using MCNP. Although MCNP takes into account geometry effects due to the location of each cask with respect to the dose point, Equations 2 through 5 do not incorporate any geometry effects. It is assumed that geometry effects have no significant impact, on the values calculated using Equations 2 through 5, for the following reasons: 1) The nearest site boundary and the nearest resident are located beyond the ISFSI berm, therefore, the dose rates at these locations are mostly due to skyshine radiation and the impact of geometry becomes less significant for skyshine radiation. 2) The nearest site boundary and the nearest resident dose rates are calculated using bounding dose rate values (Section 4.0). 3) The nearest site boundary and the nearest resident are located at large distances from the ISFSI (i.e., greater than 100 meters). For large distances the ISFSI resembles a point source in radiation transport models, therefore geometry effects become less significant.

4.0 Methodology and Acceptance Criteria

This calculation determines the total normal operation radiation dose values at the nearest site boundary and at the nearest resident when including the dose contribution due to the 16 additional casks for the expansion ISFSI pad design (i.e., total of 64 TN-40/TN-40HT casks on existing and expansion ISFSI). The objective of this calculation is to demonstrate that the total normal operation radiation doses will be in accordance with the requirements of 10 CFR 72.104(a), 40 CFR 190.10(a), and 10 CFR 20.1301(a).

In addition, for information purposes, this calculation determines the additional dose rates and collective doses to station personnel and the offsite population due to the 16 additional casks for the expansion ISFSI pad design.

This dose analysis does not consider dose contributions due to radioactivity releases from the fuel-loaded and sealed casks during normal, off-normal, or accident situations. This dose analysis also does not determine a direct shine dose due to accident conditions (Assumption 3.1).

A picture of the ISFSI as taken from the CON is shown in Figure 4.0-1 of this calculation (Figure 3-8 of Reference 7.2). Note that this picture does not show the 2017 cask loading condition (i.e., 40 casks). The existing two ISFSI pads are aligned horizontally in the east-west direction as shown in Figure 4.0-2 of this calculation. The proposed location of the expansion ISFSI pad is directly south of the existing east pad. This is shown on Drawings NF-120941 [Reference 7.11] and SK-PINGP-EC601000000444-S-02 [Reference 7.12], which show the new location and structural design. Figure 4.0-2 of this calculation shows a snapshot of the expansion ISFSI as taken from Drawing NF-120941. Per EC 601000000444, the southeast position was chosen to address concerns with undermining the existing pads during construction activities for the new pad, and it also efficiently uses space in the ISFSI for additional future expansion to the west. Figure 4.0-3 of this calculation illustrates portions of the site boundary, which is also the site exclusion area boundary and the ISFSI controlled area boundary defined in 10 CFR 20.1003 and 10 CFR 72.3 (Section 7.3.2.1.2 of the CON). The site boundary is also shown in Figure 1.2-1 of the ISFSI SAR. The nearest resident location is shown in Figure 2.1-2 of the ISFSI SAR, which is illustrated as a snapshot in Figure 4.0-4 of this calculation.

The calculated nearest site boundary and nearest resident total dose for the expanded ISFSI pad design includes 1) the dose contribution due to the existing ISFSI (at fully loaded conditions), 2) dose due to other uranium fuel cycle operations conducted on the site, and 3) dose due to the 16 fuel-loaded casks on the expansion ISFSI pad.

Existing ISFSI Dose Contribution

The dose contribution due to the existing ISFSI includes the dose contribution associated with storage casks that have already been loaded and placed on the existing ISFSI pads and storage casks that have yet to be loaded on the existing ISFSI pads (which totals to 48 casks). The nearest site boundary from the existing ISFSI is located 110 meters from the western edge of the ISFSI concrete pads (Design Input 2.2). The

dose rate at the nearest site boundary due to the existing ISFSI is based on the design basis calculation for the fully loaded ISFSI (i.e., 48 casks) and is obtained using the information from Table 2.1-1. The dose rate at 100 meters from the north/south face of the existing ISFSI is 3.13E-01 mrem/hr. Using a distance of 100 meters from the ISFSI face versus 110 meters from the ISFSI face is conservative and using the dose rates from the "North/South" faces are bounding compared to the dose rates from the "East/West" faces or the dose rates from the ISFSI corners (Tables 2.1-1, 2.1-2, and 2.1-3). This is because the ISFSI self-shielding due to blocking of radiation from one cask by the other casks in the array is less pronounced when considering "North" or "South" directions. The blocking for "West" or "East" directions is maximal. The nearest resident from the existing ISFSI is located 724 meters northwest from the ISFSI site (Design Input 2.3). The dose at the nearest resident due to the existing ISFSI is based on the design basis calculation for the fully loaded ISFSI (i.e., 48 casks) and is obtained using the information from Table 2.1-3. The dose rate at 704.03 meters from the center of the existing ISFSI is 3.05E+00 mrem/yr [i.e., 3.48E-04 mrem/hr (linearly interpolated from the "Corner" dose rates in Table 2.1-3) x 8760 hr/yr]. Using a distance of 704.03 meters from the center of the ISFSI versus 724 meters from the center of the ISFSI is conservative and using the "Corners" dose rates from the ISFSI center is bounding compared to the dose rates at the same distance from the "North/South" and "East/West" ISFSI centers (Tables 2.1-1, 2.1-2, and 2.1-3).

Uranium Fuel Cycle Contribution

The dose contribution due to other uranium fuel cycle operations conducted on the site includes the dose contribution from direct shine and dose due to radionuclide releases from the plant. The dose at the nearest site boundary due to other uranium fuel cycle operations is assumed to be negligible when compared to the radiation level associated with the ISFSI (Assumption 3.2). The dose at the nearest resident due to other uranium fuel cycle operations is obtained from the 2017 Annual Radioactive Effluent Report. The dose at the nearest resident due to other uranium fuel cycle operations is 1.50E-02 mrem/yr (Design Input 2.5).

Expansion ISFSI Contribution

The dose contribution due to 16 fuel-loaded casks on the expansion ISFSI pad is determined by using the dose rate versus distance information and the equations from Calculation TN40HT.0512 for the existing ISFSI pads. Calculation TN40HT.0512 provides the dose rates as a function of distance from the edge of the pads in the north/south, east/west, and corner directions for the existing ISFSI loaded with 48 TN-40HT fuel-loaded casks. The gamma and neutron total (direct plus skyshine) dose rates at different distances are listed in Tables 2.1-1 through 2.1-3 of this calculation and the gamma and neutron skyshine dose rates are listed in Tables 2.1-4 through 2.1-6.

Section A7.2.6 of the ISFSI SAR addresses the design basis fuel chosen for Calculation TN40HT.0512. Section A7.2.6 of the ISFSI SAR states that the design basis bounding source terms for radiation shielding are obtained from the Westinghouse 14x14 standard fuel assembly with a U-235 enrichment of 3.40 wt.%, a burnup of 60,000 MWD/MTU, and a cooling time of 18 years. The design basis bounding source term was determined

by considering seven limiting combinations of burnup and cooling time as shown in Table A7.2-11 of the ISFSI SAR. Section A7A.7 of the ISFSI SAR states that the offsite dose rate calculation conservatively bounds ISFSI operation with a mixture of TN-40 and TN-40HT casks. As such, the existing dose analysis (i.e., Calculation TN40HT.0512) which uses the TN-40HT cask and the bounding design basis source term is bounding and applicable for the expansion ISFSI pad analysis.

Direct scaling of the ISFSI dose versus distance information from the 48 cask ISFSI to obtain dose versus distance for the 16 cask expansion ISFSI (i.e., using a scaling factor of 16/48) is not accurate because the dose versus distance information takes credit for radiodecay due to scheduled ISFSI loading. As such, direct scaling of the 48 cask ISFSI doses for 16 casks would be nonconservative. Distance dependent dose rates from Calculation TN40HT.0512 are provided in Tables 2.1-1 through 2.1-6 based on loading 48 TN-40HT casks over a 22 year period assuming 4 storage casks are loaded every 2 years. Calculation TN40HT.0512 explains how a reduction in the source term source strength is determined for the MCNP model to account for the total source strength taking into account radiodecay. Specifically, the source strength at any cooling time is expressed with the following equation:

$$A(t) = A(0)e^{-\mu(t-18)} \qquad \text{\{Equation 1\}}$$

$where$

$A(t) = source\ strength\ at\ time\ t\ in\ yrs\ (18 < t < 40)$
$A(0) = source\ strength\ at\ 18\ years$
$\mu = decay\ constant.$

Decay constants of 0.025 years^{-1} (corresponds to approximately 27.7 years half-life for fission gammas), 0.0358 years^{-1} (corresponds to approximately 19.4 years half-life for neutrons), and 0.1315 years^{-1} (corresponds to 5.27 years half-life for activation gammas) are provided (Design Input 2.6). Since Equation 1 reduces the source strength as if all the different gammas with their different half-lives and energies decay in unison at the specified rate, the dose rate is directly proportional to the gamma source strength and A(0) and A(t) can be replaced by dose rates, D(0) and D(t). Given a gamma dose rate D(t) at a particular distance from the ISFSI [e.g., 8.04E-02 mrem/hr at 104.03 meters from Table 2.1-1 which represents the dose rate at 104.03 meters from the fully loaded (i.e., 48 cask) ISFSI] the contribution to the dose rate from any cask can be determined by solving Equation 2 for D(0). D(0) represents the dose rate for a cask with no radiodecay since the cask was placed on the ISFSI. The dose rate from any cask on the ISFSI is the product of D(0) and the exponent (which accounts for radiodecay for the specified number of years the cask has been on the ISFSI).

Note that the already-determined gamma dose value of 8.04E-02 mrem/hr (noted above) for the 48 cask existing ISFSI is used in Equation 2 below to calculate D(0), which is then used to calculate new dose values for the 16 cask expansion ISFSI (see Equation 3 below). This approach is illustrated in the solving of Equations 2 through 5 below

(Equations 4 and 5 are for neutron dose). The final results used in this analysis for the 48 cask existing ISFSI are obtained from Tables 2.1-1 through 2.1-3, which are from Calculation TN40HT.0512.

$$D(t)_{48} = 8.04E-02\frac{mrem}{hr} = 4D(0) + 4D(0)e^{(-0.025yr^{-1}\times 2yr)} + 4D(0)e^{(-0.025yr^{-1}\times 4yr)} + 4D(0)e^{(-0.025yr^{-1}\times 6yr)} + 4D(0)e^{(-0.025yr^{-1}\times 8yr)} + 4D(0)e^{(-0.025yr^{-1}\times 10yr)} + 4D(0)e^{(-0.025yr^{-1}\times 12yr)} + 4D(0)e^{(-0.025yr^{-1}\times 14yr)} + 4D(0)e^{(-0.025yr^{-1}\times 16yr)} + 4D(0)e^{(-0.025yr^{-1}\times 18yr)} + 4D(0)e^{(-0.025yr^{-1}\times 20yr)} + 4D(0)e^{(-0.025yr^{-1}\times 22yr)}$$ {Equation 2}.

Solving for D(0) gives D(t) = 8.04E-02 mrem/hr = 37.00497 D(0), therefore D(0) = 2.17E-03 mrem/hr which is the dose rate for a cask with no additional radiodecay (other than 18 years). The gamma dose rate for 16 casks at 104.3 meters is therefore:

$$D(t)_{16} = 2.17E-03\frac{mrem}{hr}\times\left(4 + 4e^{(-0.025yr^{-1}\times 2yr)} + 4e^{(-0.025yr^{-1}\times 4yr)} + 4e^{(-0.025yr^{-1}\times 6yr)}\right) = 3.23E-02\frac{mrem}{hr}$$ {Equation 3}.

Similarly, the neutron contribution to the dose rate from any cask at 104.03 meters from the "North/South" face is determined by solving the following equation for D(0):

$$D(t)_{48} = 2.32E-01\frac{mrem}{hr} = 4D(0) + 4D(0)e^{(-0.0358yr^{-1}\times 2yr)} + 4D(0)e^{(-0.0358yr^{-1}\times 4yr)} + 4D(0)e^{(-0.0358yr^{-1}\times 6yr)} + 4D(0)e^{(-0.0358yr^{-1}\times 8yr)} + 4D(0)e^{(-0.0358yr^{-1}\times 10yr)} + 4D(0)e^{(-0.0358yr^{-1}\times 12yr)} + 4D(0)e^{(-0.0358yr^{-1}\times 14yr)} + 4D(0)e^{(-0.0358yr^{-1}\times 16yr)} + 4D(0)e^{(-0.0358yr^{-1}\times 18yr)} + 4D(0)e^{(-0.0358yr^{-1}\times 20yr)} + 4D(0)e^{(-0.0358yr^{-1}\times 22yr)}$$ {Equation 4}.

Solving for D(0) gives D(t) = 2.32E-01 mrem/hr = 33.37342 D(0), therefore D(0) = 6.95E-03 mrem/hr which is the dose rate at 104.03 meters for a cask with no additional radiodecay (other than 18 years). The neutron dose rate for 16 casks at 104.03 meters is therefore:

$$D(t)_{16} = 6.95E-03\frac{mrem}{hr}\times\left(4 + 4e^{(-0.0358yr^{-1}\times 2yr)} + 4e^{(-0.0358yr^{-1}\times 4yr)} + 4e^{(-0.0358yr^{-1}\times 6yr)}\right) = 1.00E-01\frac{mrem}{hr}$$ {Equation 5}.

Note that the gamma dose rate versus distance results in Table 2.1-1 include activation gammas; however, treating the activation gammas as fission gammas in Equations 2 and 3 (i.e., only using a decay constant of 0.025 $years^{-1}$) is conservative since the effective half-life for the fission gammas (i.e., 27.7 years) is longer than that for the activation gammas (i.e., 5.27 years).

Equations 2 through 5 are solved using the gamma and neutron dose rates versus distance values from Tables 2.1-1 through 2.1-3 (i.e., for north/south ISFSI faces, east/west ISFSI faces, and ISFSI corners) to determine the gamma and neutron ISFSI dose rates as a function of distance for the 16 cask expansion ISFSI. Note that this approach assumes that the cask loading schedule of 4 storage casks every 2 years remains the same for the expansion ISFSI pad (Assumption 3.3). The dose rates as a function of distance for the 16 cask expansion ISFSI are listed in Section 5.1. The nearest site boundary from the existing ISFSI is located 110 meters from the western edge of the ISFSI concrete pads. The expansion ISFSI pad is located farther east, and thus farther from the nearest site boundary than are the existing ISFSI pads (Figure 4.0-2 and Figure 4.0-3 of this calculation) and so the distance would be greater than 110 meters. For conservatism, a distance of 100 meters from the ISFSI face is used for determining the dose rate at the nearest site boundary for the expansion ISFSI pad. The dose rate at the nearest site boundary due to spent fuel stored on the expansion ISFSI pad is given in Table 5.1-1 of this calculation. The dose rate at 100 meters from the north/south face of the expansion ISFSI pad is 1.33E-01 mrem/hr. Using the dose rate values for the “North/South” directions is bounding. The nearest resident from the existing ISFSI is located 724 meters northwest from the ISFSI site (Design Input 2.3). The expansion ISFSI pad is located farther southeast, and thus farther from the nearest resident than is the existing ISFSI (Figure 4.0-2 and Figure 4.0-4 of this calculation) and so the distance would be greater than 724 meters. For conservatism, a distance of 704.03 meters from the center of the ISFSI and the ISFSI “Corners” dose rates are used for determining the annual dose to the nearest resident for the expansion ISFSI pad. The dose at the nearest resident due to spent fuel stored on the expansion ISFSI pad is determined from information in Table 5.1-3 of this calculation. The annual dose at 704.03 meters from the center of the ISFSI is 1.27E+00 mrem/yr [i.e., 1.45E-04 mrem/hr (linearly interpolated from Table 5.1-3) x 8760 hr/yr]. Using the “Corners” dose rates from the ISFSI center is bounding compared to the dose rates at the same distance from the “North/South” and “East/West” ISFSI centers (Tables 5.1-1, 5.1-2, and 5.1-3).

Expansion ISFSI Contribution (Skyshine Radiation)

For information purposes, the skyshine radiation contribution from the expansion ISFSI is also calculated in Section 5.2 using a simplified scaling approach. The gamma and neutron skyshine dose rates versus distance values from Tables 2.1-4 through 2.1-6 are used to determine scaling factors that then can be applied to the expansion ISFSI gamma and neutron total dose rates versus distance values determined in Section 5.1.

Station Personnel and Offsite Population Dose Rates and Collective Doses

For information purposes, the additional dose rates and collective doses to station personnel and the offsite population due to the 16 additional casks for the expansion ISFSI is calculated. These dose rates and collective doses are calculated using the same approach described above for calculating the nearest site boundary and nearest resident expansion ISFSI contributions; the only major difference being the nearest site boundary and nearest resident locations (or distances) are replaced with the station personnel and offsite population locations. These new locations are provided in Tables 2.7-1, 2.7-2, and 2.8-1. For conservatism, the station personnel and offsite population distances are not adjusted for the new location of the expansion ISFSI pad. Using the same distances as were used for the existing ISFSI pad results in bounding doses for the expansion ISFSI because the expansion ISFSI is farther from the dose point locations. The station personnel and offsite population locations are located northeast and northwest of the existing ISFSI pad, as shown in Attachment B (station personnel) and as indicated in Section 2.1.4 of the ISFSI SAR (offsite population - Treasure Island Casino). The expansion ISFSI pad is located south of the existing ISFSI pad (Figure 4.0-2), and thus farther from the station personnel and offsite population locations than is the existing ISFSI. Note: it is not immediately clear whether or not the “PI community center, government center, and clinic” listed in Table 2.8-1 are located in the north direction from the existing ISFSI pad. However, the dose rate listed in Table 2.8-1 for this location (0.8 mile, i.e., 1287.5 meters) is based on 1000 meters (Section 6 of Calculation TN40HT.0512) and is therefore well within any expected change in distance that would be attributed to the 40 feet difference between the existing ISFSI pad location and the expansion ISFSI pad location (Figure 4.0-2).

The other difference to the approach is that the gamma contribution and neutron contribution are not separately calculated since these contributions are not separately provided in Tables 2.7-1, 2.7-2, and 2.8-1. Instead, the bounding coefficient and decay constant from Equations 2 through 5 are conservatively used for calculating the total contribution. This translates to the use of 33.37342 for the D(0) constant (neutron parameter) and 0.025 $years^{-1}$ for the decay constant (gamma parameter).

The station personnel dose rates and collective doses for the 16 cask expansion ISFSI are listed in Section 5.3 of this calculation. The offsite population dose rates and collective doses for the 16 cask expansion ISFSI are listed in Section 5.4 of this calculation.

ISFSI Loading Scheme Impact

Note that this calculation does not establish any restrictions on cask placement. All dose points are closer to the existing ISFSI pads than to the new ISFSI pad. The locations of the dose points with respect to the ISFSI pads and the various conservative approaches used in this analysis, as detailed in the discussions above, allow there to be no impact on the results of this calculation due to the chosen loading scheme. The analysis in this calculation bounds any distribution of 64 TN-40HT (or TN-40) casks across the three ISFSI pads (i.e., 40 to 48 casks on the existing ISFSI pads and 16 to 24 casks on the new ISFSI pad).

Acceptance Criteria

The objective of this calculation is to demonstrate that the total normal operation radiation doses (i.e., sum of the direct dose from the existing ISFSI, from the expansion ISFSI, and the dose from normal plant operations) will be in accordance with the requirements of 10 CFR 72.104(a), 40 CFR 190.10(a), and 10 CFR 20.1301(a). Therefore, the acceptance criteria for this calculation is to verify that the total doses are below the dose limits provided in the aforementioned regulations. The dose limits for each regulation are provided below.

10 CFR 72.104(a):

(a) During normal operations and anticipated occurrences, the annual dose equivalent to any real individual who is located beyond the controlled area must not exceed 0.25 mSv (25 mrem) to the whole body, 0.75 mSv (75 mrem) to the thyroid and 0.25 mSv (25 mrem) to any other critical organ as a result of exposure to:
(1) Planned discharges of radioactive materials, radon and its decay products excepted, to the general environment,
(2) Direct radiation from ISFSI or MRS operations, and
(3) Any other radiation from uranium fuel cycle operations within the region.

40 CFR 190.10(a):

(a) The annual dose equivalent does not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations.

10 CFR 20.1301(a):

(a) Each licensee shall conduct operations so that -
(1) The total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem (1 mSv) in a year, exclusive of the dose contributions from background radiation, from any administration the individual has received, from exposure to individuals administered radioactive material and released under § 35.75, from voluntary participation in medical research programs, and from the licensee's disposal of radioactive material into sanitary sewerage in accordance with § 20.2003, and
(2) The dose in any unrestricted area from external sources, exclusive of the dose contributions from patients administered radioactive material and released in accordance with § 35.75, does not exceed 0.002 rem (0.02 millisievert) in any one hour.

Figure 4.0-1

Prairie Island ISFSI and Plant Site

[NOT-PUBLIC DATA BEGINS

Figure 4.0-2

Prairie Island Expansion ISFSI Layout

NOT-PUBLIC DATA ENDS]

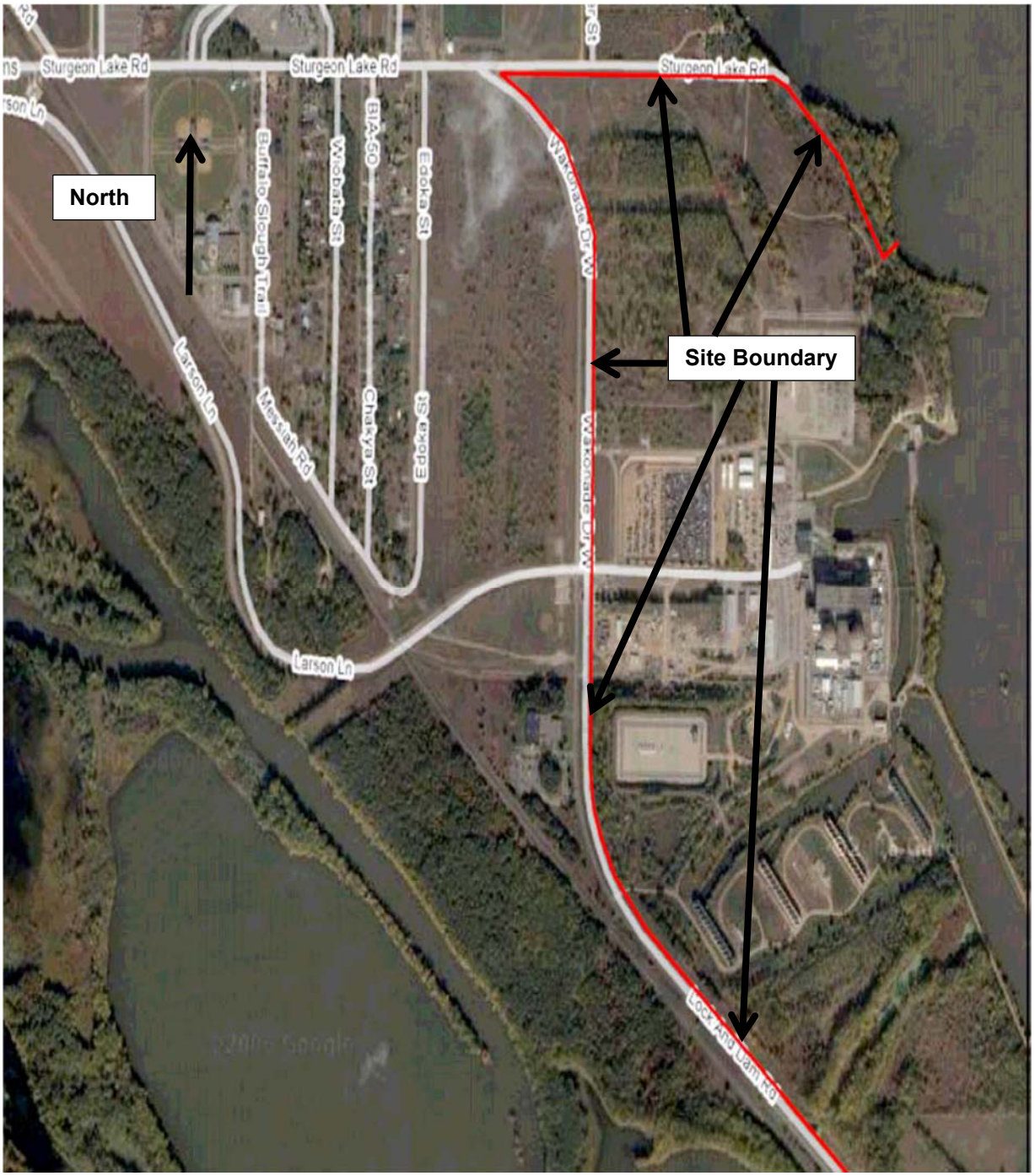

Figure 4.0-3

Prairie Island ISFSI Site Boundaries [Figure 7-10 of Reference 7.2]
(Boundary Shown in Red)

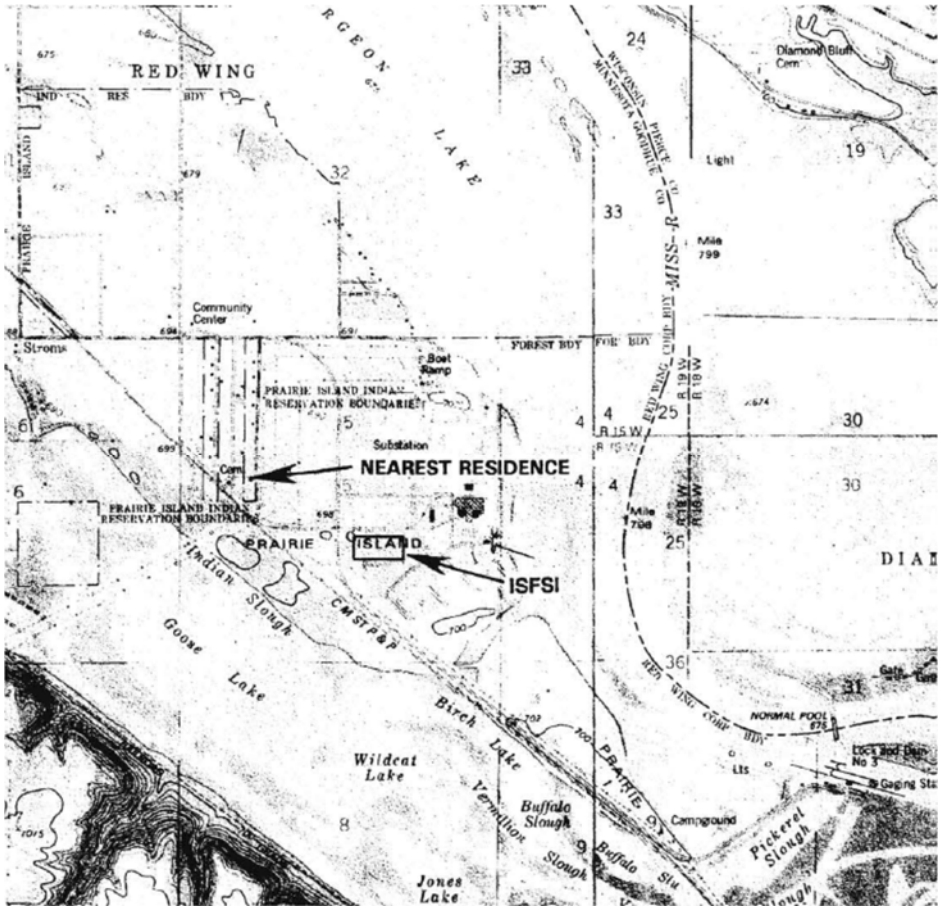

Figure 4.0-4

Prairie Island Nearest Residence Location

5.0 Calculations

5.1 16 Cask Expansion ISFSI Dose Rates

Table 5.1-1
16 Cask Expansion ISFSI Dose Rates from North/South Faces
Total Dose Rates (Direct plus Skyshine)

Distance from Face (m)	Distance from Center (m)	Gamma D0[(1)] (mrem/hr)	Neutron D0[(2)] (mrem/hr)	Total (mrem/hr)	Gamma DT[(3)] (mrem/hr)	Neutron DT[(4)] (mrem/hr)	Total (mrem/hr)
0	4.03	1.51E-01	1.99E-01	3.50E-01	2.25E+00	2.87E+00	5.12E+00
10	14.03	1.02E-01	1.43E-01	2.45E-01	1.51E+00	2.06E+00	3.57E+00
45	49.03	3.08E-02	4.61E-02	7.70E-02	4.58E-01	6.65E-01	1.12E+00
100	104.03	2.17E-03	6.95E-03	9.12E-03	3.23E-02	1.00E-01	1.33E-01
200	204.03	5.38E-04	1.34E-03	1.87E-03	8.00E-03	1.93E-02	2.73E-02
300	304.03	1.63E-04	3.42E-04	5.04E-04	2.42E-03	4.92E-03	7.34E-03
400	404.03	5.46E-05	9.89E-05	1.53E-04	8.12E-04	1.43E-03	2.24E-03
500	504.03	2.06E-05	3.18E-05	5.24E-05	3.06E-04	4.58E-04	7.64E-04
600	604.03	8.57E-06	1.22E-05	2.07E-05	1.27E-04	1.75E-04	3.03E-04
700	704.03	3.86E-06	4.55E-06	8.42E-06	5.75E-05	6.57E-05	1.23E-04
800	804.03	1.89E-06	1.73E-06	3.63E-06	2.82E-05	2.50E-05	5.32E-05
900	904.03	9.43E-07	8.66E-07	1.81E-06	1.40E-05	1.25E-05	2.65E-05
1000	1004.03	4.76E-07	2.98E-07	7.74E-07	7.07E-06	4.30E-06	1.14E-05

Notes:
1) Determined by solving Equation 2 in Section 4.0 for a given gamma dose rate (D(t)) from Table 2.1-1 (i.e., D(t) = 37.00497 D(0)). For example, D(0) at 4.03 m from the ISFSI center = 5.59 mrem/hr (Table 2.1-1) / 37.00497 = **1.51E-01 mrem/hr**.
2) Determined by solving Equation 4 in Section 4.0 for a given neutron dose rate (D(t)) from Table 2.1-1 (i.e., D(t) = 33.37342 D(0)). For example, D(0) at 4.03 m from the ISFSI center = 6.65 mrem/hr (Table 2.1-1) / 33.37342 = **1.99E-01 mrem/hr**.
3) Determined by applying Equation 3 in Section 4.0 to each calculated D(0). For example, D(T) at 4.03 m from the ISFSI center = 1.51E-01 mrem/hr x [4 + 4 x exp(-0.025 yr^{-1} x 2 yr) + 4 x exp(-0.025 yr^{-1} x 4 yr) + 4 x exp(-0.025 yr^{-1} x 6 yr)] = **2.25E+00 mrem/hr**.
4) Determined by applying Equation 5 in Section 4.0 to each calculated D(0). For example, D(T) at 4.03 m from the ISFSI center = 1.99E-01 mrem/hr x [4 + 4 x exp(-0.0358 yr^{-1} x 2 yr) + 4 x exp(-0.0358 yr^{-1} x 4 yr) + 4 x exp(-0.0358 yr^{-1} x 6 yr)] = **2.87E+00 mrem/hr**.

Table 5.1-2
16 Cask Expansion ISFSI Dose Rates from East/West Faces
Total Dose Rates (Direct plus Skyshine)

Distance from Face (m)	Distance from Center (m)	Gamma D0 (mrem/hr)	Neutron D0 (mrem/hr)	Total (mrem/hr)	Gamma DT (mrem/hr)	Neutron DT (mrem/hr)	Total (mrem/hr)
0	70.47	9.35E-01	8.72E-01	1.81E+00	1.39E+01	1.26E+01	2.65E+01
10	80.47	7.70E-02	1.35E-01	2.12E-01	1.15E+00	1.94E+00	3.08E+00
45	115.47	1.77E-03	8.36E-03	1.01E-02	2.64E-02	1.21E-01	1.47E-01
100	170.47	8.76E-04	3.18E-03	4.05E-03	1.30E-02	4.58E-02	5.88E-02
200	270.47	2.16E-04	6.17E-04	8.34E-04	3.22E-03	8.90E-03	1.21E-02
300	370.47	6.70E-05	1.60E-04	2.27E-04	9.96E-04	2.30E-03	3.30E-03
400	470.47	2.31E-05	5.54E-05	7.85E-05	3.43E-04	7.99E-04	1.14E-03
500	570.47	8.94E-06	1.70E-05	2.59E-05	1.33E-04	2.45E-04	3.77E-04
600	670.47	4.27E-06	6.68E-06	1.10E-05	6.35E-05	9.63E-05	1.60E-04
700	770.47	1.72E-06	2.41E-06	4.13E-06	2.56E-05	3.47E-05	6.03E-05
800	870.47	8.00E-07	1.22E-06	2.02E-06	1.19E-05	1.75E-05	2.94E-05
900	970.47	4.19E-07	4.64E-07	8.83E-07	6.23E-06	6.70E-06	1.29E-05
1000	1070.47	2.31E-07	2.31E-07	4.61E-07	3.43E-06	3.33E-06	6.75E-06

Note:
1) See Table 5.1-1 notes.

Table 5.1-3
16 Cask Expansion ISFSI Dose Rates from ISFSI Corners
Total Dose Rates (Direct plus Skyshine)

Distance from Face (m)	Distance from Center (m)	Gamma D0 (mrem/hr)	Neutron D0 (mrem/hr)	Total (mrem/hr)	Gamma DT (mrem/hr)	Neutron DT (mrem/hr)	Total (mrem/hr)
10	77.91	1.01E-01	1.49E-01	2.50E-01	1.50E+00	2.15E+00	3.65E+00
45	107.91	1.38E-02	2.36E-02	3.74E-02	2.05E-01	3.40E-01	5.45E-01
100	159.24	1.13E-03	3.69E-03	4.82E-03	1.68E-02	5.31E-02	7.00E-02
200	256.49	3.11E-04	7.55E-04	1.07E-03	4.62E-03	1.09E-02	1.55E-02
300	355.27	9.92E-05	2.02E-04	3.01E-04	1.47E-03	2.92E-03	4.39E-03
400	454.58	3.78E-05	5.90E-05	9.69E-05	5.62E-04	8.51E-04	1.41E-03
500	554.14	1.44E-05	2.16E-05	3.60E-05	2.15E-04	3.11E-04	5.26E-04
600	653.84	6.13E-06	7.91E-06	1.40E-05	9.12E-05	1.14E-04	2.05E-04
700	753.61	2.78E-06	3.12E-06	5.90E-06	4.14E-05	4.49E-05	8.63E-05
800	853.44	1.41E-06	1.09E-06	2.50E-06	2.09E-05	1.57E-05	3.67E-05
900	953.31	7.24E-07	5.33E-07	1.26E-06	1.08E-05	7.69E-06	1.85E-05
1000	1053.20	4.03E-07	2.24E-07	6.26E-07	5.99E-06	3.23E-06	9.21E-06

Note:
1) See Table 5.1-1 notes.

Table 5.1-4
Total ISFSI Dose Rates (Existing and 16 Cask Expansion ISFSIs) from North/South Faces
Total Dose Rates (Direct plus Skyshine)

Distance from Face (m)	Distance from Center (m)	Gamma(1) (mrem/hr)	Neutron(1) (mrem/hr)	Total (mrem/hr)
0	4.03	7.84E+00	9.52E+00	1.74E+01
10	14.03	5.27E+00	6.83E+00	1.21E+01
45	49.03	1.60E+00	2.21E+00	3.80E+00
100	104.03	1.13E-01	3.32E-01	4.45E-01
200	204.03	2.79E-02	6.39E-02	9.18E-02
300	304.03	8.44E-03	1.63E-02	2.48E-02
400	404.03	2.83E-03	4.73E-03	7.56E-03
500	504.03	1.07E-03	1.52E-03	2.59E-03
600	604.03	4.44E-04	5.81E-04	1.03E-03
700	704.03	2.00E-04	2.18E-04	4.18E-04
800	804.03	9.83E-05	8.29E-05	1.81E-04
900	904.03	4.89E-05	4.14E-05	9.03E-05
1000	1004.03	2.47E-05	1.42E-05	3.89E-05

Note:
1) Gamma and neutron dose rates are the sum of the corresponding dose rates from Tables 2.1-1 and 5.1-1.

Table 5.1-5
Total ISFSI Dose Rates (Existing and 16 Cask Expansion ISFSIs) from East/West Faces
Total Dose Rates (Direct plus Skyshine)

Distance from Face (m)	Distance from Center (m)	Gamma(1) (mrem/hr)	Neutron(1) (mrem/hr)	Total (mrem/hr)
0	70.47	4.85E+01	4.17E+01	9.02E+01
10	80.47	4.00E+00	6.43E+00	1.04E+01
45	115.47	9.20E-02	4.00E-01	4.91E-01
100	170.47	4.54E-02	1.52E-01	1.97E-01
200	270.47	1.12E-02	2.95E-02	4.07E-02
300	370.47	3.48E-03	7.63E-03	1.11E-02
400	470.47	1.20E-03	2.65E-03	3.84E-03
500	570.47	4.64E-04	8.11E-04	1.27E-03
600	670.47	2.21E-04	3.19E-04	5.41E-04
700	770.47	8.94E-05	1.15E-04	2.04E-04
800	870.47	4.15E-05	5.81E-05	9.96E-05
900	970.47	2.17E-05	2.22E-05	4.39E-05
1000	1070.47	1.20E-05	1.10E-05	2.30E-05

Note:
1) Gamma and neutron dose rates are the sum of the corresponding dose rates from Tables 2.1-2 and 5.1-2.

Table 5.1-6
Total ISFSI Dose Rates (Existing and 16 Cask Expansion ISFSIs) from ISFSI Corners
Total Dose Rates (Direct plus Skyshine)

Distance from Face (m)	Distance from Center (m)	Gamma(1) (mrem/hr)	Neutron(1) (mrem/hr)	Total (mrem/hr)
10	77.91	5.24E+00	7.12E+00	1.24E+01
45	107.91	7.15E-01	1.13E+00	1.84E+00
100	159.24	5.87E-02	1.76E-01	2.35E-01
200	256.49	1.61E-02	3.61E-02	5.22E-02
300	355.27	5.14E-03	9.67E-03	1.48E-02
400	454.58	1.96E-03	2.82E-03	4.78E-03
500	554.14	7.49E-04	1.03E-03	1.78E-03
600	653.84	3.18E-04	3.78E-04	6.96E-04
700	753.61	1.44E-04	1.49E-04	2.93E-04
800	853.44	7.30E-05	5.21E-05	1.25E-04
900	953.31	3.76E-05	2.55E-05	6.31E-05
1000	1053.20	2.09E-05	1.07E-05	3.16E-05

Note:
1) Gamma and neutron dose rates are the sum of the corresponding dose rates from Tables 2.1-3 and 5.1-3.

5.2 16 Cask Expansion ISFSI Dose Rates (Skyshine Radiation)

Table 5.2-1
16 Cask Expansion ISFSI Skyshine Radiation Dose Rates from North/South Faces

Distance from Face (m)	Distance from Center (m)	Gamma Skyshine Factor(1)	Neutron Skyshine Factor(2)	Gamma Skyshine DT(3) (mrem/hr)	Neutron Skyshine DT(4) (mrem/hr)	Total Skyshine (mrem/hr)
0	4.03	0.87	1.00	1.95E+00	2.87E+00	4.82E+00
10	14.03	0.87	1.00	1.31E+00	2.06E+00	3.37E+00
45	49.03	0.87	1.00	3.97E-01	6.65E-01	1.06E+00
100	104.03	0.92	1.00	2.98E-02	1.00E-01	1.30E-01
200	204.03	0.93	1.00	7.43E-03	1.93E-02	2.67E-02
300	304.03	0.94	1.00	2.26E-03	4.92E-03	7.19E-03
400	404.03	0.94	1.00	7.59E-04	1.43E-03	2.18E-03
500	504.03	0.93	1.00	2.84E-04	4.58E-04	7.42E-04
600	604.03	0.92	1.00	1.18E-04	1.75E-04	2.93E-04
700	704.03	0.91	1.00	5.22E-05	6.57E-05	1.18E-04
800	804.03	0.91	1.00	2.56E-05	2.50E-05	5.06E-05
900	904.03	0.90	1.00	1.27E-05	1.25E-05	2.51E-05
1000	1004.03	0.89	1.00	6.27E-06	4.30E-06	1.06E-05

Notes:
1) Determined by calculating the fraction of the total gamma dose rate which is attributed to gamma skyshine radiation. For example, gamma skyshine factor at 4.03 m from the ISFSI center = 4.85 mrem/hr (Table 2.1-4) / 5.59 mrem/hr (Table 2.1-1) = **0.87**.
2) Determined by calculating the fraction of the total neutron dose rate which is attributed to neutron skyshine radiation. For example, neutron skyshine factor at 4.03 m from the ISFSI center = 6.65 mrem/hr (Table 2.1-4) / 6.65 mrem/hr (Table 2.1-1) = **1.00**.
3) Determined by applying the gamma skyshine factor to the expansion ISFSI total gamma dose. For example, D(T) at 4.03 m from the ISFSI center = 2.25E+00 mrem/hr (Table 5.1-1) x 0.87 (Column 3) = 1**.95E+00 mrem/hr**.
4) Determined by applying the neutron skyshine factor to the expansion ISFSI total neutron dose. For example, D(T) at 4.03 m from the ISFSI center = 2.87E+00 mrem/hr (Table 5.1-1) x 1.00 (Column 3) = **2.87E+00 mrem/hr**.

Table 5.2-2
16 Cask Expansion ISFSI Skyshine Radiation Dose Rates from East/West Faces

Distance from Face (m)	Distance from Center (m)	Gamma Skyshine Factor	Neutron Skyshine Factor	Gamma Skyshine DT (mrem/hr)	Neutron Skyshine DT (mrem/hr)	Total Skyshine (mrem/hr)
0	70.47	0.85	1.00	1.19E+01	1.25E+01	2.44E+01
10	80.47	0.86	1.00	9.88E-01	1.94E+00	2.93E+00
45	115.47	0.88	1.00	2.31E-02	1.21E-01	1.44E-01
100	170.47	0.90	1.00	1.18E-02	4.58E-02	5.76E-02
200	270.47	0.91	1.00	2.94E-03	8.90E-03	1.18E-02
300	370.47	0.91	1.00	9.08E-04	2.30E-03	3.21E-03
400	470.47	0.90	1.00	3.09E-04	7.99E-04	1.11E-03
500	570.47	0.90	1.00	1.20E-04	2.45E-04	3.64E-04
600	670.47	0.90	1.00	5.70E-05	9.63E-05	1.53E-04
700	770.47	0.88	1.00	2.25E-05	3.47E-05	5.72E-05
800	870.47	0.86	1.00	1.02E-05	1.75E-05	2.77E-05
900	970.47	0.85	1.00	5.26E-06	6.70E-06	1.20E-05
1000	1070.47	0.83	1.00	2.83E-06	3.33E-06	6.15E-06

Note:
1) See Table 5.2-1 notes.

Table 5.2-3
16 Cask Expansion ISFSI Skyshine Radiation Dose Rates from ISFSI Corners

Distance from Face (m)	Distance from Center (m)	Gamma Skyshine Factor	Neutron Skyshine Factor	Gamma Skyshine DT (mrem/hr)	Neutron Skyshine DT (mrem/hr)	Total Skyshine (mrem/hr)
10	77.91	0.86	1.00	1.29E+00	2.14E+00	3.44E+00
45	107.91	0.86	1.00	1.77E-01	3.40E-01	5.17E-01
100	159.24	0.92	1.00	1.54E-02	5.31E-02	6.86E-02
200	256.49	0.93	1.00	4.30E-03	1.09E-02	1.52E-02
300	355.27	0.93	1.00	1.38E-03	2.92E-03	4.29E-03
400	454.58	0.94	1.00	5.26E-04	8.51E-04	1.38E-03
500	554.14	0.93	1.00	1.99E-04	3.11E-04	5.10E-04
600	653.84	0.92	1.00	8.40E-05	1.14E-04	1.98E-04
700	753.61	0.91	1.00	3.77E-05	4.49E-05	8.26E-05
800	853.44	0.90	1.00	1.89E-05	1.57E-05	3.46E-05
900	953.31	0.89	1.00	9.60E-06	7.69E-06	1.73E-05
1000	1053.20	0.89	1.00	5.34E-06	3.23E-06	8.57E-06

Notes:
1) See Table 5.2-1 notes.

Table 5.2-4
Total ISFSI Skyshine Radiation Dose Rates from North/South Faces

Distance from Face (m)	Distance from Center (m)	Gamma[1] (mrem/hr)	Neutron[1] (mrem/hr)	Total (mrem/hr)
0	4.03	6.80E+00	9.52E+00	1.63E+01
10	14.03	4.58E+00	6.82E+00	1.14E+01
45	49.03	1.38E+00	2.21E+00	3.59E+00
100	104.03	1.04E-01	3.32E-01	4.36E-01
200	204.03	2.59E-02	6.39E-02	8.98E-02
300	304.03	7.89E-03	1.63E-02	2.42E-02
400	404.03	2.65E-03	4.73E-03	7.37E-03
500	504.03	9.92E-04	1.52E-03	2.51E-03
600	604.03	4.11E-04	5.81E-04	9.92E-04
700	704.03	1.82E-04	2.18E-04	4.00E-04
800	804.03	8.92E-05	8.29E-05	1.72E-04
900	904.03	4.42E-05	4.14E-05	8.55E-05
1000	1004.03	2.19E-05	1.42E-05	3.61E-05

Note:
1) Gamma and neutron dose rates are the sum of the corresponding dose rates from Tables 2.1-4 and 5.2-1.

Table 5.2-5
Total ISFSI Skyshine Radiation Dose Rates from East/West Faces

Distance from Face (m)	Distance from Center (m)	Gamma[1] (mrem/hr)	Neutron[1] (mrem/hr)	Total (mrem/hr)
0	70.47	4.14E+01	4.15E+01	8.29E+01
10	80.47	3.45E+00	6.43E+00	9.88E+00
45	115.47	8.06E-02	4.00E-01	4.80E-01
100	170.47	4.11E-02	1.52E-01	1.93E-01
200	270.47	1.02E-02	2.95E-02	3.97E-02
300	370.47	3.17E-03	7.63E-03	1.08E-02
400	470.47	1.08E-03	2.65E-03	3.73E-03
500	570.47	4.18E-04	8.11E-04	1.23E-03
600	670.47	1.99E-04	3.19E-04	5.18E-04
700	770.47	7.85E-05	1.15E-04	1.93E-04
800	870.47	3.56E-05	5.81E-05	9.37E-05
900	970.47	1.84E-05	2.22E-05	4.06E-05
1000	1070.47	9.87E-06	1.10E-05	2.09E-05

Note:
1) Gamma and neutron dose rates are the sum of the corresponding dose rates from Tables 2.1-5 and 5.2-2.

Table 5.2-6
Total ISFSI Skyshine Radiation Dose Rates from ISFSI Corners

Distance from Face (m)	Distance from Center (m)	Gamma[1] (mrem/hr)	Neutron[1] (mrem/hr)	Total (mrem/hr)
10	77.91	4.51E+00	7.10E+00	1.16E+01
45	107.91	6.17E-01	1.13E+00	1.75E+00
100	159.24	5.38E-02	1.76E-01	2.30E-01
200	256.49	1.50E-02	3.61E-02	5.11E-02
300	355.27	4.81E-03	9.67E-03	1.45E-02
400	454.58	1.84E-03	2.82E-03	4.66E-03
500	554.14	6.95E-04	1.03E-03	1.73E-03
600	653.84	2.93E-04	3.78E-04	6.71E-04
700	753.61	1.31E-04	1.49E-04	2.80E-04
800	853.44	6.59E-05	5.21E-05	1.18E-04
900	953.31	3.35E-05	2.55E-05	5.90E-05
1000	1053.20	1.86E-05	1.07E-05	2.93E-05

Note:
1) Gamma and neutron dose rates are the sum of the corresponding dose rates from Tables 2.1-6 and 5.2-3.

5.3 16 Cask Expansion ISFSI Station Personnel Dose Rates and Collective Doses

[NOT-PUBLIC DATA BEGINS

Table 5.3-1
16 Cask Expansion ISFSI Station Personnel Dose Rates

Location #	Location	Distance (Feet From Center ISFSI)	Dose Rate $D0^{(1)}$ (mrem/hr)	Dose Rate $DT^{(2)}$ (mrem/hr)
1	34 OCA Gatehouse (D-2)	[redacted]	7.70E-04	1.14E-02
2	22 Receiving Warehouse (D-5) 55 13 P1ex Project Office (D-5) A 4 P1ex Project Office (D-5)		8.30E-04	1.23E-02
3	24 NPD Building (E-6) 33 NPD Annex Building (E-5) Quality Assurance Modular Office (E-5)		6.77E-04	1.01E-02
4	42 Fabrication Shop (C-5) 25 Steam Generator Mock up Building (C-5) 48 Fabrication Shop (D-5)		1.73E-04	2.57E-03
5	30 Warehouse (C-5) 31 Multiuse Warehouse (C-5) 21 Warehouse -8 (C-6)		7.01E-05	1.04E-03
6	12 Substation, SBO Structures (B-6)		1.23E-05	1.84E-04
7	23 New Administration Building (D-6) 6 Security Building (D-6)		1.00E-04	1.49E-03
8	4 Turbine Building (D-7) 28 Warehouse -2 (E-7) 3 Auxiliary Building (E-7) 13 New Service Building (D-8) 11 D5/D6 DG Building (D-7) 79 Security DG Building (D-7)		7.01E-05	1.04E-03
9	Outage Trailers (E-7)		2.11E-04	3.14E-03
10	60 Fabrication Shop (E-7) 29 Main Plant Warehouse (E-7) 66 Maintenance Storage Building (E-7)		8.81E-05	1.31E-03
11	20 Environmental Lab (B-9)		5.54E-06	8.24E-05
12	Training Center		9.47E-04	1.41E-02
13	38 Old Administration Building (D-7) 71 Administration Building Addition (D-7)		5.18E-05	7.71E-04
14	13 New Service Building (D-8)		3.15E-05	4.68E-04

Notes:
1) Determined by solving Equation 4 in Section 4.0 for a given dose rate (D(t)) from Table 2.7-1 (i.e., D(t) = 33.37342 D(0)). For example, D(0) at Location #1 = 2.57E-02 mrem/hr (Table 2.7-1) / 33.37342 = **7.70E-04 mrem/hr**.
2) Determined by applying Equation 3 in Section 4.0 to each calculated D(0). For example, D(T) at Location #1 = 7.70E-04 mrem/hr x [4 + 4 x exp(-0.025 yr^{-1} x 2 yr) + 4 x exp(-0.025 yr^{-1} x 4 yr) + 4 x exp(-0.025 yr^{-1} x 6 yr)] = **1.14E-02 mrem/hr**.

NOT-PUBLIC DATA ENDS]

[NOT-PUBLIC DATA BEGINS

Table 5.3-2
Total ISFSI Station Personnel Dose Rates

Location #	Location	Distance (Feet From Center ISFSI)	Full Time (Personnel)	Outage (Personnel)	Dose Rate(1) (mrem/hr)
1	34 OCA Gatehouse (D-2)	[redacted]	2	0	3.71E-02
2	22 Receiving Warehouse (D-5) 55 13 P1ex Project Office (D-5) A 4 P1ex Project Office (D-5)		30	0	4.00E-02
3	24 NPD Building (E-6) 33 NPD Annex Building (E-5) Quality Assurance Modular Office (E-5)		60	1	3.27E-02
4	42 Fabrication Shop (C-5) 25 Steam Generator Mock up Building (C-5) 48 Fabrication Shop (D-5)		2	45	8.33E-03
5	30 Warehouse (C-5) 31 Multiuse Warehouse (C-5) 21 Warehouse -8 (C-6)		0	2	3.38E-03
6	12 Substation, SBO Structures (B-6)		0	2	5.96E-04
7	23 New Administration Building (D-6) 6 Security Building (D-6)		287	25	4.83E-03
8	4 Turbine Building (D-7) 28 Warehouse -2 (E-7) 3 Auxiliary Building (E-7) 13 New Service Building (D-8) 11 D5/D6 DG Building (D-7) 79 Security DG Building (D-7)		180	192	3.38E-03
9	Outage Trailers (E-7)		5	40	1.02E-02
10	60 Fabrication Shop (E-7) 29 Main Plant Warehouse (E-7) 66 Maintenance Storage Building (E-7)		23	45	4.25E-03
11	20 Environmental Lab (B-9)		2	0	2.67E-04
12	Training Center		49	0	4.57E-02
13	38 Old Administration Building (D-7) 71 Administration Building Addition (D-7)		68	0	2.50E-03
14	13 New Service Building (D-8)		9	0	1.52E-03

Note:
1) Dose rate is the sum of the dose rates from Tables 2.7-1 and 5.3-1.

NOT-PUBLIC DATA ENDS]

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Table 5.3-3
16 Cask Expansion ISFSI Station Personnel Collective Doses

Location #	Location	Distance (Feet From Center ISFSI)	Full Time D0[1] (person-rem)	Outage D0[2] (person-rem)	Full Time DT[3] (person-rem)	Outage DT[4] (person-rem)	Total (person-rem)
1	34 OCA Gatehouse (D-2)	[redacted]	3.90E-03	0.00E+00	5.79E-02	0.00E+00	5.79E-02
2	22 Receiving Warehouse (D-5) 55 13 P1ex Project Office (D-5) A 4 P1ex Project Office (D-5)		6.23E-02	0.00E+00	9.27E-01	0.00E+00	9.27E-01
3	24 NPD Building (E-6) 33 NPD Annex Building (E-5) Quality Assurance Modular Office (E-5)		1.02E-01	3.66E-04	1.51E+00	5.43E-03	1.52E+00
4	42 Fabrication Shop (C-5) 25 Steam Generator Mock up Building (C-5) 48 Fabrication Shop (D-5)		8.99E-04	4.19E-03	1.34E-02	6.24E-02	7.57E-02
5	30 Warehouse (C-5) 31 Multiuse Warehouse (C-5) 21 Warehouse -8 (C-6)		0.00E+00	7.58E-05	0.00E+00	1.13E-03	1.13E-03
6	12 Substation, SBO Structures (B-6)		0.00E+00	1.33E-05	0.00E+00	1.98E-04	1.98E-04
7	23 New Administration Building (D-6) 6 Security Building (D-6)		7.16E-02	1.50E-03	1.06E+00	2.23E-02	1.09E+00
8	4 Turbine Building (D-7) 28 Warehouse -2 (E-7) 3 Auxiliary Building (E-7) 13 New Service Building (D-8) 11 D5/D6 DG Building (D-7) 79 Security DG Building (D-7)		3.15E-02	7.19E-03	4.68E-01	1.07E-01	5.75E-01
9	Outage Trailers (E-7)		2.70E-03	4.49E-03	4.01E-02	6.68E-02	1.07E-01
10	60 Fabrication Shop (E-7) 29 Main Plant Warehouse (E-7) 66 Maintenance Storage Building (E-7)		5.09E-03	2.10E-03	7.57E-02	3.12E-02	1.07E-01
11	20 Environmental Lab (B-9)		2.77E-05	0.00E+00	4.12E-04	0.00E+00	4.12E-04
12	Training Center		1.16E-01	0.00E+00	1.72E+00	0.00E+00	1.72E+00
13	38 Old Administration Building (D-7) 71 Administration Building Addition (D-7)		8.69E-03	0.00E+00	1.29E-01	0.00E+00	1.29E-01
14	13 New Service Building (D-8)		5.99E-04	0.00E+00	8.91E-03	0.00E+00	8.91E-03

Notes:
1) Determined by solving Equation 4 in Section 4.0 for a given collective dose (D(t)) from Table 2.7-2 (i.e., D(t) = 33.37342 D(0)). For example, D(0) at Location #1 = 0.13 person-rem (Table 2.7-2) / 33.37342 = **3.90E-03 person-rem**.
2) Determined by solving Equation 4 in Section 4.0 for a given collective dose (D(t)) from Table 2.7-2 (i.e., D(t) = 33.37342 D(0)). For example, D(0) at Location #3 = 1.22E-02 person-rem (Table 2.7-2) / 33.37342 = **3.66E-04 person-rem**.
3) Determined by applying Equation 3 in Section 4.0 to each calculated D(0). For example, D(T) at Location #1 = 3.90E-03 person-rem x [4 + 4 x exp(-0.025 yr^{-1} x 2 yr) + 4 x exp(-0.025 yr^{-1} x 4 yr) + 4 x exp(-0.025 yr^{-1} x 6 yr)] = **5.79E-02 person-rem**.
4) Determined by applying Equation 3 in Section 4.0 to each calculated D(0). For example, D(T) at Location #3 = 3.66E-04 person-rem x [4 + 4 x exp(-0.025 yr^{-1} x 2 yr) + 4 x exp(-0.025 yr^{-1} x 4 yr) + 4 x exp(-0.025 yr^{-1} x 6 yr)] = **5.43E-03 person-rem**.

NOT-PUBLIC DATA ENDS]

[NOT-PUBLIC DATA BEGINS

Table 5.3-4
Total ISFSI Station Personnel Collective Doses

Location #	Location	Distance (Feet From Center ISFSI)	Full Time[1] (person-rem)	Outage[1] (person-rem)	Total Exposure (person-rem)
1	34 OCA Gatehouse (D-2)	[redacted]	1.88E-01	0.00E+00	1.88E-01
2	22 Receiving Warehouse (D-5) 55 13 P1ex Project Office (D-5) A 4 P1ex Project Office (D-5)	[redacted]	3.01E+00	0.00E+00	3.01E+00
3	24 NPD Building (E-6) 33 NPD Annex Building (E-5) Quality Assurance Modular Office (E-5)	[redacted]	4.90E+00	1.76E-02	4.92E+00
4	42 Fabrication Shop (C-5) 25 Steam Generator Mock up Building (C-5) 48 Fabrication Shop (D-5)	[redacted]	4.34E-02	2.02E-01	2.46E-01
5	30 Warehouse (C-5) 31 Multiuse Warehouse (C-5) 21 Warehouse -8 (C-6)	[redacted]	0.00E+00	3.66E-03	3.66E-03
6	12 Substation, SBO Structures (B-6)	[redacted]	0.00E+00	6.43E-04	6.43E-04
7	23 New Administration Building (D-6) 6 Security Building (D-6)	[redacted]	3.45E+00	7.23E-02	3.53E+00
8	4 Turbine Building (D-7) 28 Warehouse -2 (E-7) 3 Auxiliary Building (E-7) 13 New Service Building (D-8) 11 D5/D6 DG Building (D-7) 79 Security DG Building (D-7)	[redacted]	1.52E+00	3.47E-01	1.86E+00
9	Outage Trailers (E-7)	[redacted]	1.30E-01	2.17E-01	3.47E-01
10	60 Fabrication Shop (E-7) 29 Main Plant Warehouse (E-7) 66 Maintenance Storage Building (E-7)	[redacted]	2.46E-01	1.01E-01	3.47E-01
11	20 Environmental Lab (B-9)	[redacted]	1.34E-03	0.00E+00	1.34E-03
12	Training Center	[redacted]	5.59E+00	0.00E+00	5.59E+00
13	38 Old Administration Building (D-7) 71 Administration Building Addition (D-7)	[redacted]	4.19E-01	0.00E+00	4.19E-01
14	13 New Service Building (D-8)	[redacted]	2.89E-02	0.00E+00	2.89E-02
Total			1.95E+01	9.61E-01	2.05E+01

Note:
1) Full time and outage doses are the sum of the corresponding doses from Tables 2.7-2 and 5.3-3.

NOT-PUBLIC DATA ENDS]

5.4 16 Cask Expansion ISFSI Offsite Population Dose Rates and Collective Doses

Table 5.4-1
16 Cask Expansion ISFSI Offsite Population Dose Rates and Collective Doses

Offsite Population	Description	Distance	Occupancy Times	Population	Dose Rate D0[1] (mrem/hr)	Dose Rate DT[2] (mrem/hr)	Collective Exposure D0[3] (person-rem)	Collective Exposure DT[4] (person-rem)
Permanent Population Within 2 Mile Radius	2 mile - radius	> 0.45 mile	8760	398	8.72E-06	1.30E-04	3.04E-02	4.52E-01
Transient Employee Population	2 mile - PI community center, government center, and clinic	0.8 mile	2000	80	9.98E-07	1.48E-05	1.60E-04	2.37E-03
	2 mile - Employees at Treasure Island Casino	0.8 mile	8760	435	9.98E-07	1.48E-05	3.80E-03	5.65E-02
Transient Recreational Population	2 mile - Treasure Island Casino	0.8 mile	8760	5400	9.98E-07	1.48E-05	4.72E-02	7.02E-01
Marina and RV Park	2 mile - PI community center, government center, and clinic	0.8 mile	1160	450	9.98E-07	1.48E-05	5.21E-04	7.74E-03
	Total Collective Within 2 Mile							**1.22E+00**

Notes:
1) Determined by solving Equation 4 in Section 4.0 for a given dose rate (D(t)) from Table 2.8-1 (i.e., D(t) = 33.37342 D(0)). For example, D(0) at Permanent Population Within 2 Mile Radius = 2.91E-04 mrem/hr (Table 2.8-1) / 33.37342 = **8.72E-06 mrem/hr**.
2) Determined by applying Equation 3 in Section 4.0 to each calculated D(0). For example, D(T) at Permanent Population Within 2 Mile Radius = 8.72E-06 mrem/hr x [4 + 4 x exp(-0.025 yr^{-1} x 2 yr) + 4 x exp(-0.025 yr^{-1} x 4 yr) + 4 x exp(-0.025 yr^{-1} x 6 yr)] = **1.30E-04 mrem/hr**.
3) Determined by solving Equation 4 in Section 4.0 for a given collective dose (D(t)) from Table 2.8-1 (i.e., D(t) = 33.37342 D(0)). For example, D(0) at Permanent Population Within 2 Mile Radius = 1.01 person-rem (Table 2.8-1) / 33.37342 = **3.04E-02 person-rem**.
4) Determined by applying Equation 3 in Section 4.0 to each calculated D(0). For example, D(T) at Permanent Population Within 2 Mile Radius = 3.04E-02 person-rem x [4 + 4 x exp(-0.025 yr^{-1} x 2 yr) + 4 x exp(-0.025 yr^{-1} x 4 yr) + 4 x exp(-0.025 yr^{-1} x 6 yr)] = **4.52E-01 person-rem**.

Table 5.4-2
Total ISFSI Offsite Population Dose Rates and Collective Doses

Offsite Population	Description	Distance	Occupancy Times	Population	Dose Rate[1] (mrem/hr)	Collective Exposure[1] (person-rem)
Permanent Population Within 2 Mile Radius	2 mile - radius	> 0.45 mile	8760	398	4.21E-04[2]	1.47E+00
Transient Employee Population	2 mile - PI community center, government center, and clinic	0.8 mile	2000	80	4.81E-05	7.70E-03
	2 mile - Employees at Treasure Island Casino	0.8 mile	8760	435	4.81E-05	1.83E-01
Transient Recreational Population	2 mile - Treasure Island Casino	0.8 mile	8760	5400	4.81E-05	2.28E+00
Marina and RV Park	2 mile - PI community center, government center, and clinic	0.8 mile	1160	450	4.81E-05	2.51E-02
	Total Collective Within 2 Mile					**3.96E+00**

Note:
1) Dose rates and collective doses are the sum of the corresponding values from Tables 2.8-1 and 5.4-1.
2) 4.21E-04 mrem/hr x (1 rem/1000 mrem) x (8760 hr/1 year) = 3.69E-03 rem/year.

6.0 Results and Conclusions

Results

This calculation determines the total normal operation radiation dose values at the nearest site boundary and at the nearest resident when including the dose contribution due to the 16 additional casks for the expansion ISFSI pad design (i.e., total of 64 TN-40/TN-40HT casks on the existing and expansion ISFSI). The objective of this calculation is to demonstrate that the total normal operation radiation doses will be in accordance with the applicable requirements of 10 CFR 72.104(a), 40 CFR 190.10(a), and 10 CFR 20.1301(a).

Comparisons between normal operation radiation dose values determined in this calculation and the dose limits of 10 CFR 72.104(a), 40 CFR 190.10(a), and 10 CFR 20.1301(a) are presented in Tables 6.0-1 through 6.0-3.

Table 6.0-1
Summation of 10 CFR 72.104 (a) and 40 CFR 190.10 (a) Annual Dose (Nearest Resident)

Source	Dose Contribution (mrem/yr)	Total (mrem/yr)	Criteria (mrem/yr)	Margin (mrem/yr)
Existing ISFSI (Fully Loaded)	3.05E+00	**4.34**	**25**	**20.66**
New ISFSI (16 Loaded Casks)	1.27E+00			
Planned Discharges	1.50E-02			

Table 6.0-2
Summation of 10 CFR 20.1301 (a)(1) Annual Dose (Nearest Resident)

Source	Dose Contribution (mrem/yr)	Total (mrem/yr)	Criteria (mrem/yr)	Margin (mrem/yr)
Licensed Operation	4.34	**4.34**	**100**	**95.66**

Table 6.0-3
Summation of 10 CFR 20.1301 (a)(2) Dose Rate (Site Boundary)

Source	Dose Contribution (mrem/hr)	Total (mrem/hr)	Criteria (mrem/hr)	Margin (mrem/hr)
Existing ISFSI (Fully Loaded)	3.13E-01	**0.45**	**2**	**1.55**
New ISFSI (16 Loaded Casks)	1.33E-01			
Other Sources	0.00E+00			

Conclusions

The calculated dose values at the nearest site boundary and at the nearest resident meet the acceptance criteria of 10 CFR 72.104(a), 40 CFR 190.10(a), and 10 CFR 20.1301(a). Therefore, the expansion ISFSI design is considered to be acceptable with respect to the radiation levels at the nearest site boundary and at the nearest resident.

Doses calculated in this analysis are based on the assumption that no more than 4 casks are loaded onto the expansion ISFSI pad every 2 years (Assumption 3.3). This is the same limitation that is applied to the dose analysis used for the existing ISFSI [i.e., Calculation TN40HT.0512, Reference 7.7].

Note that this calculation does not establish any restrictions on cask placement (Section 4.0). The analysis in this calculation bounds any distribution of 64 TN-40HT (or TN-40) casks across the three ISFSI pads (i.e., 40 to 48 casks on the existing ISFSI pads and 16 to 24 casks on the new ISFSI pad).

7.0 References

7.1 Prairie Island Independent Spent Fuel Storage Installation, Safety Analysis Report, Revision 18.

7.2 Xcel Energy, Application to the Minnesota Public Utilities Commission for Certificates of Need for the Prairie Island Nuclear Generating Plant for Additional Dry Cask Storage Docket No. E002/CN-08-510 and Extended Power Uprate Docket No. E002/CN-08-509, May 16, 2008.

7.3 Design Change Package, EC 601000000444, ISFSI Expansion Project, Revision 0.

7.4 U.S. Nuclear Regulatory Commission Regulation, 10 CFR 72.104, Criteria for Radioactive Materials in Effluents and Direct Radiation from an ISFSI or MRS.

7.5 Environmental Protection Agency Regulation, 40 CFR 190.10, Standards for Normal Operations.

7.6 U.S. Nuclear Regulatory Commission Regulation, 10 CFR 20.1301, Dose Limits for Individual Members of the Public.

7.7 Orano Calculation TN40HT.0512, Dose Rates and Occupational Exposure Estimate for Prairie Island ISFSI Comprised with TN40HT Casks Loaded with WE 14x14 STD Fuel Assemblies, Revision 1.

7.8 Prairie Island Nuclear Generating Plant, Units 1 and 2, 2017 Annual Radioactive Effluent Report, ML18134A310, May 14, 2018.

7.9 Transnuclear Calculation TN40HT-0503, TN-40HT Confinement Analysis, Revision 1.

7.10 Stone & Webster Calculation 12911.54-UR(D)-003, Dose Rate at the ISFSI Restricted Area Boundary, Revision 4.

7.11 Prairie Island Nuclear Generating Plant, Drawing Number NF-120941, Independent Spent Fuel Storage Installation Site Plan, Revision 75.

7.12 Prairie Island Nuclear Generating Plant, Drawing Number SK-PINGP-EC601000000444-S-02, ISFSI South-East Cask Storage Pad Geotechnical Notes, Revision 0A-0 (Included as Attachment A to this calculation).

7.13 Prairie Island Nuclear Generating Plant, Units 1 and 2, 2017 Annual Radiological Environmental Monitoring Program Report, ML18134A012, May 14, 2018.

7.14 Prairie Island Nuclear Generating Plant, Units 1 and 2, 2016 Annual Radioactive Effluent Report, ML17130A969, May 8, 2017.

7.15 Prairie Island Nuclear Generating Plant, Units 1 and 2, 2015 Annual Radioactive Effluent Report, ML16126A211, May 5, 2016.

7.16 Prairie Island Nuclear Generating Plant, Units 1 and 2, 2016 Annual Radiological Environmental Monitoring Program Report, ML17130A954.

7.17 Prairie Island Nuclear Generating Plant, Units 1 and 2, 2015 Annual Radiological Environmental Monitoring Program Report, ML16126A283, May 5, 2016.

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