Development of EAL Threshold values from NEE-323-CALC-004

Calculated values are provided in Calc-004 as shown below.

Table 2 – Recommended RA1 Liquid EALs

Rad Monitor	Equip.	Modes 1,2,3	Modes 4, 5
		cps	cps
GSW	RE-4767	2.32E+4	1.04E+4
RHRSW/ESW	RE-1997	1.60E+4	7.20E+3
RHRSW Dilution Line	RE-4268	2.42E+4	1.09E+4

The following table of threshold values was developed for use in the DAEC EAL scheme by averaging the separate Mode 1-3 and Mode 4-5 thresholds from Calc-004, and then rounding the average values for ease of EAL evaluator use, as well as to provide a step-wise progression through the emergency classification.

	Monitor	GE	SAE	Alert
Liquid	GSW rad monitor (RIS-4767)	---	---	2.0E+04 cps
	RHRSW & ESW rad monitor (RM-1997)	---	---	1.0E+04 cps
	RHRSW & ESW Rupture Disc rad monitor (RM-4268)	---	---	2.0E+04 cps

Title:	Revised Liquid Radiological EALs per NEI 99-01	**Client:** Duane Arnold Energy Center **Project Identifier:** NEE-323

Item	Cover Sheet Items	Yes	No
1	Does this calculation contain any open assumptions, including preliminary information, that require confirmation? (If **YES**, identify the assumptions.)	☐	☒
2	Does this calculation serve as an "Alternate Calculation"? (If **YES**, identify the design verified calculation.) **Design Verified Calculation No.** _____	☐	☒
3	Does this calculation supersede an existing Calculation? (If **YES**, identify the design verified calculation.) **Superseded Calculation No.** _____	☐	☒

Scope of Revision:

Initial Issue

Revision Impact on Results:

Initial Issue

Study Calculation ☐ **Final Calculation** ☒

Safety-Related ☐ **Non-Safety-Related** ☒

(Print Name and Sign)

Originator: Jay Bhatt	**Date:** **12/12/17**
Design Verifier[1] (Reviewer if NSR): Ryan Skaggs	**Date:** **12/12/17**
Approver: Zachary Rose	**Date:** **12/12/17**

Note 1: For non-safety-related calculation, design verification can be substituted by review.

CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
00	12/12/17	Initial Issue

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
All	00		

APPENDIX/ATTACHMENT REVISION STATUS

APPENDIX NO.	NO. OF PAGES	REVISION NO.	ATTACHMENT NO.	NO. OF PAGES	REVISION NO.
A	12	00	1	4	0
			2	3	0

List of Attachments

1.0 Purpose and Scope

The Duane Arnold Energy Center is implementing the guidance of Revision 6 to NEI 99-01, "Development of Emergency Action Levels for Non-Passive Reactors," which is the industry-developed methodology for emergency classification for the current operating fleet. Changes to the definitions of the condition for entry into the Emergency Action Level (EAL) RA1 result in the development of a new entry threshold value for this EAL.

This calculation determines the liquid radiation monitor readings that correspond to the new EAL thresholds for the release of liquid radioactivity resulting in offsite dose greater than 10 mrem Total Effective Dose Equivalent (TEDE) or 50 mrem thyroid Committed Dose Equivalent (CDE) for one hour of exposure.

2.0 Summary of Results and Conclusions

A spreadsheet was used to calculate the monitor counts per second (cps) reading necessary to reach offsite dose of 10 mrem TEDE or 50 mrem child thyroid organ dose as described in Section 7.0. The output from that spreadsheet is seen below.

Table 1 – Monitor Response for Liquid Radiological EAL Thresholds

Rad Monitor	Equip. ID	Modes 1,2,3 2 Hour Decay cps		Modes 4, 5 36 Hour Decay cps	
		10 mrem TEDE	50 mrem Thyroid	10 mrem TEDE	50 mrem Thyroid
General Service Water (GSW)	RE-4767	23,200	49,100	10,400	14,000
Residual Heat Removal Service Water (RHRSW)/Essential Service Water (ESW)	RE-1997	16,000	33,800	7,200	9,650
RHRSW Dilution Line	RE-4268	24,200	51,300	10,900	14,650

For a given scenario, the threshold is always met for the TEDE dose before it is met for the organ dose.

The recommended RA1 Liquid EALs are:

Table 2 – Recommended RA1 Liquid EALs

Rad Monitor	Equip.	Modes 1,2,3	Modes 4, 5
		cps	cps
GSW	RE-4767	2.32E+4	1.04E+4
RHRSW/ESW	RE-1997	1.60E+4	7.20E+3
RHRSW Dilution Line	RE-4268	2.42E+4	1.09E+4

3.0 References

3.1 DAEC Offsite Dose Assessment Manual (ODAM), Rev. 37.

3.2 Federal Guidance Report No. 12, External Exposure to Radionuclides in Air, Water, and Soil, 1993.

3.3 Code of Federal Regulations, 10CFR20, January 2013.

3.4 NUREG-1940, RASCAL 4: Description of Models and Methods, United States Nuclear Regulatory Commission, Office of Nuclear Security and Incident Response, 2012.

3.5 American National Standard Institute (ANSI/ANS). 1999. "Radioactive Source Term for Normal Operation of Light-Water Reactors," ANSI/ANS-18.1-1999, American Nuclear Society, La Grange Park, IL.

3.6 Plant Chemistry Procedure PCP 8.7, Alarm Setpoints for Liquid Rad. Monitors.

3.7 NEI 99-01, "Development of Emergency Action Levels for Non-Passive Reactors", Rev. 6.

4.0 Assumptions

4.1 For the calculation determining the RA1 EAL for Reactor Modes 1, 2 and 3, the source is assumed to have decayed for 2 hours before reaching the receptor. This decay time is appropriate to produce best estimate results for liquid effluent thresholds for the corresponding Reactor Modes.

4.2 For the calculation determining the RA1 EAL for Reactor Modes 4 and 5, the source is assumed to have decayed for 36 hours before reaching the receptor. This decay time is appropriate to produce best estimate results for liquid effluent thresholds for the corresponding Reactor Modes.

4.3 Per the ODAM, a mixing ratio of 5 is assumed when the effluent mixes with the water in the river. This correlates to a dilution ratio of 1/5 = 0.2. While the ODAM

Section 2.3 states that a dilution factor of 10 can be used for drinking water, using a mixing ratio of 5 is appropriate for determining the EAL thresholds.

5.0 Design Inputs

5.1 Data for each of the Service Water Radiation monitors, taken from ODAM Table I-2 and Attachment 2, is presented here:

Table 3 – Service Water Radiation Monitor Design Inputs

Rad Monitor	Equip. ID	Range cps	Efficiency cps/µci/ml	Efficiency Source Document
GSW	RE-4767	0.1-10^6	2.19E+06	Attachment 2
RHRSW/ESW	RE-1997	0.1-10^6	1.51E+06	Attachment 2
RHRSW Dilution Line*	RE-4268	0.1-10^6	2.29E+06	Attachment 2

*RE-4268 was previously known as the RHRSW Rupture Disk

5.2 The isotopic mixture and half-lives used in this calculation are taken or developed from NUREG-1940 Table 1-2 and Table A-4.

Table 4 – Isotopic Mixture and Half-lives

Isotope	BWR Coolant Concentration (Ci/g)	Half-life (hr)	Isotope	BWR Coolant Concentration (Ci/g)	Half-life (hr)
Ag-110m	1.00E-12	6.00E+03	**Na-24**	2.00E-09	1.50E+01
Ba-140	4.00E-10	3.05E+02	**Np-239**	8.00E-09	5.66E+01
Ce-141	3.00E-11	7.80E+02	**P-32**	4.00E-11	5.83E+02
Ce-144*	3.00E-12	6.82E+03	**Rb-89**	5.00E-09	2.54E-01
Co-58	1.00E-10	1.70E+03	**Ru-103**	2.00E-11	9.43E+02
Co-60	2.00E-10	4.61E+04	**Ru-106**	3.00E-12	8.83E+03
Cr-51	3.00E-09	6.65E+02	**Sr-89**	1.00E-10	1.21E+03
Cs-134	3.00E-11	1.81E+04	**Sr-90**	7.00E-12	2.54E+05
Cs-136	2.00E-11	3.14E+02	**Sr-91**	4.00E-09	9.50E+00
Cs-137*	8.00E-11	2.64E+05	**Sr-92**	1.00E-08	2.71E+00
Cs-138	1.00E-08	5.38E-01	**Te-129m**	4.00E-11	8.06E+02
Cu-64	3.00E-09	1.27E+01	**Te-131m**	1.00E-10	3.00E+01
Fe-59	3.00E-11	1.07E+03	**Te-132**	1.00E-11	7.82E+01
I-131	2.20E-09	1.93E+02	**W-187**	3.00E-10	2.39E+01
I-132	2.20E-08	2.29E+00	**Y-91**	4.00E-11	1.40E+03
I-133	1.50E-08	2.08E+01	**Y-92**	6.00E-09	3.55E+00
I-134	4.30E-08	8.76E-01	**Y-93**	4.00E-09	1.01E+01
I-135	2.20E-08	6.60E+00	**Zn-65**	1.00E-10	5.86E+03
Mn-54	3.50E-11	7.51E+03	**Zr-95**	8.00E-12	1.54E+03
Mn-56	2.50E-08	2.57E+00	**Fe-55**	1.00E-09	2.37E+04
Mo-99	2.00E-09	6.60E+01	**H-3**	1.00E-08	1.08E+05
			Ni-63	1.00E-12	8.40E+05

5.3 Dose Coefficient from Water Immersion/ Annual Limit for Intake (ALI)

The dose coefficient for water immersion for each isotope are from Table III.2 of FGR12.

The Annual Limit for Intake (ALI), which represents the number of microcuries that would have to be ingested to cause a dose of 5 rem to an occupationally exposed worker is taken from 10CFR20, Appendix B, Table 1 Column One.

Table 5 – FGR 12 and ALI

Isotope	FGR 12	ALI	Isotope	FGR 12	ALI
	Sv m³ / Bq s	µCi		Sv m³ / Bq s	µCi
Ag-110m	2.94E-16	5.00E+02	**Na-24**	4.73E-16	4.00E+03
Ba-140	1.87E-17	6.00E+02	**Np-239**	1.70E-17	2.00E+03
Ce-141	7.62E-18	2.00E+03	**P-32**	1.90E-19	6.00E+02
Ce-144	1.91E-18	3.00E+02	**Rb-89**	2.30E-16	6.00E+04
Co-58	1.03E-16	2.00E+03	**Ru-103**	4.89E-17	2.00E+03
Co-60	2.74E-16	2.00E+02	**Ru-106**	2.24E-17	2.00E+02
Cr-51	3.30E-18	4.00E+04	**Sr-89**	1.49E-19	5.00E+02
Cs-134	1.64E-16	7.00E+01	**Sr-90**	1.46E-20	4.00E+01
Cs-136	2.31E-16	4.00E+02	**Sr-91**	7.48E-17	2.00E+03
Cs-137	1.49E-20	1.00E+02	**Sr-92**	1.47E-16	3.00E+03
Cs-138	2.62E-16	3.00E+04	**Te-129m**	3.39E-18	5.00E+02
Cu-64	1.98E-17	1.00E+04	**Te-131m**	1.52E-16	6.00E+02
Fe-59	1.29E-16	8.00E+02	**Te-132**	2.28E-17	7.00E+02
I-131	3.98E-17	9.00E+01	**W-187**	4.97E-17	2.00E+03
I-132	2.43E-16	9.00E+03	**Y-91**	5.44E-19	6.00E+02
I-133	6.39E-17	5.00E+02	**Y-92**	2.81E-17	3.00E+03
I-134	2.82E-16	3.00E+04	**Y-93**	1.03E-17	1.00E+03
I-135	1.73E-16	3.00E+03	**Zn-65**	6.29E-17	4.00E+02
Mn-54	8.88E-17	2.00E+03	**Zr-95**	7.82E-17	1.00E+03
Mn-56	1.86E-16	5.00E+03	**Fe-55**	0.00E+00	9.00E+03
Mo-99	1.58E-17	1.00E+03	**H-3**	0.00E+00	8.00E+04
			Ni-63	0.00E+00	9.00E+03

5.4 Dose transfer factors for radionuclides in effluent water for a child through the potable water pathway are taken from ODAM Appendix C, and shown in Table 9.

6.0 Methodology

6.1 General Approach

With a given mixture of radionuclides, the dose received by an individual offsite is a function of the gross activity present in the liquid mixture.

The resultant dose received by an offsite receptor is dependent not only on the gross radioactivity levels of the effluent but also upon the isotopic mixture present in the

liquid. This calculation predicts the relative contribution of each radionuclide to the gross radiation monitored by the liquid effluent monitor.

For a liquid release, the only phenomenon affecting the mixture is radioactive decay.

With the mixture known, a given gross output reading (cps) from a liquid effluent radiation monitor can be scaled to determine the concentration of each isotope present in the liquid effluent.

The calculation then uses liquid dilution factors as described in the Offsite Dose Assessment Manual to determine the resultant concentration of radionuclides to which an individual offsite would be exposed.

Dose conversion factors are used to determine the dose (mrem) to an individual offsite due to their exposure to the liquid mixture of radionuclides.

With the given radionuclide mixture and dilution factors understood, an iterative process can be used to relate the liquid effluent monitor reading to a target offsite dose.

Two types of radiation dose are calculated:

- Thyroid CDE or Committed Dose Equivalent is the radiation dose to the thyroid due to an uptake of radioactive material. In this case, the uptake is limited to ingestion of radioactive material present in river water.
- TEDE or Total Effective Dose Equivalent is the summation of the Effective Dose Equivalent (EDE) and the Committed Effective Dose Equivalent (CEDE): TEDE = EDE + CEDE.
- EDE is the dose due to an individual being directly exposed (by submersion) to the radiation present in the liquid release. For this scenario, the individual is not actually immersed in the liquid, but boating above it so a correction factor is applied.
- CEDE is the sum of the CDE for each organ of the body with weighting factors applied for each organ.

6.2 Scenario

The ODAM described dose pathways focus on long term ingestion of radionuclides through various food pathways. This is in sharp contrast to the NEI thresholds which limit the exposure to one hour. To meet the prescribed one hour exposure scenario, the following scenario will be used:

- An adult and a child are fishing from a boat on the Cedar River downstream of the facility. While they are there, a radioactive liquid release from the facility occurs. The release lasts one hour.
- During that time frame each of the individuals ingests 500 milliliters of river water.
- The individuals leave the area one hour after the start of the exposure when they heed the announcement from the ERO siren system.

The pathways thus indicated are <u>drinking water</u> and <u>boating</u>.

6.3 Radioactive Source

The gross radioactive concentration is converted from cps to μCi/ml using the monitor efficiencies from Design Input 5.1. For example, the gross radioactive concentration in the GSW system with an indication of 10000 cps from the GSW Rad. Monitor is calculated as follows:

10000	~~cps~~	1	μCi/ml	=	4.57E-03 μCi/ml
		2.19E+06	~~cps~~		

With the total concentration of the effluent known, given a mixture of isotopes where the relative amount of each isotope is known, the isotopic mixture in the effluent can be determined. The isotopic mixture and half-lives used in this calculation come from Design Input 5.2.

In order to determine the radiation dose to the receptor, the concentrations affecting the receptor must be known.

For Plant Modes 1, 2, and 3, a source decay time of two hours is assumed to account for transit time (Assumption 4.1). For Plant Modes 4 and 5, a source decay time of 36 hours is assumed (Assumption 4.2).

The NUREG-1940 source is decayed using Design Input 5.2. The Ag-110m computation is displayed (indicated as row 7) as an example:

Table 6 – Source Decay

Isotope	NUREG-1940 Concentration Ci/g	Half-life hr	lambda hrs-1	Conc. 2 Hr Decay	Conc. 36 Hr Decay
A	B	C	D	E	F
Ag-110m	1.00E-12	6.00E+03	=(LN(2))/C7	= B7*(EXP(-D7*2))	= B7*(EXP(-D7*36))
Ag-110m	1.00E-12	6.00E+03	1.16E-04	1.00E-12	9.96E-13
Ba-140	4.00E-10	3.05E+02	2.27E-03	3.98E-10	3.69E-10
Ce-141	3.00E-11	7.80E+02	8.89E-04	2.99E-11	2.91E-11
Ce-144*	3.00E-12	6.82E+03	1.02E-04	3.00E-12	2.99E-12
Co-58	1.00E-10	1.70E+03	4.08E-04	9.99E-11	9.85E-11
Co-60	2.00E-10	4.61E+04	1.50E-05	2.00E-10	2.00E-10
Cr-51	3.00E-09	6.65E+02	1.04E-03	2.99E-09	2.89E-09
Cs-134	3.00E-11	1.81E+04	3.84E-05	3.00E-11	3.00E-11
Cs-136	2.00E-11	3.14E+02	2.20E-03	1.99E-11	1.85E-11
Cs-137*	8.00E-11	2.64E+05	2.63E-06	8.00E-11	8.00E-11
Cs-138	1.00E-08	5.38E-01	1.29E+00	7.59E-10	6.95E-29
Cu-64	3.00E-09	1.27E+01	5.46E-02	2.69E-09	4.20E-10
Fe-59	3.00E-11	1.07E+03	6.49E-04	3.00E-11	2.93E-11
I-131	2.20E-09	1.93E+02	3.59E-03	2.18E-09	1.93E-09
I-132	2.20E-08	2.29E+00	3.02E-01	1.20E-08	4.16E-13
I-133	1.50E-08	2.08E+01	3.33E-02	1.40E-08	4.52E-09
I-134	4.30E-08	8.76E-01	7.91E-01	8.83E-09	1.83E-20
I-135	2.20E-08	6.60E+00	1.05E-01	1.78E-08	5.02E-10
Mn-54	3.50E-11	7.51E+03	9.23E-05	3.50E-11	3.49E-11
Mn-56	2.50E-08	2.57E+00	2.70E-01	1.46E-08	1.51E-12
Mo-99	2.00E-09	6.60E+01	1.05E-02	1.96E-09	1.37E-09
Na-24	2.00E-09	1.50E+01	4.62E-02	1.82E-09	3.79E-10
Np-239	8.00E-09	5.66E+01	1.22E-02	7.81E-09	5.15E-09
P-32	4.00E-11	5.83E+02	1.19E-03	3.99E-11	3.83E-11
Rb-89	5.00E-09	2.54E-01	2.72E+00	2.15E-11	1.26E-51
Ru-103	2.00E-11	9.43E+02	7.35E-04	2.00E-11	1.95E-11
Ru-106	3.00E-12	8.83E+03	7.85E-05	3.00E-12	2.99E-12
Sr-89	1.00E-10	1.21E+03	5.72E-04	9.99E-11	9.80E-11
Sr-90	7.00E-12	2.54E+05	2.72E-06	7.00E-12	7.00E-12
Sr-91	4.00E-09	9.50E+00	7.29E-02	3.46E-09	2.90E-10
Sr-92	1.00E-08	2.71E+00	2.56E-01	6.00E-09	1.01E-12
Te-129m	4.00E-11	8.06E+02	8.60E-04	3.99E-11	3.88E-11
Te-131m	1.00E-10	3.00E+01	2.31E-02	9.55E-11	4.35E-11
Te-132	1.00E-11	7.82E+01	8.86E-03	9.82E-12	7.27E-12
W-187	3.00E-10	2.39E+01	2.90E-02	2.83E-10	1.06E-10
Y-91	4.00E-11	1.40E+03	4.94E-04	4.00E-11	3.93E-11
Y-92	6.00E-09	3.55E+00	1.95E-01	4.06E-09	5.34E-12
Y-93	4.00E-09	1.01E+01	6.86E-02	3.49E-09	3.38E-10
Zn-65	1.00E-10	5.86E+03	1.18E-04	1.00E-10	9.96E-11
Zr-95	8.00E-12	1.54E+03	4.51E-04	7.99E-12	7.87E-12
Fe-55	1.00E-09	2.37E+04	2.93E-05	1.00E-09	9.99E-10
H-3	1.00E-08	1.08E+05	6.40E-06	1.00E-08	1.00E-08
Ni-63	1.00E-12	8.40E+05	8.25E-07	1.00E-12	1.00E-12

6.4 TEDE Dose

To determine the TEDE dose for a one hour exposure, two components are considered.

1. Direct exposure to the radioactive water present in the river is considered, commonly described as Effective Dose Equivalent (**EDE**).
2. Committed Effective Dose Equivalent (**CEDE**) is considered, which is the dose commitment due to the ingestion or inhalation of a mixture of radioactive material.

6.4.1 EDE

Immersion dose is calculated with guidance provided in Federal Guidance Report 12 (FGR12).

With the isotopic concentration at the receptor known (Table 6), the dose (mrem) at the receptor can be calculated:

$$Dose = \sum_i (x_{ir} * hT_i)$$

Where

$x_{ir} =$ concentration of radionuclide ***i*** present in the water at the receptor (µCi/ ml)

$i =$ each isotope present in the liquid release

$hT_i =$ factor from FGR12 for converting the liquid concentration to effective dose equivalent from Design Input 5.3 (mrem ml / sec µCi)

The dose coefficients in Design Input 5.3 from FGR12 relate the radioactive concentration of a liquid to the dose received by a person who is immersed in the liquid. FGR 12 also provides this statement about the relationship between immersion dose and dose received while boating:

> **Exposure during boating activities**
>
> The dose coefficients for immersion in contaminated water in Table III.2 assume immersion in an infinite pool and, thus, are appropriate for exposure while swimming. External exposure to contaminated water can also occur during boating activities. For photon exposure, a dose-reduction factor of 0.5 during boating activities is a reasonable value that is unlikely to underestimate external dose equivalents.

6.4.2 CEDE

To calculate the Committed Effective Dose Equivalent due to the consumption of contaminated water, the ALI values from Design Input 5.3 are used. The first column of

the table lists the ALI for each isotope. The ALI value is the Annual Limit for Intake and represents the number of microcuries that would have to be ingested to cause a dose of 5 rem to an occupationally exposed worker.

Following the conversion of the ALI values to units of *"mrem per µCi"* the following equation can be used to determine radiation dose due to ingestion of a liquid mixture of radioisotopes.

$$Dose = \sum_i (x_{ir} * v * hE_i)$$

Where

$x_{ir} =$ concentration of the radionuclide ***i*** present in the water at the receptor (µCi/ml)

$i =$ each isotope present in the gaseous release

$hE_i =$ factor converting the gas concentration to effective dose equivalent (mrem/µCi)

$v =$ volume of water ingested (ml)

10CFR20 includes a statement regarding the use of Table 1 Column One values for members of the public:

> ...a factor of 2 to adjust the occupational values (derived for adults) so that they are applicable to other age groups.

Spreadsheets are used in section 7.1 to calculate EDE and CEDE from all of the isotopes in the mixture.

6.5 Organ dose

Methods to calculate Organ Dose are taken from ODAM section 2.6 titled "Accumulated Personal Maximum Dose". The guidance is provided here:

$$\Delta D_{ank} = 3.785 \bullet x\,10^{-3} \sum_i C_{ik} \bullet \Delta T_k \sum_e \frac{F1_k}{F2_{ek}} \bullet A_{eani}$$

$$D_{an} = \sum_k \Delta D_{ank}$$

where

ΔD_{ank} = the dose commitment (mrem) to organ *n* of age group *a* due to the isotopes identified in analysis *k*, where

the analyses are those required by Table 7.1-2. Thus the contribution to the dose from gamma emitters become available on a batch basis for batch releases and on a weekly basis for continuous releases. Similarly the contributions from H-3 is available on a monthly basis and the contributions from Fe-55, Sr-89, and Sr-90 become available on a quarterly basis.

D_{an} = the dose commitment during the quarter-to-date to organ *n*, including whole body, of the maximally exposed person in age group *a* (mrem)

A_{eani} = transfer factor relating a unit release of radionuclide *i* (Ci) in a unit stream flow (gal/min) to dose commitment to organ *n*, or whole body, of an exposed person in age group *a* $\left[\frac{mrem\ gal}{Ci\ \min}\right]$ via environmental pathway *e*.

C_{ik} = the concentration of radionuclide *i* in the undiluted liquid waste represented by sample *k* to be discharged (µCi/mL)

Δt_k = duration of radioactive release represented by sample *k* which occurs within time boundaries TB and TE and during which concentration C_{ik} and flows $F1_k$ and $F2_k$ exist. (min.)

$3.785 \bullet 10^{-3}$ = conversion constant (3785 mL/gal • 10^{-6} Ci/µCi)

$F1_k$ = flow in the radioactive waste release line (gal/min)* represented by sample *k*.

$F2_{ke}$ = flow into which radioactive release represented by sample *k* is mixed in the river at the point of exposure or withdrawal of water for use (same units as $F1_k$)*

For this calculation,

- Δ_{tk} is set to 60 minutes
- $F_{1k/2ke}$ is 0.2 per Assumption 4.3.

- A_{eani} values are taken from ODAM Appendix C (Design Input 5.4)
- Based on the scenario, only the child thyroid organ is considered, as this bounds the adult, and is used in Iowa as the basis for Protective Action Guidelines.
- Based on the scenario, only the drinking water pathway is considered.

Spreadsheets are used in section 7.2 to calculate CDE-Thyroid from all of the isotopes in the mixture.

7.0 Calculation

7.1 TEDE Dose

A Microsoft Excel spreadsheet uses an iterative process to determine the cps output readings from each of the three monitors that correspond to a TEDE Dose of 10 mrem.

Sections of the spreadsheet are presented here. This is the spreadsheet for the RHRSW/ESW Monitor.

Ingestion Dose:	8.24	mrem
+ Boating Dose:	1.79	mrem
Resultant Total mRem:	10.0	mrem

Variables

Monitor: RHRSW/ESW RM1997

FGR12 Units Conversion Factor:	3.70E+15		FGR12 Boating/Immersion Reduction Factor:	0.50
Monitor c[s:	16,000	cps		
Monitor Efficiency:	1.51E+6	cps / uCi/ml	10CFR20 Ingestion Age Consideration Factor:	2
			Decay Hrs:	2
Volume Consumed:	500	mL		
			Dilution Factor:	0.20

Resultant River Gamma Concentration for the Given CPS Reading :

$$\frac{16000\ \text{cps}}{} \left| \frac{\mu Ci/ml}{1.51E+06\ \text{cps}} \right| \frac{0.20}{} = \frac{2.12E\text{-}03}{} \left| \mu Ci/ml \right.$$

The mrem values seen above are calculated in the spreadsheet on the following pages. As can be seen above, the dilution factor **(0.20)** is included in the efficiency equation to account for the fact that the concentration in the river will be only 20% of the concentration seen by the effluent radiation monitor per Assumption 4.3.

7.1.1 Boating Dose

The concentrations for the individual isotopes are scaled to the gross concentration determined above. In this case, the value is 2.12E-03 µCi/ml. The value of 2.12E-03 is calculated based on the monitor cps reading entered by the spreadsheet user. Through an iterative process, the user enters the monitor cps necessary to determine the desired resultant total dose (in mrem).

The dose coefficient for water immersion for each isotope in column B in Table 7 is taken from Design Input 5.3. FGR 12 displays dose factors in the SI units of SV m^3/ bq sec. Traditional units of mrem mL/sec µCi sec are desired.

FGR 12:

1	~~SV~~	~~m3~~	1E+05	mRem	1	~~bq~~	1E+06	mL		~~Ci~~	=	3.70E+15	mRem	mL
	~~bq~~	sec		~~SV~~	2.7E-11	~~Ci~~		~~m3~~	1E+06	µCi			sec	µCi

The conversion factor from SV m^3/bq sec to mrem cm^3/µCi sec is 3.70E+15.

The decayed mixture from column E is taken from Table 6. Note that the concentration values present in the (starting) mixture do not affect the result. It is the ratios of the isotopes to the gross concentration (Section 7.1 - Column G) in the mixture that are needed. Per Section 6.4.1, a 0.5 dose-reduction factor is applied in Column I. For illustrative purposes, for the isotope AG-110m, the cell formulas are displayed.

Table 7 – Boating Dose

	A	B	C	D	E	F	G	H	I
1	Nuclide	FGR 12: SV m3 / bq sec	FGR12 Units Conv.	mrem mL / µCi sec	Decayed Mix µCi / mL	Fraction	River µCi/mL	Immersion mrem / Sec	Boating mrem / Hr
2	Ag-110m	2.94E-16	3.70E+15	1.09E+0	Table 6	=E2/ 1.17E-7	=F2*2.12E-3	=D2*G2	=H2*3600 * 0.5
	Ag-110m	2.94E-16	3.70E+15	1.09E+0	1.00E-12	0.00%	1.81E-8	1.97E-8	3.54E-5
	Ba-140	1.87E-17	3.70E+15	6.92E-2	3.98E-10	0.34%	7.20E-6	4.98E-7	8.97E-4
	Ce-141	7.62E-18	3.70E+15	2.82E-2	2.99E-11	0.03%	5.41E-7	1.53E-8	2.75E-5
	Ce-144*	1.91E-18	3.70E+15	7.07E-3	3.00E-12	0.00%	5.42E-8	3.83E-10	6.90E-7
	Co-58	1.03E-16	3.70E+15	3.81E-1	9.99E-11	0.09%	1.81E-6	6.88E-7	1.24E-3
	Co-60	2.74E-16	3.70E+15	1.01E+0	2.00E-10	0.17%	3.62E-6	3.67E-6	6.60E-3
	Cr-51	3.30E-18	3.70E+15	1.22E-2	2.99E-09	2.55%	5.41E-5	6.61E-7	1.19E-3
	Cs-134	1.64E-16	3.70E+15	6.07E-1	3.00E-11	0.03%	5.42E-7	3.29E-7	5.92E-4
	Cs-136	2.31E-16	3.70E+15	8.55E-1	1.99E-11	0.02%	3.60E-7	3.08E-7	5.54E-4
	Cs-137*	1.49E-20	3.70E+15	5.51E-5	8.00E-11	0.07%	1.45E-6	7.97E-11	1.44E-7
	Cs-138	2.62E-16	3.70E+15	9.69E-1	7.59E-10	0.65%	1.37E-5	1.33E-5	2.39E-2
	Cu-64	1.98E-17	3.70E+15	7.33E-2	2.69E-09	2.29%	4.86E-5	3.56E-6	6.41E-3
	Fe-59	1.29E-16	3.70E+15	4.77E-1	3.00E-11	0.03%	5.42E-7	2.59E-7	4.65E-4
	I-131	3.98E-17	3.70E+15	1.47E-1	2.18E-09	1.86%	3.95E-5	5.82E-6	1.05E-2
	I-132	2.43E-16	3.70E+15	8.99E-1	1.20E-08	10.26%	2.17E-4	1.95E-4	3.52E-1
	I-133	6.39E-17	3.70E+15	2.36E-1	1.40E-08	11.97%	2.54E-4	6.00E-5	1.08E-1
	I-134	2.82E-16	3.70E+15	1.04E+0	8.83E-09	7.54%	1.60E-4	1.67E-4	3.00E-1
	I-135	1.73E-16	3.70E+15	6.40E-1	1.78E-08	15.21%	3.22E-4	2.06E-4	3.71E-1
	Mn-54	8.88E-17	3.70E+15	3.29E-1	3.50E-11	0.03%	6.33E-7	2.08E-7	3.74E-4

	A	B	C	D	E	F	G	H	I
1	Nuclide	FGR 12: SV m3 / bq sec	FGR12 Units Conv.	mrem mL / µCi sec	Decayed Mix µCi / mL	Fraction	River µCi/mL	Immersion mrem / Sec	Boating mrem / Hr
	Mn-56	1.86E-16	3.70E+15	6.88E-1	1.46E-08	12.43%	2.63E-4	1.81E-4	3.26E-1
	Mo-99	1.58E-17	3.70E+15	5.85E-2	1.96E-09	1.67%	3.54E-5	2.07E-6	3.73E-3
	Na-24	4.73E-16	3.70E+15	1.75E+0	1.82E-09	1.56%	3.30E-5	5.77E-5	1.04E-1
	Np-239	1.70E-17	3.70E+15	6.29E-2	7.81E-09	6.66%	1.41E-4	8.88E-6	1.60E-2
	P-32	1.90E-19	3.70E+15	7.03E-4	3.99E-11	0.03%	7.22E-7	5.07E-10	9.13E-7
	Rb-89	2.30E-16	3.70E+15	8.51E-1	2.15E-11	0.02%	3.89E-7	3.31E-7	5.95E-4
	Ru-103	4.89E-17	3.70E+15	1.81E-1	2.00E-11	0.02%	3.61E-7	6.53E-8	1.18E-4
	Ru-106	2.24E-17	3.70E+15	8.29E-2	3.00E-12	0.00%	5.42E-8	4.49E-9	8.09E-6
	Sr-89	1.49E-19	3.70E+15	5.51E-4	9.99E-11	0.09%	1.81E-6	9.96E-10	1.79E-6
	Sr-90	1.46E-20	3.70E+15	5.40E-5	7.00E-12	0.01%	1.27E-7	6.84E-12	1.23E-8
	Sr-91	7.48E-17	3.70E+15	2.77E-1	3.46E-09	2.95%	6.25E-5	1.73E-5	3.11E-2
	Sr-92	1.47E-16	3.70E+15	5.44E-1	6.00E-09	5.12%	1.08E-4	5.90E-5	1.06E-1
	Te-129m	3.39E-18	3.70E+15	1.25E-2	3.99E-11	0.03%	7.22E-7	9.06E-9	1.63E-5
	Te-131m	1.52E-16	3.70E+15	5.62E-1	9.55E-11	0.08%	1.73E-6	9.71E-7	1.75E-3
	Te-132	2.28E-17	3.70E+15	8.44E-2	9.82E-12	0.01%	1.78E-7	1.50E-8	2.70E-5
	W-187	4.97E-17	3.70E+15	1.84E-1	2.83E-10	0.24%	5.12E-6	9.41E-7	1.69E-3
	Y-91	5.44E-19	3.70E+15	2.01E-3	4.00E-11	0.03%	7.23E-7	1.45E-9	2.62E-6
	Y-92	2.81E-17	3.70E+15	1.04E-1	4.06E-09	3.46%	7.34E-5	7.63E-6	1.37E-2
	Y-93	1.03E-17	3.70E+15	3.81E-2	3.49E-09	2.98%	6.31E-5	2.40E-6	4.33E-3
	Zn-65	6.29E-17	3.70E+15	2.33E-1	1.00E-10	0.09%	1.81E-6	4.21E-7	7.57E-4
	Zr-95	7.82E-17	3.70E+15	2.89E-1	7.99E-12	0.01%	1.45E-7	4.18E-8	7.53E-5
	Fe-55	0.00E+00	3.70E+15	0.00E+0	1.00E-09	0.85%	1.81E-5	0.00E+0	0.00E+0
	H-3	0.00E+00	3.70E+15	0.00E+0	1.00E-08	8.53%	1.81E-4	0.00E+0	0.00E+0
	Ni-63	0.00E+00	3.70E+15	0.00E+0	1.00E-12	0.00%	1.81E-8	0.00E+0	0.00E+0
					1.17E-7	100.00%	2.12E-3 **2.12E-3**	9.97E-4	**1.79 mrem**

7.1.2 Ingestion Dose

Ingestion dose is calculated in the section of the spreadsheet seen below. ALIs (column D) from Design Input 5.3 are converted to mrem/µCi factors (column E) as shown in the example below for Co-60 which has an ALI of 200 µCi:

$$\frac{5 \text{ rem}}{2E+02\ \mu Ci} \times \frac{1000 \text{ mrem}}{1 \text{ Rem}} = \frac{25 \text{ mRem}}{\mu Ci}$$

The resultant dose (in mrem) caused by ingesting 500 ml of the liquid is calculated per Section 6.4.2. The decayed mixture from column F is taken from Table 6.

An **example** demonstrating dose caused by drinking 500 ml of water containing cobalt-60 with a concentration of 0.001 µCi/ml:

$$\frac{25 \text{ mrem}}{\cancel{\mu Ci}} \times \frac{0.001 \ \cancel{\mu Ci}}{\cancel{ml}} \times 500 \ \cancel{ml} = 12.5 \text{ mrem}$$

For an occupationally exposed worker, drinking those 500 milliliters of water contaminated with Co-60 would result in a dose of 12.5 mrem. Per Section 6.4.2, this is multiplied by 2, generating 25 mrem.

Note that there are three hard-to-detect isotopes (HTDs) present in the mixture: Fe-55, H-3 and Ni-63. Because they do not emit gamma rays, they are not detected by the service water radiation monitor. Therefore, they are effectively removed from the gross gamma calculation calibrating the monitor response (Columns H, I, and J). The HTDs are then scaled back into the calculation of the applied dose.

For illustrative purposes, for the isotope Ag-110m, the cell formulas are displayed. The decayed mixture from column F is taken from Table 6. Column M contains the multiplier for the 500 ml volume consumed and the 2x multiplier factor for members of the public.

Table 8 – Ingestion Dose

B	C	D	E	F	G	H	I	J	K	L	M
1		10CFR20 ALI	mrem / µCi	Mix Ci / ml	Mix Fraction	Mix Gamma Ci / ml	Mix Gamma Fraction	River Gamma µCi / ml	River µCi / ml	River Fraction	mrem
2	Ag-110m	5.00E+02	=1/(D2/5000)	Table 6	=F2*1.17E-7	=F2	=H2/1.06E-7	=I2*2.12E-3	=J2	=K2/2.32E-3	=K2*E2*2*500
	Ag-110m	5.00E+02	1.00E+1	1.00E-12	0.0%	1.00E-12	0.0%	1.99E-8	1.99E-8	0.0%	1.99E-04
	Ba-140	6.00E+02	8.33E+0	3.98E-10	0.3%	3.98E-10	0.4%	7.95E-6	7.95E-6	0.3%	6.62E-02
	Ce-141	2.00E+03	2.50E+0	2.99E-11	0.0%	2.99E-11	0.0%	5.98E-7	5.98E-7	0.0%	1.49E-03
	Ce-144*	3.00E+02	1.67E+1	3.00E-12	0.0%	3.00E-12	0.0%	5.98E-8	5.98E-8	0.0%	9.97E-04
	Co-58	1.00E+03	5.00E+0	9.99E-11	0.1%	9.99E-11	0.1%	1.99E-6	1.99E-6	0.1%	9.97E-03
	Co-60	2.00E+02	2.50E+1	2.00E-10	0.2%	2.00E-10	0.2%	3.99E-6	3.99E-6	0.2%	9.98E-02
	Cr-51	4.00E+04	1.25E-1	2.99E-09	2.6%	2.99E-9	2.8%	5.97E-5	5.97E-5	2.6%	7.47E-03
	Cs-134	7.00E+01	7.14E+1	3.00E-11	0.0%	3.00E-11	0.0%	5.99E-7	5.99E-7	0.0%	4.28E-02
	Cs-136	4.00E+02	1.25E+1	1.99E-11	0.0%	1.99E-11	0.0%	3.97E-7	3.97E-7	0.0%	4.97E-03
	Cs-137*	1.00E+02	5.00E+1	8.00E-11	0.1%	8.00E-11	0.1%	1.60E-6	1.60E-6	0.1%	7.98E-02
	Cs-138	3.00E+04	1.67E-1	7.59E-10	0.6%	7.59E-10	0.7%	1.51E-5	1.51E-5	0.7%	2.52E-03
	Cu-64	1.00E+04	5.00E-1	2.69E-09	2.3%	2.69E-9	2.5%	5.37E-5	5.37E-5	2.3%	2.68E-02
	Fe-59	8.00E+02	6.25E+0	3.00E-11	0.0%	3.00E-11	0.0%	5.98E-7	5.98E-7	0.0%	3.74E-03
	I-131	9.00E+01	5.56E+1	2.18E-09	1.9%	2.18E-9	2.1%	4.36E-5	4.36E-5	1.9%	2.42E+00
	I-132	9.00E+03	5.56E-1	1.20E-08	10.3%	1.20E-8	11.3%	2.40E-4	2.40E-4	10.3%	1.33E-01
	I-133	5.00E+02	1.00E+1	1.40E-08	12.0%	1.40E-8	13.2%	2.80E-4	2.80E-4	12.1%	2.80E+00
	I-134	3.00E+04	1.67E-1	8.83E-09	7.5%	8.83E-9	8.3%	1.76E-4	1.76E-4	7.6%	2.94E-02
	I-135	3.00E+03	1.67E+0	1.78E-08	15.2%	1.78E-8	16.8%	3.56E-4	3.56E-4	15.3%	5.93E-01
	Mn-54	2.00E+03	2.50E+0	3.50E-11	0.0%	3.50E-11	0.0%	6.98E-7	6.98E-7	0.0%	1.75E-03
	Mn-56	5.00E+03	1.00E+0	1.46E-08	12.4%	1.46E-8	13.7%	2.91E-4	2.91E-4	12.5%	2.91E-01
	Mo-99	1.00E+03	5.00E+0	1.96E-09	1.7%	1.96E-9	1.8%	3.91E-5	3.91E-5	1.7%	1.95E-01
	Na-24	4.00E+03	1.25E+0	1.82E-09	1.6%	1.82E-9	1.7%	3.64E-5	3.64E-5	1.6%	4.55E-02
	Np-239	2.00E+03	2.50E+0	7.81E-09	6.7%	7.81E-9	7.4%	1.56E-4	1.56E-4	6.7%	3.89E-01
	P-32	6.00E+02	8.33E+0	3.99E-11	0.0%	3.99E-11	0.0%	7.96E-7	7.96E-7	0.0%	6.64E-03
	Rb-89	6.00E+04	8.33E-2	2.15E-11	0.0%	2.15E-11	0.0%	4.29E-7	4.29E-7	0.0%	3.57E-05

B	C	D	E	F	G	H	I	J	K	L	M
1		10CFR20 ALI	mrem/µCi	Mix Ci/ml	Mix Fraction	Mix Gamma Ci/ml	Mix Gamma Fraction	River Gamma µCi/ml	River µCi/ml	River Fraction	mrem
	Ru-103	2.00E+03	2.50E+0	2.00E-11	0.0%	2.00E-11	0.0%	3.98E-7	3.98E-7	0.0%	9.96E-04
	Ru-106	2.00E+02	2.50E+1	3.00E-12	0.0%	3.00E-12	0.0%	5.99E-8	5.99E-8	0.0%	1.50E-03
	Sr-89	5.00E+02	1.00E+1	9.99E-11	0.1%	9.99E-11	0.1%	1.99E-6	1.99E-6	0.1%	1.99E-02
	Sr-90	4.00E+01	1.25E+2	7.00E-12	0.0%	7.00E-12	0.0%	1.40E-7	1.40E-7	0.0%	1.75E-02
	Sr-91	2.00E+03	2.50E+0	3.46E-09	2.9%	3.46E-9	3.3%	6.90E-5	6.90E-5	3.0%	1.72E-01
	Sr-92	3.00E+03	1.67E+0	6.00E-09	5.1%	6.00E-9	5.6%	1.20E-4	1.20E-4	5.2%	1.99E-01
	Te-129m	5.00E+02	1.00E+1	3.99E-11	0.0%	3.99E-11	0.0%	7.97E-7	7.97E-7	0.0%	7.97E-03
	Te-131m	6.00E+02	8.33E+0	9.55E-11	0.1%	9.55E-11	0.1%	1.91E-6	1.91E-6	0.1%	1.59E-02
	Te-132	7.00E+02	7.14E+0	9.82E-12	0.0%	9.82E-12	0.0%	1.96E-7	1.96E-7	0.0%	1.40E-03
	W-187	2.00E+03	2.50E+0	2.83E-10	0.2%	2.83E-10	0.3%	5.65E-6	5.65E-6	0.2%	1.41E-02
	Y-91	6.00E+02	8.33E+0	4.00E-11	0.0%	4.00E-11	0.0%	7.97E-7	7.97E-7	0.0%	6.64E-03
	Y-92	3.00E+03	1.67E+0	4.06E-09	3.5%	4.06E-9	3.8%	8.10E-5	8.10E-5	3.5%	1.35E-01
	Y-93	1.00E+03	5.00E+0	3.49E-09	3.0%	3.49E-9	3.3%	6.96E-5	6.96E-5	3.0%	3.48E-01
	Zn-65	4.00E+02	1.25E+1	1.00E-10	0.1%	1.00E-10	0.1%	1.99E-6	1.99E-6	0.1%	2.49E-02
	Zr-95	1.00E+03	5.00E+0	7.99E-12	0.0%	7.99E-12	0.0%	1.59E-7	1.59E-7	0.0%	7.97E-04
	Fe-55	9.00E+03	5.56E-1	1.00E-09	0.9%				1.81E-5	0.8%	1.00E-02
	H-3	8.00E+04	6.25E-2	1.00E-08	8.5%				1.81E-4	7.8%	1.13E-02
	Ni-63	9.00E+03	5.56E-1	1.00E-12	0.0%				1.81E-8	0.0%	1.00E-05
				1.17E-7	100%	1.06E-07	100.0%	2.12E-3 **2.12E-3**	2.32E-3	100.0%	**8.24** mrem

The initial HTD value is scaled to the total value of the gammas present. Using those ratios, the new HTD concentrations are determined by multiplying the ratios by the revised sum of the gamma emitters.

Hard-to-Detect Determination

HTD	Conc1 Ci/ml	∑gammas Ci/ml	Ratio	HTD	∑gammas µCi/ml	Conc2 µCi/ml
Fe-55	1.00E-9	1.17E-07	8.53E-3	Fe-55	2.12E-3	1.81E-5
H-3	1.00E-8	1.17E-07	8.53E-2	H-3	2.12E-3	1.81E-4
Ni-63	1.00E-12	1.17E-07	8.53E-6	Ni-63	2.12E-3	1.81E-8

7.2 Organ Dose

The organ dose calculation is similar to the TEDE calculation above in that it uses a spreadsheet to determine the monitor cps reading necessary to reach the EAL threshold. The calculation is also similar in that it uses liquid concentrations and dose conversion factors to determine dose. The first part of the spreadsheet is presented here showing the gross concentration developed from section 6.5.

Child Thyroid: 50.0 mRem

Variables

Monitor:	RHRSW/ESW	RM1997	
Decay Hours	2	ODAM Conversion Factor:	3.785E-03
Monitor CPS:	33,800 cps		
Monitor Efficiency:	1.51E+6 cps / uCi/ml	Exposure Time (Mins.):	60
Dilution Factor:	0.20	Combining Factor:	2.271E-01

Resultant Gamma Concentration for the Given CPS Reading :

$$\frac{33800\ \text{cps}}{} \times \frac{\text{uCi/ml}}{1.51\text{E+06 cps}} \times 0.20 = 4.48\text{E-03 uCi/ml}$$

The dose value seen above is calculated in the spreadsheet on the following pages. As can be seen above, the dilution factor **(0.20)** is included in the efficiency equation to account for the fact that the concentration in the river will be only 20% of the concentration seen by the effluent rad monitor per Assumption 4.3.

The concentrations for the individual isotopes are scaled to the gross concentration determined above. In this case, the value is 4.48E-03 µCi/ml. This value is calculated based on the monitor cps reading entered by the spreadsheet user. Through an iterative process, the user enters the monitor cps necessary to determine the desired resultant total dose (in mrem).

Resultant river concentrations are presented in the section of the spreadsheet seen on the next page.

In this spreadsheet, all of the isotopes present in Appendix C of the ODAM (Design Input 5.4) are included. In many instances, there is no corresponding isotope available from the NUREG-1940 reference. The entire list was included to simplify the spreadsheet calculation.

The decayed mixture is taken from Table 6. Note that the concentration values present in the (starting) mixture do not affect the result. It is the ratios of the isotopes to the gross concentration in the mixture that are needed. These fractions are calculated in the same way as section 7.1. As in section 7.1.2, HTDs present in the mixture (Fe-55, H-3, and Ni-63) are removed from the gross gamma calculation and then scaled back into the calculation of the applied dose (see below for scaling).

The ODAM Appendix C dose transfer factors for the thyroid (Design Input 5.4) are displayed on the second to last column from the right.

Using ODAM calculation methods described in section 6.5, the H-3 dose component of the child thyroid pathway is calculated individually here as an example:

3.82E-04 µCi/mL * 2.97E+01 mrem gal/ Ci min * 3.785E-03 mL Ci/gal µCi * 60 min = 2.58E-03 mrem

Where

3.785E-03 is the conversion factor from the ODAM.

2.97E+01 is the H-3 dose transfer factor for the thyroid (Design Input 5.4).

3.82E-04 is the concentration of H-3 in the river corresponding to the monitor reading developed from Table 6 (see below for scaling).

AND the dispersion term (0.20) is not included here because it has already been included above in the concentration calculation.

Table 9 – Thyroid Dose

ODAM Isotopes	Decayed Mix Ci/gm	Mix Fraction	Mix Gamma Ci/gm	Mix Gamma Fraction	River Gamma µCi/ml	River Water Gamma Fraction	River µCi/ml	Dose Transfer Factor Thyroid (mrem gal)/(Ci min)	Thyroid Dose mrem
H 3	1.00E-08	8.532%		0.000%		0.00%	3.82E-4	2.97E+1	2.58E-3
C 14		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	6.19E+2	0.00E+0
NA 24	1.82E-09	1.556%	1.82E-09	1.717%	7.69E-05	1.72%	7.69E-5	4.91E+2	8.57E-3
P 32	3.99E-11	0.034%	3.99E-11	0.038%	1.68E-06	0.04%	1.68E-6	0.00E+0	0.00E+0
CR 51	2.99E-09	2.554%	2.99E-09	2.819%	1.26E-04	2.82%	1.26E-4	1.23E+0	3.52E-5
MN 54	3.50E-11	0.030%	3.50E-11	0.033%	1.48E-06	0.03%	1.48E-6	0.00E+0	0.00E+0
MN 56	1.46E-08	12.432%	1.46E-08	13.720%	6.14E-04	13.72%	6.14E-4	0.00E+0	0.00E+0
FE 55	1.00E-09	0.853%		0.000%		0.00%	3.82E-5	0.00E+0	0.00E+0
FE 59	3.00E-11	0.026%	3.00E-11	0.028%	1.26E-06	0.03%	1.26E-6	0.00E+0	0.00E+0
CO 58	9.99E-11	0.085%	9.99E-11	0.094%	4.21E-06	0.09%	4.21E-6	0.00E+0	0.00E+0
CO 60	2.00E-10	0.171%	2.00E-10	0.188%	8.43E-06	0.19%	8.43E-6	0.00E+0	0.00E+0
NI 63	1.00E-12	0.001%		0.000%		0.00%	3.82E-8	0.00E+0	0.00E+0
NI 65		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
CU 64	2.69E-09	2.295%	2.69E-09	2.532%	1.13E-04	2.53%	1.13E-4	0.00E+0	0.00E+0
ZN 65	1.00E-10	0.085%	1.00E-10	0.094%	4.21E-06	0.09%	4.21E-6	0.00E+0	0.00E+0
ZN 69		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
BR 83		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
BR 84		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
BR 85		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
RB 86		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
RB 88		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
RB 89	2.15E-11	0.018%	2.15E-11	0.020%	9.06E-07	0.02%	9.06E-7	0.00E+0	0.00E+0
SR 89	9.99E-11	0.085%	9.99E-11	0.094%	4.21E-06	0.09%	4.21E-6	0.00E+0	0.00E+0
SR 90	7.00E-12	0.006%	7.00E-12	0.007%	2.95E-07	0.01%	2.95E-7	0.00E+0	0.00E+0
SR 91	3.46E-09	2.950%	3.46E-09	3.255%	1.46E-04	3.26%	1.46E-4	0.00E+0	0.00E+0
SR 92	6.00E-09	5.117%	6.00E-09	5.647%	2.53E-04	5.65%	2.53E-4	0.00E+0	0.00E+0
Y 90		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
Y 91M		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
Y 91	4.00E-11	0.034%	4.00E-11	0.038%	1.68E-06	0.04%	1.68E-6	0.00E+0	0.00E+0

ODAM Isotopes	Decayed Mix Ci/gm	Mix Fraction	Mix Gamma Ci/gm	Mix Gamma Fraction	River Gamma µCi/ml	River Water Gamma Fraction	River µCi/ml	Dose Trans-fer Factor Thyroid (mrem gal)/(Ci min)	Thyroid Dose mrem
Y 92	4.06E-09	3.465%	4.06E-09	3.824%	1.71E-04	3.82%	1.71E-4	0.00E+0	0.00E+0
Y 93	3.49E-09	2.975%	3.49E-09	3.283%	1.47E-04	3.28%	1.47E-4	0.00E+0	0.00E+0
ZR 95	7.99E-12	0.007%	7.99E-12	0.008%	3.37E-07	0.01%	3.37E-7	0.00E+0	0.00E+0
ZR 97		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
NB 95		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
MO 99	1.96E-09	1.671%	1.96E-09	1.844%	8.26E-05	1.84%	8.26E-5	0.00E+0	0.00E+0
TC 99M		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
TC101		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
RU103	2.00E-11	0.017%	2.00E-11	0.019%	8.42E-07	0.02%	8.42E-7	0.00E+0	0.00E+0
RU105		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
RU106	3.00E-12	0.003%	3.00E-12	0.003%	1.26E-07	0.00%	1.26E-7	0.00E+0	0.00E+0
AG110M	1.00E-12	0.001%	1.00E-12	0.001%	4.21E-08	0.00%	4.21E-8	0.00E+0	0.00E+0
TE125M		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	8.09E+2	0.00E+0
TE127M		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	1.76E+3	0.00E+0
TE127		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	1.41E+1	0.00E+0
TE129M	3.99E-11	0.034%	3.99E-11	0.038%	1.68E-06	0.04%	1.68E-6	3.94E+3	1.51E-3
TE129		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	1.44E-5	0.00E+0
TE131M	9.55E-11	0.081%	9.55E-11	0.090%	4.02E-06	0.09%	4.02E-6	7.52E+2	6.87E-4
TE131		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
TE132	9.82E-12	0.008%	9.82E-12	0.009%	4.14E-07	0.01%	4.14E-7	1.35E+3	1.27E-4
I 130		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	4.32E+4	0.00E+0
I 131	2.18E-09	1.864%	2.18E-09	2.057%	9.21E-05	2.06%	9.21E-5	1.34E+6	2.80E+1
I 132	1.20E-08	10.258%	1.20E-08	11.321%	5.07E-04	11.32%	5.07E-4	1.26E+1	1.45E-3
I 133	1.40E-08	11.973%	1.40E-08	13.213%	5.92E-04	13.21%	5.92E-4	1.56E+5	2.10E+1
I 134	8.83E-09	7.538%	8.83E-09	8.318%	3.72E-04	8.32%	3.72E-4	2.55E-5	2.16E-9
I 135	1.78E-08	15.214%	1.78E-08	16.790%	7.52E-04	16.79%	7.52E-4	5.73E+3	9.78E-1
CS134	3.00E-11	0.026%	3.00E-11	0.028%	1.26E-06	0.03%	1.26E-6	0.00E+0	0.00E+0
CS136	1.99E-11	0.017%	1.99E-11	0.019%	8.39E-07	0.02%	8.39E-7	0.00E+0	0.00E+0
CS137	8.00E-11	0.068%	8.00E-11	0.075%	3.37E-06	0.08%	3.37E-6	0.00E+0	0.00E+0
CS138	7.59E-10	0.647%	7.59E-10	0.714%	3.20E-05	0.71%	3.20E-5	0.00E+0	0.00E+0
BA139		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
BA140	3.98E-10	0.340%	3.98E-10	0.375%	1.68E-05	0.37%	1.68E-5	0.00E+0	0.00E+0
BA141		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
BA142		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
LA140		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
LA142		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
CE141	2.99E-11	0.026%	2.99E-11	0.028%	1.26E-06	0.03%	1.26E-6	0.00E+0	0.00E+0
CE143		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
CE144	3.00E-12	0.003%	3.00E-12	0.003%	1.26E-07	0.00%	1.26E-7	0.00E+0	0.00E+0
PR143		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
PR144		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
ND147		0.000%	0.00E+00	0.000%	0.00E+00	0.00%	0.00E+0	0.00E+0	0.00E+0
W 187	2.83E-10	0.242%	2.83E-10	0.267%	1.19E-05	0.27%	1.19E-5	0.00E+0	0.00E+0
NP239	7.81E-09	6.660%	7.81E-09	7.350%	3.29E-04	7.35%	3.29E-4	0.00E+0	0.00E+0
	1.17E-07	100.0%	1.06E-07	100%	4.48E-03	100.00%	4.90E-3	1.55E+6	5.00E+1
					4.48E-3				

The HTD isotopes displayed in this spreadsheet were scaled into the results as they were in the TEDE spreadsheet.

Hard to Detect Determination						
HTD	Conc1	∑gammas	Ratio	HTD	∑gammas	Conc2
Fe-55	1.00E-9	1.17E-07	8.53E-3	Fe-55	4.48E-3	3.82E-5
H-3	1.00E-8	1.17E-07	8.53E-2	H-3	4.48E-3	3.82E-4
Ni-63	1.00E-12	1.17E-07	8.53E-6	Ni-63	4.48E-3	3.82E-8

Spreadsheet cases are run for all three monitors at decay times of 2 hours and 36 hours in consideration of EAL entry thresholds that are mode dependent.

See Section 2.0 for results.

8.0 Computer Software

No computer software was used in this calculation.

9.0 Impact Assessment

This calculation is based on "realistic" assumptions for the purpose of declaring EALs, rather than typical conservative "bounding" type design basis analyses. The calculation results are intended to provide order of magnitude setpoints to assist Operations and Emergency Response personnel in determining the state of the three fission product barriers in accordance with NEI 99-01 Rev. 6.

Ingestion Dose:	8.24	mrem
+ Boating Dose:	1.79	mrem
Resultant Total mRem:	10.0	mrem

Monitor: GSW RIS4767

Variables

FGR12 Units Conversion Factor:	3.70E+15		FGR12 Boating/Immersion Reduction Factor:	0.50
Monitor c[s:	23,200	cps		
Monitor Efficiency:	2.19E+6	cps / uCi/ml	10CFR20 Ingestion Age Consideration Factor:	2
			Decay Hrs:	2
Volume Consumed:	500	mL	Dilution Factor:	0.20

Resultant River Gamma Concentration for the Given CPS Reading :

23200	~~cps~~		μCi/ml	0.20	=	2.12E-03	μCi/ml
		2.19E+06	~~cps~~				

Child Thyroid: 50.0 **mRem**

Variables

Monitor: GSW RIS4767

Decay Hours 2

ODAM Conversion Factor: 3.785E-03

Monitor CPS: 49,100 cps

Exposure Time (Mins.): 60

Monitor Efficiency: 2.19E+6 cps / uCi/ml

Dilution Factor: 0.20

Combining Factor: 2.271E-01

Resultant Gamma Concentration for the Given CPS Reading :

49100	~~cps~~		uCi/ml	0.20	=	4.48E-03	uCi/ml
		2.19E+06	~~cps~~				

Ingestion Dose:	9.78	mrem
+ Boating Dose:	0.19	mrem
Resultant Total mRem:	10.0	mrem

Monitor: GSW RIS4767

Variables

FGR12 Units Conversion Factor:	3.70E+15		FGR12 Boating/Immersion Reduction Factor:	0.50
Monitor c[s:	10,400	cps		
Monitor Efficiency:	2.19E+6	cps / uCi/ml	10CFR20 Ingestion Age Consideration Factor:	2
			Decay Hrs:	36
Volume Consumed:	500	mL	Dilution Factor:	0.20

Resultant River Gamma Concentration for the Given CPS Reading :

$$\frac{10400\ \text{cps}}{} \times \frac{\mu Ci/ml}{2.19E{+}06\ \text{cps}} \times 0.20 = 9.50E{-}04\ \mu Ci/ml$$

Child Thyroid: 49.9 **mRem**

Variables

Monitor: GSW RIS4767

Decay Hours	**36**	**ODAM Conversion Factor:**	**3.785E-03**
Monitor CPS:	**14,000** cps		
Monitor Efficiency:	**2.19E+6** cps uCi/ml	**Exposure Time (Mins.):**	**60**
Dilution Factor:	**0.20**	**Combining Factor:**	2.271E-01

Resultant Gamma Concentration for the Given CPS Reading :

14000	~~cps~~		uCi/ml	0.20	=	**1.28E-03**	uCi/ml
		2.19E+06	~~cps~~				

Ingestion Dose:	8.24	mrem
+ Boating Dose:	1.79	mrem
Resultant Total mRem:	10.0	mrem

Monitor: RHRSW/ESW RM1997

Variables

FGR12 Units Conversion Factor:	3.70E+15		FGR12 Boating/Immersion Reduction Factor:	0.50
Monitor c[s:	16,000	cps		
Monitor Efficiency:	1.51E+6	cps / uCi/ml	10CFR20 Ingestion Age Consideration Factor:	2
			Decay Hrs:	2
Volume Consumed:	500	mL	Dilution Factor:	0.20

Resultant River Gamma Concentration for the Given CPS Reading :

16000	~~cps~~		μCi/ml	0.20	=	2.12E-03	μCi/ml
		1.51E+06	~~cps~~				

Child Thyroid: 50.0 **mRem**

Variables

Monitor: RHRSW/ESW RM1997

Decay Hours 2

ODAM Conversion Factor: 3.785E-03

Monitor CPS: 33,800 cps

Exposure Time (Mins.): 60

Monitor Efficiency: 1.51E+6 cps / uCi/ml

Dilution Factor: 0.20

Combining Factor: 2.271E-01

Resultant Gamma Concentration for the Given CPS Reading :

33800	~~cps~~		uCi/ml	0.20	=	4.48E-03	uCi/ml
		1.51E+06	~~cps~~				

Ingestion Dose:	9.82	mrem
+ Boating Dose:	0.19	mrem
Resultant Total mRem:	10.0	mrem

Monitor: RHRSW/ESW RM1997

Variables

FGR12 Units Conversion Factor:	3.70E+15		FGR12 Boating/Immersion Reduction Factor:	0.50
Monitor c[s:	7,200	cps		
Monitor Efficiency:	1.51E+6	cps / uCi/ml	10CFR20 Ingestion Age Consideration Factor:	2
			Decay Hrs:	36
Volume Consumed:	500	mL	Dilution Factor:	0.20

Resultant River Gamma Concentration for the Given CPS Reading :

7200	~~cps~~		µCi/ml	0.20	=	9.54E-04	µCi/ml
		1.51E+06	~~cps~~				

Child Thyroid: 49.9 **mRem**

Variables

Monitor: **RHRSW/ESW** **RM1997**

Decay Hours	**36**	**ODAM Conversion Factor:**	**3.785E-03**
Monitor CPS:	**9,650** cps		
Monitor Efficiency:	**1.51E+6** cps / uCi/ml	**Exposure Time (Mins.):**	**60**
Dilution Factor:	**0.20**	**Combining Factor:**	2.271E-01

Resultant Gamma Concentration for the Given CPS Reading :

9650	~~cps~~		uCi/ml	0.20	=	**1.28E-03**	uCi/ml
		1.51E+06	~~cps~~				

Ingestion Dose:	8.22	mrem
+ Boating Dose:	1.79	mrem
Resultant Total mRem:	**10.0**	**mrem**

Monitor: RHRSW Dilution Line RM4268

Variables

FGR12 Units Conversion Factor:	3.70E+15		**FGR12 Boating/Immersion Reduction Factor:**	0.50
Monitor c[s:	24,200	cps		
Monitor Efficiency:	2.29E+6	cps / uCi/ml	**10CFR20 Ingestion Age Consideration Factor:**	2
			Decay Hrs:	2
Volume Consumed:	500	mL	**Dilution Factor:**	0.20

Resultant River Gamma Concentration for the Given CPS Reading :

$$\frac{24200\ \text{cps}}{} \times \frac{\mu\text{Ci/ml}}{2.29\text{E+06 cps}} \times 0.20 = 2.11\text{E-03}\ \mu\text{Ci/ml}$$

Child Thyroid: 50.0 **mRem**

Monitor: RHRSW Dilution Line RM4268

Variables

Decay Hours 2

ODAM Conversion Factor: 3.785E-03

Monitor CPS: 51,300 cps

Exposure Time (Mins.): 60

Monitor Efficiency: 2.29E+6 cps / uCi/ml

Dilution Factor: 0.20

Combining Factor: 2.271E-01

Resultant Gamma Concentration for the Given CPS Reading :

51300	~~cps~~		uCi/ml	0.20	=	**4.48E-03**	uCi/ml
		2.29E+06	~~cps~~				

Ingestion Dose:	9.80	mrem
+ Boating Dose:	0.19	mrem
Resultant Total mRem:	10.0	mrem

Monitor: RHRSW Dilution Line RM4268

Variables

FGR12 Units Conversion Factor:	3.70E+15		FGR12 Boating/Immersion Reduction Factor:	0.50
Monitor c[s:	10,900	cps		
Monitor Efficiency:	2.29E+6	cps / uCi/ml	10CFR20 Ingestion Age Consideration Factor:	2
			Decay Hrs:	36
Volume Consumed:	500	mL	Dilution Factor:	0.20

Resultant River Gamma Concentration for the Given CPS Reading :

10900	~~cps~~		μCi/ml	0.20	=	9.52E-04	μCi/ml
		2.29E+06	~~cps~~				

Child Thyroid: 49.9 **mRem**

Monitor: RHRSW Dilution Line RM4268

Variables

Decay Hours	**36**	**ODAM Conversion Factor:**	**3.785E-03**
Monitor CPS:	**14,650** cps		
Monitor Efficiency:	**2.29E+6** cps uCi/ml	**Exposure Time (Mins.):**	**60**
Dilution Factor:	**0.20**	**Combining Factor:**	2.271E-01

Resultant Gamma Concentration for the Given CPS Reading :

14650	~~cps~~		uCi/ml	0.20	=	1.28E-03	uCi/ml
		2.29E+06	~~cps~~				

CHECKLIST ITEMS[1]	YES	NO	N/A
GENERAL REQUIREMENTS			
1. If the calculation is being performed to a client procedure, is the procedure being used the latest revision?	☐	☐	☒
The calculation is being prepared to ENERCON's procedures.			
2. Are the proper forms being used and are they the latest revision?	☒	☐	☐
3. Have the appropriate client review forms/checklists been completed?	☐	☐	☒
The calculation is being prepared to ENERCON's procedures.			
4. Are all pages properly identified with a calculation number, calculation revision and page number consistent with the requirements of the client's procedure?	☒	☐	☐
5. Is all information legible and reproducible?	☒	☐	☐
6. Is the calculation presented in a logical and orderly manner?	☒	☐	☐
7. Is there an existing calculation that should be revised or voided?	☐	☒	☐
This is a new calculation to support implementing NEI 99-01 Rev. 6			
8. Is it possible to alter an existing calculation instead of preparing a new calculation for this situation?	☐	☒	☐
9. If an existing calculation is being used for design inputs, are the key design inputs, assumptions and engineering judgments used in that calculation valid and do they apply to the calculation revision being performed.	☐	☐	☒
10. Is the format of the calculation consistent with applicable procedures and expectations?	☒	☐	☐
11. Were design input/output documents properly updated to reference this calculation?	☐	☐	☒
12. Can the calculation logic, methodology and presentation be properly understood without referring back to the originator for clarification?	☒	☐	☐
OBJECTIVE AND SCOPE			
13. Does the calculation provide a clear concise statement of the problem and objective of the calculation?	☒	☐	☐
14. Does the calculation provide a clear statement of quality classification?	☒	☐	☐
15. Is the reason for performing and the end use of the calculation understood?	☒	☐	☐
16. Does the calculation provide the basis for information found in the plant's license basis?	☐	☒	☐
17. If so, is this documented in the calculation?	☐	☐	☒
18. Does the calculation provide the basis for information found in the plant's design basis documentation?	☐	☒	☐

CHECKLIST ITEMS[1]		YES	NO	N/A
19.	If so, is this documented in the calculation?	☐	☐	☒
20.	Does the calculation otherwise support information found in the plant's design basis documentation?	☐	☒	☐
21.	If so, is this documented in the calculation?	☐	☐	☒
22.	Has the appropriate design or license basis documentation been revised, or has the change notice or change request documents being prepared for submittal?	☐	☐	☒
DESIGN INPUTS				
23.	Are design inputs clearly identified?	☒	☐	☐
24.	Are design inputs retrievable or have they been added as attachments?	☒	☐	☐
25.	If Attachments are used as design inputs or assumptions are the Attachments traceable and verifiable?	☒	☐	☐
26.	Are design inputs clearly distinguished from assumptions?	☒	☐	☐
27.	Does the calculation rely on Attachments for design inputs or assumptions? If yes, are the attachments properly referenced in the calculation?	☒	☐	☐
28.	Are input sources (including industry codes and standards) appropriately selected and are they consistent with the quality classification and objective of the calculation?	☒	☐	☐
29.	Are input sources (including industry codes and standards) consistent with the plant's design and license basis?	☒	☐	☐
30.	If applicable, do design inputs adequately address actual plant conditions?	☒	☐	☐
31.	Are input values reasonable and correctly applied?	☒	☐	☐
32.	Are design input sources approved?	☒	☐	☐
33.	Does the calculation reference the latest revision of the design input source?	☒	☐	☐
34.	Were all applicable plant operating modes considered?	☒	☐	☐
ASSUMPTIONS				
35.	Are assumptions reasonable/appropriate to the objective?	☒	☐	☐
36.	Is adequate justification/basis for all assumptions provided?	☒	☐	☐
37.	Are any engineering judgments used?	☐	☒	☐
38.	Are engineering judgments clearly identified as such?	☐	☐	☒
39.	If engineering judgments are utilized as design inputs, are they reasonable and can they be quantified or substantiated by reference to site or industry standards, engineering principles, physical laws or other appropriate criteria?	☐	☐	☒

CHECKLIST ITEMS[1]		YES	NO	N/A
METHODOLOGY				
40.	Is the methodology used in the calculation described or implied in the plant's licensing basis?	☐	☒	☐
41.	If the methodology used differs from that described in the plant's licensing basis, has the appropriate license document change notice been initiated?	☐	☐	☒
42.	Is the methodology used consistent with the stated objective?	☒	☐	☐
43.	Is the methodology used appropriate when considering the quality classification of the calculation and intended use of the results?	☒	☐	☐
BODY OF CALCULATION				
44.	Are equations used in the calculation consistent with recognized engineering practice and the plant's design and license basis?	☒	☐	☐
45.	Is there reasonable justification provided for the use of equations not in common use?	☐	☐	☒
46.	Are the mathematical operations performed properly and documented in a logical fashion?	☒	☐	☐
47.	Is the math performed correctly?	☒	☐	☐
48.	Have adjustment factors, uncertainties and empirical correlations used in the analysis been correctly applied?	☒	☐	☐
49.	Has proper consideration been given to results that may be overly sensitive to very small changes in input?	☒	☐	☐
SOFTWARE/COMPUTER CODES				
50.	Are computer codes or software languages used in the preparation of the calculation?	☐	☒	☐
51.	Have the requirements of CSP 3.09 for use of computer codes or software languages, including verification of accuracy and applicability been met?	☐	☐	☒
52.	Are the codes properly identified along with source vendor, organization, and revision level?	☐	☐	☒
53.	Is the computer code applicable for the analysis being performed?	☐	☐	☒
54.	If applicable, does the computer model adequately consider actual plant conditions?	☐	☐	☒
55.	Are the inputs to the computer code clearly identified and consistent with the inputs and assumptions documented in the calculation?	☐	☐	☒
56.	Is the computer output clearly identified?	☐	☐	☒
57.	Does the computer output clearly identify the appropriate units?	☐	☐	☒

CHECKLIST ITEMS[1]	YES	NO	N/A
58. Are the computer outputs reasonable when compared to the inputs and what was expected?	☐	☐	☒
59. Was the computer output reviewed for ERROR or WARNING messages that could invalidate the results?	☐	☐	☒
RESULTS AND CONCLUSIONS			
60. Is adequate acceptance criteria specified?	☒	☐	☐
61. Are the stated acceptance criteria consistent with the purpose of the calculation, and intended use?	☒	☐	☐
62. Are the stated acceptance criteria consistent with the plant's design basis, applicable licensing commitments and industry codes, and standards?	☒	☐	☐
63. Do the calculation results and conclusions meet the stated acceptance criteria?	☒	☐	☐
64. Are the results represented in the proper units with an appropriate tolerance, if applicable?	☒	☐	☐
65. Are the calculation results and conclusions reasonable when considered against the stated inputs and objectives?	☒	☐	☐
66. Is sufficient conservatism applied to the outputs and conclusions?	☒	☐	☐
67. Do the calculation results and conclusions affect any other calculations?	☐	☒	☐
68. If so, have the affected calculations been revised?	☐	☐	☒
69. Does the calculation contain any conceptual, unconfirmed or open assumptions requiring later confirmation?	☐	☒	☐
70. If so, are they properly identified?	☐	☐	☒
DESIGN REVIEW			
71. Have alternate calculation methods been used to verify calculation results?	☐	☐	☒
No, a Design Review was performed.			

Note:

1. Where required, provide clarification/justification for answers to the questions in the space provided below each question. An explanation is required for any questions answered as "No' or "N/A".

Originator: Jay Bhatt — 12/12/17

Print Name and Sign — Date

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ATTACHMENT 1

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LIQUID EFFLUENT RADIOACTIVITY MONITOR SETPOINT

1. Sample No. 15 - 7198 ✓ 2. Sample Date & Time 12-1-15 / 11:03 ✓
3. Stream/Monitor Description GSW rad monitor RM-4767 ✓
4. Effluent Monitor Reading (cps) 10 ✓
5. Effluent Flow (gpm) 9600 gpm ✓
6. Average effluent flow during time represented by sample, F_1 (gpm) NR ✓
7. Average dilution (discharge canal) flow during time represented by sample, F_2 (gpm) NR ✓
8. Monitor calibration factor, g, (cps/µCi/mL) ~~[illegible]~~ 2.19 e6 ✓
9. Previous alarm value setpoint (cps) 765 cps ✓
10. Fraction to apply as a safety margin, A = 0.5

$$\textbf{Setpoint} = 10 \times \left[\frac{\Sigma_i K_i}{\Sigma_i (K_i \div WEC_i)} \times g \times \frac{F_2}{F_1} \times A \right] + Bkg \quad = \quad \text{Setpoint} = 10 \times \left[\frac{(15)(8)(7)}{(16)(6)} \times (10) \right] + (4)$$

$$\text{Setpoint} = 5 \times \left[\frac{(15)(8)(7)}{(16)(6)} \right] + (4)$$

$$\text{Setpoint} = 5 \times \left[\frac{(9.43e^{-3})(2.19e^{6})(NR)}{(177.54)(NR)} \right] + (10)$$

11. Setpoint = 592 ✓

Fractional Change = $\frac{\text{New value - Previous Value}}{\text{Previous Value}} = \frac{(11) - (9)}{(9)} = \frac{(592) - (765)}{(765)}$

12. Fractional Change = -.226 ✓

If fractional change is greater than ±0.3, adopt a new monitor alarm setting.

Continuous Monitor Hi Alarm = Setpoint

13. Monitor Hi Alarm = 765 cps ✓

14. Radwaste Monitor Hi Alarm = .16 (11) = .16 ( ) = N/A cps ✓

w/o 40328724

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ATTACHMENT 1

LIQUID EFFLUENT RADIOACTIVITY MONITOR SETPOINT

1. Sample No. 15-4896 2. Sample Date & Time 8-29-15 / 0027
3. Stream/Monitor Description RM-1997 (RHRSW/ESW)
4. Effluent Monitor Reading (cps) 30
5. Effluent Flow (gpm) 4800
6. Average effluent flow during time represented by sample, F_1 (gpm) N/A
7. Average dilution (discharge canal) flow during time represented by sample, F_2 (gpm) N/A
8. Monitor calibration factor, g, (cps/µCi/mL) 1.51e6 (margin: 1 / .62e-7)
9. Previous alarm value setpoint (cps) 614
10. Fraction to apply as a safety margin, A = 0.5

$$\textbf{Setpoint} = 10\times\left[\frac{\Sigma_i K_i}{\Sigma_i (K_i \div WEC_i)} \times g \times \frac{F_2}{F_1} \times A\right] + Bkg \quad = \quad \text{Setpoint}=10\times\left[\frac{(15)(8)(7)}{(16)(6)}\times(10)\right]+(4)$$

$$\text{Setpoint} = 5\times\left[\frac{(15)(8)(7)}{(16)(6)}\right]+(4)$$

$$\text{Setpoint} = 5\times\left[\frac{(\ 1.10e^{-2}\ \text{(corrected from 1.01e-2)})(\ 1.51e^{6}\ )(\ N/A\ )}{(\ 153.84\ \text{(corrected from 108.07)}\ )(\ N/A\ )}\right] + (\ 30\ )$$

11. Setpoint = ~~735.6~~ 569.85

Fractional Change = New value - Previous Value / Previous Value = (11) - (9) / (9) = (~~235.6~~ 569.9 8-29-15) - (614) / (614)

12. Fractional Change = ~~0.20~~ -0.07

If fractional change is greater than ±0.3, adopt a new monitor alarm setting.

Continuous Monitor Hi Alarm = Setpoint

13. Monitor Hi Alarm = 614

14. Radwaste Monitor Hi Alarm = .16 (11) = .16 ( ) = N/A cps

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ATTACHMENT 1

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LIQUID EFFLUENT RADIOACTIVITY MONITOR SETPOINT

1. Sample No. 14-884 2. Sample Date & Time 2-14-14 / 0021
3. Stream/Monitor Description RHRSW/ESW RUPTURE: RM 4268
4. Effluent Monitor Reading (cps) 20
5. Effluent Flow (gpm) RHRSW 'A' = 4800gpm, RHRSW 'B' - 4800gpm
6. Average effluent flow during time represented by sample, F_1 (gpm) N/A
7. Average dilution (discharge canal) flow during time represented by sample, F_2 (gpm) N/A
8. Monitor calibration factor, g, (cps/µCi/mL) 2.29E6 ✓
9. Previous alarm value setpoint (cps) 863 ✓
10. Fraction to apply as a safety margin, A = 0.5

Setpoint $= 10 \times \left[\frac{\Sigma_i K_i}{\Sigma_i (K_i \div WEC_i)} \times g \times \frac{F_2}{F_1} \times A \right] + Bkg$ = Setpoint$=10\times\left[\frac{(15)(8)(7)}{(16)(6)}\times(10)\right]+(4)$

Setpoint = $5\times\left[\frac{(15)(8)(7)}{(16)(6)}\right]+(4)$

Setpoint = $5\times\left[\frac{(7.67E\text{-}3)(2.29E^6)(N/A)}{(111.86)(N/A)}\right]+(20)$

11. Setpoint = 805 ✓

Fractional Change = $\frac{\text{New value - Previous Value}}{\text{Previous Value}} = \frac{(11) - (9)}{(9)} = \frac{(805) - (863)}{(863)}$

12. Fractional Change = -0.07 ✓

If fractional change is greater than ±0.3, adopt a new monitor alarm setting.

Continuous Monitor Hi Alarm = Setpoint ⇒ OLD SETPOINT ✓

13. Monitor Hi Alarm = 863 ✓

14. Radwaste Monitor Hi Alarm = .16 (11) = .16 (N/A) = N/A cps