DMA-TR-048

Dade Moeller & Associates, Inc.

Technical Report

Data Supporting Dose Calculations for Impacts from Normal Operations

Supplemental Environmental Impact Statement for the Production of Tritium in Commercial Light Water Reactors

January 2012

Dade Moeller & Associates, Inc.
1835 Terminal Drive, Suite 200
Richland, WA 99354

LIMITATIONS

Dade Moeller & Associates has prepared this evaluation based on information received from TVA. Our work is based on information available at the time of publication. Information provided in this report by Dade Moeller & Associates Inc., is intended exclusively for the use of the Department of Energy. The findings and conclusions discussed in this report are based on the observations and information provided, and our current understanding and interpretation of regulatory agency regulations, guidance and policies. The professional services have been performed in accordance with practices generally accepted by other health physicists practicing in this field. No other warranty, either expressed or implied, is made.

Report prepared by:

original signed by	May 17, 2012
Ali A. Simpkins	Date
Dade Moeller & Associates, Inc. Richland, WA 99354	

TABLE OF CONTENTS

Summary 5
Introduction 5
Methodology 5
Parameter Justification 5
Affected Environment 5
Environmental Radiological Impacts 6
Dose from Atmospheric Releases 6
Doses from Liquid Releases 7
Doses to Workers 8
Attachment A. Population Data 9
Attachment B. Worker Doses Provided by TVA 13
Attachment C. Meteorological Data 15
References 19

Page left intentionally blank.

Summary

Dose calculations were performed in support of the *Production of Tritium in a Commercial Light Water Reactor Supplemental Environmental Impact Statement* (CLWR SEIS). This report includes the justification of those inputs used for the dose calculations that required a more detailed discussion. The remaining inputs are included in Appendix C of the CLWR SEIS. Inputs discussed include population data, meteorological data, source terms, and maximally exposed individual locations.

Introduction

In 1999 an environmental impact statement (EIS) was prepared for the production of tritium in a commercial light water reactor (DOE 1999). This SEIS is being prepared to analyze (1) the potential environmental impacts associated with increased tritium permeation levels observed since 2004, (2) the maximum number of TPBARs necessary to supply the reasonably foreseeable tritium requirements, and (3) proposed changes to facilities that TVA could use for future tritium production. Radiological impacts from normal operations at levels need to be addressed. The calculations needed for these radiological impacts include many input parameters which are documented herein and in Appendix C of the CLWR SEIS. Those input parameters which required a more detailed explanation have been included here. All other parameters are documented within Appendix C of the CLWR SEIS.

Methodology

The GENII computer code (PNNL 2009) was used to perform the dose calculations for releases of radionuclides during normal operations at the Watts Bar and Sequoyah commercial nuclear power stations. Site-specific parameters were applied whenever possible using primarily the information contained within the offsite dose calculation manuals (TVA 2010a and TVA 2010 b). For the affected environment sections, additional data was used as provided by TVA.

Parameter Justification

Affected Environment

Maximally exposed offsite individual doses and population doses for current operations were reported in the annual effluent and waste disposal reports for Watts Bar (TVA 2011a) and Sequoyah (2011b). The following information supports the development of Table 3.2.11-2 of the SEIS.

Maximally exposed offsite individual doses were taken from Table 8 of TVA (2011a) and Table 9 of TVA (2011b). Quarterly doses were summed to produce the annual doses. Population doses were taken from Tables 6 and 7 of TVA (2011a) and Table 5 through 8 of TVA (2011b). For average doses to the population within an 80-km radius, the population doses were divided by the population. The Watts Bar and Sequoyah the total 80-km populations for 2010 were used as are shown in Attachment A. The 50-mile river populations were taken from the Offsite Dose Calculation Manuals for each site (TVA 2010a and TVA 2010b). The populations were reported in Table 6.1 of each report. The same population growth factors as reported in Attachment A

were applied as needed to the river populations to determine the population for the year 2000. For the Sequoyah population reported in the offsite dose manual, no year was reported so it was assumed to be for 2010. Worker doses were supplied by TVA and have been included in Attachment B.

Environmental Radiological Impacts

Dose from Atmospheric Releases

Source terms for normal operations at Watts Bar and Sequoyah were provided by TVA (2011). Source terms for the various alternatives were then added to these normal operations source terms. However, the normal operations tritium release was assumed to be 2,400 Ci from each unit for a total of 4,800 Ci per plant. Therefore the tritium source terms used are shown in the table below. The amount of tritium released per TPBAR was assumed to be 10 Ci and 90% of this is assumed to be released via the water pathway and 10% to the air.

Table 1. Tritium Source Term used for Each Alternative (curies)

			Watts Bar		Sequoyah	
			Air	Liquid	Air	Liquid
4,800 Ci assume from Normal Operations			480	4320	480	4320
		TPBARs				
No Action	Watts Bar Sequoyah	680 1360	1160	10440	1840	16560
Alt 1	Watts Bar Only	2500	2980	26820	480	4320
Alt 2	Sequoyah Only	2500	480	4320	2980	26820
Alt 3	Watts Bar and Sequoyah	1250	1730	15570	1730	15570

The location of the maximally exposed individual was assumed to be at the site boundary. Distances to the site boundary are shown for each of the 16 sectors for both Watts Bar and Sequoyah in Table 2 as supplied by TVA. Meteorological data was provided by TVA and is shown in Attachment C.

For Watts Bar, doses were calculated using the sectors and distances. In accordance with the offsite dose calculation manual (TVA 2010a) doses were multiplied by the terrain adjustment factor as taken from table 7-3 of the offsite dose calculation manual. Terrain adjustment factors are needed at Watts Bar and not Sequoyah because of the spatial and temporal variations in the airflow expected from the southwest-northeast aligned river valley with respect to Watts Bar. After application of the terrain adjustment factor the sector with the highest dose was the northeast sector (distance 1,580 m). The sector with the highest dose for Sequoyah was South with a distance of 1,570 m. These sectors and distances were then used to determine the dose for each of the alternatives.

Table 2. Distance to the Site Boundary

Sector	Watts Bar Distance (m)	Sequoyah Distance (m)
N	1580	950
NNE	1980	2260
NE	1580	1910
ENE	1370	1680
E	1280	1570
ESE	1250	1460
SE	1250	1460
SSE	1250	1550
S	1340	1570
SSW	1550	1840
SW	1670	2470
WSW	1430	910
W	1460	670
WNW	1400	660
NW	1400	660
NNW	1460	730

For the population doses, population projections as shown for 2025 were used. For Watts Bar a terrain adjustment factor was applied. Since population doses are calculated for the entire 80-km region for all sectors an average terrain adjustment factor of 1.78 was applied. This factor was simply the average of the terrain adjustment factors for all sixteen sectors.

Doses from Liquid Releases

According to the offsite dose calculation manuals (TVA 2010a and TVA 2010b) boating and swimming on the Tennessee River downriver of the Watts Bar and Sequoyah Plants are not significant exposure pathways and therefore were not included in dose calculations. Exposure pathways include ingestion of drinking water and fish and exposure to contaminants during recreation along the river. River flow rates were taken from the effluent reports (TVA 2011a and TVA 2011b). For Watts Bar the average flow rates per quarter from Tables 7-A and 7-B were averaged to determine a yearly average. For Sequoyah, the same method was used applying the flow rates in Tables 5 through 8. This resulted in a flow rate of 712 m^3/s and 868 m^3/s being used for Watts Bar and Sequoyah, respectively.

For population dose calculations from liquid releases, the appropriate down river populations were considered as recorded in the offsite dose calculation manuals for Watts Bar (Table 6.1) and Sequoyah (Table 6.1). Recreational values were also taken from these Tables.

The total fish consumption values for the downriver populations were determined using the methods prescribed in the offsite dose calculation manuals (TVA 2010a and TVA 2010 b). Fish

production was calculated using the total acres of watershed multiplied by a fish production value of 1.36 kg/acre/yr. Using these methods, the total fish production was calculated to be 53,000 kg/yr for Watts Bar and 39,000 kg/yr for Sequoyah.

Doses to Workers

Worker doses were provided by TVA during the data call. To determine the incremental doses from production of TPBARS, values from the 1999 EIS were used and incremental tritium doses were added as appropriate for each scenario. Worker doses were taken from Tables 5-5 and 5-15 of the 1999 EIS (DOE 1999).

Attachment A. Population Data

Table A.1 Fifty-mile population for Watts Bar, Year 2010 (USCB 2012)

Direction	Sector Distance (miles)										
(sector)	1	2	3	4	5	10	20	30	40	50	Sum
N	0	1	16	22	91	921	2636	2581	3244	4125	13637
NNE	0	2	55	126	71	705	8243	15702	12105	864	37873
NE	0	3	219	109	140	933	3775	16993	20392	65175	107739
ENE	0	2	29	156	115	380	2559	14883	54496	180946	253566
E	0	3	40	122	74	833	9817	13630	13803	21940	60262
ESE	3	4	38	37	55	827	5120	13526	4850	201	24661
SE	4	8	14	49	76	678	20031	10728	2443	5530	39561
SSE	10	30	9	31	57	923	5905	7102	3672	5902	23641
S	5	35	24	65	364	2117	2422	36414	48082	13608	103136
SSW	0	39	13	4	53	791	3456	13544	41418	146452	205770
SW	0	4	13	26	4	652	7484	9989	46699	102062	166933
WSW	0	5	29	71	51	1609	11900	2250	9632	6626	32173
W	0	12	68	97	125	1048	1309	4796	2107	2177	11739
WNW	1	33	89	113	175	362	1290	3180	3198	16550	24991
NW	0	38	113	191	243	2453	970	12090	7844	9088	33030
NNW	0	0	59	240	152	1105	1180	22386	8103	7162	40387
SUM	23	219	828	1459	1846	16337	88097	199794	282088	588408	**1,179,099**

Table A.2 Estimated fifty-mile population for Watts Bar, Year 2025 (growth multiplier of 1.4% per year from 2010)

	Sector Distance (miles)										
Direction (sector)	1	2	3	4	5	10	20	30	40	50	Sum
N	0	1	20	27	112	1135	3247	3179	3996	5082	16799
NNE	0	2	68	155	87	868	10154	19343	14912	1064	46655
NE	0	4	270	134	172	1149	4650	20933	25121	80288	132722
ENE	0	2	36	192	142	468	3152	18334	67133	222904	312364
E	0	4	49	150	91	1026	12093	16791	17004	27028	74236
ESE	4	5	47	46	68	1019	6307	16662	5975	248	30379
SE	5	10	17	60	94	835	24676	13216	3009	6812	48735
SSE	12	37	11	38	70	1137	7274	8749	4523	7271	29123
S	6	43	30	80	448	2608	2984	44858	59231	16763	127051
SSW	0	48	16	5	65	974	4257	16685	51022	180412	253484
SW	0	5	16	32	5	803	9219	12305	57528	125728	205642
WSW	0	6	36	87	63	1982	14659	2772	11865	8162	39633
W	0	15	84	119	154	1291	1613	5908	2596	2682	14461
WNW	1	41	110	139	216	446	1589	3917	3940	20388	30786
NW	0	47	139	235	299	3022	1195	14893	9663	11195	40689
NNW	0	0	73	296	187	1361	1454	27577	9982	8823	49752
SUM	28	270	1020	1797	2274	20125	108525	246123	347499	724850	**1,452,512**

Table A.3 Fifty-mile population for Sequoyah, Year 2010 (USCB 2012)

Direction (sector)	Sector Distance (miles) 1	2	3	4	5	10	20	30	40	50	SUM
N	1	51	110	114	311	2324	8066	3299	4179	23106	41561
NNE	0	37	65	89	86	642	9662	7343	8313	12146	38383
NE	2	46	124	157	114	1010	3321	6926	8490	17878	38068
ENE	0	62	171	287	283	1408	4721	10421	28439	22221	68013
E	0	70	103	229	161	1236	24102	7774	3291	4117	41083
ESE	0	143	186	355	101	2445	49149	6528	790	16812	76509
SE	0	157	309	379	192	1479	9188	7912	5197	10344	35157
SSE	0	115	533	1005	680	4802	10457	24587	67541	13042	122762
S	0	55	264	757	1236	9003	44372	31072	26524	13450	126733
SSW	0	30	137	441	494	7468	89236	55056	20221	10191	183274
SW	19	394	562	1247	591	11005	82373	24615	14232	8999	144037
WSW	5	598	696	1265	2399	13444	25804	5212	13557	8318	71298
W	14	113	385	954	1758	4704	2511	6944	4973	8063	30419
WNW	30	156	457	731	686	1920	5572	3911	4579	3712	21754
NW	46	141	225	546	716	1987	2105	3223	1666	14963	25618
NNW	22	39	60	162	360	2317	1119	3924	3728	5599	17330
SUM	139	2207	4387	8718	10168	67194	371758	208747	215720	192961	**1,081,999**

Table A.2 Estimated fifty-mile population for Sequoyah, Year 2025 (growth multiplier of 1.2% per year from 2010)

	Sector Distance (miles)										
Direction (sector)	1	2	3	4	5	10	20	30	40	50	SUM
N	0	61	132	136	372	2779	9647	3945	4998	27634	49704
NNE	0	44	78	106	103	768	11555	8782	9942	14526	45905
NE	2	55	148	188	136	1208	3972	8283	10154	21381	45528
ENE	0	74	205	343	338	1684	5646	12463	34012	26576	81341
E	0	84	123	274	193	1478	28825	9297	3936	4924	49134
ESE	0	171	222	425	121	2924	58780	7807	945	20107	91502
SE	0	188	370	453	230	1769	10989	9462	6215	12371	42046
SSE	0	138	637	1202	813	5743	12506	29405	80777	15598	146819
S	0	66	316	905	1478	10767	53067	37161	31722	16086	151568
SSW	0	36	164	527	591	8931	106723	65845	24184	12188	219189
SW	23	471	672	1491	707	13162	98515	29439	17021	10762	172263
WSW	6	715	832	1513	2869	16079	30861	6233	16214	9948	85270
W	17	135	460	1141	2103	5626	3003	8305	5948	9643	36380
WNW	36	187	547	874	820	2296	6664	4677	5476	4439	26017
NW	55	169	269	653	856	2376	2518	3855	1992	17895	30638
NNW	26	47	72	194	431	2771	1338	4693	4459	6696	20726
SUM	165	2639	5247	10426	12161	80362	444609	249654	257993	230774	**1,294,030**

Attachment B. Worker Doses Provided by TVA

Table B.1. Sequoyah Worker Doses as supplied by TVA

	Number	TEDE (rem)
No measurable exposure	1860	0.000
Meas. - 0.100	666	22.364
0.100 - 0.250	113	16.990
0.250 - 0.500	43	14.289
0.500 - 0.750	6	3.313
0.750 - 1.000	0	0.000
1.000 - 2.000	0	0.000
2.000 - 3.000	0	0.000
3.000 - 4.000	0	0.000
4.000 - 5.000	0	0.000
5.000 - 6.000	0	0.000
6.000 - 7.000	0	0.000
7.000 - 8.000	0	0.000
8.000 - 9.000	0	0.000
9.000 - 10.00	0	0.000
10.00 - 11.00	0	0.000
11.00 - 12.00	0	0.000
> 12.00	0	0.000
Number with Measurable:	828	
Total Monitored:	2688	
Collective TEDE (rem):		56.956

Average Exposure – All – 56956 mrem/2688 workers = 21.2 mrem/worker

Highest dose individual – 647 mrem

Exposure is a result of the following nuclides:
Co-58 - 35%
Co-60 - 24%
Nb-95 - 14%
Cr-51 - 12%
Be-7 - 4%
Zr-95 - 4%
Mn-54 - 2%
Cs-134 -2%
Cs-137 - 2%

Other – 1%

Table B-2. Watts Bar Worker Doses supplied by TVA

	Number	TEDE
No measurable exp	4830	0.000
Meas.- 0.100	114	3.634
0.100 - 0.250	15	2.559
0.250 - 0.500	0	0.000
0.500 - 0.750	0	0.000
0.750 - 1.000	0	0.000
1.000 - 2.000	0	0.000
2.000 - 3.000	0	0.000
3.000 - 4.000	0	0.000
4.000 - 5.000	0	0.000
5.000 - 6.000	0	0.000
6.000 - 7.000	0	0.000
7.000 - 8.000	0	0.000
8.000 - 9.000	0	0.000
9.000 - 10.00	0	0.000
10.00 - 11.00	0	0.000
11.00 - 12.00	0	0.000
> 12.00	0	0.000
Number with Measurable:	129	
Total Monitored:	4959	
Total Collective TEDE (rem):		6.193
Total CDE:		0.000
Total CEDE:		0.000

Average Exposure – All – 6193 mrem/4959 workers = 1.25 mrem/worker
Highest dose individual – 247 mrem Exposure is a result of the following nuclides:

Co-60 - 66%
Co-58 - 10%
Mn-54 - 10%
Nb-95 - 10%
Other – 4%

Attachment C. Meteorological Data

Watts Bar Joint Frequency Distribution Data file name ‘wbjfd.txt’

The meteorological data shown below is of the form specified in Table 4.1 of the GENII User’s Guide (PNNL 2010). For description of data refer to User’s Guide.

```
 WB Met
  JFD 2010
8   7    1    1    9.72
0.3   1.0    2.45   4.45   6.45   9.95   15.45  21.45
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.06 0.01 0.04 0.00 0.01 0.00 0.00 0.01 0.04 0.02 0.04 0.00 0.01 0.00 0.01 0.04
0.22 0.15 0.08 0.04 0.01 0.01 0.00 0.00 0.08 0.36 0.21 0.07 0.01 0.00 0.02 0.09
0.31 0.31 0.07 0.04 0.00 0.01 0.02 0.04 0.10 0.36 0.08 0.02 0.04 0.06 0.13 0.25
0.44 0.35 0.00 0.00 0.00 0.01 0.00 0.00 0.04 0.22 0.00 0.02 0.08 0.17 0.29 0.44
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.02 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.02 0.04 0.02 0.02 0.00 0.00 0.02 0.02 0.02 0.05 0.00 0.04 0.01 0.01 0.01 0.02
0.25 0.24 0.07 0.07 0.00 0.01 0.02 0.05 0.16 0.50 0.30 0.10 0.02 0.01 0.07 0.05
0.13 0.28 0.08 0.00 0.01 0.00 0.01 0.04 0.09 0.31 0.10 0.01 0.04 0.04 0.06 0.12
0.16 0.28 0.00 0.00 0.00 0.00 0.00 0.00 0.06 0.14 0.00 0.01 0.05 0.07 0.16 0.12
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.00 0.01 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.07 0.13 0.04 0.05 0.04 0.02 0.05 0.06 0.12 0.20 0.12 0.06 0.00 0.05 0.02 0.09
0.18 0.21 0.21 0.08 0.02 0.02 0.02 0.09 0.39 0.64 0.25 0.08 0.06 0.06 0.09 0.06
0.12 0.21 0.00 0.00 0.00 0.00 0.01 0.01 0.12 0.22 0.01 0.04 0.05 0.07 0.07 0.09
0.20 0.17 0.01 0.00 0.00 0.00 0.00 0.00 0.06 0.09 0.00 0.00 0.01 0.06 0.14 0.17
0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.07 0.04 0.01 0.06 0.05 0.09 0.06 0.09 0.07 0.12 0.14 0.08 0.07 0.10 0.08 0.01
0.68 0.79 0.75 0.91 0.58 0.41 0.39 0.98 1.05 1.69 0.90 0.61 0.31 0.48 0.40 0.51
0.77 0.91 1.01 0.51 0.27 0.12 0.09 0.24 1.13 1.91 0.68 0.41 0.23 0.48 0.61 0.62
0.97 0.97 0.40 0.10 0.04 0.01 0.01 0.04 0.31 0.69 0.10 0.23 0.31 0.48 0.63 1.09
1.00 0.62 0.08 0.00 0.00 0.01 0.01 0.04 0.29 0.36 0.06 0.06 0.32 0.33 0.62 1.45
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.02 0.04 0.00 0.00 0.00 0.01 0.01 0.02
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.07 0.04 0.05 0.07 0.13 0.12 0.17 0.28 0.33 0.53 0.81 0.56 0.60 0.46 0.24 0.08
0.50 0.47 0.56 0.86 0.36 0.10 0.10 0.25 0.91 1.90 1.17 0.78 0.88 0.84 0.84 0.59
0.47 0.25 0.22 0.13 0.02 0.01 0.01 0.07 0.30 1.07 0.27 0.10 0.24 0.29 0.33 0.33
0.35 0.07 0.02 0.00 0.01 0.01 0.01 0.02 0.12 0.30 0.07 0.06 0.09 0.07 0.14 0.33
0.05 0.01 0.00 0.00 0.00 0.00 0.00 0.05 0.20 0.13 0.02 0.01 0.00 0.01 0.07 0.05
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
```

0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00
0.13	0.08	0.09	0.14	0.13	0.07	0.07	0.10	0.18	0.43	0.61	1.02	1.51	1.32	1.01	0.21
0.16	0.10	0.14	0.17	0.07	0.01	0.06	0.05	0.25	0.55	0.79	0.71	0.99	0.89	0.62	0.31
0.02	0.01	0.01	0.01	0.00	0.00	0.02	0.01	0.01	0.13	0.04	0.01	0.02	0.05	0.01	0.06
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.03	0.01
0.27	0.14	0.17	0.14	0.08	0.14	0.10	0.08	0.38	0.48	0.73	1.46	2.33	1.92	1.50	0.55
0.07	0.06	0.06	0.00	0.05	0.04	0.01	0.02	0.04	0.23	0.39	0.60	0.90	0.73	0.48	0.23
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.02	0.01
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Sequoyah Joint Frequency Distribution Data file name ‘sqjfd.txt’

```
 Seq Met
 JFD 2010
8  7   1   1   9.72
0.3  1.0   2.45  4.45  6.45  9.95  15.45 21.45
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.01 0.00 0.06 0.02 0.02 0.04 0.01 0.00 0.01 0.05 0.05 0.00 0.00 0.00 0.00 0.00
0.10 0.52 0.55 0.16 0.04 0.06 0.08 0.04 0.20 0.99 0.98 0.09 0.01 0.01 0.01 0.00
0.24 0.55 0.25 0.01 0.00 0.00 0.01 0.08 0.10 0.47 0.43 0.04 0.04 0.04 0.09 0.12
0.21 0.16 0.12 0.00 0.00 0.00 0.00 0.04 0.05 0.06 0.00 0.04 0.07 0.04 0.23 0.14
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.01 0.04 0.09 0.06 0.05 0.05 0.01 0.01 0.02 0.07 0.12 0.00 0.00 0.00 0.00 0.00
0.08 0.36 0.21 0.08 0.01 0.01 0.09 0.07 0.17 0.63 0.48 0.02 0.01 0.01 0.02 0.01
0.10 0.30 0.13 0.00 0.00 0.00 0.00 0.00 0.01 0.15 0.14 0.06 0.02 0.06 0.10 0.10
0.17 0.12 0.04 0.00 0.00 0.00 0.00 0.01 0.02 0.04 0.02 0.02 0.06 0.01 0.08 0.08
0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.01 0.04 0.09 0.06 0.05 0.05 0.01 0.01 0.02 0.07 0.12 0.00 0.00 0.00 0.00 0.00
0.08 0.36 0.21 0.08 0.01 0.01 0.09 0.07 0.17 0.63 0.48 0.02 0.01 0.01 0.02 0.01
0.10 0.30 0.13 0.00 0.00 0.00 0.00 0.00 0.01 0.15 0.14 0.06 0.02 0.06 0.10 0.10
0.17 0.12 0.04 0.00 0.00 0.00 0.00 0.01 0.02 0.04 0.02 0.02 0.06 0.01 0.08 0.08
0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.10 0.07 0.05 0.00 0.00 0.01 0.01 0.00 0.09 0.06 0.05 0.06 0.02 0.04 0.06 0.05
1.09 1.82 1.31 0.52 0.32 0.23 0.30 0.35 1.20 1.99 1.51 0.50 0.17 0.14 0.35 0.61
1.47 2.58 0.64 0.06 0.04 0.00 0.06 0.16 1.02 1.81 1.31 0.41 0.32 0.17 0.45 0.76
1.33 1.61 0.17 0.01 0.00 0.01 0.01 0.06 0.30 0.51 0.25 0.16 0.31 0.23 0.54 0.90
0.61 0.97 0.05 0.00 0.00 0.00 0.00 0.05 0.23 0.13 0.12 0.16 0.33 0.33 0.37 0.45
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.40 0.48 0.36 0.13 0.10 0.09 0.13 0.23 0.25 0.29 0.20 0.20 0.17 0.13 0.17 0.37
3.23 3.90 0.73 0.09 0.07 0.13 0.21 0.46 1.00 2.40 1.94 1.08 0.60 0.44 0.73 1.50
1.07 1.35 0.17 0.02 0.00 0.00 0.06 0.17 0.39 0.73 0.73 0.35 0.15 0.09 0.28 0.55
0.22 0.27 0.01 0.00 0.00 0.01 0.00 0.07 0.22 0.31 0.18 0.20 0.08 0.02 0.09 0.13
0.00 0.02 0.00 0.00 0.00 0.00 0.00 0.07 0.21 0.04 0.04 0.05 0.01 0.02 0.01 0.01
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
```

0.31	0.60	0.61	0.21	0.21	0.17	0.23	0.24	0.22	0.12	0.14	0.04	0.04	0.01	0.00	0.12
1.39	3.30	1.05	0.05	0.09	0.10	0.07	0.13	0.29	0.61	0.64	0.22	0.05	0.13	0.10	0.30
0.13	0.07	0.02	0.00	0.02	0.00	0.01	0.04	0.00	0.02	0.04	0.01	0.00	0.01	0.01	0.04
0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.15	0.28	0.18	0.14	0.13	0.16	0.27	0.20	0.24	0.01	0.02	0.00	0.00	0.00	0.00
0.10	0.79	0.70	0.10	0.01	0.05	0.02	0.05	0.17	0.41	0.22	0.05	0.00	0.00	0.00	0.02
0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

References

DOE (U.S. Department of Energy), 1999, *Final Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (CLWR EIS) (DOE/EIS-0288). March.

PNNL (Pacific Northwest Laboratory), 2009, *GENII Version 2 Software Design Document*, PNNL-14584, Rev. 3, Richland, Washington, December.

PNNL (Pacific Northwest Laboratory), 2010, *GENII Version 2 Users' Guide*, PNNL-14583 Rev. 3a Richland, Washington, June.

TVA (Tennessee Valley Authority), 2010a, *Watts Bar Nuclear Plant Offsite Dose Calculation Manual*, Revision 56, February 12, 2010.

TVA (Tennessee Valley Authority), 2010b, *Sequoyah Nuclear Plant Offsite Dose Calculation Manual*, Revision 56, September 21, 2010.

TVA (Tennessee Valley Authority) 2011a, *Effluent and Waste Disposal Annual Report Watts Bar Nuclear Plant 2010*.

TVA (Tennessee Valley Authority) 2011b, *Effluent and Waste Disposal Annual Report Sequoyah Nuclear Plant 2010*.

USCB (U.S. Census Bureau) 2012. "2010 Census Interactive Population Search – Tennessee." Available online at: http://2010.census.gov/2010census/popmap/ipmtext.php?fl=47 (accessed May 15, 2012).