ZIONSOLUTIONS LLC
An EnergySolutions Company

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U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Zion Nuclear Power Station, Units 1, 2 and ISFSI
Facility Operating License Nos. DPR-39 and DPR-48
NRC Docket Nos. 50-295, 50-304 and 72-1037

Subject: Radioactive Effluent Release Report, Radioactive Effluent Control Program Report, Offsite Dose Calculation Manual and Process Control Program for 2015

In accordance with Facility Operation License Nos. DPR-39 and DPR-48, Quality Assurance Project Plan Appendix B Section 5.7.3, "Radioactive Effluent Release Report," for Zion Nuclear Power Station, Units 1 and 2, this is the submittal of a Radioactive Effluent Release Report for the year 2015. The report is required to be submitted prior to May 1, 2016 and is provided as Attachments 1 through 6 to this letter. Certificate of Compliance No. 1031 for the MAGNASTOR SYSTEM, Appendix A, Technical Specifications 5.1.1 and 5.1.3 require submittal of an Annual Radioactive Effluent Control Program report which is included in this document.

Pursuant to 10 CFR 50.4 and Offsite Dose Calculation Manual (ODCM) 12.7.4, there were changes made to the Zion Station Liquid Effluent Treatment System during the period of January through December 2015. The changes to the Liquid Effluent Treatment System are summarized in Attachment 1, Section 7, for the calendar year of 2015. There were surveillances conducted for an inoperable plant monitoring system that exceeded the time listed in ODCM Section 12.2.2. ODCM Section 12.7.2 requires an explanation as to why the inoperability requirements of the monitoring system was not corrected in the time specified. Attachment 1, Section 8, provides this explanation and a summary of the results of the station review conducted to restore the plant monitoring system to operable status.

There were changes made to the ODCM including a complete re-write of the ODCM for post fuel transfer operations in 2015. Per ODCM 12.7.3.1c, a summary of changes made during each revision and a complete copy of the current ODCM is submitted in Attachment 6. There were no changes to the Process Control Program during 2015.

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There are no new regulatory commitments in this submittal.

If you have any questions about this submittal please contact Mr. Christopher Keene at (224)789-4073.

Respectfully,

Gerard van Noordennen

Gerard van Noordennen
Vice President of Regulatory Affairs

Attachments:

1. Radioactive Effluent Release Report
2. ECN# 400577 Extending liquid effluent discharge line through the discharge tunnel
3. ECN# 400657 Installing additional liquid effluent discharge flowmeters
4. ECN# 400986 Increased capacity dilution water pump of 10,000 gpm and associated flowmeters
5. ECN# 2015-04 Installation of new liquid effluent radiation monitor for 0RT-PR04 and dilution flow permissive for lake discharge valve 0SOV-WD010
6. Current Copy of Zion Station ODCM, Rev. 5

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Service List (Cover letter only, no attachments)

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ATTACHMENT 1

Radioactive Effluent Release Report

List of Sections

Section #	Description
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	2.1 Unit 1 Gaseous Effluent
	2.2 Unit 2 Gaseous Effluent
	2.3 Liquid Effluent
	2.4 Direct Radiation
	2.5 LLD's
	2.6 Error Estimation
3	Solid Waste and Irradiated Fuel Shipments
4	Radiological Impact on Man, 40CFR190 & 10CFR72 Compliance summary
	4.1 Unit 1
	4.2 Unit 2
	4.3 ISFSI
	4.4 Combined 40CFR190 report
5	Meteorology Data
6	Errata Data from previous years
7	Summary of Liquid Radwaste System Changes
8	Corrective Actions for Inoperable Rad Monitor
9	Changes to the ODCM

Section 1: Supplemental Information

1. Regulatory Limits: The dose to a member of the public from direct radiation, liquid and gaseous effluents released from each unit to areas at or beyond site boundary shall be limited to the following:

    a. Fission and Activation products:
        i. Tech Spec Whole Body: 500 mrem/year
        ii. Tech Spec Skin: 3000 mrem/year
    b. Particulates with half-lives > 8 days, tritium and Iodine:
        i. Tech Spec Organ: 1500 mrem/year
        ii. 10CFR50 Organ: 7.5 mrem/quarter, 15 mrem/year
    c. Liquid Effluents:
        i. 10CFR50 Whole body: 1.5 mrem/quarter, 3 mrem/year
        ii. 10CFR50 Organ: 5 mrem/quarter, 10 mrem/year
    d. Combined dose to real individual beyond controlled area:
        i. 10CFR72 Whole body: 25 mrem/year
        ii. 10CFR72 Thyroid: 75 mrem/year
        iii. 10CFR72 Organ: 25 mrem/year

2. Effluent Concentration Limits (ECL): Limits used in determining allowable release rates or concentrations.

    a. Gaseous Effluents: 10CFR20 Appendix B Table 2 Column 1.
    b. Liquid Effluents: 10 X 10CFR20 Appendix B Table 2 Column 2.

3. Measurements and Approximations of Total Radioactivity.

    a. Fission and Activation Products: 100% Kr-85 is assumed in calculations since other isotopes have decayed. Vent stack activity is continuously monitored for fission and activation gases. In January of 2015 all fuel was removed from the Fuel Handling Building and Transferred to the ISFSI. After the last fuel assembly was transferred, noble gases are no longer present as potential gaseous effluents.
    b. Particulate and tritium releases are continuously monitored and samples collected and analyzed weekly. Particulate filters are sent to an independent lab for quarterly composite analysis. During periods when 1RIA-PR49 and 2RIA-PR49 were Out of Service for maintenance, particulate activity was continuously monitored. The air samples were analyzed daily while decommissioning activities were in progress in each of the areas feeding into the respective Units vent stack (i.e. Unit 1 purge system for Unit 1 vent stack and Unit 2 purge system, Aux. building, Fuel Handling Building for Unit 2 vent stack). A separate composite was sent to an independent lab for composite analysis for each area monitored. Tritium activity in gaseous releases in Unit 2 vent stack were monitored during the weekly sampling. Due to pumping down the reactor cavities and spent fuel pool, the remainder of the Tritium present was monitored and calculated in liquid effluent releases instead of estimating the release via evaporation. For the purpose of freeze protection of the liquid effluent release line, an air compressor was used to blow air through the line. The air compressor drew air from a room in the Auxiliary Building thus this pathway was added to gaseous release calculations.. The air in the room from which the air compressor

drew its suction was continuously monitored and the samples analyzed daily. Any activity detected in this air sample was added to continuous abnormal gaseous releases and the samples sent for quarterly composite analysis per ODCM requirements.

c. Liquid effluents are continuously monitored and isotopic analysis performed weekly. Liquid batch releases are mixed and a representative sample taken and analyzed prior to batch release. A complete analysis of all liquid volumes was performed by an offsite laboratory to determine hard to detect nuclide activity. A conservative ratio to Co-60 was calculated for each hard to detect nuclide. Prior to each batch release, these scaling factors were used to calculate the concentration of these hard to detect nuclides. During 2015, all potential radioactive inputs were removed from the turbine building fire sump, and the 0R-PR25 fire sump monitor was removed as it was no longer required. To facilitate turbine building demolition, the fire sump compositor was moved to the Waste Water Treatment Facility (WWTF) which receives input from the remaining turbine building drains. Weekly samples and quarterly composites are analyzed on the WWTF compositor to verify there are no radioactive isotopes in the water discharged via the WWTF.
d. Occupancy factors were used in determining direct radiation dose to the maximally exposed member of the public based on habits of a real individual in ES&H Technical Support Document 13-009 "Member of the Public Dose from All Onsite Sources."

4. Batch Releases:
    a. Liquid:
        1. There were 67 liquid batch releases in 2015
        2. Total time period for batch releases: 2.32E+05 min.
        3. Maximum time period for a batch release: 1.13E+04 min.
        4. Average time period for batch release: 3.46E+03 min.
        5. Minimum time period for a batch release: 6.12E+02 min.
    b. Gaseous: There were no gaseous batch releases in 2015.

5. Abnormal Releases:
    a. Liquid: There were no abnormal liquid releases in 2015.
    b. Gaseous: Auxiliary Building Air Compressor freeze protection discharged a total of 3.05E+10 ccs. of air from 12/22/2015 to 1/1/2016.

6. Gaseous and Liquid Waste Treatment Systems and Process Control Program

    Zion Station ODCM Section 12.6.4 requires major changes to the Gaseous and Liquid Waste Treatment Systems to be reported in the Annual Radioactive Effluent Release Report. There were some changes to the Liquid Waste Treatment System, these changes and their technical bases are described in Section 7.

    Zion Station ODCM Section 12.7.2 requires major changes to the Process Control Program(PCP) to be submitted in the Annual Radioactive Effluent Release Report.

The Waste Gas Hold-up System was permanently vented. In Zion's defueled configuration this system is no longer applicable.

In Zion's defueled configuration, the charcoal iodine removal system is no longer applicable.

Due to radioactive decay and no means of production, radioactive iodine is not a concern at Zion.

7. Limiting Conditions of Operation (LCOs)

   Zion Station ODCM Section 12.7.2 requires explanation as to why the inoperability of liquid or gaseous monitoring instrumentation was not corrected within the time specified in the ODCM to be submitted with the Annual Radioactive Effluent Release Report.

   0R-PR04 Lake Release Tank liquid effluent radiation monitor was Out of Service for a period greater than 14 days. A detailed discussion of the reasons and resolution to this issue is described in Section 8.

8. Liquid Holdup Tanks and Gas Storage Tanks

   Zion Station ODCM Section 12.7.2 requires a description of events leading to liquid holdup tanks or gas storage tanks exceeding technical specification limits to be included in the Annual Radioactive Effluent Release Report.

   The contents of the six gas decay tanks have been sampled and determined to have negligible activity. The Gas Decay Tanks have been decommissioned.

   No liquid holdup tanks exceeded the limits of Permanently Defueled Technical Specifications 5.6.3 during 2015.

9. Offsite Dose Calculation Manual (ODCM)

   Changes to the ODCM and Process Control Program are required by Zion Station Permanently Defueled Technical Specification 5.6.1. and ODCM Section 12.6.3 to be submitted as part of, or concurrent with, the Annual Radioactive Effluent Release Report.

   a. ODCM Revisions: There was a major re-write to the ODCM for the purpose of the change in licensing to Post Fuel Transfer operations. The ODCM chapters were consolidated into a single document and the revision number was reset to revision 0. A list of changes made during 2015 are listed in Section 9.
   b. Process Control Program(PCP): There were no changes to the PCP in 2015.

10. Switchyard Area

The switchyard is an onsite area that is monitored for direct radiation dose. Access to the site is controlled by Commonwealth Edison and is not accessible to members of the general public. The dose limits for this area are regulated differently than the general offsite dose areas and comply with 10CFR20 annual dose limit of 100 mrem/year. ES&H TSD 13-009 lists the evaluation performed to determine habits of the real individual working in the switchyard and are calculated to be occupied no more than 2088 hours/year.

Section 2.1 – Unit 1 Gaseous Releases

GASEOUS EFFLUENTS - SUMMATION OF ALL RELEASES
Unit 1 Vent Stack - GROUND RELEASES

REPORT FOR 2015	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Gases						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	uCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Iodine-131						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	uCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Particulates Half Life >= 8 days						
1. Total Release	Ci	0.00E+00	2.57E-06	9.04E-04	3.43E-05	9.41E-04
2. Avg. Release Rate	uCi/sec	0.00E+00	3.27E-07	1.15E-04	4.36E-06	2.99E-05
Tritium						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	uCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	uCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD

GASEOUS EFFLUENTS - GROUND RELEASES - CONTINUOUS MODE

REPORT FOR 2015	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Gases		<LLD	<LLD	<LLD	<LLD	<LLD
Iodines		<LLD	<LLD	<LLD	<LLD	<LLD

Particulates Half Life >= 8 days						
CO-60	Ci	<LLD	0.00E+00	7.46E-04	2.62E-05	7.72E-04
CS-137	Ci	<LLD	2.57E-06	1.58E-04	8.12E-06	1.69E-04
Totals for Period...	Ci	<LLD	2.57E-06	9.04E-04	3.43E-05	9.41E-04
Tritium		<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity		<LLD	<LLD	<LLD	<LLD	<LLD

GASEOUS EFFLUENTS - GROUND RELEASES - BATCH MODE

REPORT FOR 2015	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR

No Batch Releases.

LLD values are listed in Section 2.5
Total Error values are listed in Section 2.6

Section 2.2 – Unit 2 Gaseous Releases

GASEOUS EFFLUENTS - SUMMATION OF ALL RELEASES
Unit 2 Vent Stack – GROUND RELEASES

REPORT FOR 2015	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Gases						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	uCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Iodine-131						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	uCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Particulates Half Life >= 8 days						
1. Total Release	Ci	4.99E-06	2.72E-06	1.40E-05	3.40E-06	2.51E-05
2. Avg. Release Rate	uCi/sec	6.34E-07	3.46E-07	1.78E-06	4.32E-07	7.97E-07
Tritium						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	uCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	uCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD

GASEOUS EFFLUENTS - GROUND RELEASES - CONTINUOUS MODE

REPORT FOR 2015	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Gases		<LLD	<LLD	<LLD	<LLD	<LLD
Iodines		<LLD	<LLD	<LLD	<LLD	<LLD

Particulates Half Life >= 8 days						
CO-60	Ci	3.28E-07	2.72E-06	7.89E-06	0.00E+00	1.09E-05
CS-137	Ci	4.66E-06	0.00E+00	6.07E-06	3.40E-06	1.41E-05
Totals for Period...	Ci	4.99E-06	2.72E-06	1.40E-05	3.40E-06	2.51E-05
Tritium		<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity		<LLD	<LLD	<LLD	<LLD	<LLD

GASEOUS EFFLUENTS - GROUND RELEASES - BATCH MODE

REPORT FOR 2015	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR

No Batch Releases.

LLD values are listed in Section 2.5
Total Error values are listed in Section 2.6

Section 2.3 – Liquid Effluent Releases

LIQUID EFFLUENTS - SUMMATION OF ALL RELEASES (Unit 1 & Unit 2 combined)

REPORT FOR 2015	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Products						
AG-108M	Ci	0.00E+00	0.00E+00	1.04E-05	2.51E-06	1.29E-05
C-14	Ci	4.41E-06	3.85E-04	3.50E-04	1.86E-04	9.25E-04
CO-60	Ci	1.00E-05	8.09E-04	7.82E-04	4.15E-04	2.02E-03
CS-137	Ci	0.00E+00	1.28E-05	9.54E-06	1.30E-05	3.54E-05
FE-55	Ci	1.57E-06	1.13E-04	1.08E-04	5.73E-05	2.79E-04
NI-59	Ci	3.01E-06	2.11E-04	1.06E-04	5.65E-05	3.77E-04
NI-63	Ci	1.31E-04	1.08E-02	8.83E-03	4.69E-03	2.45E-02
PU-241	Ci	1.03E-07	9.00E-06	8.75E-06	4.65E-06	2.25E-05
SR-90	Ci	1.69E-06	9.47E-05	4.31E-06	2.29E-06	1.03E-04
Totals for Period...	Ci	1.52E-04	1.24E-02	1.02E-02	5.43E-03	2.82E-02
Tritium						
H-3	Ci	6.64E-03	2.57E-01	2.57E-01	5.43E-01	1.06E+00
Totals for Period...	Ci	6.64E-03	2.57E-01	2.57E-01	5.43E-01	1.06E+00
Dissolved and Entrained Gases						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity						
ALPHA	Ci	0.00E+00	7.22E-06	4.90E-06	6.55E-06	1.87E-05
Totals for Period...	Ci	0.00E+00	7.22E-06	4.90E-06	6.55E-06	1.87E-05
Volume of liquid waste	liters	1.27E+06	1.82E+06	2.23E+06	1.01E+07	1.54E+07
Volume of dil. water	liters	1.23E+09	1.24E+09	2.48E+09	5.01E+09	9.96E+09

LLD values are listed in Section 2.5
Total Error values are listed in Section 2.6

Section 2.3 – Liquid Effluent Releases (cont.)

LIQUID EFFLUENTS - CONTINUOUS MODE (Unit 1 & Unit 2 combined)

REPORT FOR 2015	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Products		<LLD	<LLD	<LLD	<LLD	<LLD
Tritium		<LLD	<LLD	<LLD	<LLD	<LLD
Dissolved and Entrained Gases		<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity		<LLD	<LLD	<LLD	<LLD	<LLD

LLD values are listed in Section 2.5
Total Error values are listed in Section 2.6

Section 2.3 – Liquid Effluent Releases (cont.)

LIQUID EFFLUENTS - BATCH MODE (Unit 1 & Unit 2 combined)

REPORT FOR 2015	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Products						
AG-108M	Ci	0.00E+00	0.00E+00	1.04E-05	2.51E-06	1.29E-05
C-14	Ci	4.41E-06	3.85E-04	3.50E-04	1.86E-04	9.25E-04
CO-60	Ci	1.00E-05	8.09E-04	7.82E-04	4.15E-04	2.02E-03
CS-137	Ci	0.00E+00	1.28E-05	9.54E-06	1.30E-05	3.54E-05
FE-55	Ci	1.57E-06	1.13E-04	1.08E-04	5.73E-05	2.79E-04
NI-59	Ci	3.01E-06	2.11E-04	1.06E-04	5.65E-05	3.77E-04
NI-63	Ci	1.31E-04	1.08E-02	8.83E-03	4.69E-03	2.45E-02
PU-241	Ci	1.03E-07	9.00E-06	8.75E-06	4.65E-06	2.25E-05
SR-90	Ci	1.69E-06	9.47E-05	4.31E-06	2.29E-06	1.03E-04
Totals for Period...	Ci	1.52E-04	1.24E-02	1.02E-02	5.43E-03	2.82E-02
Tritium						
H-3	Ci	6.64E-03	2.57E-01	2.57E-01	5.43E-01	1.06E+00
Totals for Period...	Ci	6.64E-03	2.57E-01	2.57E-01	5.43E-01	1.06E+00
Dissolved and Entrained Gases		N/A	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity						
ALPHA	Ci	0.00E+00	7.22E-06	4.90E-06	6.55E-06	1.87E-05
Totals for Period...	Ci	0.00E+00	7.22E-06	4.90E-06	6.55E-06	1.87E-05

LLD values are listed in Section 2.5
Total Error values are listed in Section 2.6

Section 2.3 – Liquid Effluent Releases (cont.)

SUPPLEMENTAL INFORMATION
LIQUID EFFLUENTS - BATCH MODE

REPORT FOR 2015	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Number of releases		1	16	17	33	67
Total release time	minutes	2.57E+03	7.87E+04	4.93E+04	1.01E+05	2.32E+05
Maximum release time	minutes	2.57E+03	1.13E+04	9.22E+03	4.32E+03	1.13E+04
Average release time	minutes	2.57E+03	4.92E+03	2.90E+03	3.08E+03	3.46E+03
Minimum release time	minutes	2.57E+03	1.19E+03	6.17E+02	1.92E+03	6.17E+02
Permit dilution vol	ltr	2.58E+07	9.92E+08	1.62E+09	3.84E+09	6.48E+09
Permit dilution flow	gpm	2.65E+03	3.33E+03	8.68E+03	1.00E+04	7.38E+03
Permit max total diluted concentration (no H-3)	uCi/ml	5.89E-09	6.46E-08	2.17E-08	5.17E-09	6.46E-08
Period dilution vol	ltr	1.23E+09	1.24E+09	2.48E+09	5.01E+09	9.96E+09
Period dilution flow	gpm	2.51E+03	2.50E+03	4.95E+03	9.99E+03	5.01E+03

Section 2.4-Direct Radiation

Maximally exposed sector: J (25mrem/year limit)

Unit	Qtr 1 (mrem)	Qtr 2 (mrem)	Qtr 3 (mrem)	Qtr 4 (mrem)	2015 (mrem)
Unit 1	8.25E-01	1.57E+00	1.83E+00	1.57E+00	5.80E+00
Unit 2	8.25E-01	1.57E+00	1.83E+00	1.57E+00	5.80E+00
ISFSI – gamma	8.25E-01	1.57E+00	1.83E+00	1.57E+00	5.80E+00
ISFSI – neutron	3.00E-01	4.70E-01	7.15E-01	4.20E-01	1.91E+00
Sum:	2.78E+00	5.18E+00	6.21E+00	5.13E+00	**1.93E+01**

Maximally exposed sector Switchyard South (100mrem/year limit)

Switchyard	Qtr 1 (mrem)	Qtr 2 (mrem)	Qtr 3 (mrem)	Qtr 4 (mrem)	2015 (mrem)
Gamma	2.61E+01	1.81E+01	2.23E+01	1.58E+01	8.23E+01
Neutron	3.10E+00	1.80E+00	2.90E+00	1.40E+00	9.20E+00
Sum	2.92E+01	1.99E+01	2.52E+01	1.72E+01	**9.15E+01**

Section 2.5-LLD's

Various detectors were used on different counting platforms for the gaseous and liquid weekly effluent samples. The lower limit of detection(LLD) accompanies each counted sample and is verified to meet the following maximum LLD's:

A. Liquid

Sample frequency	Type of analysis	Lower Limit of Detection (LLD) uCi/mL
Weekly/prior to each release	Principal Gamma Emitters:	<5.00E-07
	Dissolved and Entrained Gases	<1.00E-05
Monthly composite	Tritium	<1.00E-05
	Gross Alpha	<1.00E-07
Quarterly composite	Sr-90	5.00E-08
	Fe-55, Ni-63	1.00E-06

B. Gaseous

Sample frequency	Type of analysis	Lower Limit of Detection (LLD) uCi/mL
Continuous/daily/weekly	Principle gamma emitters	<1.00E-11
Continuous	Noble gas	<1.00E-06
Monthly	Noble Gas / Principle gamma emitters	<1.00E-04
	Tritium	1.00E-06
Quarterly composite	Sr-90	<1.00E-11
	Fe-55	<3.00E-11
	Ni-63	<1.00E-11
	Gross Alpha	<1.00E-11

Estimates of Total Error

The following is a calculated estimate of the maximum potential total error associated with reported values in the Annual Radioactive Effluent Release Report. The Total error is determined by calculating the square root of the sum of the squares of the individual errors.

a. Gaseous Effluents

Sampling Error	5%
Calibration Error	10%
Counting Statistics Error	17%
Sample Volume Error	10%
Total Error	23%

b. Liquid Effluents

Sampling Error	5%
Calibration Error	10%
Counting Statistics Error	16%
Sample Volume Error	2%
Total Error	20%

Section 3- Solid Waste and Irradiated Fuel Shipments

A. Solid Waste Shipped Offsite for Burial or Disposal (Not irradiated fuel)

1. Types of Waste

Types of Waste	Total Quantity (m^3)	Total Activity (Ci)	Period	Est. Total Error %
a. Spent Resins, filter sludges, evaporator bottoms	6.993E+01	1.157E+02	2015	2.50E+01
b. Dry compressible waste, contaminated equipment	3.115E+03	1.804E+02	2015	2.50E+01
c. Irradiated components, control rods, etc.	4.958E+02	8.316E+03	2015	2.50E+01
d. Other (describe)	0.00E+00	0.00E+00	2015	2.50E+01

Section 3- Solid Waste and Irradiated Fuel Shipments (cont.)

2. Estimate of major nuclide composition (by waste type)

Major Nuclide Composition	Waste Type a. Resins, sludges bottoms (%)	Waste Type b. DAW contaminated equipment (%)	Waste Type d. Irradiated components (%)	Waste Type d. Other %
Ag-108m	0.00E+00	2.26E-03	0.00E+00	0.00
Ag-110m	0.00E+00	0.00E+00	0.00E+00	0.00
Am-241	2.75E-03	2.30E-02	4.66E-05	0.00
C-14	1.50E-02	5.43E-02	5.64E-02	0.00
Ce-144	1.03E-03	5.86E-02	1.73E-04	0.00
Cm-242	3.91E-05	8.57E-05	1.78E-07	0.00
Cm-243	9.25E-04	7.19E-03	1.68E-05	0.00
Cm-244	0.00E+00	4.22E-03	8.82E-06	0.00
Co-60	4.36E+01	2.98E+01	6.49E+01	0.00
Cs-134	0.00E+00	0.00E+00	2.61E-07	0.00
Cs-137	1.02E+01	5.37E+00	3.22E-03	0.00
Fe-55	2.19E-01	3.60E+00	9.23E+00	0.00
H-3	5.87E-03	6.75E-02	1.43E-01	0.00
I-129	1.08E-03	5.97E-03	2.45E-05	0.00
Mn-54	0.00E+00	1.76E-02	1.05E-04	0.00
Nb-94	5.29E-03	2.44E-02	1.06E-03	0.00
Ni-59	3.81E+00	7.63E-01	3.26E-01	0.00
Ni-63	4.18E+01	5.86E+01	4.10E-04	0.00
Ni-63am	0.00E+00	1.18E+00	2.54E+01	0.00
Np-237	0.00E+00	6.69E-11	0.00E+00	0.00
Pu-238	1.50E-03	1.49E-02	2.17E-05	0.00
Pu-239	8.11E-04	5.21E-03	8.55E-06	0.00
Pu-240	0.00E+00	1.12E-03	6.65E-06	0.00
Pu-241	3.76E-02	9.07E-02	2.86E-04	0.00
Pu-242	4.45E-06	1.68E-04	4.03E-07	0.00
Ra-226	0.00E+00	7.58E-04	1.01E-05	0.00
Sb-125	6.59E-03	6.86E-02	1.42E-04	0.00
Sr-89	1.98E-03	1.73E-02	7.33E-06	0.00
Sr-90	2.69E-01	6.58E-02	6.50E-05	0.00
Tc-99	1.18E-02	5.34E-02	1.96E-04	0.00
EU-152	0.00E+00	6.69E-03	0.00E+00	0.00
EU-154	0.00E+00	9.29E-04	0.00E+00	0.00
U-235	0.00E+00	1.31E-03	0.00E+00	0.00
U-236	0.00E+00	4.34E-05	0.00E+00	0.00
U-237	0.00E+00	1.10E-05	0.00E+00	0.00
U-238	0.00E+00	4.67E-07	0.00E+00	0.00
Zn-65	6.39E-03	5.29E-02	9.34E-05	0.00

* Ni-63AM – activated metal

3. Solid Waste Disposition

Number of shipments	Mode of Transportation	Destination
34	Truck	Clive CWF
0	Rail	Clive CWF
12	Truck	Clive BWF
32	Rail	Clive BWF
12	Truck	WCS

B. Irradiated Fuel Shipments (disposition)

Number of shipments	Mode of Transportation	Destination
0		

C. Changes to the Process Control Program:

None

Section 4– 40CFR190 & 10CRF72 Compliance Summary

UNIT 1, 2 & ISFSI (DOCKET Numbers 50-295, 50-304 & 72-1037)

EXECUTIVE SUMMARY

A review of 2015 effluent data indicates that the activity released from the station was far below any regulatory limit. There was no noble gas released in 2015. This trend can be attributed to the shutdown of both units since late September 1997.

Airborne

	Dose to Maximally Exposed Receptor from Unit 1	Dose to Maximally Exposed Receptor from Unit 2
Gamma Air	0.00E+00 mrad	0.00E+00 mrad
Beta Air	0.00E+00 mrad	0.00E+00 mrad
Total Body	2.94E-02 mrem	2.94E-02 mrem
Skin	0.00E+00 mrem	0.00E+00 mrem
Organ	6.75E-02 mrem (Infant Liver)	6.75E-02 mrem (Infant Liver)

Aquatic

	Dose to Maximally Exposed Receptor (Any) from Unit 1	Dose to Maximally Exposed Receptor (Any) from Unit 2
Total Body	1.82E-03 mrem	1.82E-03 mrem
Organ	5.00E-02 mrem(Child Bone)	5.00E-02 mrem(Child Bone)

Direct Radiation

	Dose to Maximally Exposed Member of the public from Unit 1	Dose to Maximally Exposed Member of the public from Unit 2	Dose to Maximally Exposed Member of the public from ISFSI
Total Body	5.80E+00mrem (Sec J)	5.80E+00mrem (Sec J)	7.71E+00mrem (Sec J)

Switchyard Direct Radiation (10CFR20 limit 100mrem/year)

Switchyard	Qtr 1 (mrem)	Qtr 2 (mrem)	Qtr 3 (mrem)	Qtr 4 (mrem)	2015 (mrem)
Gamma	2.61E+01	1.81E+01	2.23E+01	1.58E+01	8.23E+01
Neutron	3.10E+00	1.80E+00	2.90E+00	1.40E+00	9.20E+00
Sum	2.92E+01	1.99E+01	2.52E+01	1.72E+01	9.15E+01

Section 4.1 – Unit 1

I. Unit 1 (Docket Number 50-295)

A. 10 CFR20 & 40CFR190 Compliance Assessment: The demonstration of compliance with 40CFR190 will be used to demonstrate compliance with 10CFR20.

1. Total Effective Dose Equivalent	5.83E+00 mrem/year
2. 40 CFR 190 Whole body limit	25 mrem/year
3. 40 CFR 190 Max exposed organ	25 mrem (75 mrem thyroid)
4. % Whole body limit	2.33E+01%
5. % Max exposed organ	2.36E+01% child bone

	Qtr 1 mrem	Qtr 2 mrem	Qtr 3 mrem	Qtr 4 mrem	2015 mrem
TBody	8.25E-01	1.57E+00	1.86E+00	1.57E+00	5.83E+00
	Adult Tbody	Child Tbody	Adult Tbody	Adult Tbody	Adult Tbody
Organ	8.26E-01	1.62E+00	1.89E+00	1.58E+00	5.90E+00
	Child Bone	Child Bone	Child Bone	Child Bone	Child Bone

B. Maximally Exposed Receptor:

1. Airborne

	Qtr Obj	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Yearly limit 10CFR 50 App. I	Total Dose 2015	% of Yearly limit
Gamma air (mrad)	5.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	10.0	0.00E+00	0.00E+00
Beta Air (mrad)	10.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	20.0	0.00E+00	0.00E+00
Total Body (mrem)	7.5	2.48E-04	2.01E-04	2.76E-02	1.30E-03	15.0	2.94E-02	1.96E-01
Skin (mrem)	7.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	15.0	0.00E+00	0.00E+00
Organ (mrem)	7.5	1.23E-03	7.40E-04	6.20E-02	3.71E-03	15.0	6.75E-02	4.50E-01
Critical Organ		Infant liver	Infant liver	Infant liver	Infant liver		Infant liver	Infant liver

2. Aquatic

	Qtr Obj	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Yearly limit 10CFR 50 App. I	Total Dose **2015**	% of Yearly limit
Total Body (mrem)	2.5	1.97E-05	1.64E-03	6.35E-04	2.16E-04	3.0	1.82E-03	6.01E-02
Organ (mrem)	2.5	5.95E-04	4.70E-02	1.73E-02	4.64E-03	10.0	5.00E-02	5.00E-01
Critical Organ		Child bone	Child bone	Child bone	Child bone		Child bone	Child bone

3. Direct (gamma) Maximally Exposed Sector: J

	Qtr Obj	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Yearly limit 40CFR 190	Total Dose **2015**	% of Yearly limit
Total body (mrem)	6.25	8.25E-01	1.57E+00	1.83E+00	1.57E+00	25.0	5.80E+00	2.32E+01

II. Unit 2 (Docket Number 50-304)

A. 10 CFR20 & 40CFR190 Compliance Assessment: The demonstration of compliance with 40CFR190 will be used to demonstrate compliance with 10CFR20.

1. Total Effective Dose Equivalent — 5.83E+00 mrem/year
2. 40 CFR 190 Whole body limit — 25 mrem/year
3. 40 CFR 190 Max exposed organ — 25 mrem (75 mrem thyroid)
4. % Whole body limit — 2.33E+01%
5. % Max exposed organ — 2.36E+01% child bone

	Qtr 1 mrem	Qtr 2 mrem	Qtr 3 mrem	Qtr 4 mrem	2015 mrem
TBody	8.25E-01	1.57E+00	1.86E+00	1.57E+00	5.83E+00
	Adult Tbody	Child Tbody	Adult Tbody	Adult Tbody	Adult Tbody
Organ	8.26E-01	1.62E+00	1.89E+00	1.58E+00	5.90E+00
	Child Bone	Child Bone	Child Bone	Child Bone	Child Bone

B. Maximally Exposed Receptor:

1. Airborne

	Qtr Obj	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Yearly limit 10CFR 50 App. I	Total Dose **2015**	% of Yearly limit
Gamma air (mrad)	5.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	10.0	0.00E+00	0.00E+00
Beta Air (mrad)	10.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	20.0	0.00E+00	0.00E+00
Total Body (mrem)	7.5	2.48E-04	2.01E-04	2.76E-02	1.30E-03	15.0	2.94E-02	1.96E-01
Skin (mrem)	7.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	15.0	0.00E+00	0.00E+00
Organ (mrem)	7.5	1.23E-03	7.40E-04	6.20E-02	3.71E-03	15.0	6.75E-02	4.50E-01
Critical Organ		Infant liver	Infant liver	Infant liver	Infant liver		Infant liver	Infant liver

2. Aquatic

	Qtr Obj	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Yearly limit 10CFR 50 App. I	Total Dose **2015**	% of Yearly limit
Total Body (mrem)	2.5	1.97E-05	1.64E-03	6.35E-04	2.16E-04	3.0	1.82E-03	6.01E-02
Organ (mrem)	2.5	5.95E-04	4.70E-02	1.73E-02	4.64E-03	10.0	5.00E-02	5.00E-01
Critical Organ		Child bone	Child bone	Child bone	Child bone		Child bone	Child bone

3. Direct (gamma) Maximally Exposed Sector: J

	Qtr Obj	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Yearly limit 40CFR 190	Total Dose **2015**	% of Yearly limit
Total body (mrem)	6.25	8.25E-01	1.57E+00	1.83E+00	1.57E+00	25.0	5.80E+00	2.32E+01

III. ISFSI (Docket Number 72-1037)

A. 10CFR72 & 40CFR190 Compliance Assessment:

1. Total Effective Dose Equivalent 7.71+00 mrem/year
2. 40 CFR190 / 10CFR72 Whole body limit 25 mrem/year
3. 40 CFR190 / 10CFR72 Max exposed organ 25 mrem (75 mrem thyroid)
4. % Whole body limit 3.08E+01%
5. % Max exposed organ (child bone/thyroid) 3.08E+01% / 1.03E+01%

	Qtr 1 mrem	Qtr 2 mrem	Qtr 3 mrem	Qtr 4 mrem	2015 mrem
TEDE	1.13E+00	2.04E+00	2.55E+00	1.99E+00	7.71E+00
TODE	1.13E+00	2.04E+00	2.55E+00	1.99E+00	7.71E+00

B. Maximally Exposed Receptor Sector: J

1. Direct (gamma + neutron)

	Qtr Obj	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Yearly limit 40CFR190/ 10CFR72.104	Total Dose **2015**	% of Yearly limit
Total body (mrem)	6.25	1.13E+00	2.04E+00	2.55+00	1.99E+00	25.0	7.71E+00	3.08E+01

IV. Combined 40CFR190 Report:

40CFR190 URANIUM FUEL CYCLE DOSE REPORT

LIQUID ANNUAL DOSE SUMMARY

Year..................: 2015
From Unit.............: 1
To Unit...............: 2
Liquid Receptor.......: 0 Liquid Receptor

=== MAXIMUM PERIOD DOSE TO LIMIT (Any Organ) ===

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Admin Limit	Admin % of Limit	T.Spec Limit	T.Spec % of Limit
Quarter 1	CHILD	BONE	1.19E-03	Quarter	2.50E+00	4.76E-02	2.50E+00	4.76E-02
Quarter 2	CHILD	BONE	9.40E-02	Quarter	2.50E+00	3.76E+00	2.50E+00	3.76E+00
Quarter 3	CHILD	BONE	3.46E-02	Quarter	2.50E+00	1.38E+00	2.50E+00	1.38E+00
Quarter 4	CHILD	BONE	9.27E-03	Quarter	2.50E+00	3.71E-01	2.50E+00	3.71E-01
Annual	CHILD	BONE	1.00E-01	Annual	5.00E+00	2.00E+00	5.00E+00	2.00E+00

=== MAXIMUM PERIOD DOSE TO LIMIT (Tot Body)) ===

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Admin Limit	Admin % of Limit	T.Spec Limit	T.Spec % of Limit
Quarter 1	CHILD	TBODY	3.93E-05	Quarter	1.50E+00	2.62E-03	1.50E+00	2.62E-03
Quarter 2	CHILD	TBODY	3.28E-03	Quarter	1.50E+00	2.18E-01	1.50E+00	2.18E-01
Quarter 3	CHILD	TBODY	1.27E-03	Quarter	1.50E+00	8.48E-02	1.50E+00	8.48E-02
Quarter 4	ADULT	TBODY	4.31E-04	Quarter	1.50E+00	2.87E-02	1.50E+00	2.87E-02
Annual	CHILD	TBODY	3.64E-03	Annual	3.00E+00	1.21E-01	3.00E+00	1.21E-01

Section 4.4– Combined 40CRF190 Report (cont.)

40CFR190 URANIUM FUEL CYCLE DOSE REPORT

GAS ANNUAL DOSE SUMMARY

Year..................: 2015
From Unit.............: 1
To Unit...............: 2
Coefficient Type......: Historical
Gas Receptor..........: 5 Composite Crit. Receptor - IP
Distance (meters).....: 0.00
Compass Point.........: NA

=== MAXIMUM PERIOD DOSE TO LIMIT (Any Organ) ===

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Admin Limit	Admin % of Limit	T.Spec Limit	T.Spec % of Limit
Quarter 1	INFANT	LIVER	2.46E-03	Quarter	5.63E+00	4.38E-02	7.50E+00	3.28E-02
Quarter 2	INFANT	LIVER	1.48E-03	Quarter	5.63E+00	2.64E-02	7.50E+00	1.98E-02
Quarter 3	INFANT	LIVER	1.24E-01	Quarter	5.63E+00	2.20E+00	7.50E+00	1.65E+00
Quarter 4	INFANT	LIVER	7.42E-03	Quarter	5.63E+00	1.32E-01	7.50E+00	9.90E-02
Annual	INFANT	LIVER	1.35E-01	Annual	1.13E+01	1.20E+00	1.50E+01	9.01E-01

=== MAXIMUM PERIOD DOSE TO LIMIT (Tot Body)) ===

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Admin Limit	Admin % of Limit	T.Spec Limit	T.Spec % of Limit
Quarter 1	ADULT	TBODY	4.95E-04	Quarter	5.25E+00	9.43E-03	7.50E+00	6.60E-03
Quarter 2	ADULT	TBODY	4.02E-04	Quarter	5.25E+00	7.66E-03	7.50E+00	5.37E-03
Quarter 3	ADULT	TBODY	5.52E-02	Quarter	5.25E+00	1.05E+00	7.50E+00	7.37E-01
Quarter 4	ADULT	TBODY	2.59E-03	Quarter	5.25E+00	4.93E-02	7.50E+00	3.45E-02
Annual	ADULT	TBODY	5.87E-02	Annual	1.05E+01	5.59E-01	1.50E+01	3.92E-01

Section 4.5– Combined 40CRF190 Report (cont.)

40CFR190 URANIUM FUEL CYCLE DOSE REPORT

COMBINED MAXIMUM ANNUAL DOSE SUMMARY

Year..................: 2015
From Unit.............: 1
To Unit...............: 2
Liquid Receptor.......: 0 Liquid Receptor
Coefficient Type......: Historical
Gas Receptor..........: 5 Composite Crit. Receptor - IP
Distance (meters).....: 0.00
Compass Point.........: NA

=== MAXIMUM PERIOD DOSE TO LIMIT (Any Organ) ===

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Limit	Percent of Limit
Quarter 1	CHILD	BONE	2.83E-03	Quarter	6.25E+00	4.53E-02
Quarter 2	CHILD	BONE	9.50E-02	Quarter	6.25E+00	1.52E+00
Quarter 3	CHILD	BONE	1.29E-01	Quarter	6.25E+00	2.07E+00
Quarter 4	CHILD	BONE	1.47E-02	Quarter	6.25E+00	2.35E-01
Annual	CHILD	BONE	2.03E-01	Annual	2.50E+01	8.12E-01

=== MAXIMUM PERIOD DOSE TO LIMIT (Tot Body)) ===

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Limit	Percent of Limit
Quarter 1	ADULT	TBODY	5.25E-04	Quarter	6.25E+00	8.40E-03
Quarter 2	CHILD	TBODY	3.62E-03	Quarter	6.25E+00	5.80E-02
Quarter 3	ADULT	TBODY	5.64E-02	Quarter	6.25E+00	9.03E-01
Quarter 4	ADULT	TBODY	3.02E-03	Quarter	6.25E+00	4.83E-02
Annual	ADULT	TBODY	6.23E-02	Annual	2.50E+01	2.49E-01

Section 5-Meteorological Data

1. Introduction

The purpose of the meteorological program conducted at Zion Station site was to provide information sufficient to assess the local weather conditions and was used to determine the degree of atmospheric dispersion of airborne radioactive effluent from the station.

During the first quarter of 2015, all fuel had been removed to the ISFSI location and continuous meteorological monitoring was no longer required. The previous 6 years of data from Jan. 1, 2009 to Dec. 31, 2014 was queried to generate the historic average wind rose and atmospheric dispersion parameters for future airborne effluents from Zion Station.

The method of dose calculation that will be used going forward is ground level release and relevant information that is applicable to this method of effluent dose calculation has been included in this report.

The meteorological tower that was used in calculation of these historical averages was 250 ft. in elevation and was instrumented at two levels. Wind speed and direction measured at 35 ft. and 250 ft. Ambient temperature was measured at 35 ft. Differential temperature, referenced to 35 ft. was measured at 250 ft. Dew point temperature was measured approximately ten feet from the tower at an elevation of 5 ft. Precipitation was measured by a rain gauge located on the roof of the meteorological shelter building.

Joint frequency stability wind rose tables of wind direction, wind speed, and stability were routinely tabulated from hourly measurements during the six year period of this historical average. The six year historical average data tables are included in this report.

2. Summary

For the six year period from Jan. 1 2009 to Dec. 31, 2014 considered in calculating the historical average, Zion Stations meteorological monitoring program generated 51,918 total hours of valid data out of a possible 52596 total hours, 678 total hours of data were lost representing a 98.71% data recovery rate.

The stability wind rose tables included in this report have been generated using the 35 ft. wind data with the 250-35 ft. differential temperature data.

3. Data Acquisition

Information regarding Data Acquisition, Data Analysis and instruments used can be found in the meteorological monitoring sections of prior Zion Stations Annual Radioactive Environmental Monitoring Reports from 2009 to 2014.

4. The following two programs were used to calculate doses resulting from radioactive releases:

   a. XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations (NUREG/CR-2919)

The program is based on the theory that material released to the atmosphere will be normally distributed (Gaussian) about the plume centerline. A straight-line trajectory is assumed between the point of release and all receptors.

The program implements the assumptions outlined in Section C of NRC Regulatory Guide 1.111. In evaluating routine releases from nuclear power plants, it primarily is designed to calculate annual relative effluent concentrations, X/Q values and annual average relative deposition, D/Q values.

The historical average output from the XOQDOQ program from 2009-2014 was used to develop the input to the RETDAS program.

b. RETDAS: Radiological Effluent Tracking and Dose Assessment Software.

RETDAS is a program written for the evaluation of radiological impacts due to the release of radioactive material to the environment during normal operation of reactors. The RETDAS code implements the radiological impact models of NRC Regulatory Guide 1.109 Rev. 1, for atmospheric releases. The program is used to estimate the maximum individual doses at the maximally exposed location in the vicinity of the plant.

5. Detailed information regarding the meteorological maintenance and calibration information of the meteorological tower and instruments used during the historical average evaluation time period can be found in prior Zion Station Annual Radioactive Environmental Operating Reports from 2009 to 2014.

6. Stability Wind Rose Data

The historical stability wind roses are given in Tables 4 through 8. For the year, winds measured at 35ft. most frequently came from the West (10.86%) and fell into the 3.6 to 7.5 mph wind speed class (34.94%). Calms (wind speeds at or below 1mph were measured at 0.16% of the time and speeds greater than 24.5 mph were measured 0.09% of the time.

Stability based on the 250-35 ft. differential temperature most frequently fell into the neutral classification(39.58%)

Table 1

<u>Wind Direction Classes</u>

Wind Direction Class	Compass Direction the Wind is Coming From		
N	348.75^0	$<$ WD $\leq$	11.25^0
NNE	11.25^0	$<$ WD $\leq$	11.25^0
NE	33.75^0	$<$ WD $\leq$	33.75^0
ENE	56.25^0	$<$ WD $\leq$	56.25^0
E	78.75^0	$<$ WD $\leq$	78.75^0
ESE	101.25^0	$<$ WD $\leq$	101.25^0
SE	123.75^0	$<$ WD $\leq$	123.75^0
SSE	146.25^0	$<$ WD $\leq$	146.25^0
S	168.75^0	$<$ WD $\leq$	168.75^0
SSW	191.25^0	$<$ WD $\leq$	191.25^0
SW	213.75^0	$<$ WD $\leq$	213.75^0
WSW	236.25^0	$<$ WD $\leq$	236.25^0
W	258.75^0	$<$ WD $\leq$	258.75^0
WNW	281.25^0	$<$ WD $\leq$	281.25^0
NW	303.75^0	$<$ WD $\leq$	303.75^0
NNW	326.25^0	$<$ WD $\leq$	348.75^0

Table 2

<u>Wind Speed Classes</u>

Wind Speed Class	Wind Speeds are in miles per hour (mph)		
1	0.0	$<$ WS $\leq$	0.7
2	0.7	$<$ WS $\leq$	3.5
3	3.5	$<$ WS $\leq$	7.5
4	7.5	$<$ WS $\leq$	12.5
5	12.5	$<$ WS $\leq$	18.5
6	18.5	$<$ WS $\leq$	24.5
7	24.5	$<$ WS	

Table 3

Atmospheric Stability Classes

Class	Differential Temperature Interval (in $^0C/100m$)(1)	Differential Temperature Interval (in ^0F over the 250-35 ft. interval)(2)
A – Extremely Unstable	$\Delta T \leq -1.9$	$\Delta T \leq -2.3$
B – Moderately Unstable	$-1.9 < \Delta T \leq -1.7$	$-2.3 < \Delta T \leq -2.1$
C – Slightly Unstable	$-1.7 < \Delta T \leq -1.5$	$-2.1 < \Delta T \leq -1.8$
D – Neutral	$-1.5 < \Delta T \leq -0.5$	$-1.8 < \Delta T \leq -0.6$
E – Slightly Stable	$-0.5 < \Delta T \leq 1.5$	$-0.6 < \Delta T \leq 1.7$
F – Moderately Stable	$1.5 < \Delta T \leq 4.0$	$1.7 < \Delta T \leq 4.7$
G – Extremely Stable	$4.0 < \Delta T$	$4.7 < \Delta T$

(1) From ANSI/ANS 2.5

(2) ANSI/ANS 2.5 intervals scaled for instrument heights on the Zion meteorological tower.

Table 4

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: A - Extremely Unstable

Elevation: Ground Level Release

Wind Speed (mph) at 10m Level

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0	0	0.031	0.156	0.254	0.04	0.002	0.48
NNE	0	0	0.176	0.98	0.287	0.006	0	1.45
NE	0	0.002	0.391	0.559	0.075	0.004	0	1.03
ENE	0	0.002	0.368	0.22	0.019	0.002	0	0.61
E	0	0.004	0.412	0.133	0.023	0	0	0.57
ESE	0	0.002	0.379	0.141	0	0	0	0.52
SE	0	0	0.272	0.219	0.01	0	0	0.5
SSE	0	0	0.05	0.249	0.035	0	0	0.33
S	0	0	0.01	0.046	0.019	0	0	0.08
SSW	0	0.002	0.015	0.068	0.144	0.01	0	0.24
SW	0	0.002	0.041	0.319	0.331	0.015	0.006	0.71
WSW	0	0	0.133	0.516	0.366	0.021	0.004	1.04
W	0	0	0.12	0.577	0.401	0.01	0	1.11
WNW	0	0	0.089	0.492	0.187	0.002	0	0.77
NW	0	0.006	0.068	0.404	0.112	0	0	0.59
NNW	0	0	0.039	0.058	0.037	0	0	0.13
Total:	0	0.019	2.591	5.137	2.3	0.11	0.012	10.17

Table 4(cont.)

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: B - Moderately Unstable

Elevation: Ground Level Release

Wind Speed (mph) at 10m Level

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0	0	0.039	0.102	0.119	0.015	0	0.28
NNE	0	0	0.112	0.196	0.058	0.004	0.002	0.37
NE	0	0.012	0.108	0.052	0.014	0.004	0	0.19
ENE	0	0.012	0.068	0.029	0.014	0	0	0.12
E	0	0.004	0.077	0.025	0.002	0	0	0.11
ESE	0	0.008	0.066	0.045	0	0	0	0.12
SE	0	0	0.097	0.041	0	0	0	0.14
SSE	0	0	0.06	0.164	0.025	0	0	0.25
S	0	0	0.01	0.052	0.008	0.002	0	0.07
SSW	0	0	0.013	0.058	0.098	0.008	0.002	0.18
SW	0	0.002	0.033	0.149	0.158	0.013	0.002	0.36
WSW	0	0	0.062	0.193	0.089	0.012	0.002	0.36
W	0	0.002	0.068	0.211	0.129	0.004	0	0.41
WNW	0	0	0.06	0.179	0.081	0.004	0	0.32
NW	0	0.004	0.049	0.191	0.052	0	0	0.29
NNW	0	0.002	0.021	0.054	0.027	0.002	0	0.11
Total:	0	0.044	0.938	1.739	0.872	0.067	0.008	3.67

Section 5-Meteorological Data (cont.)

Table 4(cont.)

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: C - Slightly Unstable

Elevation: Ground Level Release

Wind Speed (mph) at 10m Level

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0	0.004	0.086	0.243	0.177	0.013	0.008	0.53
NNE	0	0.01	0.183	0.31	0.079	0.004	0	0.59
NE	0	0.023	0.15	0.102	0.031	0.01	0.006	0.32
ENE	0	0.023	0.1	0.044	0.021	0.012	0.002	0.2
E	0	0.01	0.146	0.025	0.018	0	0	0.2
ESE	0	0.019	0.115	0.037	0.014	0	0	0.18
SE	0	0.006	0.181	0.054	0.016	0	0	0.26
SSE	0	0.006	0.106	0.351	0.11	0.01	0	0.58
S	0	0.004	0.066	0.101	0.021	0	0	0.19
SSW	0	0.002	0.041	0.119	0.154	0.017	0.004	0.34
SW	0	0	0.094	0.244	0.189	0.023	0.006	0.56
WSW	0	0.004	0.11	0.252	0.139	0.01	0.002	0.52
W	0	0.008	0.133	0.277	0.165	0.008	0	0.59
WNW	0	0.008	0.127	0.308	0.079	0	0	0.52
NW	0	0.01	0.096	0.206	0.096	0	0	0.41
NNW	0	0.01	0.033	0.133	0.045	0.004	0	0.22
Total:	0	0.145	1.768	2.806	1.352	0.11	0.027	6.21

Section 5-Meteorological Data (cont.)

Table 4(cont.)

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: D - Neutral

Elevation: Ground Level Release

Wind Speed (mph) at 10m Level

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0	0.102	0.597	1.392	1.05	0.21	0.06	3.41
NNE	0	0.142	0.758	1.123	0.769	0.042	0.031	2.87
NE	0	0.161	0.528	0.57	0.405	0.046	0.025	1.74
ENE	0.001	0.137	0.348	0.346	0.347	0.092	0.008	1.28
E	0	0.121	0.392	0.303	0.353	0.094	0.013	1.28
ESE	0	0.148	0.489	0.289	0.163	0.035	0.002	1.13
SE	0	0.127	0.567	0.378	0.149	0.008	0	1.23
SSE	0	0.075	0.523	1.258	0.944	0.168	0.054	3.02
S	0	0.106	0.686	0.805	0.314	0.015	0	1.93
SSW	0	0.128	0.641	0.994	0.774	0.087	0.008	2.63
SW	0	0.152	0.612	1.443	1.003	0.108	0.015	3.33
WSW	0.001	0.138	0.849	1.327	0.659	0.042	0.002	3.02
W	0	0.146	1.1	1.766	0.961	0.029	0.002	4
WNW	0	0.169	1.139	1.402	0.52	0.012	0	3.24
NW	0	0.164	1	1.404	0.489	0.021	0	3.08
NNW	0	0.098	0.655	1.21	0.387	0.039	0.006	2.39
Total:	0.006	2.117	10.886	16.01	9.286	1.048	0.225	39.58

Section 5-Meteorological Data (cont.)

Table 4(cont.)

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: E - Slightly Stable

Elevation: Ground Level Release

Wind Speed (mph) at 10m Level

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24. 5	Total :
N	0.005	0.302	0.672	0.53	0.173	0.021	0.012	1.72
NNE	0.004	0.245	0.564	0.447	0.058	0.013	0	1.33
NE	0.004	0.204	0.314	0.167	0.075	0.002	0	0.77
ENE	0.003	0.154	0.212	0.092	0.071	0.01	0	0.54
E	0.003	0.148	0.212	0.082	0.11	0.054	0.008	0.62
ESE	0.002	0.129	0.233	0.091	0.052	0.017	0	0.52
SE	0.003	0.163	0.456	0.273	0.079	0.004	0	0.98
SSE	0.004	0.192	0.452	0.84	0.291	0.029	0.019	1.83
S	0.005	0.292	1.375	0.839	0.166	0.004	0	2.68
SSW	0.005	0.441	1.19	0.661	0.154	0.015	0	2.47
SW	0.006	0.324	0.855	0.607	0.183	0.013	0	1.99
WSW	0.004	0.277	1.008	0.503	0.069	0.002	0	1.86
W	0.005	0.353	1.349	0.649	0.117	0.006	0.002	2.48
WNW	0.005	0.38	1.136	0.599	0.05	0.002	0	2.17
NW	0.005	0.319	1.069	0.48	0.073	0	0	1.95
NNW	0.004	0.252	0.593	0.203	0.058	0	0	1.11
Total:	0.065	4.178	11.692	7.063	1.779	0.193	0.04	25.01

Section 5-Meteorological Data (cont.)

Table 4(cont.)

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: F - Moderately Stable

Elevation: Ground Level Release

Wind Speed (mph) at 10m Level

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0.002	0.151	0.162	0.043	0	0	0	0.36
NNE	0.001	0.094	0.106	0.019	0	0	0	0.22
NE	0.001	0.083	0.086	0.025	0	0	0	0.2
ENE	0.001	0.076	0.064	0.024	0.014	0.002	0	0.18
E	0.001	0.079	0.077	0.027	0.01	0	0	0.19
ESE	0.001	0.077	0.111	0.045	0.016	0	0	0.25
SE	0.001	0.072	0.156	0.07	0.006	0	0	0.3
SSE	0.001	0.068	0.154	0.351	0.118	0.013	0	0.7
S	0.003	0.24	0.714	0.368	0.08	0.002	0	1.41
SSW	0.004	0.472	0.51	0.031	0.004	0	0	1.02
SW	0.005	0.454	0.334	0.023	0.002	0	0	0.82
WSW	0.005	0.495	0.368	0.015	0	0	0	0.88
W	0.005	0.416	0.637	0.015	0	0	0	1.07
WNW	0.003	0.307	0.458	0.008	0	0	0	0.78
NW	0.004	0.333	0.466	0.012	0	0	0	0.82
NNW	0.003	0.202	0.165	0.002	0.002	0	0	0.37
Total:	0.042	3.618	4.571	1.075	0.251	0.017	0	9.57

Section 5-Meteorological Data (cont.)

Table 4(cont.)

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: G - Extremely Stable

Elevation: Ground Level Release

Wind Speed (mph) at 10m Level

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0.001	0.058	0.025	0	0	0	0	0.08
NNE	0.001	0.034	0.028	0	0	0	0	0.06
NE	0.001	0.03	0.01	0.008	0.002	0	0	0.05
ENE	0.001	0.029	0.018	0.008	0.012	0	0	0.07
E	0.001	0.033	0.029	0.02	0.008	0	0	0.09
ESE	0.001	0.039	0.058	0.021	0.004	0	0	0.12
SE	0.001	0.034	0.066	0.029	0.002	0	0	0.13
SSE	0.001	0.052	0.095	0.167	0.054	0	0	0.37
S	0.002	0.116	0.424	0.316	0.057	0	0	0.91
SSW	0.005	0.256	0.11	0.006	0	0	0	0.38
SW	0.005	0.258	0.189	0	0	0	0	0.45
WSW	0.006	0.481	0.316	0	0	0	0	0.8
W	0.008	0.586	0.609	0	0	0	0	1.2
WNW	0.007	0.353	0.401	0	0	0	0	0.76
NW	0.003	0.104	0.108	0	0	0	0	0.22
NNW	0.003	0.071	0.016	0	0	0	0	0.09
Total:	0.048	2.534	2.498	0.574	0.139	0	0	5.79

Table 5
Percent Wind Direction by Stability Class

Wind Direction	Stability Class A	B	C	D	E	F	G	Total
N	0.48	0.28	0.53	3.4	1.72	0.36	0.08	6.86
NNE	1.45	0.37	0.59	2.9	1.33	0.22	0.06	6.89
NE	1.03	0.19	0.32	1.7	0.77	0.2	0.05	4.3
ENE	0.61	0.12	0.2	1.3	0.54	0.18	0.07	3
E	0.57	0.11	0.2	1.3	0.62	0.19	0.09	3.06
ESE	0.52	0.12	0.18	1.1	0.52	0.25	0.12	2.84
SE	0.5	0.14	0.26	1.2	0.98	0.3	0.13	3.54
SSE	0.33	0.25	0.58	3.0	1.83	0.7	0.37	7.08
S	0.08	0.07	0.19	1.9	2.68	1.41	0.91	7.27
SSW	0.24	0.18	0.34	2.6	2.47	1.02	0.38	7.26
SW	0.71	0.36	0.56	3.3	1.99	0.82	0.45	8.22
WSW	1.04	0.36	0.52	3.02	1.86	0.88	0.8	8.48
W	1.11	0.41	0.59	4	2.48	1.07	1.2	10.86
WNW	0.77	0.32	0.52	3.24	2.17	0.78	0.76	8.56
NW	0.59	0.29	0.41	3.08	1.95	0.82	0.22	7.36
NNW	0.13	0.11	0.22	2.39	1.11	0.37	0.09	4.42
TOTAL	10.17	3.67	6.21	39.58	25.01	9.57	5.79	100

Section 5-Meteorological Data (cont.)

Table 6
Percent Wind Direction by Wind Speed

Wind Speed in mph

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0.008	0.617	1.612	2.466	1.773	0.299	0.082	6.86
NNE	0.006	0.525	1.927	3.075	1.251	0.069	0.033	6.89
NE	0.006	0.515	1.587	1.483	0.602	0.066	0.031	4.3
ENE	0.006	0.433	1.178	0.763	0.498	0.118	0.01	3
E	0.005	0.399	1.345	0.615	0.524	0.148	0.021	3.06
ESE	0.004	0.422	1.451	0.669	0.249	0.052	0.002	2.84
SE	0.005	0.402	1.795	1.064	0.262	0.012	0	3.54
SSE	0.006	0.393	1.44	3.38	1.577	0.22	0.073	7.08
S	0.01	0.758	3.285	2.527	0.665	0.023	0	7.27
SSW	0.014	1.301	2.52	1.937	1.328	0.137	0.014	7.26
SW	0.016	1.192	2.158	2.785	1.866	0.172	0.029	8.22
WSW	0.016	1.395	2.846	2.806	1.322	0.087	0.01	8.48
W	0.018	1.511	4.016	3.495	1.773	0.057	0.004	10.86
WNW	0.015	1.217	3.41	2.988	0.917	0.02	0	8.56
NW	0.012	0.94	2.856	2.697	0.822	0.021	0	7.36
NNW	0.01	0.635	1.522	1.66	0.556	0.045	0.006	4.42
Total	0.161	12.655	34.944	34.404	15.979	1.545	0.312	100

Section 5-Meteorological Data (cont.)

Table 7
Percent Speed by Stability Class

Speed (mph)	Stability Class A	B	C	D	E	F	G	Total
<1	0	0	0	0.006	0.065	0.042	0.048	0.161
1 - 3.5	0.227	0.177	0.524	4.22	6.601	4.625	3.303	19.677
3.6 - 7.5	2.591	0.938	1.768	10.886	11.692	4.571	2.498	34.944
7.6 - 12.5	5.137	1.739	2.806	16.01	7.063	1.075	0.574	34.404
12.6 - 18.5	2.3	0.872	1.352	9.286	1.779	0.251	0.139	15.979
18.6 - 24.5	0.11	0.067	0.11	1.048	0.193	0.017	0	1.545
>24.5	0.012	0.008	0.027	0.225	0.04	0	0	0.312
Total:	10.17	3.67	6.21	39.58	25.01	9.57	5.79	100

Section 6 - Errata data

There are no errata corrections from prior years reports in 2015

Section 7 - Changes to Zion Station Liquid Radwaste System Gaseous Effluent Treatment and Monitoring Systems.

Summary: All of the changes to the Liquid Radwaste System were evaluated and were either system improvements, had the effect of lowering the dose to the public, or had no impact on dose to the public. There was no change to the Gaseous Effluent System. There were changes to the continuous liquid process monitoring system, the liquid effluent batch release system, and the associated liquid dilution flow system as follows:

1. Turbine Building Fire Sump continuous effluent monitor system: All potential radioactive inputs from the auxiliary building and fuel handling building were removed from the turbine building fire sump prior to removing 0R-PR25. The potential inputs (spent fuel pool secondary cooling water quality system monitor blow down and air conditioning condensate drains from the aux building) were removed. An evaluation was performed to determine impact of minute quantities of historical radioactivity found in the turbine building, no activity could be detected greater than ODCM required lower limits of detection. With no potential for any future introduction of radioactive material into the fire sump and historically no detectable traces of radioactive material from the turbine building floor drains, it was determine 0R-PR25 was no longer required. There was no change in the flowpath or system structural piping. The fire sump discharges to the Waste Water Treatment Facility (WWTF) for processing. The compositor in this flowpath is sampled and analyzed weekly for radioactive material and a quarterly composite is sent to an offsite laboratory for analysis as was previously done.

2. Lake Release Tank liquid effluent batch release system: With the high concentration of Boron in the Spent Fuel Pool, the Boron concentration was the limiting component of batch releases. New calibrated low flowrate flowmeters had to be installed to ensure the flowrate of the discharge was within the calibrated range of the instruments. One flowmeter was installed for each Lake Release Tank, and an additional common discharge line flowmeter was installed as a backup. 0RT-PR04 failed in February of 2015 and an entirely new liquid radwaste effluent monitor was designed with higher capabilities than the previously used monitor. This monitor was designed, constructed and tested and was found to outperform the previous liquid radiation monitor. The liquid radwaste discharge line which entered the Unit 2 discharge tunnel was extended to travel the entire length of the discharge tunnel, inside the tunnel, to allow final status survey of the discharge tunnel. The new location of the liquid effluent discharge is approximately 5 feet downstream of the dilution flow at the valve house area.

3. Dilution flow system: The service water system with a minimum flowrate of 2500 gpm. was replaced with a new dilution flow pump with a minimum output of 10,000 gpm. This change was done to allow for a larger discharge flowrate while still maintaining the Boron concentration within Federal limits.

All applicable changes have been evaluated in accordance with 10CFR 50.59 by ANSI qualified technical review personnel. Doses to members of the public have been evaluated during system design to ensure that the system continues to maintain doses to the public and workers are as low as reasonably attainable and well within limits.

The Engineering Change packages (ECNs) for the system changes are included in Attachments 2-5.

Section 8 – Correction Action for Inoperable Rad Monitor

0RT-PR04 Liquid Effluent Radiation Monitor Inoperable for > 30 days

Per ODCM 12.2.1.A.3:

3. Restore the inoperable effluent monitor to OPERABLE status within 30 days, if unsuccessful, explain in the next Annual Radioactive Effluent Release Report the reasons as detailed in Section 12.7.2 and perform a review to determine course of action to restore to OPERABLE status.

0RT-PR04 became inoperable on 2/20/2015. Batch releases from the Lake Release Tanks continued in accordance with ODCM surveillance requirements listed in Table 12.2-1. During the period of inoperability, every attempt was made to locate and acquire repair parts for the radiation monitor. Due to the age of the equipment, it was not possible to locate the parts needed for repair. After review, an alternate plan of restoring the radiation monitor to operable status was determined. Identical detector elements were available from Ludlum instruments and on-hand Zion Station repair parts. The malfunctioning meter was removed from 0RT-PR04 and an adapter interface was redesigned and tied into the alarm system. Additional features were available that were not present in the old system. The new monitor was tested and new efficiencies calculated. Calibration parameters and alarm setpoints were created. The work resulted in an overall improvement to the system and was verified to outperform the old monitor. Additionally, repair parts are available to the new system for future maintenance. 0RT-PR04 was declared operable on 9/9/2015.

Section 9 List of Changes to the ODCM

In accordance with ODCM section 12.7.3.1.c. Many changes were made to the ODCM, including an interim change for post-fuel transfer operations and a finalized change for post-fuel transfer operations. A summarized list of the changes is presented here, along with a complete copy of the current ODCM.

1. Ch.12 Rev 29

Page	Section	Change Summary
12-i		PDTS changed to QAPP Appendix B
12-iii	TOC 12.4	Removed Dose-Noble Gases, I-131,I-133
12-3	12.1.26	Added definition for unventilated building releases
12-3	12.1.27	Removed line stating effects on noble gas and iodine.
12-4	Table 12.1-1	Removed duplicate notation on REMP program frequency limitation.
12-5	12.2.1.C	Removed notation 'within the plant' to broaden bases to entire site.
12-6	Table 12.2-1	Removed words (Boric Acid Tanks (BAT). Added note related to surveillance 1.
12-7	Table 12.2-1	Surveillance 1, removed limitation of 14 days for inoperable monitor
12-8	Table 12.2-2	Removed words Boric Acid Tanks (BAT)
12-9	12.2.2.C	Removed words 'within the plant' to expand bases for entire site. Removed the word 'record' as printer function is unavailable.
12-11	Table 12.2-3	2R-PR49A(Channel 1) renamed to 2R-PR49. Removed 2R-PR49E (channel 5) entirely. Removed Fuel building monitoring section. (0RT-AR13, 0RT-AR21, 0RT-AR22, 0RT-AR24)
12-12	Table 12.2-3	Surveillance 8: Removed 'operations' as chemistry personnel are qualified to perform this surveillance. Changed 'station review' to 'review' Changed 'panel' to 'equipment'. Surveillance 10: Deleted, Surveillance 11-3 deleted (covered by surveillance 8), Surveillance 12: Deleted, Surveillance 13: Deleted
12-13	Table 12.2-4	2R-PR49A (Channel 1) renamed to 2R-PR49. Gas Activity Monitor 2R-PR49E (channel 5) deleted. Fuel Building Monitoring 0RT-AR13,21,22,24 deleted.
12-14	Table 12.2-4	Changed control room alarm annunciation occurs to 'alarms occur.' Deleted note (3) and (4)
12-15	12.3.1.A.1	Deleted 'For dissolved or entrained noble gases sentence.
12-17	Table 12.3-1	Deleted page
12-18	Table 12.3-2	Deleted (Boric Acid Tank) verbiage. Deleted sampling and analysis requirements for dissolved and entrained noble gases.
12-24	12.4.1.A	12.4.1.A.1. Deleted. 12.4.1.A.2. Removed I-131, I-133. 12.4.1.C removed 3000 mrem/year to the skin noble gas dose calculation.

Page	Section	Change Summary
12-25	Table 12.4-1	Moved Unit 2, FHB, AB sample requirement to combine with Unit 1 requirements. Added modular HEPA ventilation requirements (if applicable). Removed sampling and LLD limits for noble gas.
12-26	Table 12.4-1	Removed Unit 2, AB, FHB sample requirements and moved to Unit 1. Added note to explain sampling requirements for unventilated releases. Deleted note using old unventilated releases definition.
12-27	Table 12.4-1	Deleted notes: d, g, I, j
12-28	12.4.2	Deleted entire section. Dose-Noble Gas
12-29	12.4.2.C	Deleted section- Bases of dose-noble Gas
12-30	12.4.3	Deleted I-131, I-133
12-32	12.4.4.A	Deleted 1,2 mrad gamma, beta dose from noble gas.
12-37	Table 12.5-1	Changed 30 TLD stations to 31 TLD stations. Deleted ISFSI Indicator TLD locations.
12-39	Table 12.5-1	Added 5. Vegetation, sampling frequency and type of analysis
12-41	Table 12.5-2	Added Vegetation reporting activity concentration
12-42	Table 12.5-3	Added Vegetation LLD concentration.
12-45	12.5.2	A. Added a nearest garden census must be performed, C. Removed from Bases that a nearest garden census is not required.
12-49	12.7.2.1	Changed Tech Specs. to QAPP
12-51	12.7.3.1	Changed Tech Specs. to QAPP

2. Ch.12 Rev 30

Page	Section	Change Summary
12-6	Table 12.2-1	Removed 0R-PR25, changed Turbine Building Fire Sump to WWTF
12-7	Table 12.2-1	Deleted Surveillance 2
12-8	Table 12.2-2	Removed 0R-PR25 changed Turbine Building Fire Sump to WWTF
12-18	Table 12.3-2	Changed Turbine Building Fire Sump to WWTF
12-20	Table 12.3-2	Changed Turbine Building Fire Sump to WWTF

3. ODCM Rev 0

Page	Section	Change Summary – Post Fuel Transfer Operations re-write
All	All	Consolidation of all Chapters and appendices into a single document. Removal of Exelon generic information that is not applicable to Zion such as river flows and boiling water reactor requirements. Removal of requirements to maintain meteorological tower. Groundwater sampling surveillances added. Added gaseous effluent considerations for future open-air demolition. Remove requirement to monitor tritium from vent stack as the tritium in water volumes is released via liquid effluents. Aerial site photographs and maps have been updated to better illustrate TLD placement locations. 14 day limitation for OOS 0R-PR04 had been changed to 30 days.

4. ODCM Rev 1

Page	Section	Change Summary
35	10.1.2.1	Clarified description of Aux Building Vent Stack Effluent Monitor
39	10.4.1	Editorial change, clarified wording
39	10.4.2	Editorial change, clarified wording
59	Table 12.2-1	Added 0FI-WD005A and 0FI-WD006A low flow flowmeters
61	Table 12.2-2	Added surveillance and calibration requirements for0FI-WD005A and 0FI-WD006A
64	Table 12.2-3	Clarified surveillance 8 for 1&2 LP-084 panel sample pump operation requirements.
69	Table 12.3-2	Added wording to clarify WWTF compositor sampling required only during release.
71	Table 12.3-2	Clarified section f to require WWTF only during system operation.

5. ODCM Rev 2

Page	Section	Change Summary
44	Table 11-1.1	Changed location of Air Sampler Z-03 from 0.25 miles sector R(NNW) to 0.2 miles sector B(NNE)
45	Table 11-1.2.b.	Changed location of TLD Z-03-1 and 2 from 0.25 miles sector R(NNW) to 0.2 miles sector B(NNE)
50	Figure 11-1a	Revised inner ring REMP map to correct sector labels. REMP sample location Z-03 moved. MET tower removed from map.
51	Figure 11-1b	Re-added REMP outer ring sample locations.
57	12.2.1.A	Added time frame of actions to take in inoperability of liquid effluent monitor referenced by section 12.7.2

Page	Section	Change Summary
58	Table 12.2-1	Added 0FIT-SW54B flowmeter for high capacity dilution pump.
59	Table 12.2-1	Added verbage to indicate the surveillance applies to the applicable (High or Low flowrate) flowmeter.
60	Table 12.2-2	Added 0FIT-SW54B
61	12.2.2.A	Moved verbage for inoperable rad monitor reporting requirements reference by section 12.7.2 to this section from surveillance 8 requirement as it is more appropriately located in the Action section.
63	Table 12.2-3	Removed verbage for returning channel to operable status time requirements from surveillance 8 to relocate to section 12.2.2.A where it is more appropriately described.
97	12.7.2	Permanently Defueled Tech Spec change to QAPP App. B

6. ODCM Rev 3

Page	Section	Change Summary
58	Table 12.2-1	Added 0FI-WD007 common discharge flowmeter
60	Table 12.2-2	Added surveillance for 0FI-WD007

7. ODCM Rev 4

Page	Section	Change Summary
58	Table 12.2-1	Deleted SW54 and 54B service water flowmeters. Added 0PI-SW01A and 0PI-SW01 Pressure Gauge
59	Table 12.2-1	Added Surveillance 2 for Service Water Pressure gauge inoperability.
60	Table 12.2-2	Deleted SW54 and SW54B flowmeters. Added 0PI-SW01A and 0PI-SW01 service water pressure gauge. Modified note 4 to indicate pressure gauge verification once per day and to estimate dilution flow once per day.

8. ODCM Rev 5

Page	Section	Change Summary
56	Table 12.1-1	Deleted Four-Hourly notation for frequency of every 4 hours.
58	Table 12.2-1	Editorial correction 0PI-SW01A and 0PI-SW01 are listed as Discharge pressure flow indicators. Note ** added to clarify either pressure indication may be used to apply to minimum channels operable. Changed surveillance requirement to surveillance 3.

Page	Section	Change Summary
59	Table 12.2-1	Deleted Surveillance 2 for Service Water Pressure gauge.
60	Table 12.2-2	Editorial correction 0FI-WD007 should be listed under common discharge Editorial correction 0PI-SW01A and 0PI-SW01 are dilution flow pressure indicators. Modified note 4 to indicate pressure indicators shall be checked once per day and pump curves used for flow estimation during lake release tank releases.

Attachment 6 is a complete copy of Zion Stations Current ODCM.

ATTACHMENT 2

ECN# 400577

Extending liquid effluent discharge line through the discharge tunnel

Engineering Change Notice
(Part 1)

ECN No. 400577
Page: 1 of ~~12~~ 11 JSL

ISSUANCE: ☒ FOR CONSTRUCTION ☐ FOR COMMENT

Station: ZION Affected Unit: Unit 2 and Common Changes to a previously Approved ECN ☐	☐ Safety Related ☒ Non-Safety Related ☐ Regulatory	Design Change No. 400576 0 Project No. (if appl.): Supp ID No. (if appl.): System: WD

Description of Design Change Request:

Problem Statement

Liquid Radioactive Waste System (LRWS) effluent has been discharged into the Unit 2 Circulating Water System (CW) Discharge Tunnel on the west end of the tunnel. This release point has added water to the tunnel that is borated and will need to be diluted prior to release to the lake to meet the Illinois Environmental Protection Agency National Pollution Discharge Elimination System (NPDES) Permit. The NPDES permit limit for boron is 1 ppm. The current SFP water boron concentration is approximately 2,000 ppm. The current release point does not support the D&D schedule if the effluent discharge point remains on the west end of the tunnel due to having to process (dilute) the borated water released into the tunnel. There is approximately 720,000 gallons of this highly borated SFP water that would be released into the Unit 2 CW Discharge Tunnel. The milestone for isolating the Unit 2 CW Outlet Isolation valve is 1/1/16. Utilizing the current release point on the west end of the tunnel will not meet the schedule milestone.

Resolution

To minimize the further addition of LRWS effluent into the west end of the Unit 2 CW Discharge Tunnel the LRWS discharge hose will be extended to the east end of the tunnel. The installation of an extension hose onto the existing LRWS discharge hose from the west end of the tunnel and route it inside the tunnel to the east end of the tunnel. The extension hose will be routed in the CW tunnel and the effluent release point will be placed past the dilution source near the Unit 2 CW Discharge Isolation Valve. This will prevent further input of borated water into the tunnel. This will also allow additional time to release the borated water currently in the tunnel to the environment that has not reached the Service Water (SW) dilution point on the west end of the tunnel.

Technical Review Letter TR-002-2015 and 50.59 Screening SCR 2015-008 completes the engineering and licensing justification for this ECN

Reason for Design Change: Change and action required (Provide reason for change, specific actions required, attach supporting documents, as applicable).

Minimize future LRWS effluent from being released to the west end of the discharge tunnel. This will shorten the duration to remove the current LRWS effluent in the tunnel while still meeting the TB demo and tunnel FSS milestones.

INTERFACING COMMENTS by:

Design Group or Discipline	Name of Commenter (Printed)	Signature of Commenter	Date	C or NC
Elect./I&C	N/A			
Mechanical				
Structural	N/A			
Others				
Others				

Engineering Change Notice
(Part 1)

Others				
Prepared by: Lee DuBois Lee DuBois Date: 1-26-15		Reviewed by: L.S. Langdon or NC Date: 01/26/2015		Approved by: Donald E. Reid Date: 1/28/2015
All affected design documents revised by (date): ______ Verified by: ______ Date: ______				

Engineering Change

EC Number : 0000400577 000
tatus/Date : REGISTER 01/12/2015
.acility : ZIN
Type/Sub-type: DCP MOD

Print Date: 02/02/2015

Exelon.

Page: 3 ~~7~~ 11 TSL

EC Title: LRWS RELEASE HOSE EXTENSION FROM U2 TB SW STANDPIPE TO U2 CW DISC
HARGE VALVE HOUSE
TYPE: ECN

Mod Nbr : 400576 KW1: NS KW2: KW3: KW4: KW5:

Master EC :	N	Work Group :		Temporary :	N
Outage :	N	Alert Group:	CFILE	Aprd Reqd Date:	
WO Required :		Image Addr :		Exp Insvc Date:	
Adv Wk Appvd:		Alt Ref. :		Expires On :	
Auto-Advance:	N	Priority :		Auto-Asbuild :	N
Caveat Outst:		Department :		Discipline :	
Resp Engr :	GARY	XXINACTIVE-MACGREGOR			
Location :					

Affected Documents List

Fac	Type	Sub-Type	Document	Sheet	Ops	Rvw	Pri	Inc
ZIN	DWGC		M-31		N	Y		N

Minor Rev: Major Rev: Updt Due:
Title: DIAGRAM OF CIRCULATING WATER PIPING - UNITS 1 & 2

Fac	Type	Sub-Type	Document	Sheet	Ops	Rvw	Pri	Inc
ZIN	DWGC		M-49	1	N	Y		N

Minor Rev: Major Rev: Updt Due:
Title: DIAGRAM OF WASTE DISPOSAL SYSTEM (LIQUID) MONITOR AND DISPOSAL SYSTEM

ECN No.: 400577
Design Change No.: 400576
Page No.: 4 of ~~12~~ 11
TSL

Back-Up Calculation Listing
(Part 2)

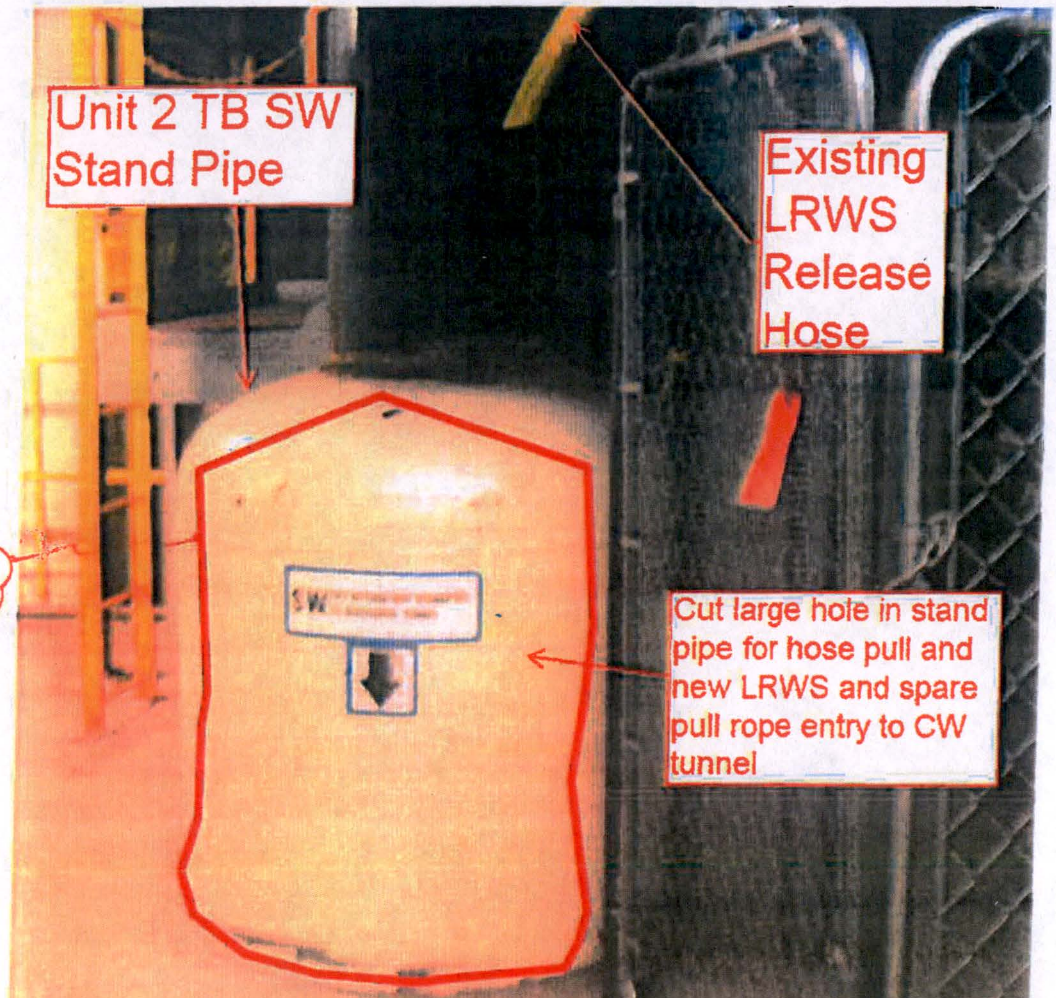
Calculation/Analysis No.	Revision No.	Description
None		

Part 4
Construction Support Information

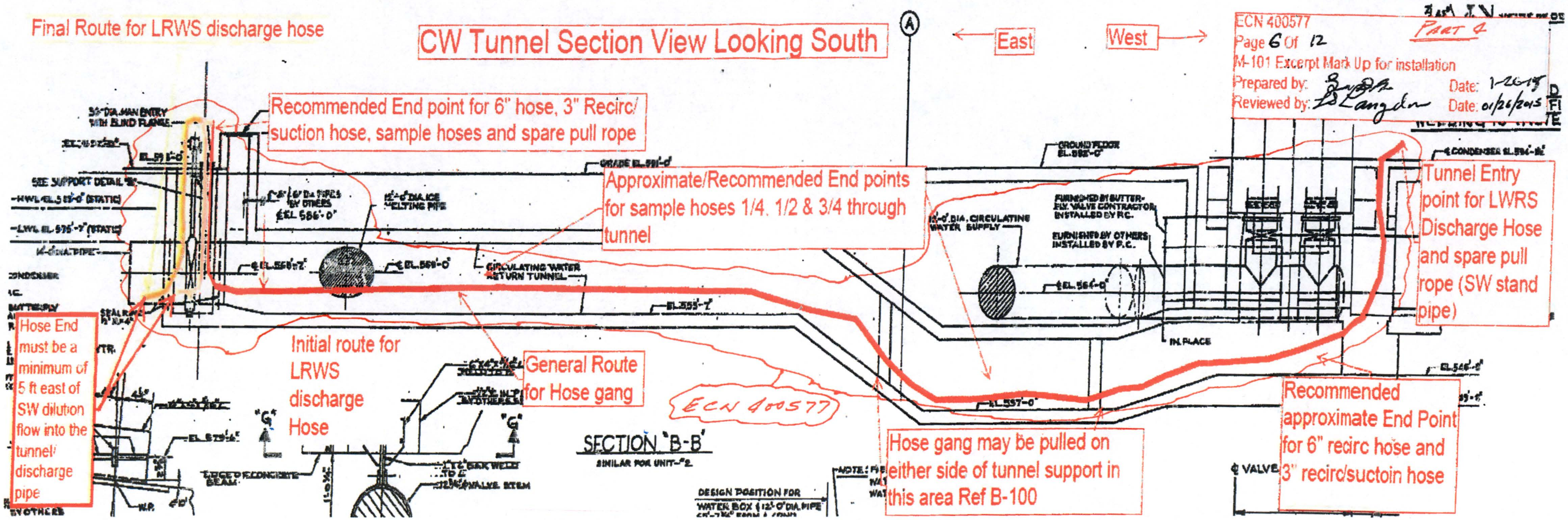
Recommended Installation Steps

1. Prepare for diving activities(i.e. Build Scaffold, Remove grating at air vent on U2 CW Discharge Valve House Vent Shaft, Remove instruments from air vent on U2 CW Discharge Valve House, safety plans, diver retrieval rig, pull rig, lay hose strings out, couple hoses, gang hoes, etc.)
2. Cut hole in U2 SW Stand Pipe per below photo. Field to determine size. Clean up/smooth off edges of hole to prevent damage to hose during pull evolution. Location is Unit 2 Turbine Building 592' Row/Column F-9

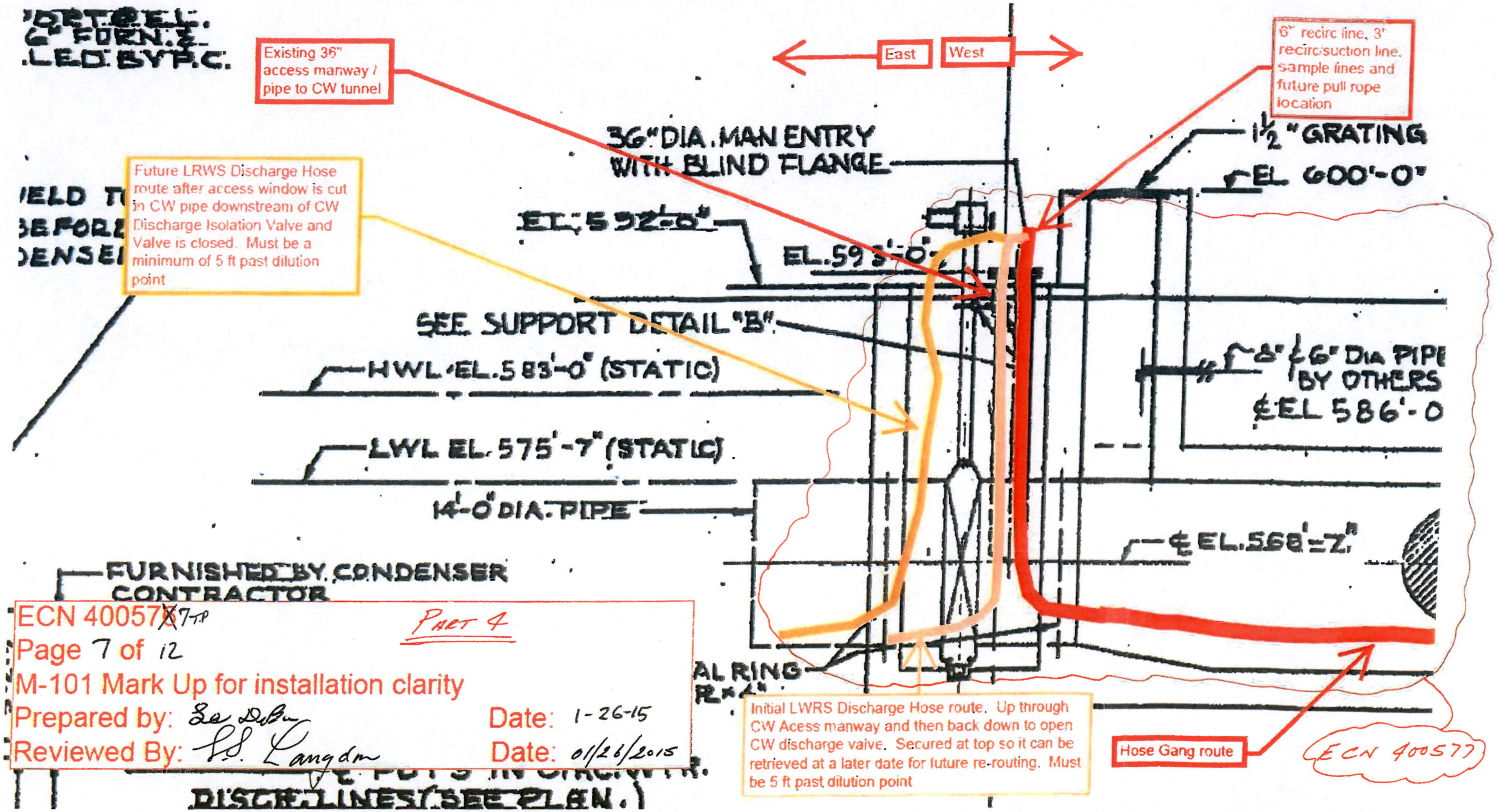
ECN 400577



3. Have diver feed pull rope through the tunnel. Diver will most likely enter the tunnel on the east end of the Unit 2 CW Discharge Tunnel into the air relief shaft.
4. Pull hose gang through the tunnel. Reference Mark ups on M-101, M-49 Sht 1 and M-31. Divers may need to assist in pull.
5. Configure and tie off hoses.
6. For LRWS discharge hose add test ends and perform a hydro or pressure decay test at ~100 psi to verify no leaks.
7. In TB connect LRWS discharge 3" hose to existing 2" LRWS hose.



Final Route for LRWS discharge hose
CW Tunnel Section View Looking South
East
West
ECN 400577
Part 4
Page 6 Of 12
M-101 Excerpt Mark Up for installation
Prepared by:
Date: 1-26-15
Reviewed by:
Date: 01/26/2015
Recommended End point for 6" hose, 3" Recirc/ suction hose, sample hoses and spare pull rope
Approximate/Recommended End points for sample hoses 1/4. 1/2 & 3/4 through tunnel
Tunnel Entry point for LWRS Discharge Hose and spare pull rope (SW stand pipe)
Hose End must be a minimum of 5 ft east of SW dilution flow into the tunnel/ discharge pipe
Initial route for LRWS discharge Hose
General Route for Hose gang
ECN 400577
Hose gang may be pulled on either side of tunnel support in this area Ref B-100
Recommended approximate End Point for 6" recirc hose and 3" recirc/suctoin hose
CIRCULATING WATER RETURN TUNNEL
SECTION "B-B"
SIMILAR FOR UNIT-"2
GROUND FLOOR EL.582'-0"
GRADE EL.581'-0"
EL.586'-0"
EL.555'-7"
EL.557'-0"
EL.564'-0"
EL.546'-0"
IN PLACE
VALVE
DESIGN POSITION FOR WATER BOX
SEE SUPPORT DETAIL
CONDENSER



DET. @ EL.
6" FURN. &
.LED. BYP.C.
Existing 36" access manway / pipe to CW tunnel
East
West
6" recirc line, 3" recirc/suction line, sample lines and future pull rope location
36" DIA. MAN ENTRY WITH BLIND FLANGE
1½" GRATING
EL. 600'-0"
Future LRWS Discharge Hose route after access window is cut in CW pipe downstream of CW Discharge Isolation Valve and Valve is closed. Must be a minimum of 5 ft past dilution point
EL. 592'-0"
EL. 593'-0"
SEE SUPPORT DETAIL "B"
HWL EL. 583'-0" (STATIC)
8" & 6" DIA PIPE BY OTHERS
℄ EL 586'-0
LWL EL. 575'-7" (STATIC)
14'-0" DIA. PIPE
℄ EL. 568'-2"
FURNISHED BY CONDENSER CONTRACTOR
ECN 400577 TP
PART 4
Page 7 of 12
M-101 Mark Up for installation clarity
Prepared by: Date: 1-26-15
Reviewed By: Date: 01/26/2015
AL RING
Initial LWRS Discharge Hose route. Up through CW Acess manway and then back down to open CW discharge valve. Secured at top so it can be retrieved at a later date for future re-routing. Must be 5 ft past dilution point
Hose Gang route
ECN 400577
DISCH. LINES (SEE PLAN.)

Bill Of Material

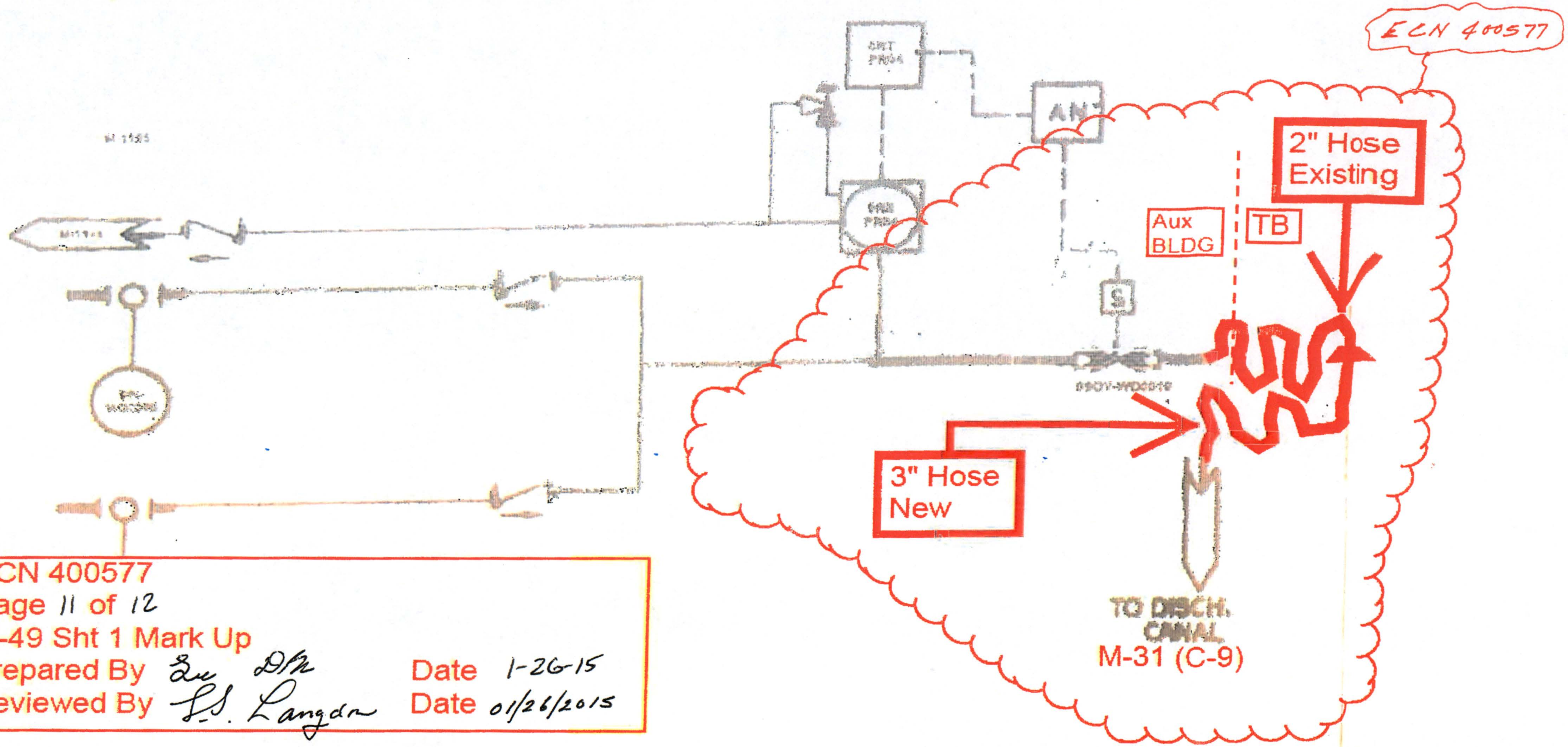
Job Name: _LRWS Hose Extension in U2 CW Tunnel_______________
Requestor: __Stan Mastalerz / Lee DuBois______________
Work Order #: _01801664__________ Purchase Order #: ______________
WBS #: ____________________ Quality Level: __________
Activity #: ________ EC#:__400576 / 400577__________

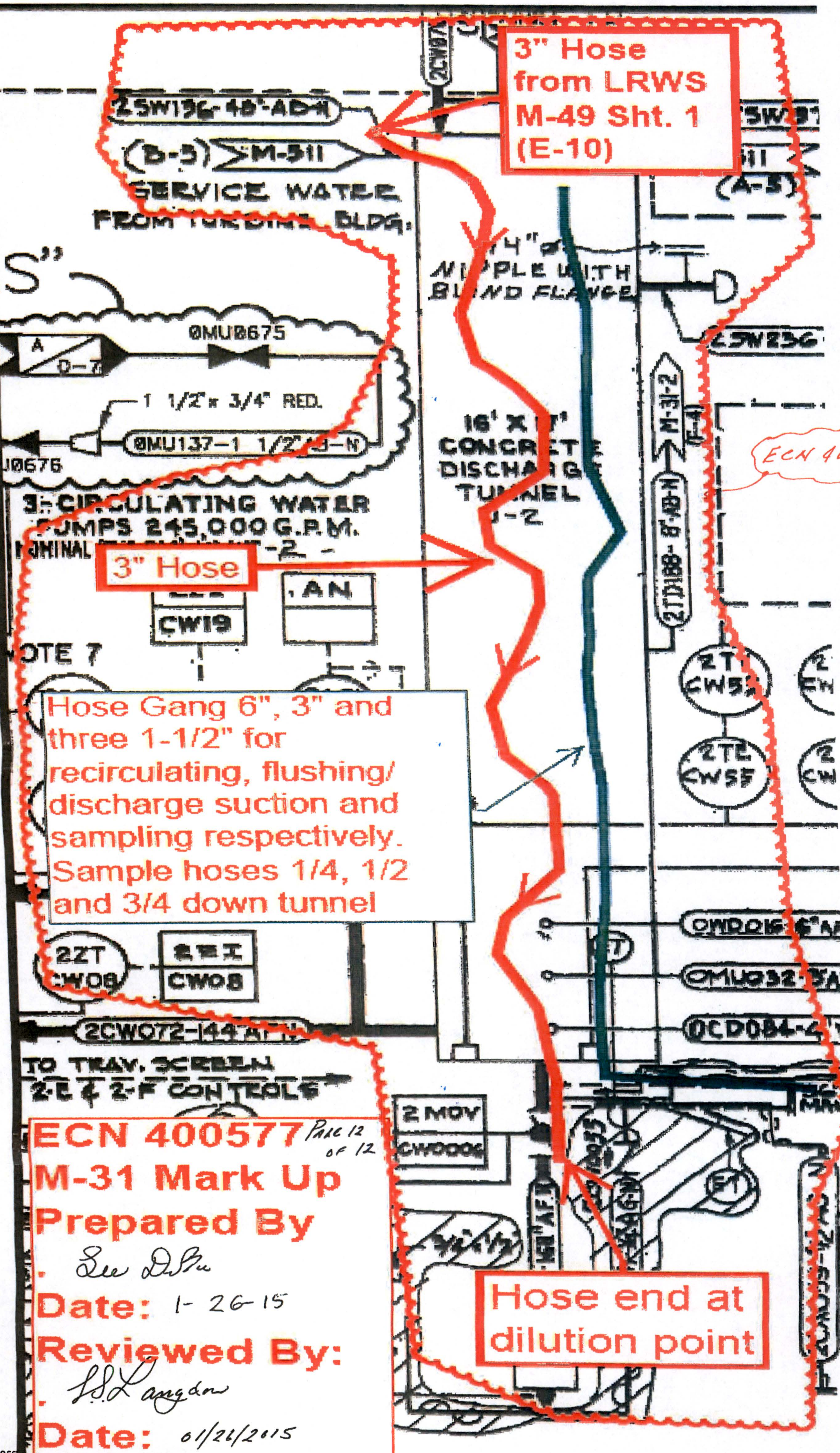
Item Description	Size	Item#	Vendor	Substitute Y/N	QTY	PRICE	COMMENTS
Hose Recirculation, 6" 75 psi minimum working pressure. Goodyear Spiraflex Red Medium Duty	6"	Spiraflex Red Medium Duty	Goodyear	N	500 ft min		May come in shorter lengths, typically 300 ft, this is acceptable.
Hose LRWS Discharge, 3" 100 psi minimum working pressure and vacuum rated. Goodyear Versiflo 150	3"	Versiflo 150	Goodyear	N	600 ft total		May come in shorter lengths, typically 100 ft, this is acceptable
Hose contingency, 3", 100 psi minimum working pressure and vacuum rated. Goodyear Versiflo 150	3"	Versiflo 150	Goodyear	N	600 ft total		May come in shorter lengths, typically 100 ft, this is acceptable
Hose Sample #1, 1-1/4", 100 psi minimum working pressure and vacuum rated, Goodyear Versiflo 150	1-1/4"	Versiflo 150	Goodyear	N	450 ft min		May come in shorter lengths, typically 100 ft, this is acceptable
Hose Sample #2, 1-1/4", 100 psi minimum working pressure and vacuum rated, Goodyear Versiflo 150	1-1/4"	Versiflo 150	Goodyear	N	300 ft min		May come in shorter lengths, typically 100 ft, this is acceptable
Hose Sample #3, 1-1/4", 100 psi minimum working pressure and vacuum rated, Goodyear Versiflo 150	1-1/4"	Versiflo 150	Goodyear	N	150 ft min		May come in shorter lengths, typically 100 ft, this is acceptable
Hose couplings, 6", shank to shank, Brass, Steel or SST 75 psi minimum working pressure.	6"		Mcmaster Carr, Goodyear or similar	Y	2		
Hose couplings, 3", shank to shank, Brass, steel or SST 100 psi minimum working pressure	3"	53605K15 or 53805K67 or 53605K36 or Similar	Mcmaster Carr or similar	Y	10		
Hose Coupling, shank to shank, 1-1/4" Brass, steel or SST 100 psi minimum working pressure	1-1/4"	53605K11 or 53605K64 or 53605K43 or	Mcmaster Carr or	Y	8		

EC 400577 Prepared By: [signature] Date: 1-26-15 Reviewed By: [signature] Date: 01/26/2015

			53605K33 or similar	similar				
	Cam and groove coupling Plug with shank connection, type E. #3 coupling by 2" hose. Brass, Steel or SST 100 psi minimum working pressure	#3 x 2"	52155K146 or Similar	Mcmaster Carr or similar	Y	1		
	Cam and groove hose coupling type C sockets with shank connection 3" hose by #3 coupling with locking levers. Brass, steel or SST. 100 psi minimum working pressure	#3 x 3"	52155K37 or 53015K37 or similar	Mcmaster Carr or similar	Y	1		
2	Low profile Hose Band Clamps/center punch hose clamps ¾" x 7"(min inside diameter) Galvanized carbon steel or SST	¾" x 7"	5655K29 or 5655K49 or 5655K28 or 5655K48 or similar	McMaster Carr or similar	y	100 pieces min		May come in multiple pieces per vendor PN
3	Heavy Duty Ratchet Action Banding tool	14	5657K42 or similar	McMaster Carr or similar	Y			
4	Pull Rope, Low-Stretch Polyester, Minimum strength 4000 lbs. 3/4" Extra-Strength Double Braid or 1" Lightweight Blend or similar	¾" or 1"	3789T19 or 8878T77 or similar	McMaster Carr or similar	Y	600 ft min		
5	Contingency Pull Rope, Low-Stretch Polyester Minimum strength 4000 lbs. ¾" Extra-Strength Double Braid or 1" Lightweight Blend or similar	¾" or 1"	3789T19 or 8878T77 or similar	McMaster Carr or similar		600 ft min		
	Special tooling. Capstan Rope Winch/puller. May be able to rent. Not permanent part of installation. As determined by D&D and dive contractor.	1500 lb pull min			Y	2		
	Misc pull hardware (i.e. hose/cable support grips; Kellem grips, shackles, rope pulleys, etc.). Not part of permanent installation. Not permanent part of installation. As determined by D&D and dive contractor.							

C 400577 Prepared By: [signature] Date: 1-26-15 Reviewed By: S Langan Date: 01/26/2015


ECN 400577
AN
S
Aux BLDG
TB
2" Hose Existing
3" Hose New
TO DISCH. CANAL
M-31 (C-9)
ECN 400577
Page 11 of 12
M-49 Sht 1 Mark Up
Prepared By Lee DB Date 1-26-15
Reviewed By L.S. Langdon Date 01/26/2015


3" Hose from LRWS M-49 Sht. 1 (E-10)
2SW196-10"-AD-H
(B-3) M-511
SERVICE WATER FROM TURBINE BLDG.
4" Ø NIPPLE WITH BLIND FLANGE
2SW236
0MU0675
1 1/2" x 3/4" RED.
0MU137-1 1/2"-AB-N
3-CIRCULATING WATER PUMPS 245,000 G.P.M.
16' X 17' CONCRETE DISCHARGE TUNNEL
M-31-2 (F-4)
2TD188-8"-AB-N
ECN 400577
3" Hose
CW19
NOTE 7
Hose Gang 6", 3" and three 1-1/2" for recirculating, flushing/ discharge suction and sampling respectively. Sample hoses 1/4, 1/2 and 3/4 down tunnel
2ZT CW08
CW08
0WD016-6"
0MU032
0CD084-4
2CW072-144"
TO TRAV. SCREEN 2-E & 2-F CONTROLS
2 MOV CW006
Hose end at dilution point
ECN 400577 Page 12 of 12
M-31 Mark Up
Prepared By
Lee DeBu
Date: 1-26-15
Reviewed By:
L.S. Langdon
Date: 01/26/2015

January 26, 2015
In reply refer to CZE-15-001

To: Anthony Orawiec

Subject: Zion Station, Unit 2 and Common
Exempt Change No. 400576
Liquid Radioactive Waste System (LRWS) Release Hose Extension from Unit 2 (U2) Turbine Building(TB) Service Water(SW) Standpipe to U2 Circulating Water(CW) Discharge Valve House

The Engineering Department has reviewed the subject Exempt Change in accordance with ZAP 510-02C and the applicable Zion Solution Quality Requirements. The applicable Design Input Requirements are discussed in this letter.

System Code: WD, SW, CW

Issue

LRWS effluent has been discharged into the Unit 2 (U2) CW Discharge Tunnel on the west end of the tunnel. The discharged effluent has boron in it. The Environmental Protection Agency National Pollutant Discharge Elimination System (NPDES) Permit has a limit of 1 part per million (PPM) of boron for lake discharge. The current LRWS effluent release point on the west end of the U2 CW has added borated water to the U2 CW Discharge Tunnel that will need to be diluted prior to release to the lake. The current release point does not support the D&D schedule if the effluent discharge point remains on the west end of the tunnel due to the increased time for releasing borated water in the tunnel. The milestone for isolating the U2 CW Discharge Tunnel outlet Isolation valve is 1/1/2016.

Resolution

To minimize the further addition of LRWS effluent into the Unit 2 CW Discharge Tunnel extend the LRWS effluent discharge hose from the west end of the tunnel and route it to the east end of the tunnel. The hose extension will be routed in the U2 CW Discharge Tunnel and the effluent release point will be placed past the dilution source near the U2 CW Discharge Isolation Valve. This will minimize future LRWS effluent from being released to the U2 CW Discharge Tunnel. This will shorten the duration to remove the current LRWS effluent in the tunnel while still meeting the TB demo and tunnel FSS milestones.

Description of Change:

This exempt change will extend the LRWS effluent discharge hose from the west end of the U2 CW Discharge Tunnel to the east end of the U2 CW Discharge Tunnel. This will place the LRWS release location past the dilution source flow therefore reducing the probability LRWS effluent from entering

the U2 CW Discharge Tunnel. Contingency hoses and pull rope will also be installed for future use if required.

Exempt Change Design Package:

The design for this exempt change will be contained in ECN 400577 and is issued "For Construction" by this letter.

10 CFR 50.59 Evaluation / Decommissioning Impact Evaluation:

A 10 CFR 50.59 Evaluation was performed in accordance with ZAP 100-06 and is being transmitted along with this letter. This activity can be implemented without prior NRC approval.
A Decommissioning Impact Evaluation was performed; and it concluded that the proposed activity is not restricted by 10 CFR 50.82.

DSAR / ODCM Impact Review:

DSAR Chapters 1 through 6 was reviewed for this exempt change. There is no impact on the DSAR. ODCM Chapters 10 and 12 were reviewed for this exempt change. There is no impact on the ODCM.

Applicable Codes and Standards:

This exempt change shall be installed in accordance with Zion Specification X-3646, which is the general work specification for mechanical work; as well as applicable site, vendor, and corporate procedures. Installation requirements identified in ECN 400577 supersede Specification X-3646 specifications. Alternate materials and standards are allowed per ECN 400577 and are justified in TR-002-2015

Installation Schedule / Outage Requirements:

Installation of this exempt change does NOT require an outage; and therefore will be scheduled via the site work schedule process.

Technical Specification Changes:

The existing Technical Specifications do not require revisions as a result of this exempt change.

ODCM Changes:
The existing ODCM does not require revisions as a result of this exempt change.

ALARA / Fire Protection Review:

This exempt change is not being performed in a radiological area. An RWP will not be required for this exempt change.

There are minimal additional combustibles being added. The combustibles being added are mainly located under water. As such there is no impact on the Fire Protection Report.

Impact of Pending Modifications or Temporary Alterations:

There are no other pending design changes that are impacted by this installation. There are no pending changes against affected design drawings that have an impact on this activity.

Other Considerations

Engineering considerations are documented in TR-002-2015 and are found to be acceptable.

Construction Drawings:

Construction is authorized to proceed in accordance with ECN 400577.

Identification of the Installer:

D & D will perform this exempt change. D&D will have to contract for diving services to perform diving activities.

Operating Procedures:

No changes are required to existing Operating Procedures. No new Operation Procedures are required.

Training Requirements:

None

Testing Requirements:

A functional leak check should be performed to verify system tightness for portions of the new hoses outside of the U2 CW Discharge Tunnel. This may be completed with a leak check or a hydro. A hydro pressure of 100 psi is acceptable.

Operating Requirements:

None

Technical Review:

The LRWS and WD system is Important to the Defueled Condition (ITDC); therefore this modification is subject to a Technical Review in accordance with the requirements of ZAP 500-08 and the ZNPS A Technical Review was completed under TR-002-2015 and found to be acceptable.

If there are any questions or comments regarding this Exempt Change, please contact Lee DuBois at 224-789-4065.

Prepared By: Lee DuBois Date: 1-26-15
Lee DuBois
D & D Project Engineering

Approved By: Donald F. Roth Date: 1/28/2015
Donald F. Roth
D & D Engineering Supervisor

cc:

	MAL	ECN	50.59
Central File	1	1	1
Tara Pratt	original	original	original
Work Planning	2	2	2
Tony Orawiec	1	1	1

TECHNICAL REVIEW LETTER

TR-002-2015

To: Anthony Orawiec
Decommissioning Plant Manager
Zion Station

Subject: Extending Liquid Radioactive Waste System (LRWS) discharge hose from west end of Unit 2 (U2) CW Discharge Tunnel to the east end of the U2 CW Discharge Tunnel.

The purpose of this letter is to document the Technical Review of the Design Change Package for Exempt Change EC # 400576 and associated ECN 400577.

Summary:

This Exempt Change provides the details for the following:

1. Extends the existing LRWS discharge 2" hose with a 3" hose extension from west end of the Unit 2 CW Discharge Tunnel to the East end of the U2 CW Discharge Tunnel.
2. Install contingency hoses for sampling and recirculation of the U2 CW Discharge Tunnel. A 6" hose will be installed as a recirculation hose. Install a 3" hose that could be used as a flush/recirculation or west end suction release hose. Install three 1-1/4" hoses that could be used to sample the tunnel.
3. Install a contingency pulling rope if additional hoses need to be pulled into the tunnel in the future.

There are multiple design considerations not covered under other modification documentation.

Mechanical Design Considerations

The design flow rate needs to be determined as well as the hose length and size.

Hose lengths-

324 ft horizontal Center Line (CL) of outlet water box to CW discharge house Ref M-100
27 ft horizontal CL outlet water box to west standpipe. Ref B-100
110 Ft vertical down then vertical up, 2 x (592' TB elev – 537' tunnel bottom) Ref M-101
50 ft additional hose to allow routing out of CW discharge house manway into CW discharge valve vault (contingency length)
200 ft from Unit 1 LRWS pump discharge to U1 LRWS pump discharge to west CW stand pipe. Estimate based on M-100

600 ft (new hose)

800 ft (for hose sizing evaluation purposes)

Flow rate sizing for LRWS

The allowable release rate determines flow rates.

Maximum Flow Rate

The boron release rate is much lower than the radioactivity release rate so it is the driving factor.
The allowable release rate is determined via 1ppm boron at the outfall.
Unit 1 cavity water is at ~356 ppm 12-18-14 analysis value
SFP boron concentration is > 2000 ppm
Assume 12,000 gpm Service Water (SW) Dilution Pump
Release rate can be up to 34 gpm of borated water.
Size hose for 35 gpm

Hose Sizing for LRWS Discharge

At 35 gpm the LRWS lake discharge pump has 110 ft of head or 47 psig

Hose losses at 35 gpm per 100 ft of hose (Goodyear tables)

2"	1.18 psi	2.7 ft
2-1/2"	0.40 psi	0.9 ft
3"	0.17 psi	0.4 ft

Loss at 800 ft of hose for only the hose at 35 gpm

2"	22 ft
2-1/2"	7 ft
3"	3 ft

To account for other fittings (valves, flow meters, pipe fittings) conservatively double the pressure loss from the hose

2"	44 ft
2-1/2"	14 ft
3"	6 ft

Recommend using 3" hose. Reason is for contingency we may need to re-circulate the tunnel; a 3" hose will allow faster recirculation.

Hose pressure rating for LRWS Discharge

This hose will be in the tunnel and protected by the tunnel from personnel, equipment and incidental contact. The rating on the hose needs to be a minimum of the pump dead head rating for industrial safety concerns just in case the hose is blocked or crimped. Pump dead head rating is 110 ft. The static head from the top of the tank to the bottom of the tunnel is 80 ft (top of tank conservatively assume 617' – 537' bottom of drained tunnel M-101). Total static head is 190 ft or 83 psi. Hoses typically have a

burst pressure of 3 times the operating pressure rating (Ref Goodyear www site). Recommend a hose rating of 100 psig minimum.

Hoses currently being used on site per walkdown:

Manufacturer	Model	Pressure(PSI)(3")	Vacuum(in HG)	Weight/ft(3")
Goodyear	Con-Ag	100	N/A	1.76
Goodyear	Versiflo	150	29	1.44
Goodyear	Plicord	150	N/A	1.37
Goodyear	Gorilla	500 (2" max size)	N/A	1.22

Utilize Goodyear VersiFlo. This hose meets the pressure rating. This hose also meets a vacuum rating as a contingency to re-purpose the hose to re-circulate and/or dilute the CW tunnel in the future. All fittings need to be rated for a minimum of 100 psi working pressure.

Contingency hoses

An additional 3" Versiflo contingency hose should be pulled into the tunnel. This hose may be used for dilution source from the east side of the site via the SW dilution pump tap valve. The current SW dilution pump could be used to supply water via this hose. This will allow the removal of water from west to east when a LRWS discharge in not in progress. The hose could also be used for recirculation, sampling or as a discharge source on the west end of the tunnel if they wanted to place a pump on the east side of the site allowing less interferences for other D&D activities. If using this hose from the existing SW dilution pump then a flow meter shall be installed to limit the flow to allowed discharge rates per the LWRS. Because this hose could be used in a pump discharge or suction condition the Versiflo hose is recommended.

As a contingency for future tunnel recirculation install a 6" hose. The hose will only be used for recirculation so the recommended hose is a Goodyear Spiraflex Red (medium duty). This hose is rated for 100 psi working pressure. Referencing Goodyear hose pressure loss table a 6" hose has a head loss of 0.79 psi per 100 ft at 500 gpm. For a conservative 600 ft hose run in the tunnel the loss would be approximately 5 psi or 11 ft of head. Based on review of typical 4-6" de-watering pumps (i.e. Flygt) we should be able to obtain a minimum of 500 gpm recirculation. The tunnel conservatively has 800,000 gallons of holding capacity; at 500 gpm the tunnel turn over time is approximately 27 hours. The hose fittings need to be rated for a minimum of 50 psi.

As a contingency for water sampling at intermediate tunnel locations; utilize 1-1/4" Goodyear Versiflo hose because it has a vacuum rating. The vacuum rating will allow it to be utilized on sample pump suction(s). As a sampling contingency up to 3 sample hoses at approximately 25%, 50% and 75% down the tunnel length. A minimum of 1 sample hose at approximately 50% down the tunnel should be run. Do to the potential to process water out of the tunnel after access to the TB is not available the sample hoses should be pulled above grade on the east end of the tunnel.

As a contingency an extra pull rope should also be routed through the tunnel and staged for future use. The pull ropes should be tied off on each end for future access.

In conclusion, the proposed Exempt Change does not affect the design or the design function of the WD System; as well, the proposed Exempt Change does not affect the ability of the LRWS to perform that design function.

Prepared By: Lee DuBois Lee DuBois Date: 01/26/2015

Required Review Disciplines: A, D, F, G Donald F. Roth
Engineering Supervisor

Qualified Technical Reviews

Signature	Discipline	Date
[illegible]	A, D, F	1-26-15
Thomas S. Langdon	A, G	January 26, 2015

I Concur and Approve: [illegible]
Decommissioning Plant Manager
Date: 1/29/15

Distribution:

Decommissioning Plant Manager
Operations Supervisor
Engineering Supervisor
SRC Coordinator
Master File

Supporting Vendor Data

GENERAL INFORMATION

FLOW DATA (continued)

WATER FLOW PRESSURE LOSS (PSI per 100 feet of hose)

Flow of water in U.S. gal. per min.	Flow of water in cu. feet per sec.	Actual Internal Diameter, Inches ½	⅝	¾	1	1¼	1½	2	2½	3
0.5	.001	0.4								
1.5	.003	3.32	1.31	0.42						
2.5	.005	7.75	2.58	1.08						
5	.011	27.8	9.27	3.85	0.95	0.32	0.13			
10	.022	99.5	33.2	13.8	3.38	1.14	0.47	0.12		
15	.033		71.0	29.5	7.25	2.45	1.01	0.25	0.08	
20	.044		121.0	50.3	12.4	4.25	1.71	0.42	0.14	
25	.055			75.5	18.7	6.34	2.60	0.64	0.22	
30	.066			105.0	26.1	8.95	3.58	0.90	0.30	0.12
35	.077			142.0	34.6	11.5	4.83	1.18	0.40	0.17
40	.085				44.7	15.1	6.20	1.52	0.51	0.21
45	.099				55.0	18.5	7.65	1.87	0.63	0.26
50	.110				67.5	22.8	9.35	2.28	0.78	0.32
60	.132				94.3	31.8	13.1	3.19	1.08	0.45
70	.154				126.0	42.5	17.5	4.25	1.44	0.60
80	.175					54.6	22.5	5.48	1.86	0.77
90	.198					67.5	27.8	6.80	2.30	0.95
100	.223					81.5	33.5	8.15	2.76	1.15
125	.278					124.0	50.6	12.4	4.20	1.72
150	.334						72.1	17.6	5.97	2.46
175	.390						94.5	23.1	7.83	3.22
200	.446						122.0	29.6	10.1	4.15
225	.501							36.8	12.5	5.15
250	.557							44.6	15.2	6.28
275	.613							53.3	18.1	7.45
300	.668							62.5	21.2	8.75
325	.724							72.6	24.5	10.2
350	.780							83.2	28.2	11.7
375	.836							94.5	32.1	13.3
400	.891							107.0	36.2	14.9
450	1.00								44.9	18.6
500	1.11								54.5	22.5
600	1.34								76.5	31.6
700	1.56								102.0	42.1
800	1.78								131.0	53.9
900	2.00									66.8
1000	2.23									81.4
1100	2.45									97.0
1200	2.67									114.0
1300	2.90									132.0
1400	3.12									
1500	3.34									
1600	3.56									
1800	4.01									
2000	4.45									

Note. The pressure loss experienced by a liquid flowing through a hose depends on the rate of flow, the viscosity of the liquid, the hose I.D., the smoothness of the tube and the hose length. This chart shows the relationship between rate of flow, I.D., and pressure loss for water at 68°F with a viscosity of one centipoise. The pressure is directly proportional to the length of the hose, therefore, the data shown can be easily extended by use of proportions, e.g., the pressure drop for 50 feet of hose length is half that for 100 feet.

GOODYEAR
ENGINEERED PRODUCTS

SPIRAFLEX® RED
MEDIUM DUTY

Product Specifications

APPLICATION: For medium-duty discharge applications in mining, construction, industry, agriculture and marine service. Limited oil and chemical application.

CONSTRUCTION TUBE: Black Pliovic® /Nitrile rubber tube

COVER: Red Pliovic, MSHA 2G-14C/16

REINFORCEMENT: Spiral synthetic yarn, one layer longitudinal synthetic yarn

TEMPERATURE: -10°F to 150°F (-23°C to 65°C)

PACKAGING: 300' continuous one piece, coiled and banded

BRANDING: Example: Goodyear® Spiraflex® Red 2" (50.8 mm) 150 psi WP (1.00 Mpa), Flame Resistant, USMSHA 2G-14C/16. Made in USA

COUPLINGS: Contact fitting manufacturer for proper fitting recommendation and coupling procedure.

NON-STOCK/SIZES: For special production run minimum requirements, see Appendix D.

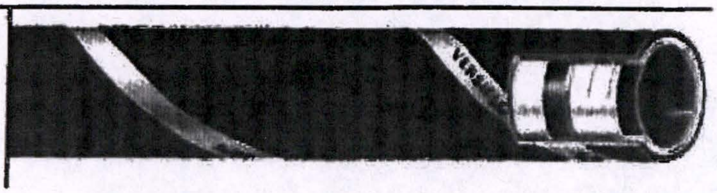
ORDER CODES: 537-521

SPIRAFLEX® RED MEDIUM DUTY

ID		NOM. OD		MAX. WP		WEIGHT	
in.	mm.	in.	mm.	psi	Mpa	lb./ft.	kg./m.
1½	38.1	1.71	43.4	150	1.03	0.23	0.34
2	50.8	2.24	56.9	150	1.03	0.36	0.54
2½	63.5	2.79	70.9	150	1.03	0.41	0.61
3	76.2	3.29	83.6	125	0.86	0.46	0.68
4	101.6	4.32	109.7	100	0.69	0.73	1.09
6	152.4	6.40	162.6	100	0.69	1.18	1.76

Note: Working pressures are rated at 72°F.

VERSIFLO® 150 WATER S&D



Product Specifications

APPLICATION: General-purpose water suction and discharge for medium- to heavy-duty applications. Can be used in Lasso® applications.

CONSTRUCTION

TUBE: Black Versigard® synthetic rubber

COVER: Black Versigard synthetic rubber (wrapped finish)

REINFORCEMENT: Plies of synthetic fabric with wire helix

TEMPERATURE: -25°F to 200°F (-32°C to 93°C)

PACKAGING: 542-528 100' lengths, coiled and polywrapped
541-528 custom lengths

BRANDING (SPIRAL): Example. Goodyear® Versiflo® 150 Water Suction & Discharge

COUPLINGS: Contact fitting manufacturer for proper fitting recommendation and coupling procedure.

NON-STOCK/SIZES: For special production run minimum requirements, see Appendix D.

ORDER CODES: 542-528 (1 1/4"–6") 541-528 (8"- 14")

VERSIFLO® 150 WATER S&D

ID		NOM. OD		MAX. WP		BEND RADIUS		VACUUM HG		WEIGHT	
in.	mm.	in.	mm.	psi	Mpa	in.	mm.	in.	mm.	lb./ft.	kg./m.
1¼	31.8	1.63	41.4	150	1.03	4	102	29	737	0.53	0.79
1½	38.1	1.87	47.5	150	1.03	4	102	29	737	0.65	0.97
2	50.8	2.39	60.7	150	1.03	7	178	29	737	0.87	1.29
2½	63.5	2.89	73.4	150	1.03	10	254	29	737	1.08	1.61
3	76.2	3.42	86.9	150	1.03	14	356	29	737	1.44	2.14
4	101.6	4.45	113.0	150	1.03	18	457	29	737	2.00	2.98
6	152.4	6.00	167.6	150	1.03	24	610	29	737	4.56	6.79
8	203.0	8.75	238.0	150	1.03	48	1200	29	737	7.40	11.00
10	254.0	10.96	278.0	150	1.03	60	1500	29	737	12.20	18.20
12	305.0	13.23	336.0	150	1.03	72	1800	29	737	18.70	27.90
14	408.0	15.57	396.0	150	1.03	84	2100	29	737	25.10	37.40

ATTACHMENT E: 50.59 APPLICABILITY REVIEW FORM

Activity/Document Number: EC 400576 and ECN 400577 **Revision Number:** 0

Address the questions below for all aspects of the Activity. If the answer is yes for any portion of the Activity, apply the identified process(es) to that portion of the Activity. Note that it is not unusual to have more than one process apply to a given Activity. See Section 4 of the Resource Manual (RM) for additional guidance.

I.	Does the proposed Activity involve a change:		
	1. Technical Specifications or Operating License (10CFR50.90)?	_X_ NO __ YES	See Section 4.2.1.1 of the RM
	2. Conditions of License Quality Assurance program (10CFR50.54(a))? Security Plan (10CFR50.54(p))? Emergency Plan (10CFR50.54(q))?	 _X_ NO __ YES _X_ NO __ YES _X_ NO __ YES	See Section 4.2.1.2 of the RM
	3. Specific Exemptions (10CFR50.12)?	_X_ NO __ YES	See Section 4.2.1.5 of the RM
	4. Radiation Protection Program (10CFR20)?	_X_ NO __ YES	See Section 4.2.1.6 of the RM
	5. Fire Protection Program (applicable UFSAR or operating license condition)?	_X_ NO __ YES	See Section 4.2.1.7 of the RM
	6. Programs controlled by the Operating License or the Technical Specifications (such as the ODCM).	_X_ NO __ YES	See Section 4.2.1.7 of the RM
	7. Environmental Protection Program	_X_ NO __ YES	See Section 4.2.1.7 of the RM
	8. Other programs controlled by other regulations.	_X_ NO __ YES	See Section 4.2.1 of the RM
II.	Does the proposed Activity involve maintenance which restores SSCs to their original condition or involve a temporary alteration supporting maintenance that will be in effect during at-power operations for 90 days or less?	_X_ NO __ YES	See Section 4.2.2 of the RM
III.	Does the proposed Activity involve a change to the:		
	1. UFSAR (including documents incorporated by reference) that is excluded from the requirement to perform a 50.59 Review by NEI 96-07 or NEI 98-03?	_X_ NO __ YES	See Section 4.2.3 of the RM
	2. Managerial or administrative procedures governing the conduct of facility operations	_X_ NO __ YES	See Section 4.2.4 of the RM
	3. Procedures for performing maintenance activities (subject to 10 CFR 50.65(a)(4))?	_X_ NO __ YES	See Section 4.2.4 of the RM
	4. Regulatory commitment not covered by another regulation based change process (see NEI 99-04)?	_X_ NO __ YES	See Section 4.2.3/4.2.4 of the RM
IV.	Does the proposed Activity involve a change to the Independent Spent Fuel Storage Installation (ISFSI) (subject to control by 10 CFR 72.48)	_X_ NO __ YES	See Section 4.2.6 of the RM
V.	Does the proposed Activity involve a change to the Packaging & Transportation of Radioactive Material? (subject to control by 10CFR71)	_X_ NO __ YES	
Vi.	Is the proposed activity a Decommissioning Activity that does NOT require a 50.59 Screening, as described in Attachment 1 of ZS-EG-100?	_X_ NO __ YES	

Check one of the following:

☐ If all aspects of the Activity are controlled by one or more of the above processes, then a 50.59 Screening is not required and the Activity may be implemented in accordance with its governing procedure.

X If any portion of the Activity is **not** controlled by one or more of the above processes, then process a 50.59 Screening for the portion not covered by any of the above processes. The remaining portion of the activity should be implemented in accordance with its governing procedure.

his Exempt Change affects systems discussed in the DSAR that are Important to Defueled Condition. **Signoff:**

50.59 Screener/50.59 Evaluator: Thomas S. Langdon Sign: Thomas S. Langdon Date: 01/26/2015
(Circle One) (Print name) (Signature)

ATTACHMENT D: 50.59 REVIEW COVERSHEET FORM

Station: Zion

Activity/Document Number: EC 400576 and associated ECN 400577 **Revision Number:** 0

Title: Liquid Radioactive Waste System (LRWS) effluent discharge hose extension in Unit 2 Circulating Water Discharge Tunnel.

NOTE: For 50.59 Evaluations, information on this form will provide the basis for preparing the biennial summary report submitted to the NRC in accordance with the requirements of 10 CFR 50.59(d)(2).

Description of Activity:
(Provide a brief, concise description of what the proposed activity involves.)

To minimize the further addition of LRWS effluent into the Unit 2 CW Discharge Tunnel extend the LRWS effluent discharge hose from the west end of the tunnel and route it to the east end of the tunnel. The hose extension will be routed in the U2 CW Discharge Tunnel and the effluent release point will be placed past the dilution source near the U2 CW Discharge Isolation Valve. This will minimize future LRWS effluent from being released to the U2 CW Discharge Tunnel. This will shorten the duration to remove the current LRWS effluent in the tunnel while still meeting the TB demo and tunnel FSS milestones.

on for Activity:
cuss why the proposed activity is being performed.)

Minimize LRWS effluent being deposited in the U2 CW Discharge Tunnel.

ffect of Activity:
Discuss how the activity impacts plant operations, design bases, or safety analyses described in the UFSAR.)

his activity does not change any descriptions in the DSAR and ODCM.

ummary of Conclusion for the Activity's 50.59 Review:
Provide justification for the conclusion, including sufficient detail to recognize and understand the essential arguments leading the conclusion. Provide more than a simple statement that a 50.59 Screening, 50.59 Evaluation, or a License Amendment equest, as applicable, is not required.)

50.59 Screening will be required because the LRWS is described in the DSAR.

tachments:
tach all 50.59 Review forms completed, as appropriate.
OTE: if both a Screening and Evaluation are completed, no Screening No. is required.)

rms Attached: (Check all that apply.)

	Applicability Review				
X	**50.59 Screening**	**50.59 Screening No.**	2015-008	**Rev.**	0
	50.59 Evaluation	**50.59 Evaluation No.**		**Rev.**	

ATTACHMENT F: 50.59 SCREENING FORM

50.59 Screening No. __2015-008__ **Rev. No.** __0__

Activity/Document Number: Exempt Change EC 400576 and ECN 400577 **Revision Number:** __0__

I. **50.59 Screening Questions** (Check correct response and provide separate written response providing the basis for the answer to each question) (See Section 5 of the Resource Manual (RM) for additional guidance):

1. Does the proposed Activity involve a change to an SSC that adversely affects an UFSAR described design function? (See Section 5.2.2.1 of the RM) ___ YES _X_ NO

   The relocation LRWS discharge point is within the licensing basis design function as described in the DSAR section 4.5.2 and Figure 4-1

   The ODCM Section 10.2 does not describe where within the CW tunnel the LRWS discharges. The ODCM refers to the DSAR.

   The LRWS is not discussed in the Technical Specifications.

   Design Basis (LRWS excerpt from DSAR 4.5.2)
   The Liquid Waste Systems are designed to collect, store, process, monitor, and dispose of liquid radioactive waste from the station. The principle design criteria for the Liquid Waste Systems are as follows:
   1. Ensure that the quantities of radioactive waste discharged from the plant during decommissioning are as low as practicable and, in any event, well within the allowable concentration limits; and
   2. Limit the inadvertent release of radioactive material from the plant so that the resulting radiation exposure to the public is as low as practicable and, in any event, well within the allowable concentration limits.
   The allowable concentration limits described above are defined as 10 times 10CFR20 limits for batch releases from the Lake Release Tanks (Boric Acid Tanks)..

2. Does the proposed Activity involve a change to a procedure that adversely affects how UFSAR described SSC design functions are performed or controlled? (See Section 5.2.2.2 of the RM) ___ YES _X_ NO

   There are no procedures that are affected by the re-route of the hoses.

3. Does the proposed Activity involve an adverse change to an element of a UFSAR described evaluation methodology, or use of an alternative evaluation methodology, that is used in establishing the design bases or used in the safety analyses? (See Section 5.2.2.3 of the RM) ___ YES _X_ NO

   DSAR Section 4.5.2 does not identify any methods of evaluation. Chapter 5 accidents do not identify a LRWS release or spill as an accident that is evaluated. No methods of evaluation are changed.

4. Does the proposed Activity involve a test or experiment not described in the UFSAR, where an SSC is utilized or controlled in a manner that is outside the reference bounds of the design for that SSC or is inconsistent with analyses or descriptions in the UFSAR? (See Section 5.2.2.4 of the RM) ___ YES _X_ NO

   The proposed activity does not involve an experiment or a test.

5. Does the proposed Activity require a change in the Technical Specifications or Operating License? (See Section 5.2.2.5 of the RM) ___ YES _X_ NO

   This proposed activity does not involve a change to the Operating License or Tech Specs.

II. List the documents (e.g., UFSAR, Technical Specifications, other licensing basis, technical, commitments, etc.) reviewed, including sections numbers where relevant information was found (if not identified in the response to each question).

DSAR Chapters 4 and 5
ODCM Section 10.2

III. Select the appropriate conditions:

X	If all questions are answered NO, then complete the 50.59 Screening and implement the Activity per the applicable governing procedure.
	If question 1, 2, 3, or 4 is answered YES and question 5 is answered NO, then a 50.59 Evaluation shall be performed.
	If questions 1, 2, 3, and 4 are answered NO and question 5 is answered YES, then a License Amendment is required prior to implementation of the Activity.
	If question 5 is answered YES for any portion of an Activity, then a License Amendment is required prior to implementation of that portion of the Activity. In addition, if question 1, 2, 3, or 4 is answered YES for the remaining portions of the Activity, then a 50.59 Evaluation shall be performed for the remaining portions of the Activity.

IV. Screening Signoffs:

50.59 Screener: THOMAS S. LANGDON (Print name) Sign: Thomas S Langdon (Signature) Date: 01/26/2015

50.59 Reviewer: DONALD F ROTH (Print name) Sign: Donald F Roth (Signature) Date: 1/28/2015

ATTACHMENT A

DECOMMISSIONING IMPACT EVALUATION

Activity: Exempt Change 400576; Extension of LRWS Discharge Hose from West End of Unit 2 CW Tunnel to East End. ECN 400577

(Work Order No., Procedure No., On Site Review No., Design Change No., etc)
TRACKING #: 50.59 Screening 2015-008

1. Does the proposed decommissioning activity result in any of the following:

   a. Foreclose the release of the site for possible unrestricted use;

   [ ] YES [x] NO

   Provide justification:
   The proposed activity does not increase the potential for the spread of radioactive contamination. The controls in place for the LRWS discharges cover this control. The proposed activity will not change the design function of the LRWS as discussed in the DSAR; and the LWRS will still be capable of performing its DSAR design function.

   b. Result in significant environmental impacts not previously reviewed;
   [ ] YES [x] NO

   Provide justification:
   All of the work associated with the proposed activity will be performed within the requirements of the DSAR and the NPDES permit.

   c. Result in there no longer being reasonable assurance that adequate funds will be available for decommissioning.

   [ ] YES [x] NO

   Provide justification:
   The proposed activity is regarded as a minor design change; and does not adversely impact the budget. The proposed activity will be funded by the decommissioning trust fund.

ATTACHMENT A
DECOMMISSIONING IMPACT EVALUATION
(Continued)

Activity: Exempt Change 400576; Extension of LRWS Discharge Hose from West End of Unit 2 CW Tunnel to East End

2. Review the answers to Step 1.a-c. If the answer to any of the questions is YES, Then the activity can NOT be completed, without prior notification to the NRC.

> **NOTE**
>
> In taking actions permitted under 10CFR50.59 following submittal of the PSDAR, the licensee may perform activities inconsistent with the PSDAR, including significant schedule changes or significant cost increases, provided prior written notification is made to the NRC, as well as a copy of the notification to the State of Illinois.

3. Is this activity inconsistent with those actions described in the Post-Shutdown Decommissioning Activities Report or cause a significant schedule change or cost increase?

   [ ] YES [x] NO

   If the answer is YES, Then notify the NRC and the State of Illinois prior to performing the activity.

   If the answer is NO, Then proceed without notification.

   Provide justification:
   This exempt change is a minor design change activity that does not conflict with any of the information provided in the DSAR. It has no impact on the decommissioning trust fund.

   Implement Changes – Based on this evaluation, I have determined that the proposed activity is not restricted by 10 CFR 50.82.

   Preparer print name: THOMAS S. LANGDON Discipline: A, G

   Thomas S. Langdon — JANUARY 26, 2015
   Preparer Signature — Date

4. Review – The reviewer agrees that the proposed activity is not restricted by 10 CFR 50.82.

   Reviewer print name: DONALD F ROTH Discipline: A, G

   Donald F. Roth — 1/28/2015
   Reviewer Signature — Date

ATTACHMENT 3

ECN# 400657

Installing additional liquid effluent discharge flowmeters

Exhibit A
NEP-08-01
Revision 1

Engineering Change Notice
(Part 1)

ECN No. 400657
Page: 1 of 13

ISSUANCE: ☒ FOR CONSTRUCTION ☐ FOR COMMENT

Station: ZION Affected Unit: 00 Changes to a previously Approved ECN ☒	☐ Safety Related ☒ Non-Safety Related ☐ Regulatory	Design Change No. 400656 Project No. (if appl.): NA Supp ID No. (if appl.): NA System: WD

Description of Design Change Request: This ECN adds an additional flowmeter to the new liquid Waste Disposal system.

Equipment identified as ABANDONED in this ECN will be de-energized and removed via decommissioning work orders.

Reason for Design Change: Change and action required (Provide reason for change, specific actions required, attach supporting documents, as applicable).

The current liquid waste system uses a flowmeter that has a minimum calibrated flowrate of 5 gpm. This ECN will allow the discharge of liquid waste at flowrates less than 5 gpm.

INTERFACING COMMENTS by:

Design Group or Discipline	Name of Commenter (Printed)	Signature of Commenter	Date	C or NC
Elect./I&C				
Mechanical				
Structural				
Others				
Others				
Others				

Prepared by: A. R. Adams Date: 2-~~13~~ 23-15	Reviewed by: L.D.Bob [signature] C or NC Date: 2-25-15	Approved by: [signature] Date: 2/26/2015

All affected design documents revised by (date): ______

Verified by: ______ Date: ______

By telecon [signature]
2-25-15

DESIGN CHANGE DOCUMENT - AFFECTED DOCUMENT LIST (Part 2)

Engineering Change

EC Number : 0000400657 000
Status/Date : REGISTER 01/21/2015
Facility : ZIN
Type/Sub-type: DCP MOD

Print Date: 02/18/2015

Exelon.

EC Title: ECN TO INSTALL ADDITIONAL INSTRUMENTATION TO THE LRWS

Mod Nbr : KW1: NS KW2: KW3: KW4: KW5:

Master EC : N
Outage : N
WO Required :
Adv Wk Appvd:
Auto-Advance: Y
Caveat Outst:
Resp Engr : FARRELL A LUKKEN
Location :

Work Group :
Alert Group:
Image Addr :
Alt Ref. :
Priority :
Department :

Temporary : N
Aprd Reqd Date:
Exp Insvc Date:
Expires On :
Auto-Asbuild : N
Discipline :

Affected Documents List

Fac	Type	Sub-Type	Document	Sheet	Ops	Rvw	Pri	Inc
ZIN	DWGC		M-1195		N	Y	1	N

Minor Rev: Major Rev: Updt Due:
Title: DIAGRAM OF CHEMICAL & VOLUME CONTROL SYSTEM (CRITICAL CONTROL ROOM DRA

Fac	Type	Sub-Type	Document	Sheet	Ops	Rvw	Pri	Inc
ZIN	DWGC		M-49	1	N	Y		N

Minor Rev: Major Rev: Updt Due:
Title: DIAGRAM OF WASTE DISPOSAL SYSTEM (LIQUID) MONITOR AND DISPOSAL SYSTEM

Affected Equipment List

Fac	Unit	Op Sys	Division	Area	System	Class
ZIN	00				WD	

Equipment : N/A WD0005A — Minor Rev:
Component : — Major Rev:
Equip. Tag: 0FI-WD0005A
State: Reviewed? N Inst/Rm: Rev Trackable: N Inc: N
Name : RELEASE TANK FLOW INDICATOR & TOTALIZER # 1A

Fac	Unit	Op Sys	Division	Area	System	Class
ZIN	00				WD	

Equipment : N/A WD0006A — Minor Rev:
Component : — Major Rev:
Equip. Tag: 0FI-WD0006A
State: Reviewed? N Inst/Rm: Rev Trackable: N Inc: N
Name : RELEASE TANK FLOW INDICATOR & TOTALIZER # 2A

DESIGN CHANGE DOCUMENT - AFFECTED DOCUMENT LIST (Part 2)

Engineering Change

EC Number : 0000400657 000
Status/Date : REGISTER 01/21/2015
Facility : ZIN
Type/Sub-type : DCP MOD

Print Date: 02/18/2015

Exelon.

ZIN 00 WD
Equipment : VIS 1116A Minor Rev:
Component : Major Rev:
Equip. Tag: 0WD1116A
State: Reviewed? N Inst/Rm: Rev Trackable: N Inc: N
Name : RELEASE TANK # 2A DISCHARGE VLV

ZIN 00 WD
Equipment : VIS 1117A Minor Rev:
Component : Major Rev:
Equip. Tag: 0WD1117A
State: Reviewed? N Inst/Rm: Rev Trackable: N Inc: N
Name : RELEASE TANK # 1A DISCHARGE VLV

DESIGN CHANGE DOCUMENT - AFFECTED DOCUMENT LIST (Part 2)

ECN No.: 400657

Design Change No.: 400656

Page No.: 4 of 13

Back-Up Calculation Listing
(Part 2)

Calculation/Analysis No.	Revision No.	Description
None		

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400657

Design Change No.: 400656

Station: ZION Affected Unit: 1 & 2 Page No.: 6 of 13

Part 4

Construction Support Information

MECHANICAL PARTS LIST

* Substitute parts may NOT be used without Eng Approval

Item numbers reference the components of the isometric Figures

#	DESCRIPTION	MANUF. PART #
1	Pipe fitting, Tee, NPT, 1-1/2", SST 150 psi min	
2	Pipe 1" Schedule 40 SST	
3	Pipe fitting, elbow 90 degrees, 1" SST, 150 psi (min)	
4*	Valve, globe, SST or Brass, 1", NPT ends	Milwaukee 590T ½ "
5	Pipe union, 1" NPT SST	
6*	1" Flow Gauge & Totalizer	Turbine Flow Meter (see below)
7	Valve, Check, 1", npt ends, SST or brass or bronze, 150 psi min working pressure	Mcmaster carr P/N 4463K66 or 4708K55 or Similar
8	Pipe fitting, Male x female hex reducing bushing, NPT 1-1/2" x 1", SST	
9	Pipe, 1-1/2", schedule 40, SST	
10	Pipe fitting Reducing Bushing Male x Female 1-1/2" MNPT x ½" FNPT SST	Mcmaster carr P/N 4464K155 or 4452K186 or similar
11	Pipe Fitting Female x Male street 90 degree elbow, ½" FNPT x ½" MNPT, SST	Mcmaster carr P/N 4464K38 or 4453K474 or similar

Prepared By: A. R. Adams signed via ~~email~~ telecon [signature] Date: 2-~~13~~ 23-15

Reviewed By: [signature] Date: 2-25-15

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400657

Design Change No.: 400656

Station: ZION   Affected Unit: 1 & 2   Page No.: 7 of 13

Part 4   Construction Support Information

MECHANICAL PARTS LIST

Continued

12	Pipe fitting, reducing coupling, 1" FNPT x ½" FNPT, SST	Mcmaster carr P/N 446K534 or 4458K263 or Similar
13	Pipe 1/2", schedule 40, SST	
14	Pipe Fitting, Reducing coupling, female x female, 2" FNPT x 1" FNPT, SST	Mcmaster carr P/N 4464K548 or 4452K277 or Similar
15	Pipe fitting, tee, 1", SST	Mcmaster carr P/N 4464K53 or 4452K2436 or Similar

*Cameron Flow Meter, Liquid Turbine style, flow element with element mounted flow analyzer, Nuflo MC-II flow analyzer and flow element; range 0.75-7.5 gpm, standard grade, standard accuracy, gallon totalizer; gallon rate indicator, body material SST, process fluid is water, Process range 33 F to 120F, process pressure 150 psi max, ambient temperature range 32 F to 120 F, 1/2 flow meter with 1" NPT x 1" NPT connections; with dated calibration certificates, flow element part number 9A-100003532

Prepared By: A. R. Adams signed via ~~email~~ telecon [initials]   Date: 2-~~13~~23-15

Reviewed By: [signature]   Date: 2-25-15

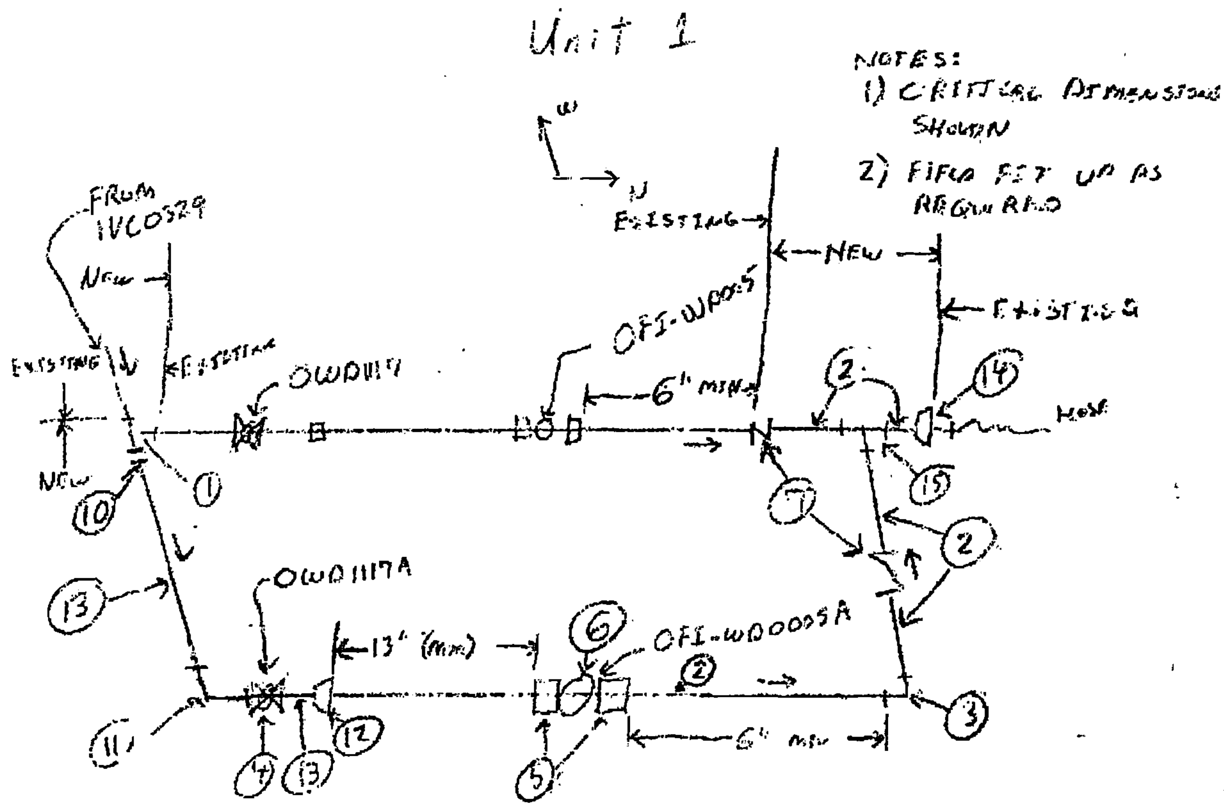


FIGURE 1

Part 4
ECN No. 400657
EC No. 400656
Page _8_ of _13__

Prepared By: A. R. Adams signed via ~~email~~ telecon 2-~~13~~ 23-15

Reviewed By: L. R. Boi

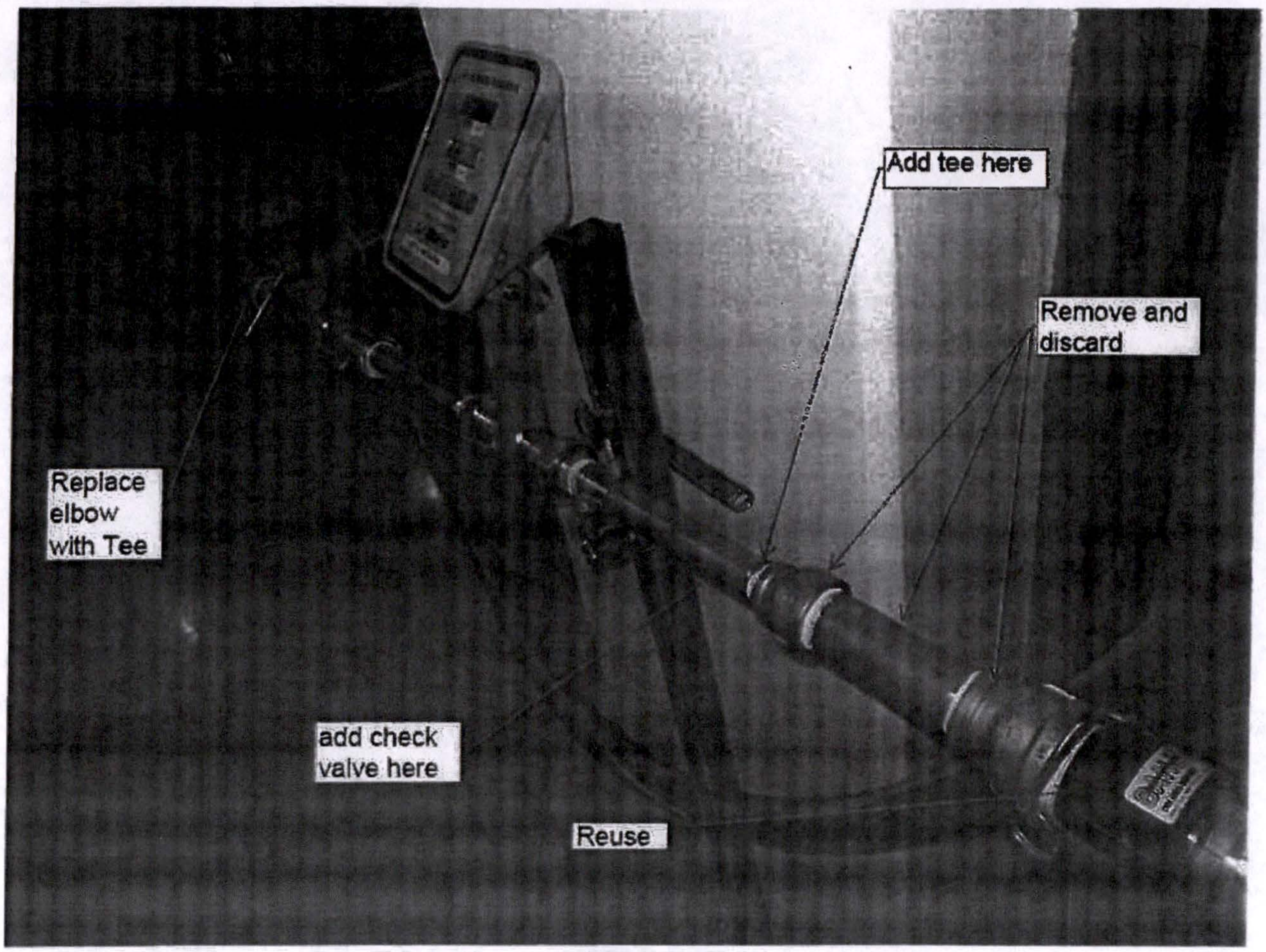


FIGURE 2

Part 4
ECN No. 400657
EC No. 400656
Page _9_ of _13__

telecon 2.27-15
Prepared By: A. R. Adams signed via ~~email 2-13-15~~

Reviewed By: L.R.Bair [signature] 2.25-15

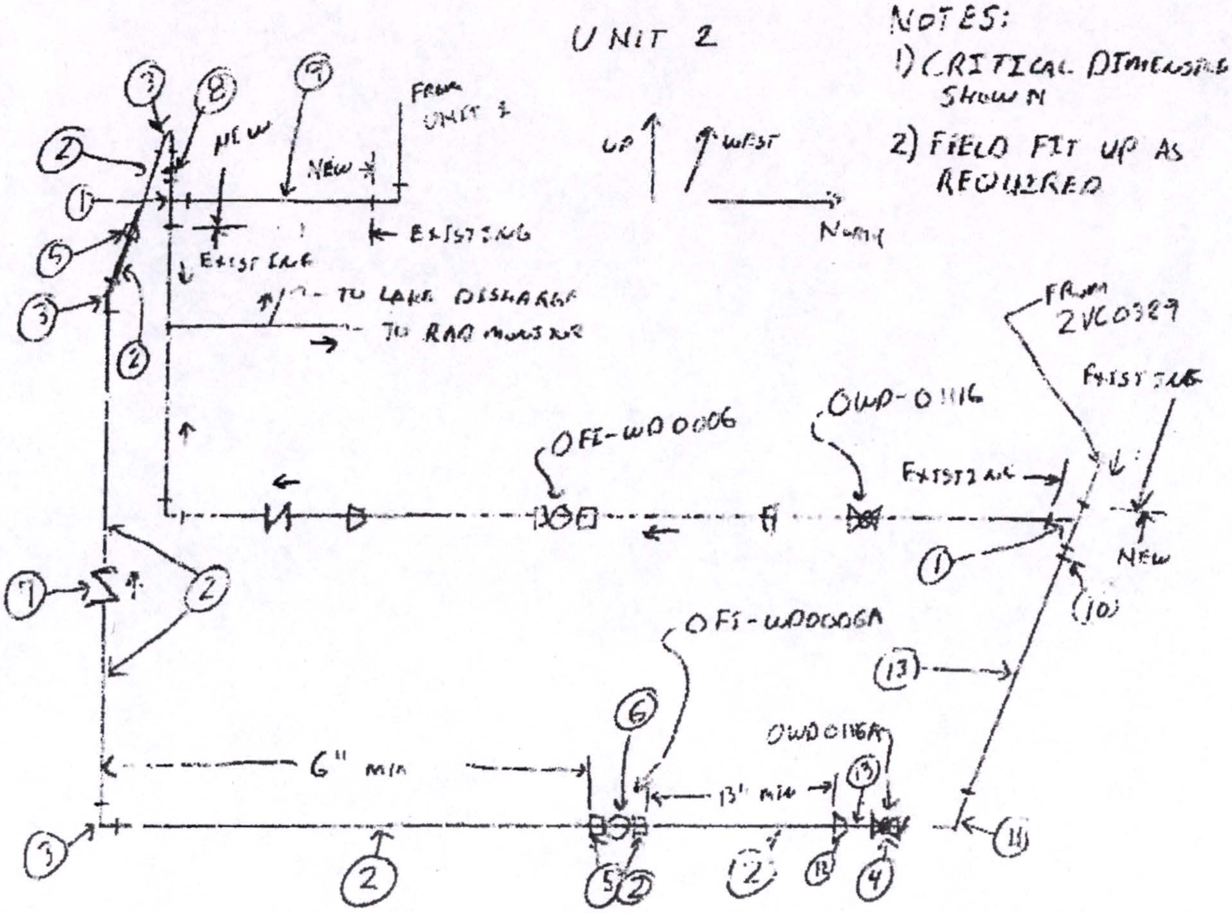


FIGURE 3

Part 4
ECN No. 400657
EC No. 400656
Page _10_ of _13__

Prepared By: A. R. Adams signed via ~~email 2-13-15~~ telecon 2-23-15

Reviewed By: L. A. Bow [signature] 2-25-15

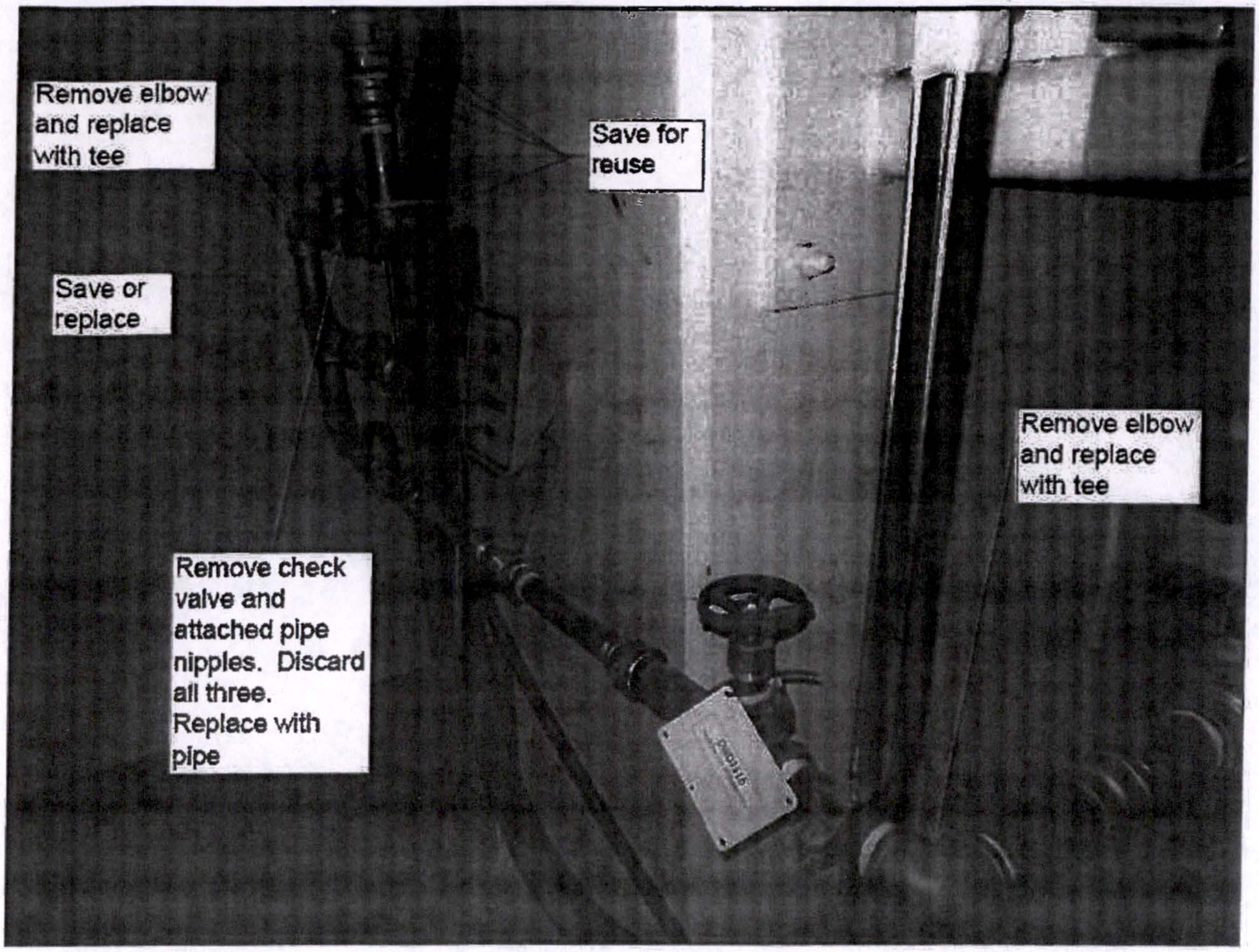


FIGURE 4

Part 4
ECN No. 400657
EC No. 400656
Page _11_ of _13__

telecon 2-27-15
Prepared By: A. R. Adams signed via ~~email 2-13-15~~

Reviewed By: Ben DiBar L. DiBiasi 2-25-15

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400657

Design Change No.: 400656

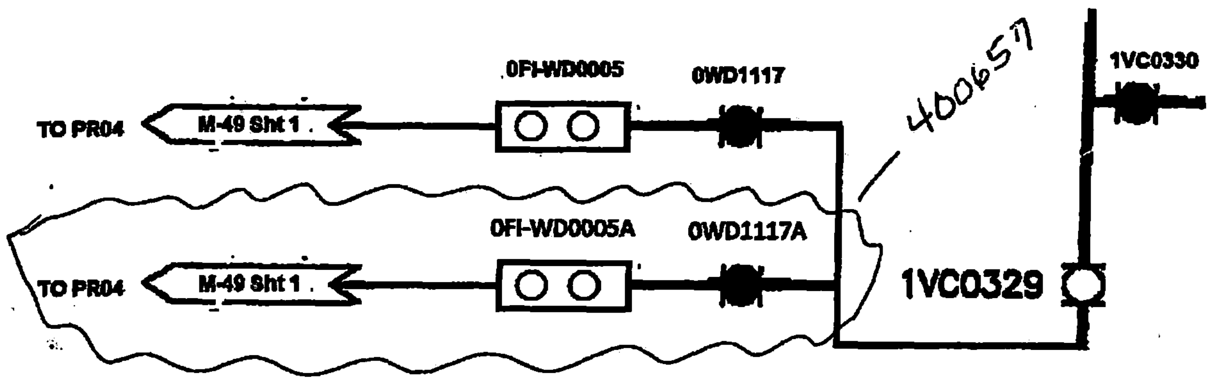
Station: ZION Affected Unit: 1 & 2 Page No.: 5 of 13

Part 4	Construction Support Information
	Note When disassembling hose and flow meter manifolds there is an estimated 15-20 gallons of water that could drain out. For contamination control insure the water can be collected.
1.	Install Unit 1 low flow assembly in parallel with existing flow assembly as shown in Figures 1 and 2 on pages ~~7~~ 8 and ~~8~~ 9. TP 3/9/15 This will require disassembly of existing Unit 1 piping; other configurations of installation are allowed with Engineering approval. The Unit 1 check valve located in the Unit 2 Lake Release Room will be removed and a new check valve is installed on the Unit 1 assembly as shown. The configuration control drawings M-49 and M-1195 are on pages ~~11~~ 8 and ~~12~~ 10. TP 3/9/15
2.	Install Unit 2 low flow assembly in parallel and with existing flow assembly as shown in Figures 3 and 4 on pages ~~9~~ 10 and ~~10~~ 11. TP 3/9/15 This will require disassembly of existing Unit 2 piping; other configurations of installation are allowed with Engineering approval. The configuration control drawings M-49 and M-1195 are on pages ~~11~~ 12 and ~~12~~ 13. TP 3/9/15

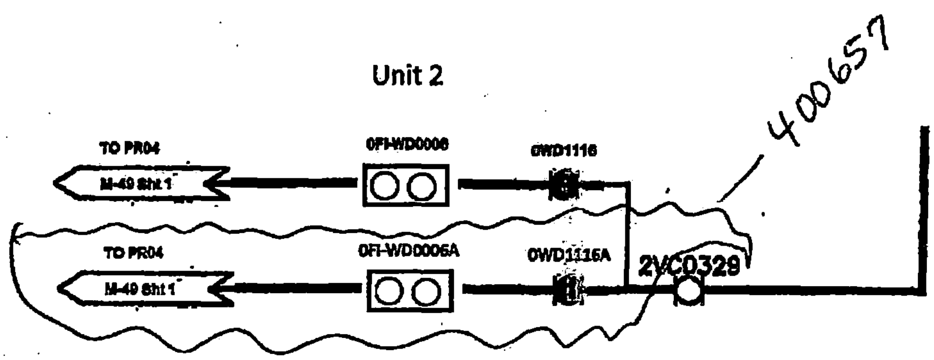
Prepared By: A. R. Adams signed via ~~email~~ telecon [signature] Date: 2-~~13~~ 23-15

Reviewed By: [signature] Date: 2.28-15

Unit 1



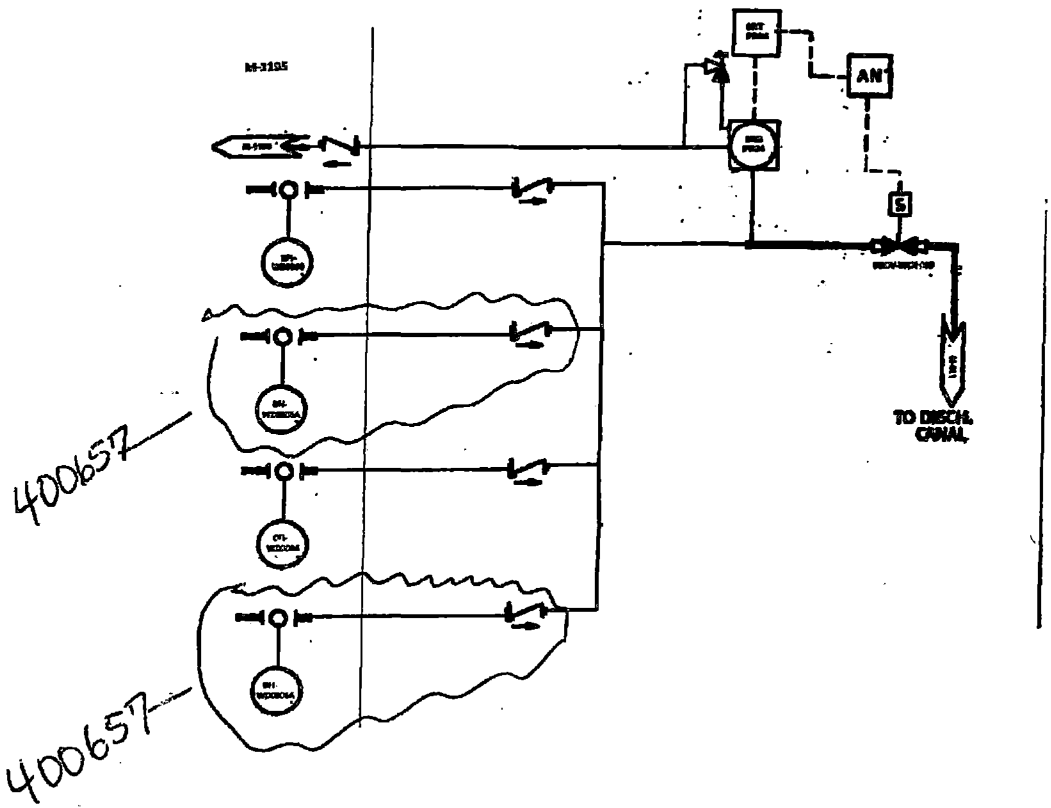
Unit 2



Part 5
ECN No. 400657
EC No. 400656
Page _12_ of _13__
Drawing No. M-1195 Rev. B

telecon 2-23-15
Prepared By: A. R. Adams signed via ~~email 2-12-15~~

Reviewed By: [illegible] C. [illegible] 2-25-15



Part 5
ECN No. 400657
EC No. 400656
Page _13_ of _13__
Drawing No. M-49 Sht 1 Rev. B

Prepared By: A. R. Adams signed via ~~email 2-13-15~~ telcom 2-23-15

Reviewed By: L DuBois for DuBois 2-25-15

February 13, 2015
In reply refer to
CZE-15-004

To: Tony Oraweic

Subject: Zion Station, Units 0, 1 & 2
Exempt Change No. 400656
Liquid Rad Waste

System Code: WD, VC

The Engineering Department has reviewed the subject exempt change in accordance with NEP-04-02 and applicable Zion Solutions Quality Requirements. Design Input Requirements (DIRs) as identified in NEP 12-01 have been reviewed and are included in the design change approval letter as applicable.

Description of Change:

This Design Change installs another flow control valve and flowmeter to the existing liquid rad-waste system to allow low flow (less than 5 gpm) releases.

Exempt Change Design Package:

The mechanical portion of the design for this Exempt Change is contained in ECN 400657 which is issued "For Construction" by this letter. There is no electrical portion for this Exempt Change.

This Exempt Change installs components to the liquid waste system installed by the previous Exempt Change 392999.

10CFR 50.59 Evaluation / Decommissioning Impact Evaluation:

A 10CFR50.59 Screening was performed in accordance with ZAP 100-06 and is being transmitted along with this letter. This activity can be implemented without prior NRC approval. A Decommissioning Impact Evaluation was performed and it was concluded that the proposed activity is not restricted by 10CFR50.82.

DSAR / ODCM Impact Review:

DSAR Chapters 1 through 6 were reviewed for this exempt change. No changes to the DSAR are required. Additionally, a review of the ODCM was conducted. Revisions to the ODCM are required as a result of this design change as identified in ZAP 510-02C, Attachment A. Attachment A is included in the DCP.

February 13, 2015
In reply refer to
CZE-15-004

Applicable Codes and Standards:

This exempt change shall be installed in accordance with Zion Specification X-3646, which is the general work specification for mechanical, structural and electrical work as well as applicable site and corporate procedures. Installation requirements identified in the ECN supersede X-3646 guidance.

Basic Functions:

This Design Change adds a second flow control valve and flowmeter in parallel to the existing flow control valve/flow meter assembly to expand the capability of the system. The existing flowmeter has a minimum calibrated flowrate of 5 gpm; the added components will allow flowrates of less than 5 gpm.

Industrial Safety:

This design change has no effect on the industrial safety of the plant.

Installation Schedule / Outage Requirements:

Installation of this exempt change will be scheduled via the site work schedule process.

Technical Specification Changes:

The existing Technical Specifications do not require revision as a result of this exempt change.

ALARA Review:

An ALARA review will not need to be performed for this exempt change.

Fire Protection Review:

No changes to the Fire Protection Report are required by this EC.

Impact of Pending Modifications or Temporary Alterations:

A review of pending design changes has been completed. This Exempt Change does not impact any pending design changes.

Construction Drawings:

Construction is authorized to proceed in accordance with ECN 400657.

Identification of the Installer:

This Exempt Change will be performed by the D&D maintenance department with assistance from the other groups as required.

Procurement Requirements:

A Bill of Material has been included with the ECN. Spare parts should be ordered as needed.

Training Requirements:

Training will be required for the Operations Department and other associated plant personnel on the operation and limitations of the new portion of the system.

Testing Requirements:

None

Operating Requirements:

Existing Zion procedures will require revision as identified in ZAP 510-02C, Attachment A. Attachment A is included in the DCP.

Due to the configuration of the flow path to the radiation monitor PR04, the actual release rates are at least 0.3 gpm less than shown on the flowmeter. This reduction in actual release rate may be accounted for administratively within the procedures.

February 13, 2015
In reply refer to
CZE-15-004

Technical Review:

The Liquid Rad Waste system is considered Important to the Defueled Condition (ITDC). Therefore, this design change is subject to a Technical Review in accordance with the requirements of ZAP 500-08. A Technical Review (TR-06-2015) has been performed and submitted with this design package.

If there are any questions regarding this exempt change, please contact Arthur (Bob) Adams at extension 4010.

Prepared By: signed via ~~email~~ telecon 2-23-15
Arthur R. Adams
Design Engineering

Approved By: Donald F. Roth
Don Roth
D&D Engineering Supervisor

cc:

	MAL	ECN	50.59
Central File	1	1	1
Darcey Neuenfeldt	originals		
Jim Denio	3	3	3
Mod Coordinator	1	1	1
J. Brandis	2	2	2

TECHNICAL REVIEW LETTER

TR-006-2015

To: Tony Orawiec
Decommissioning Plant Manager
Zion Station

Subject: EC 400~~565~~; Low Flow Meter For Liquid Waste System

Summary:

This Technical Review documents the review of the technical basis for changes to the existing liquid Rad-Waste system, and installation of the new flow meter. The new flow meter will provide the capability of release flow rates of 0.75 gpm to 7.5 gpm.

Prepared By: Arthur R. Adams Telecom Date: 2-~~09~~-15

Required Review Disciplines: A, B, G

Eng Supv

Qualified Technical Reviews

Signature	Discipline	Date
	~~A~~	~~2-26-15~~
	A, B, E, G	2/26/15

2-26-15

I Concur and Approve: Date: 2/26/15
Decommissioning Plant Manager

Distribution:
Decommissioning Plant Manager
Operations Manager
Engineering Supervisor
RP Supervisor
SRC Coordinator
Master File

ATTACHMENT D: 50.59 REVIEW COVERSHEET FORM

Station: ZION

Activity/Document Number: ECN 4006657 AP 3/9/15 **Revision Number:** 0

Title: Install Additional Flowmeter and Flow Control Valve To Liq Waste Sys

NOTE: For 50.59 Evaluations, information on this form will provide the basis for preparing the biennial summary report submitted to the NRC in accordance with the requirements of 10 CFR 50.59(d)(2).

Description of Activity:
(Provide a brief, concise description of what the proposed activity involves.)

This activity installs an additional flowmeter and flow control valve to the liquid waste system.

Reason for Activity:
(Discuss why the proposed activity is being performed.)

The existing flowmeter has a minimum calibrated flowrate of 5 gpm. The additional flowmweter and flow control valve will allow flowrates of less than 5 gpm to be released.

Effect of Activity:
(Discuss how the activity impacts plant operations, design bases, or safety analyses described in the UFSAR.)

There is no change associated with the design bases, or safety analyses described in the UFSAR.

Summary of Conclusion for the Activity's 50.59 Review:
(Provide justification for the conclusion, including sufficient detail to recognize and understand the essential arguments leading to the conclusion. Provide more than a simple statement that a 50.59 Screening, 50.59 Evaluation, or a License Amendment Request, as applicable, is not required.)

No changes to the release path from the site or controls associated with releases are changed by this revision. As such, the design function of "controlling liquid release concentrations to less than the allowable" is not changed.

Attachments:
Attach all 50.59 Review forms completed, as appropriate.
(NOTE: if both a Screening and Evaluation are completed, no Screening No. is required.)

Forms Attached: (Check all that apply.)

	Applicability Review		
X	50.59 Screening	50.59 Screening No.	2015-023
	50.59 Evaluation	50.59 Evaluation No.	

ZAP 100-06 ATTACHMENT F: 50.59 SCREENING FORM

50.59 Screening No: 2015-023 Rev No: 0

Activity/Document No: EC 400656 Revision No: 0

I. 50.59 Screening Questions (Check correct response and provide separate written response providing the basis for the answer to each question) (See Section 5 of the Resource Manual (RM) for additional guidance):

1. *Does the proposed Activity involve a change to an SSC that adversely affects an UFSAR described design function? (See Section 5.2.2.1 of the RM)* __ YES _X_ NO

Design Change 392999 installed a new liquid rad-waste system and abandoned portions of the existing system.

This change adds an additional flow control valve and flowmeter that allows release rates of less than 5 gpm. The existing flowmeter has a minimum calibrated flowrate of 5 gpm.

The dedicated release path from the site to Lake Michigan and associated control methods for monitoring releases is not changed such that the concentrations of effluent are maintained well within the allowable limits of 10CFR20 and the limits of the ODCM.

2. *Does the proposed Activity involve a change to a procedure that adversely affects how UFSAR described SSC design functions are performed or controlled? (See Section 5.2.2.2 of the RM)* __ YES _X_ NO

Procedures associated with the operation of the Liquid Waste systems will be revised under a separate 50.59.

ZAP 100-06 ATTACHMENT F: 50.59 SCREENING FORM

50.59 Screening No: 2015-023 Rev No: 0

Activity/Document No: EC 400656 Revision No: 0

3. *Does the proposed Activity involve an adverse change to an element of a UFSAR described evaluation methodology, or use of an alternative evaluation methodology, that is used in establishing the design bases or used in the safety analyses? (See Section 5.2.2.3 of the RM)* __ YES _X_ NO

The Liquid Waste system is used to store, process and release liquid effluent from the RCA to the release point of the plant. The release path is defined in the DSAR. This activity does not change or affect the dedicated release path from the site or the controls of the effluent such that the concentrations of the releases will remain within the limits of 10CFR20. This is due to the existing controls, which are not being affected by this change; (1) the release paths are controlled by plant personnel, (2) effluent flowrates are determined prior to release and controlled during release that ensures concentrations less than the allowable, and (3) the existing rad monitor terminates the release in the event of a high radiation in the discharge line.

4. *Does the proposed Activity involve a test or experiment not described in the UFSAR, where an SSC is utilized or controlled in a manner that is outside the reference bounds of the design for that SSC or is inconsistent with analyses or descriptions in the UFSAR? (See Section 5.2.2.4 of the RM)* __ YES _X_ NO

This change is not a test or experiment of the liquid waste system. The release path and controls of the release path associated with the new system has not changed.

5. *Does the proposed Activity require a change in the Technical Specifications or Operating License? (See Section 5.2.2.5 of the RM)* __ YES _X_ NO

No Tech Specs are affected by this change.

ZAP 100-06 ATTACHMENT F: 50.59 SCREENING FORM

50.59 Screening No: 2015-023 Rev No: 0

Activity/Document No: EC 400656 Revision No: 0

II. List the documents (e.g., UFSAR, Technical Specifications, other licensing basis, technical, commitments, etc.) reviewed, including sections numbers where relevant information was found (if not identified in the response to each question).

DSAR Chap 4 & 5

ODCM

EC 393000

III. Select the appropriate conditions:

X	If all questions are answered NO, **then** complete the 50.59 Screening and implement the Activity per the applicable governing procedure.
	If question 1, 2, 3, or 4 is answered YES and question 5 is answered NO, **then** a 50.59 Evaluation shall be performed.
	If questions 1, 2, 3, and 4 are answered NO and question 5 is answered YES, **then** a License Amendment is required prior to implementation of the Activity.
	If question 5 is answered YES for any portion of an Activity, **then** a License Amendment is required prior to implementation of that portion of the Activity. In addition, **if** question 1, 2, 3, or 4 is answered YES for the remaining portions of the Activity, **then** a 50.59 Evaluation shall be performed for the remaining portions of the Activity.

IV. Screening Signoffs:

50.59 Screener: Arthur R Adams Sign: via ~~email~~ telecom [signature] Date: 2 / ~~13~~ 23 / 15
(Print name) (Signature)

50.59 Reviewer: PAUL J. BEINECKE Sign: [signature] Date: 2 / 26 / 15
(Print name) (Signature)

ATTACHMENT A

DECOMMISSIONING IMPACT EVALUATION

Activity: EC 400656
(Work Order No., Procedure No., On Site Review No., Design Change No., etc)

TRACKING #: 2015-023

1. Does the proposed decommissioning activity result in any of the following:

   a. Foreclose the release of the site for possible unrestricted use;

   [ ] YES [X] NO

   Provide justification: The proposed activity involves replacing an existing flow meter with a new more sensitive flow meter. The flow meter is installed in the Crib House Forebay which is not part of the Radiologically Controlled Area (RCA) of the plant. Therefore, this activity does not increase the potential for spread of radioactive contamination and will not foreclose release of the site for possible unrestricted use.

   b. Result in significant environmental impacts not previously reviewed;

   [ ] YES [X] NO

   Provide justification: All the work associated with this activity will be performed within the envelope of the station's double fence former Resticted Area. Therefore, this activity will not have any impact on NUREG 0586 Supplement 1 criteria of land use, aquatic ecology, terrestrial ecology, threatened and endangered species, environmental justice, or cultural impacts. The amount of water used will be non-detectable, so there will be no impact on NUREG 0586 Supplement 1 criteria for water use or water quality.

   The new flow meter will be installed along the eastern edge of the plant which borders on Lake Michigan but will be shielded from the lake by a concrete wall. Therefore, this activity will have no impact on NUREG 0586 Supplement 1 criteria for aesthetics or noise. As stated above, the work will not be performed in the RCA, therefore the activity will have no impact on radiological criteria.
   Finally, this modification does not change the requirements for effluent Releases.

c. Result in there no longer being reasonable assurance that adequate funds will be available for decommissioning.

[ ] YES [X] NO

Provide justification: This is minor modification to an existing system with minimal associated costs.

ATTACHMENT A
DECOMMISSIONING IMPACT EVALUATION
(Continued)

Activity: EC 400656

2. Review the answers to Step 1.a-c. If the answer to any of the questions is YES, Then the activity can NOT be completed, without prior notification to the NRC.

> **NOTE**
>
> In taking actions permitted under 10CFR50.59 following submittal of the PSDAR, the licensee may perform activities inconsistent with the PSDAR, including significant schedule changes or significant cost increases, provided prior written notification is made to the NRC, as well as a copy of the notification to the State of Illinois.

3. Is this activity inconsistent with those actions described in the Post-Shutdown Decommissioning Activities Report or cause a significant schedule change or cost increase?

   [ ] YES [X] NO

   If the answer is YES, Then notify the NRC and the State of Illinois prior to performing the activity.

   If the answer is NO, Then proceed without notification.

   Provide justification: This is minor modification to an existing system.

4. Implement Changes – Based on this evaluation, I have determined that the proposed activity is not restricted by 10 CFR 50.82.

   Preparer print name: Arthur R. Adams Discipline: A, B, C, G

   ~~signed via email~~ Telecom [signature] 2-~~18~~ 23-15
   Preparer Signature Date

5. Review – The reviewer agrees that the proposed activity is not restricted by 10 CFR 50.82.

   Reviewer print name: Donald F. Roth Discipline: A, G

   Donald F. Roth 2/26/2015
   Reviewer Signature Date

ATTACHMENT 4

ECN# 400986

Increased capacity dilution water pump of 10,000 gpm and associated flowmeters

Exhibit A
NEP-08-01
Revision 1

Engineering Change Notice (Part 1)

ECN No. 400986
Page: 1 of 27

ISSUANCE: ☒ **FOR CONSTRUCTION** ☐ **FOR COMMENT**

Station: ZION Affected Unit: 00 Changes to a previously Approved ECN ☐	☐ Safety Related ☒ Non-Safety Related ☐ Regulatory	Design Change No. 400985 Project No. (if appl.): N/A Supp ID No. (if appl.): N/A System: SW

Description of Design Change Request:

This change will add a higher capacity SW dilution pump (OB) in the Forebay in parallel with pump OA installed under EC396794. A new SW flow meter (0FIT-SW54B) and flow control valve (0FCV-SW54B) will also be installed.

The Unit 1 & 2 Oil Separators will be capped and the Unit 1 & 2 Oil Separator Composite Samplers will be removed from service.

Reason for Design Change: Change and action required (Provide reason for change, specific actions required, attach supporting documents, as applicable).

Decommissioning schedules along with the high boron concentrations in the SFP and other LRWS discharge streams will require a higher dilution flow rate than can be achieved with the present pump.

The capping of the Oil Separator inputs will allow removal of the Oil Separator Composite Samplers allowing for the space needed for the new dilution pump discharge path.

INTERFACING COMMENTS by:

Design Group or Discipline	Name of Commenter (Printed)	Signature of Commenter	Date	C or NC
Elect./I&C	N/A			
Mechanical				
Structural	Dave Carter	[signature]	3-17-15	NC
Others	N/A			

Prepared by: LJ DuBois [signature] Date: 3-17-15	Reviewed by: PJ Beinecke [signature] C or NC Date: 3/18/15	Approved by: [signature] Donald F. Roth Date: 3/18/2015

All affected design documents revised by (date): ____________________

Verified by: ____________________ Date: ____________________

WORK ON THIS ECN BEGAN BEFORE 3/16/2015, SO IT USES OLD FORMS. THE REVISED FORMS DO NOT FUNCTIONALLY OR TECHNICALLY AFFECT THE WORK,

[signature] Donald F. Roth 3/18/2015

Exhibit A
NEP-08-01
Revision 1

DESIGN CHANGE DOCUMENT - AFFECTED DOCUMENT LIST (Part 2)

ECN No. 400986
Design Change No. 400985

Engineering Change

EC Number : 0000400986 000
Status/Date : REGISTER 02/09/2015
Facility : ZIN
Type/Sub-type: DCP MOD

Print Date: 03/18/2015

Page: 2 of 27

EC Title: ECN - INSTALL A HIGHER FLOW SW DILUTION PUMP MECH INSTALLATION

Mod Nbr : KW1: NS KW2: KW3: KW4: KW5:

Master EC : N
Outage : N
WO Required :
Adv Wk Appvd:
Auto-Advance: N
Caveat Outst:
Resp Engr :
Location :

Work Group :
Alert Group:
Image Addr :
Alt Ref. :
Priority :
Department :

Temporary : N
Aprd Reqd Date:
Exp Inavc Date:
Expires On :
Auto-Asbuild : N
Discipline :

Affected Documents List

Fac	Type	Sub-Type	Document	Sheet	Opz	Evw	Pri	Inc
ZIN	DWGC		M-100		N	Y		N

Minor Rev: Major Rev: Updt Due:
Title: CIRCULATING WATER PIPING PLAN - UNITS 1 & 2

Fac	Type	Sub-Type	Document	Sheet	Opz	Evw	Pri	Inc
ZIN	DWGC		M-31		N	Y		N

Minor Rev: Major Rev: Updt Due:
Title: DIAGRAM OF CIRCULATING WATER PIPING - UNITS 1 & 2

Fac	Type	Sub-Type	Document	Sheet	Opz	Evw	Pri	Inc
ZIN	DWGC		M-32	4	N	Y	1	N

Minor Rev: Major Rev: Updt Due:
Title: DIAGRAM OF SERVICE WATER (CRITICAL CONTROL ROOM DRAWING)

ZIN DWGC M-101

QW 3-30-15

Affected Equipment List ZIN DWG ECN-Part 4 TR 3/30/15

Fac	Unit	Op Sys	Division	Area	System	Class
ZIN	00				SW	

Equipment : -FT SW54B Minor Rev:
Component : Major Rev:
Equip. Tag: 0FIT-SW54B
State: Reviewed? N Inst/Rm: Rev Trackable: N Inc: N
Name : 0B SW PUMP DILUTION FLOW INDICATOR / TRANSMITTER

DESIGN CHANGE DOCUMENT - AFFECTED DOCUMENT LIST (Part 2)

ECN No. 400986
Design Change No. 400985

Engineering Change

EC Number : 0000400986 000
Status/Date : REGISTER 02/09/2015
Facility : ZIN
Type/Sub-type: DCP MOD

Print Date: 03/18/2015

Exelon.

ZIN 00 SW
Equipment : N/A 1001B Minor Rev:
Component : V25 < Major Rev:
Equip. Tag: 0SW1001B
State: Reviewed? N Inst/Rm: Rev Trackable: N Inc: N
Name : OB SW DILUTION WATER PUMP

ZIN 00 SW
Equipment : FCVA SW54B Minor Rev:
Component : V15 < Major Rev:
Equip. Tag: 0FCV-SW0054B
State: Reviewed? N Inst/Rm: Rev Trackable: N Inc: N
Name : OB SW DILUTION PUMP FLOW CONTROL VALVE

Back-Up Calculation Listing
(Part 2)

Calculation/Analysis No.	Revision No.	Description
None		

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985

Station: ZION Affected Unit: 00

Prerequisite

1. At the direction of Environmental Manager and Waste Operations Manager remove all oil stored on clean and dirty oil storage pad on north side of Turbine Building or protect it from oil release to the environment, Ref B-803
2. Walk down the site with Environmental Manager to determine if any mitigating actions need to be taken for any oils stored outside. Reference drawing B-803, 804, and B-876 for areas that feed the Oil Separators.
3. Verify Storm Water Pollution Prevention Plan and associated procedures and guidelines are implemented for the removal of the Oil Separators with Environmental Manager.
4. Verify the Spill Prevention Control and Countermeasures Plan and associated procedures and guidelines are implemented for the removal of the Oil Separators with Environmental Manager.

Notes:

1. **This Installation is laid out in sections.**
2. **Section 1 Unit 2 Oil Separator needs to be completed prior to starting Section 2 Step 2**

Section 1: Capping Inputs to Unit 1 and Unit 2 Storm Water Oil Separator

1. At Fuel Building Car Shed (Truck Wash Down Area) verify sealed or install mechanical plumbers plugs in floor drains. A total of 7 drains shown on drawing. Reference B-492
2. At Outdoor Clean and Dirty Oil Storage pads (North of TB) install mechanical plumbers plugs in drains. Remove manhole cover, cut a ¼" steel plate to fit manhole, seal plate to manhole, install manhole cover over plate seal plate. See Sketch 3. Ref B-803, B-876.
3. Use plumbers plugs or similar to plug input and outputs to Man Hole 2-15. Reference drawing B-803, two 4", two 24" See Sketch 3.
4. Fill Man Hole 2-15 with concrete or grout to a minimum of 1 ft above the top of the highest internal pipe. See Sketch 3.
5. Discontinue periodic sampling of the Unit 2 Storm Drain Oil Separator effluent. Notify/Contact Environmental Manager, RP Technical and Chemistry Supervisor.
6. Use plumbers plugs or similar to plug input and outputs to Man Hole 1-17 Reference drawing B-803, two 10", two 24", See Sketch 3

Prepared By: [signature] Date: 3-17-15

Reviewed By: [signature] Date: 3/18/15

7. Fill Man Hole 1-17 with concrete or grout to a minimum of 1 ft above the top of the highest internal pipe. See Sketch 3.
8. Discontinue periodic Sampling of Unit 1 Strom Water Oil Separator Effluent. Notify/Contact Environmental Manager, RP Technical and Chemistry Supervisor.
9. Verify electrically gap the Unit 1 Storm Water Oil Separator Composite Sampler and heat tracing per ECN 400987.
10. Electrically gap the Unit 2 Storm Water Oil Separator Composite Sampler and heat tracing per ECN 400987.

Bill Of Material

Quantity (Min Req'd)	Description
7	Car Shed Mechanical Plumbers Plug, Field to determine size, capable of 1 psi.
3	Clean and dirty oil storage pad drain mechanical plumbers plugs, 6"
2	4" inflatable plumbers plug. Capable of 2 psi
4	24" inflatable plumbers plug, capable of 2 psi
2	10" inflatable plumbers plug. Capable of 2 psi
4	Cu Yards of concrete
1	¼" steel plate, 24" x 24"
1	Silicone sealant or similar, Tube

Section 2-Unit 2 CW Discharge Isolation Valve House Preparations

1. Verify Section 1 capping of Unit 2 Oil Separator Inputs are complete.
2. Remove Unit 2 Oil Separator Composite Sampler. Cut back electrical cables, sample lines, supports and heat trace as required clearing the area for a hole in the floor. See Photo 2 and Electrical ECN 400987.
3. Verify relocated electrical box on south wall to west wall per ECN 400987. See Photo 3 of this ECN.
4. Remove abandon materials (conduits, cables, cameras, etc) as required in preparation to remove a portion of the south wall. See Photo 2, 4 and 6.

5. Cut hole in south wall. Leave 2 courses of block along door and along east wall. See Photos 2 and 6.
6. Cut a hole in the floor approximately 4 ft x 4 ft. Floor is 2 ft thick and has re-inforcing bar (rebar), Ref B-39. See Photo 2, Sketch 1 and Sketch 8.
7. Dive and cut relief windows in CW Discharge pipe downstream of 2MOV-CW-0006. There shall be 1 ft of pipe remaining circumferentially between each window. See M-101 Part 5 of this ECN. 3-30-15
8. If installed per ECN 400~~8~~577 then Relocate LRWS discharge hose from entering in front of 2MOV-CW-0006 into new relief windows otherwise N/A. Ensure hose is at least 5 feet on lake side of relief window. See Sketch 2 and M-101 in Part 5 of this ECN.

Section 3-Installation of Piping

1. Verify beach construction equipment traverse route with Environmental Manager.
2. Remove interference as required (i.e. conduits, yard lights, razor ribbon on aft bay wall, conduit, etc.). Coordinate with Security removal of the razor ribbon and barbed wire on the aft bay east wall. Security will determine if the security features need to be replaced. See Photo 4, 5 and 6.
3. Per Sketches 4A, 4B and Pipe Fabrication Vendor drawing and instructions install piping and pipe supports (Engineering to review and approve vendor drawings and instructions). Install all piping from Unit 2 CW Discharge Valve house to riser on the pump. Pipe does not need to be sloped for this application. See photos 4, 5, 6 and 7.
4. Install the flow meter and program meter per the vendor manual. Flow meter may be mounted at a convenient location, (i.e. next to the pump control switches)

Bill of Material

Quantity (Min Req'd)	Description
1	24" throttle valve(or equivalent). Lake Michigan Water service, 33F-85F process temperature, max system pressure 85 ft/37 psi. Part of lot 1 below. Reference Sketch 4A and 4B
1	Flexible boot assembly. General Rubber 1101-0240-100-OEE (1101 O/A 24 x 10" F/F EPDM, Open Arch, Rated for 130 psi, 30 in Hg Vacuum, 250 F, Standard 150# Drilling, with PPRS-0240-CSG (R/R Set 24 in. CSG) Set of Split Retaining rings for 24" expansion joint with standard 150# drilling, 3/8" thick, Carbon Steel Galvanized or

Prepared By: Date: 3-17-15
Reviewed By: Date: 3/18/15

	similar Provided with Lot 1 Reference Sketch 4A and 4B
1 lot	Prefabricated and spooled HDPE 24" piping, UV protected; Piping to including all flange bolting, backing rings, gaskets, valve and flexible joint. Process is Lake Michigan Water, 33F-85F process temperature, max system pressure 85 ft/37 psi, ambient temperature -10 F to 100 F. This lot will include 24" throttle valve and flexible boot above. Reference Sketch 4A and 4B. Pipe vendor/fabricator to provide engineering, layout, supports and installation requirements. (ZS Engineering to review and approve vendor drawings and instructions)
1	Ultrasonic Flow Meter with dated calibration certificate. Application 24" HPDE piping, DR-17, 4,000-15,000 gpm, process fluid is fresh lake Michigan water, temperature range of process fluid 33-85F, outdoor applications ambient -10F to +105 F; Omega FDH-1-50FT-NIST Hybrid Ultrasonic Flow Meter with dated calibration certificate with 50 ft leads.

Section 4 Installation Pump

1. Verify that the thickness of the pump mounting plate is greater than or equal to 0.75 inches. If not replace plate with one greater than or equal to 0.75 inches.
2. Cut pump access hole (34" +/-1") in the center of the pump mounting plate.
3. Lower pump onto pump mounting plate and face discharge nozzle in the North direction. (Cascade-1 Stage 20MF Mixed Flow Pump, ref Drawing 3MS7633A) using manufacturer's instructions and good work practices.
4. Shim pump as required to level pump head.
5. Drill and tap holes (3/4 – 10) in pump deck plate for pump discharge head mounting bolts.
6. Install hold down bolts and tighten.
7. Recheck pump level and adjust as necessary.
8. Install motor using manufacturer's instructions and good work practices.
9. Coupling alignment shall be done using a straight edge (or equivalent) method.

Prepared By: Lee DaBor Date: 3-17-15

Reviewed By: [signature] Date: 3/18/15

10. Install flexible boot to pump per Sketch 4A, photo 7.
11. Install riser pipe per Sketches 4A, 4B and Pipe Fabrication Vendor drawing and instructions. (Engineering to review and approve vendor drawings and instructions)
12. Install pipe anchor per Sketches 5, 6 and 7.

Bill Of Material

Quantity	Description
1	Pump and motor assembly Cascade-1 Stage 20MF Mixed Flow Pump, ref Drawing 3MS7633A
4	Studs, ¾-10 UNC x 4" long
4	Washers, ¾"
4	Nuts, ¾-10 UNC
1	Flexible boot assembly. General Rubber 1101-0240-100-OEE (1101 O/A 24 x 10" F/F EPDM, Open Arch, Rated for 130 psi, 30 in Hg Vacuum, 250 F, Standard 150# Drilling, with PPRS-0240-CSG (R/R Set 24 in. CSG) Set of Split Retaining rings for 24" expansion joint with standard 150# drilling, 3/8" thick, Carbon Steel Galvanized or similar Provided with Lot 1 in Piping Installation section.
20	Bolts, 1 1/4-7 UNC by 8" long
20	Nuts, 1 ¼-7 UNC
10 ft	Structural Steel HSS 5x5x5/16
12	Hilti Kwik Bolt 3, 3/4"
2	Plate, Steel, ¾" x 1'-6" x 2'-3"
4	Plate Steel, ¾" x 6" x 1'-8"
1	Plate, Steel, ½" x 3' x 4'

Prepared By: Ln DeBu Date: 3-17-15

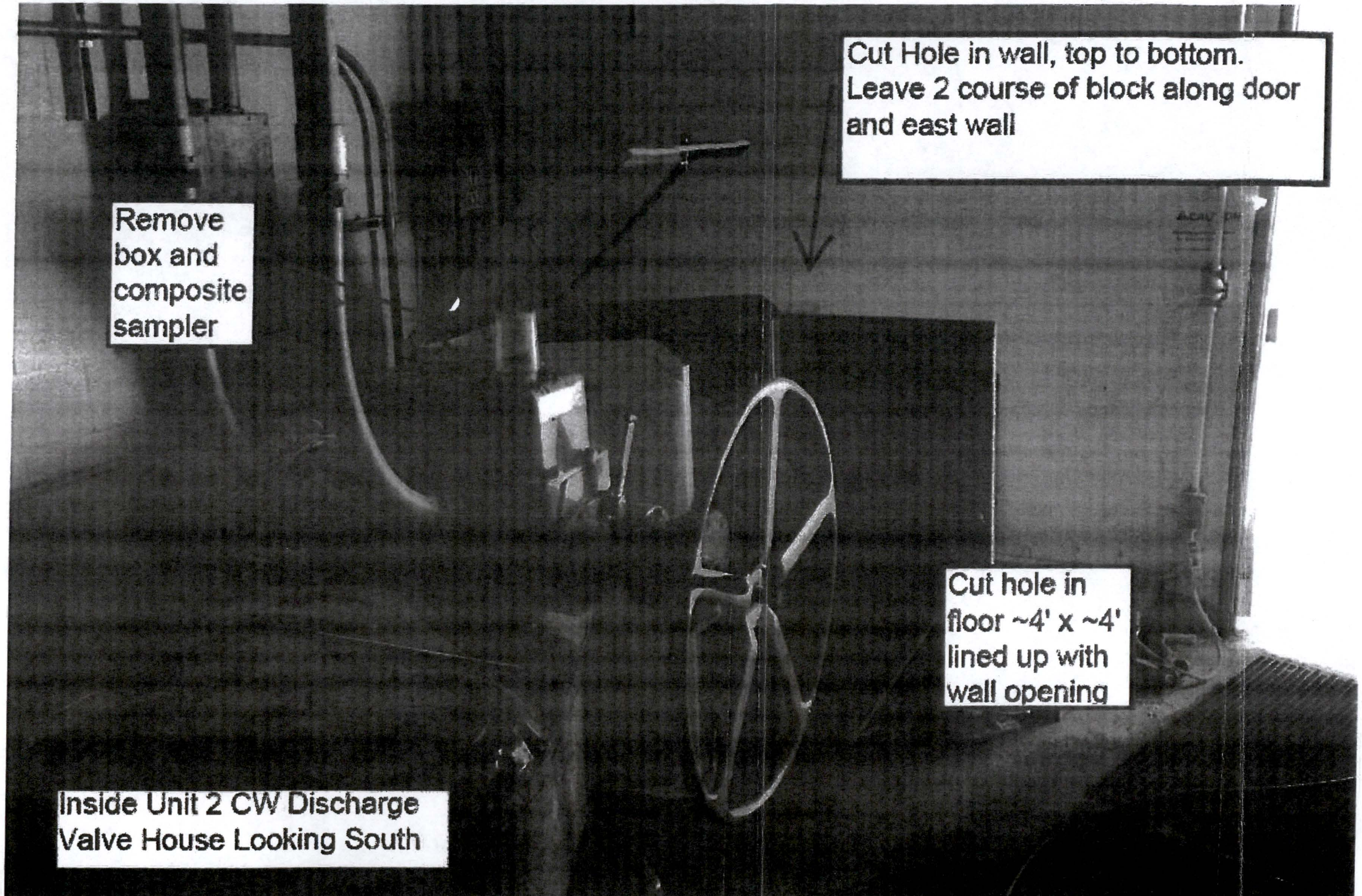
Reviewed By: [signature] Date: 3/18/15

Station: ZION Affected Unit: 00

ECN No.: 400986
Design Change No.: 400985

PART 4

Photo 2



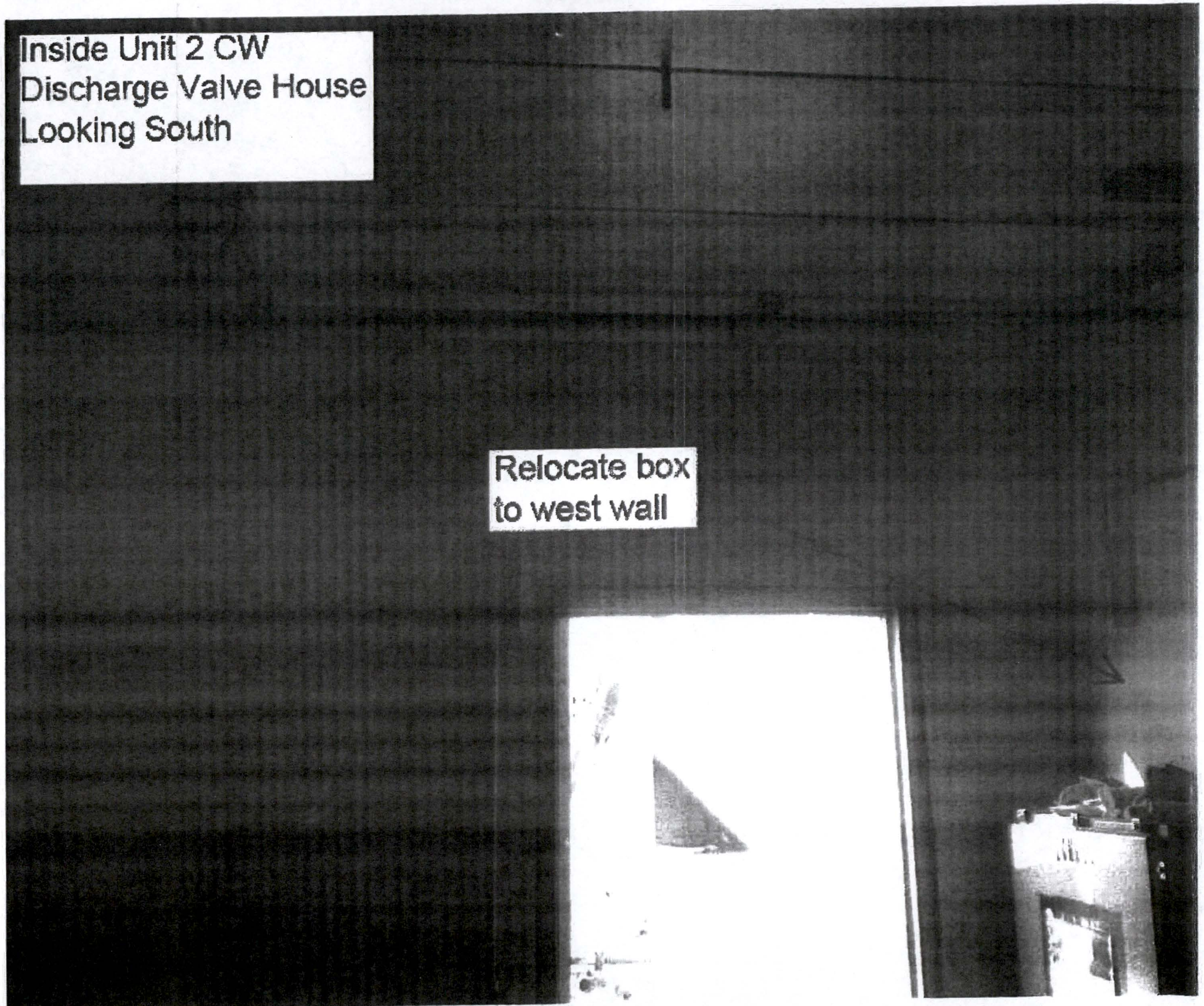
Prepared By: [signature] Date: 3-12-15

Reviewed By: [signature] Date: 3/12/15

PART 4

Station: ZION Affected Unit: 00

Photo 3



Prepared By: [signature] Date: 3-17-15

Reviewed By: [signature] Date: 3/18/15

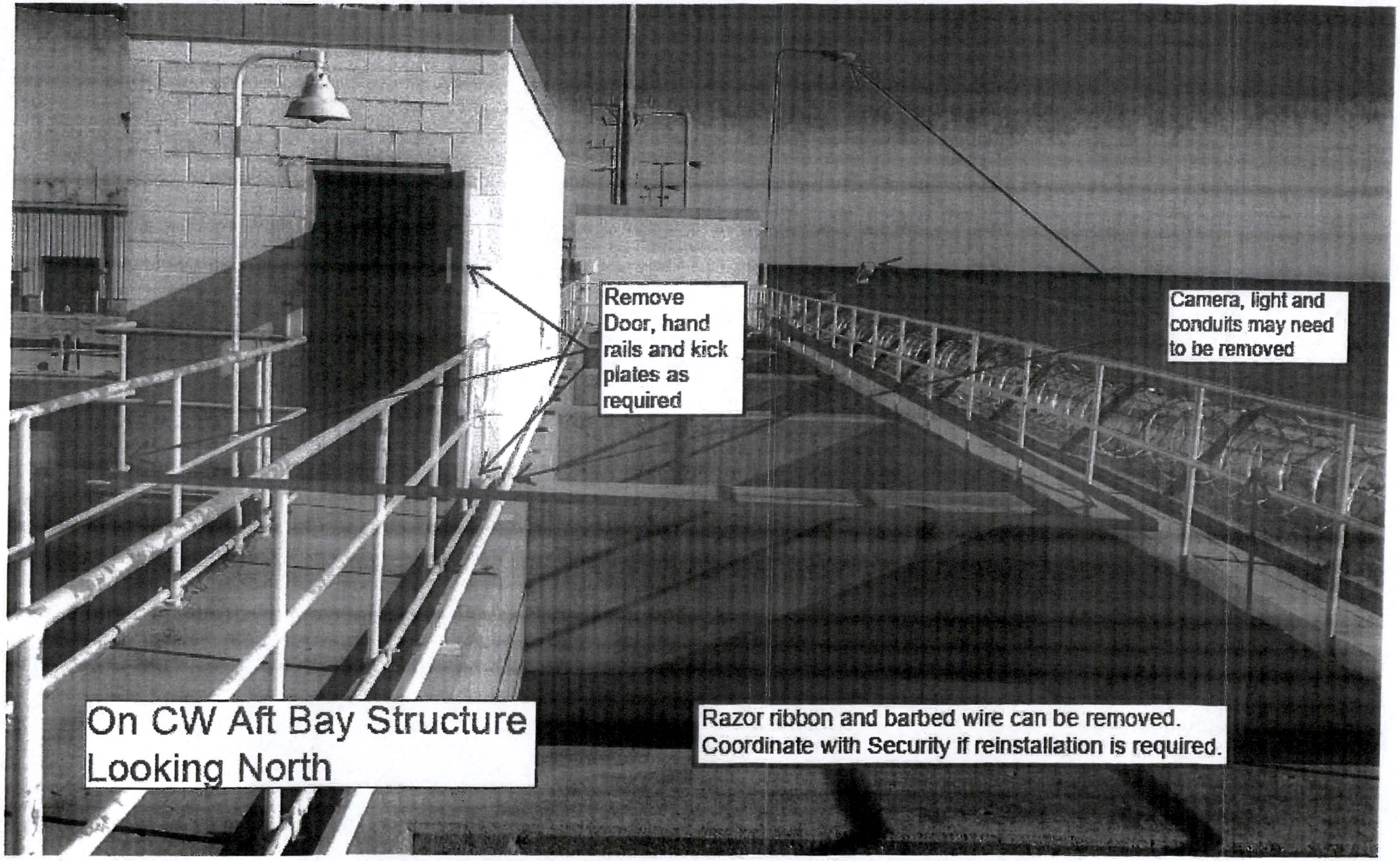
Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Page No.: 12 of 27

PART 4

Station: ZION   Affected Unit: 00

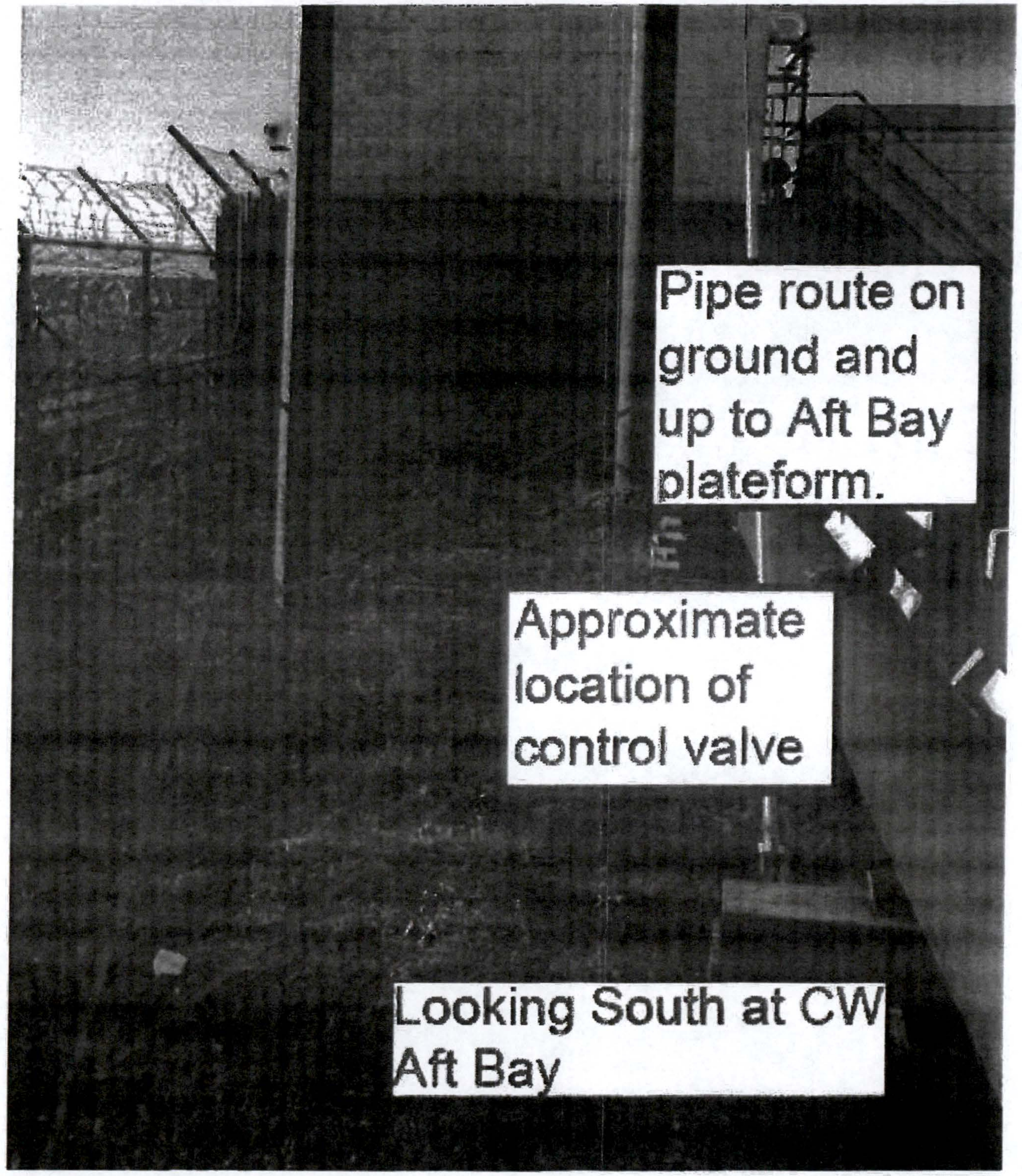
Photo 4



Prepared By: [signature]   Date: 3-17-15
Reviewed By: [signature]   Date: 3/18/15

PART 4

Photo 5



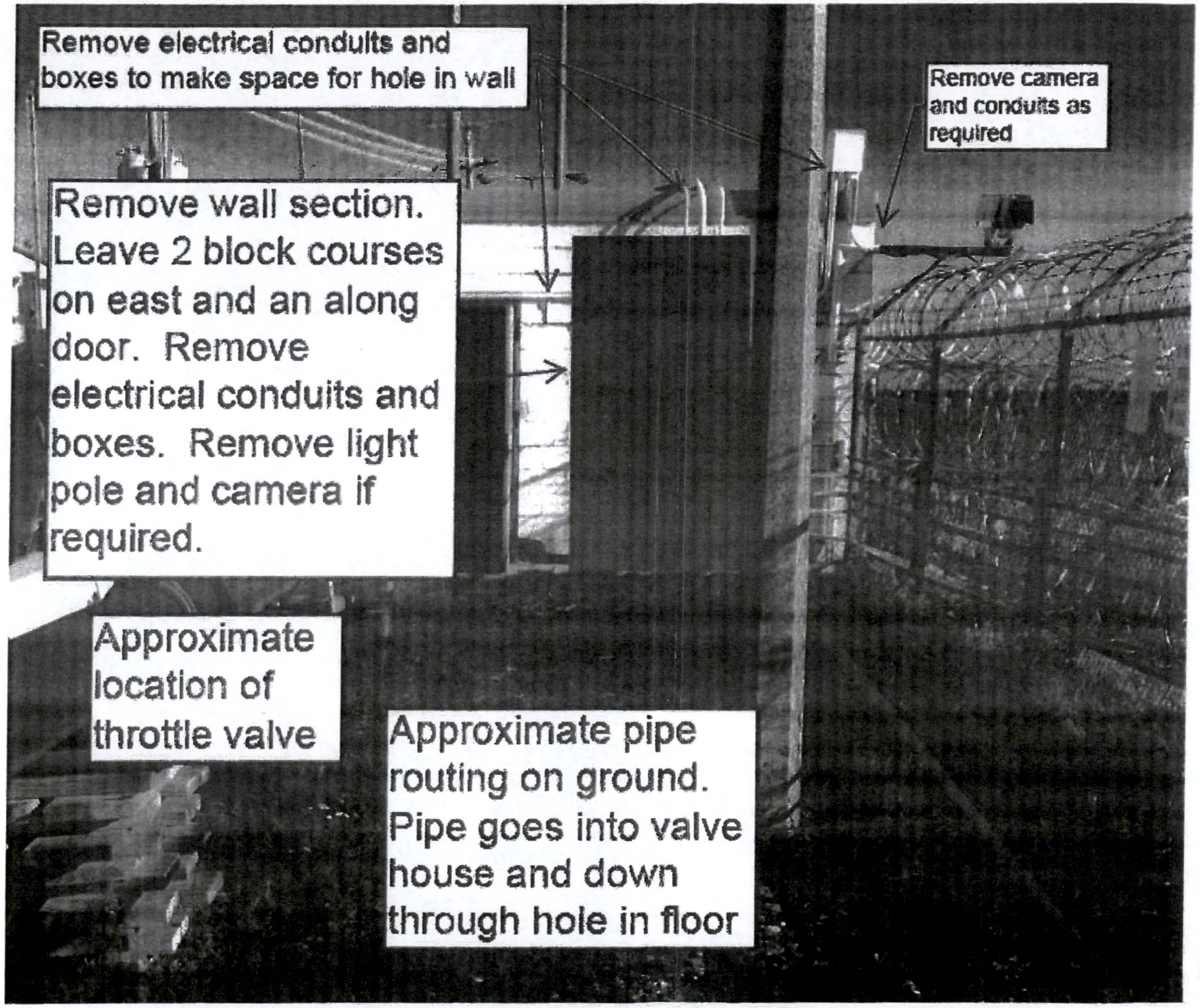
Prepared By: [signature]   Date: 3-17-15
Reviewed By: [signature]   Date: 3/18/15

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Station: ZION Affected Unit: 00 Page No.: 14 of 27

PART 4

Photo 6



Prepared By: [signature] Date: 3-17-15
Reviewed By: [signature] Date: 3/18/15

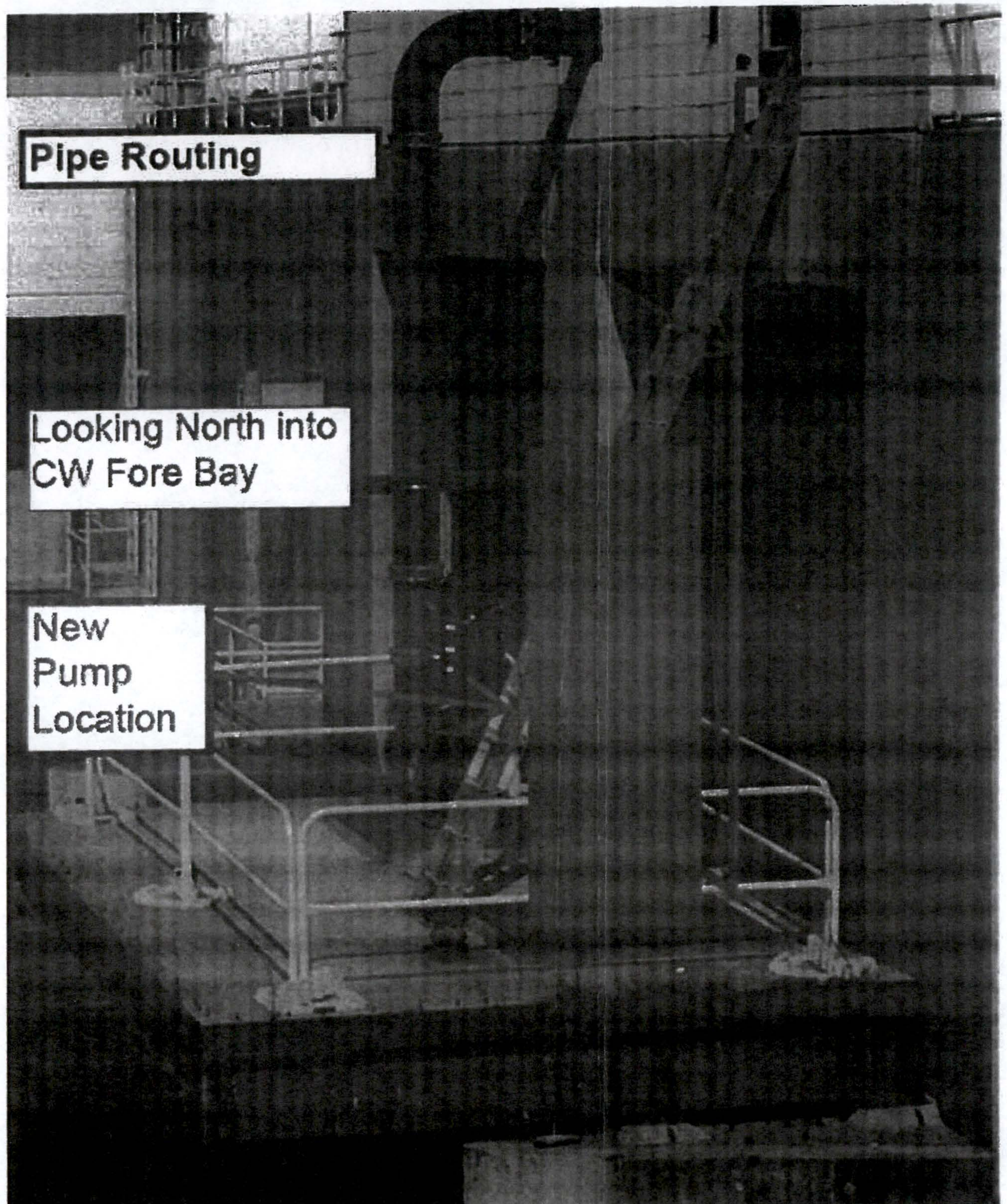
Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Page No.: 15 of 27

PART 4

Station: ZION Affected Unit: 00

Photo 7



Prepared By: Lee DB Date: 3-17-15

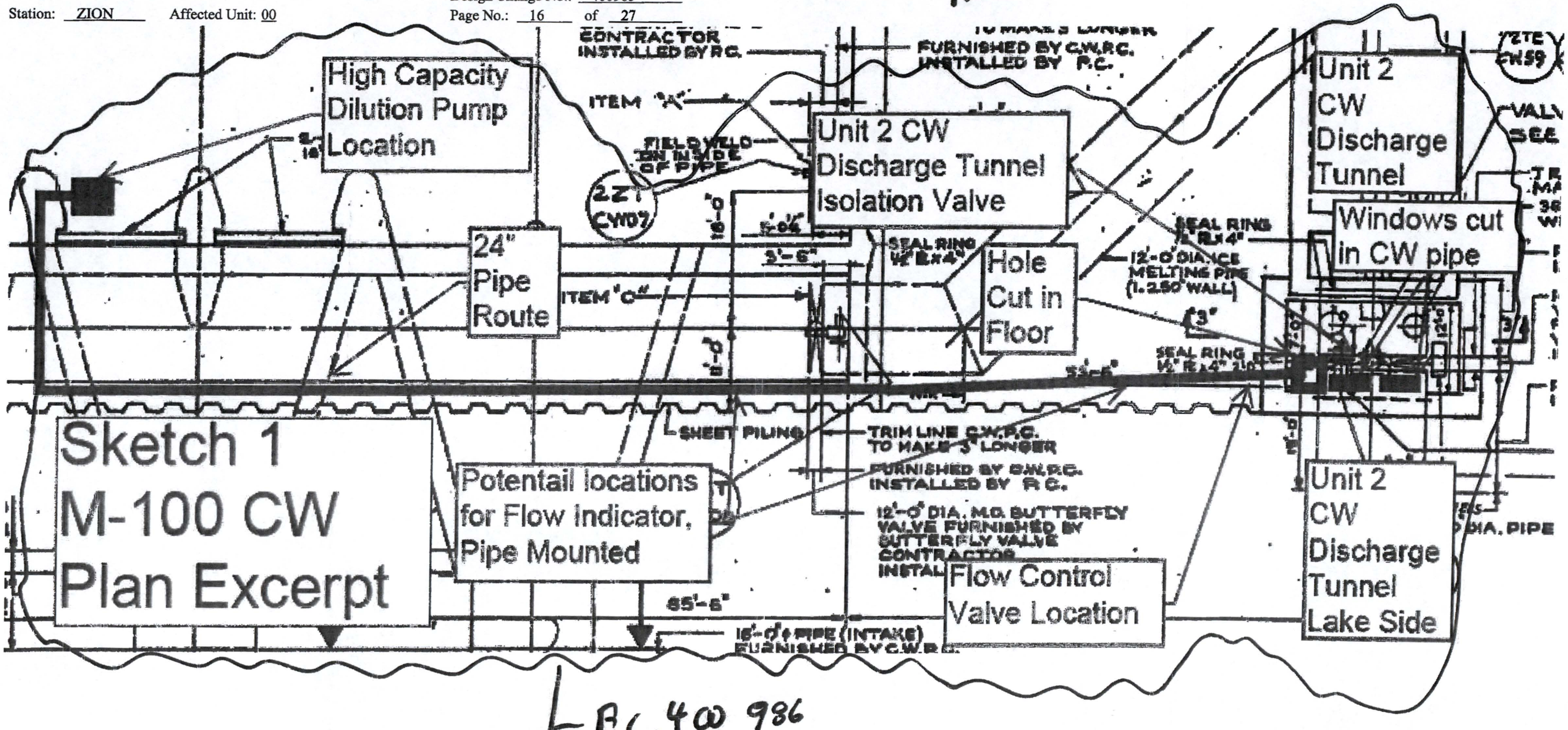
Reviewed By: Paul B Date: 3/18/15

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Page No.: 16 of 27

PART 4

Station: ZION Affected Unit: 00



LEC 400 986

Prepared By: [signature] Date: 3-17-15
Reviewed By: [signature] Date: 3/18/15

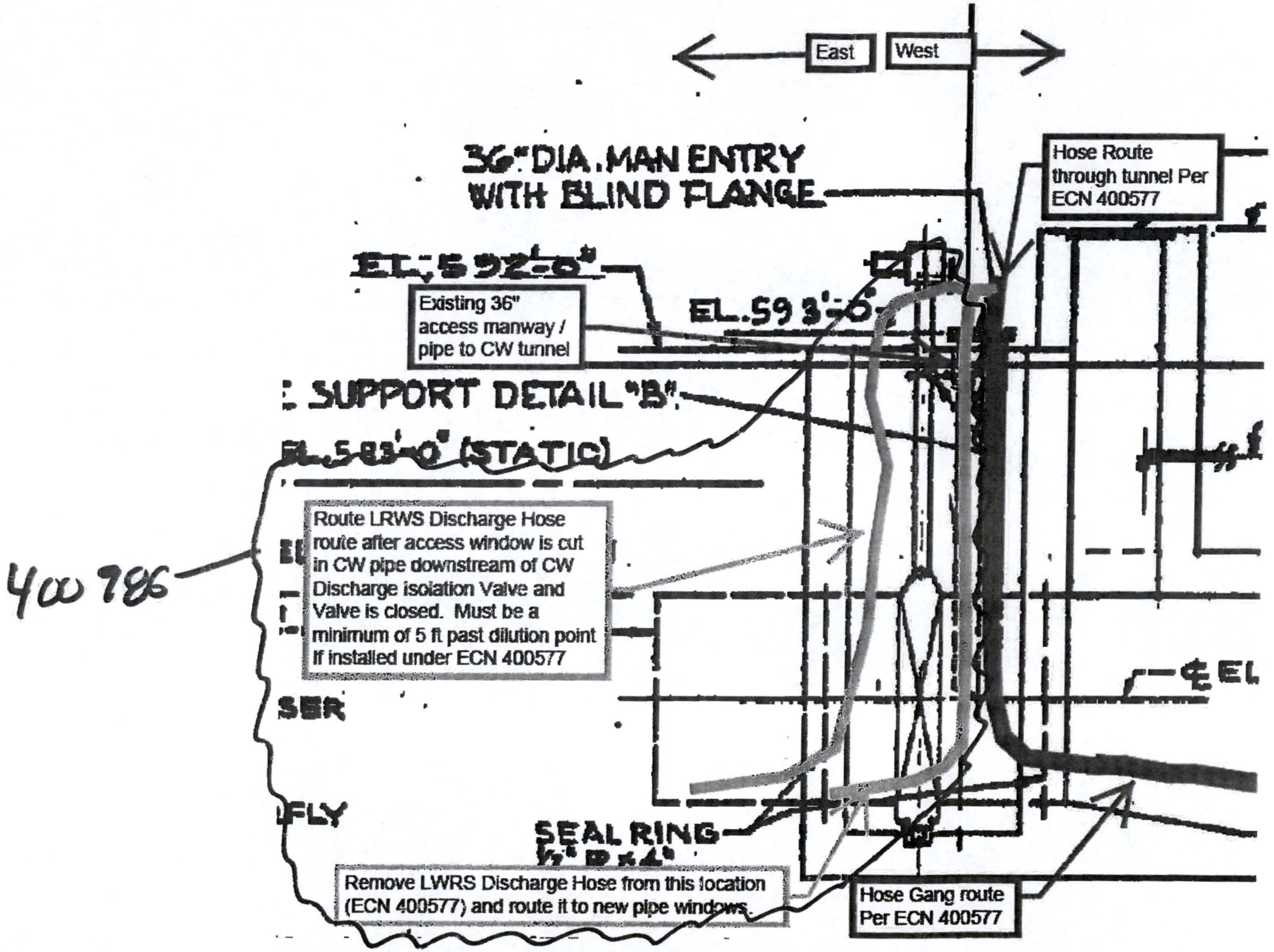
Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Page No.: 17 of 27

Station: ZION Affected Unit: 00

PART 4

Sketch 2



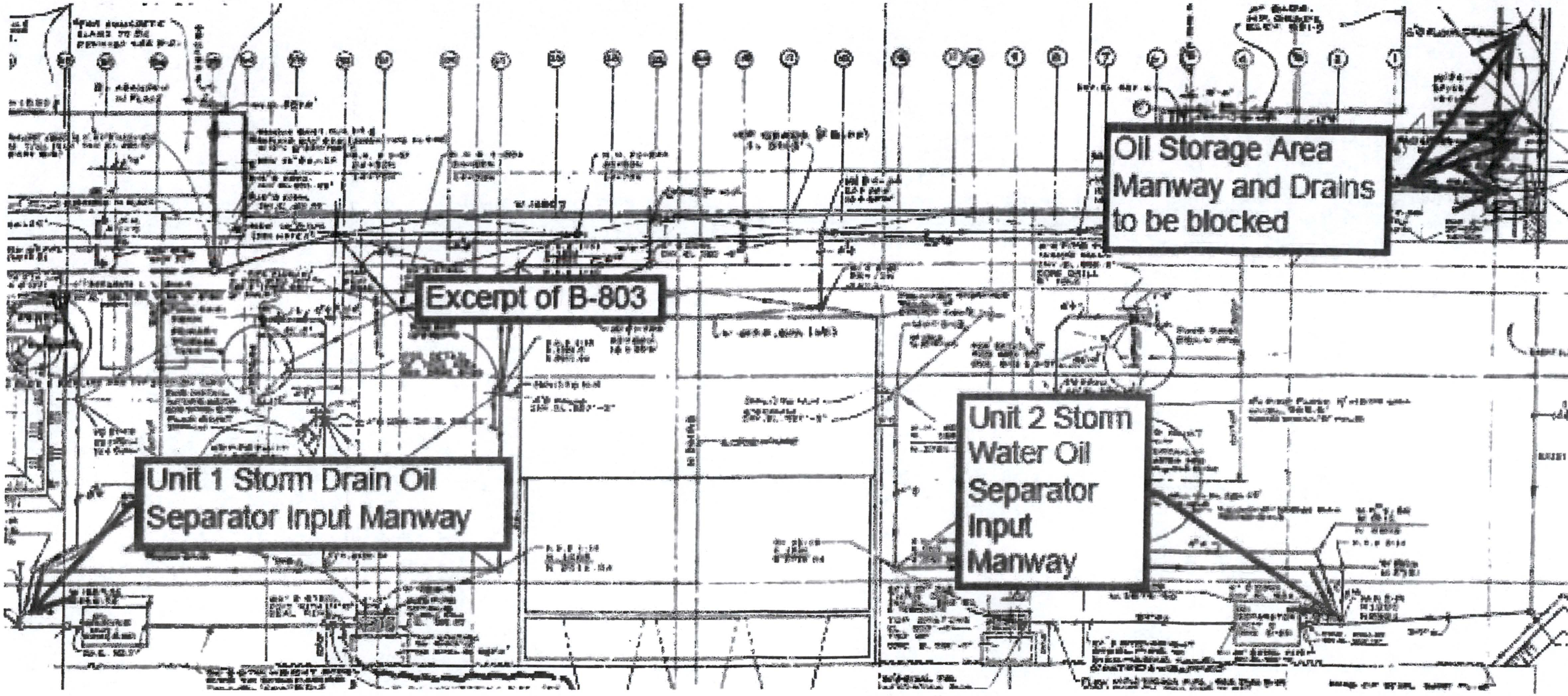
Prepared By: [signature] Date: 3-17-15
Reviewed By: [signature] Date: 3/18/15

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Station: ZION Affected Unit: 00 Page No.: 18 of 27

PART 4

Sketch 3

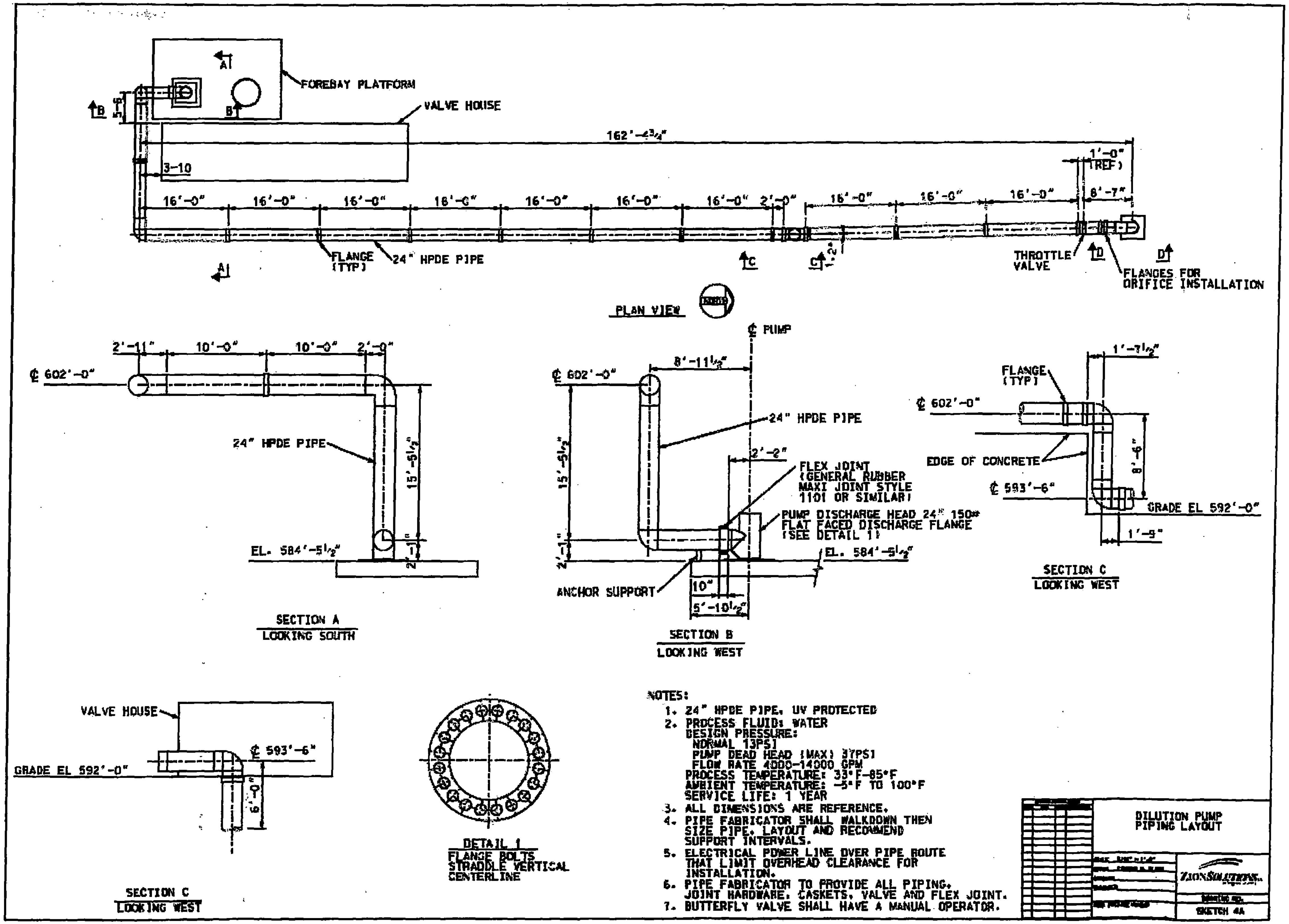


Prepared By: [signature] Date: 3-12-15
Reviewed By: [signature] Date: 3/18/15

Commonwealth Edison Company
Engineering Change Notice

PART 4

ECN No.: 400986
Design Change No.: 400985
Station: ZION Affected Unit: 00 Page No.: 19 of 27



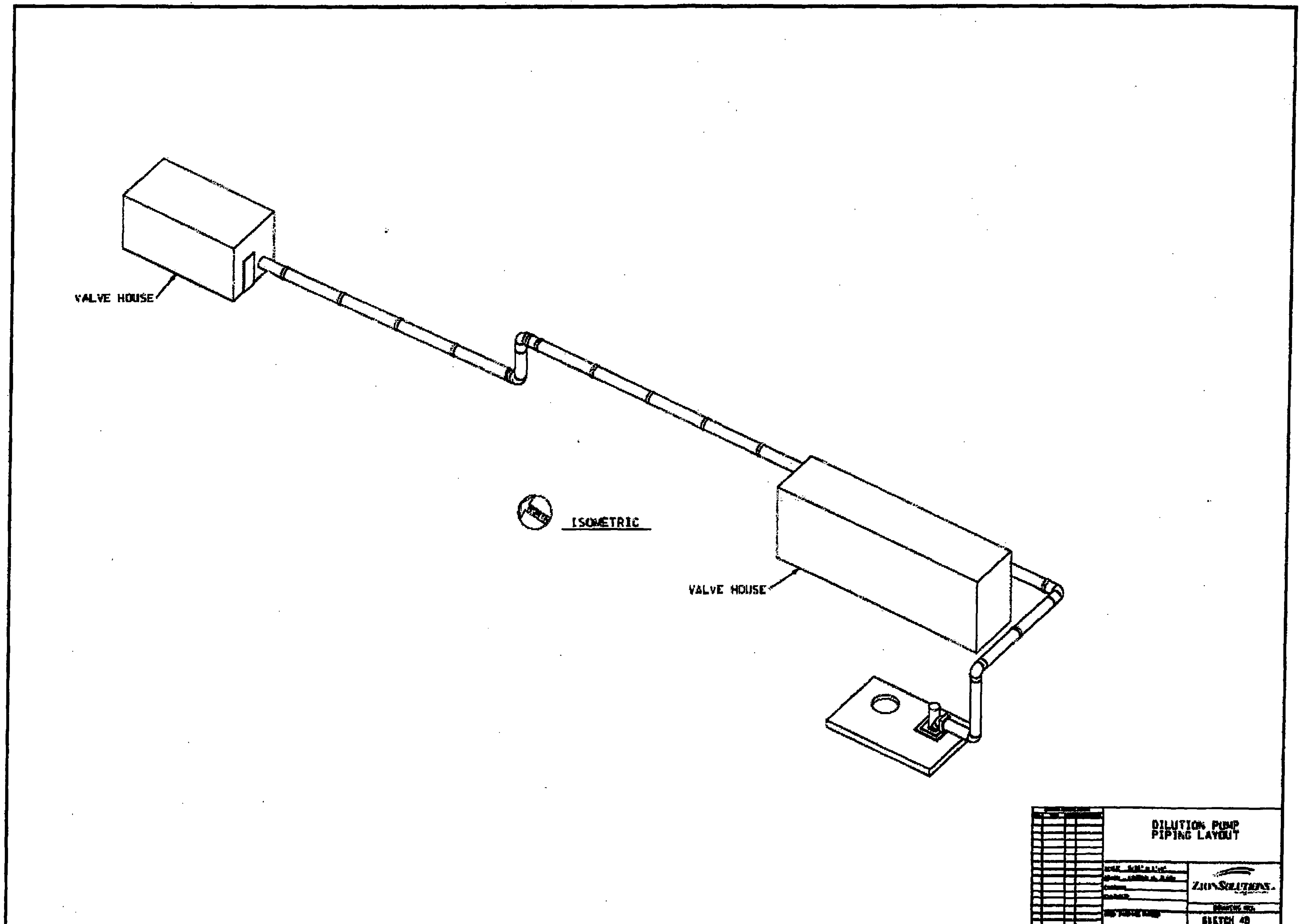
Prepared By: [signature] Date: 3-17-15
[signature] Date: 3/19/15

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Page No.: 20 of 27

PART 4

Station: ZION Affected Unit: 00



Prepared By: [signature] Date: 3-17-15

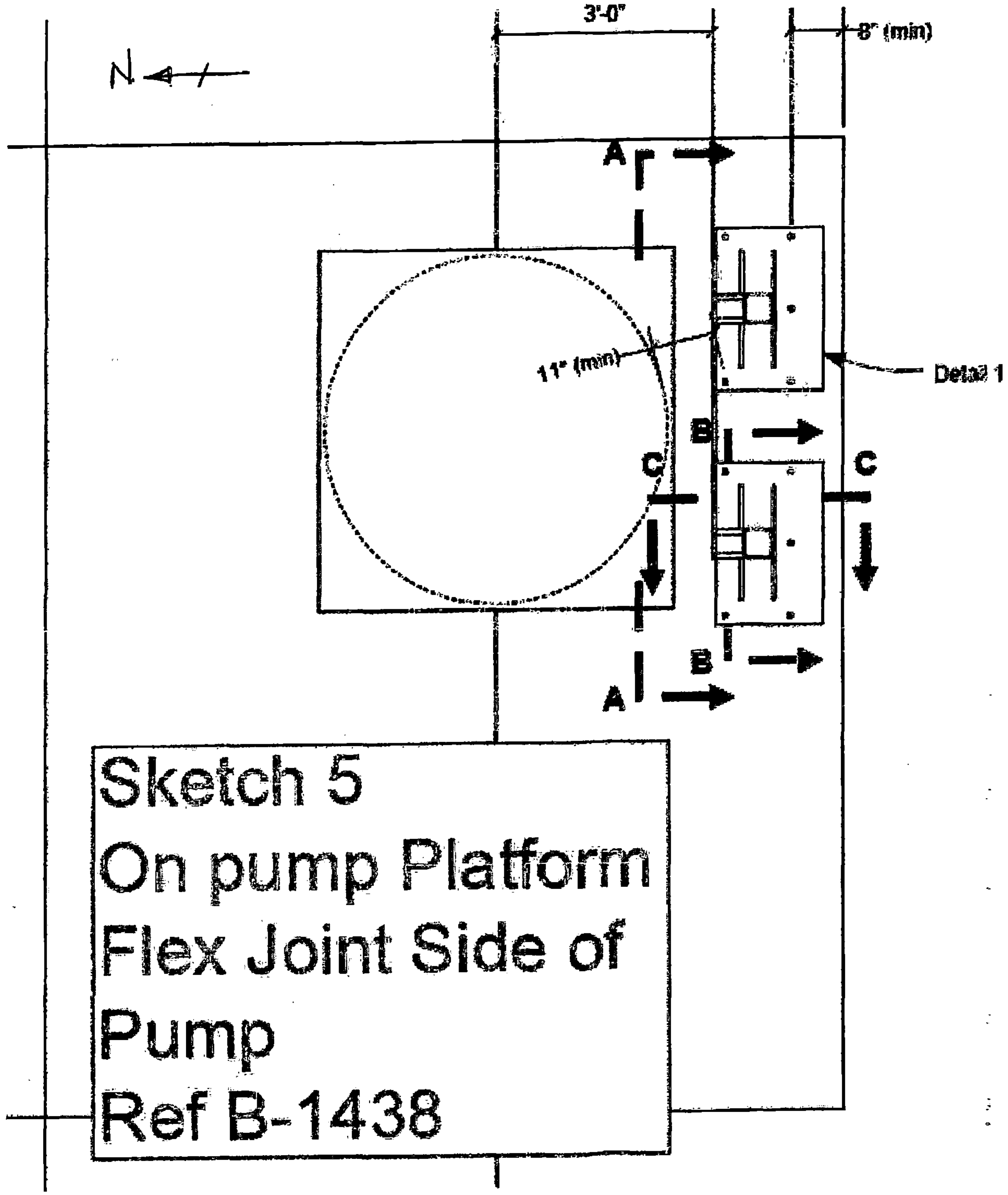
Reviewed By: [signature] Date: 3/18/15

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Page No.: 21 of 27

PART 4

Station: ZION   Affected Unit: 00



Sketch 5
On pump Platform
Flex Joint Side of
Pump
Ref B-1438

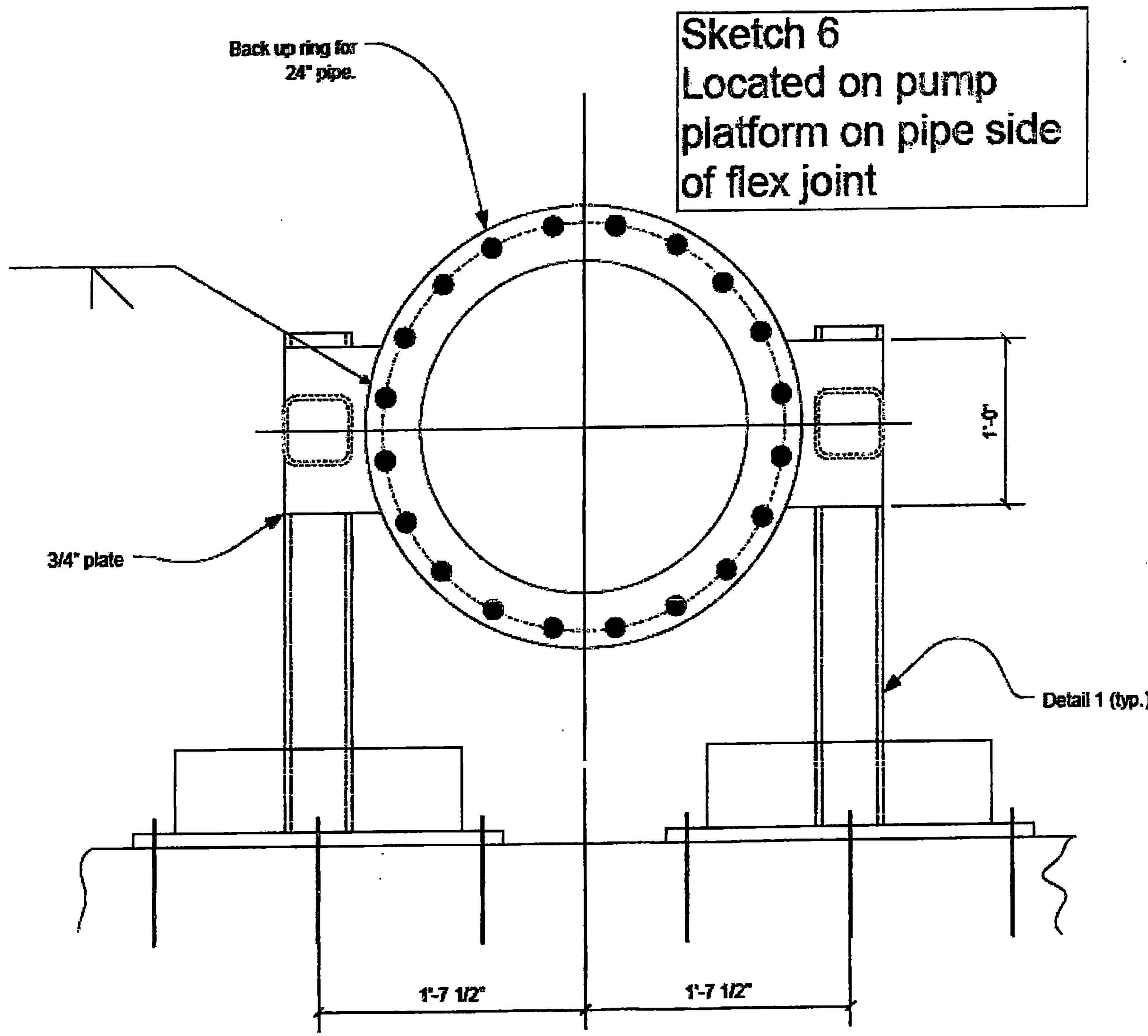
Prepared By: [signature]   Date: 3-17-15
Reviewed By: [signature]   Date: 3-17-15

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Page No.: 22 of 27

PART 4

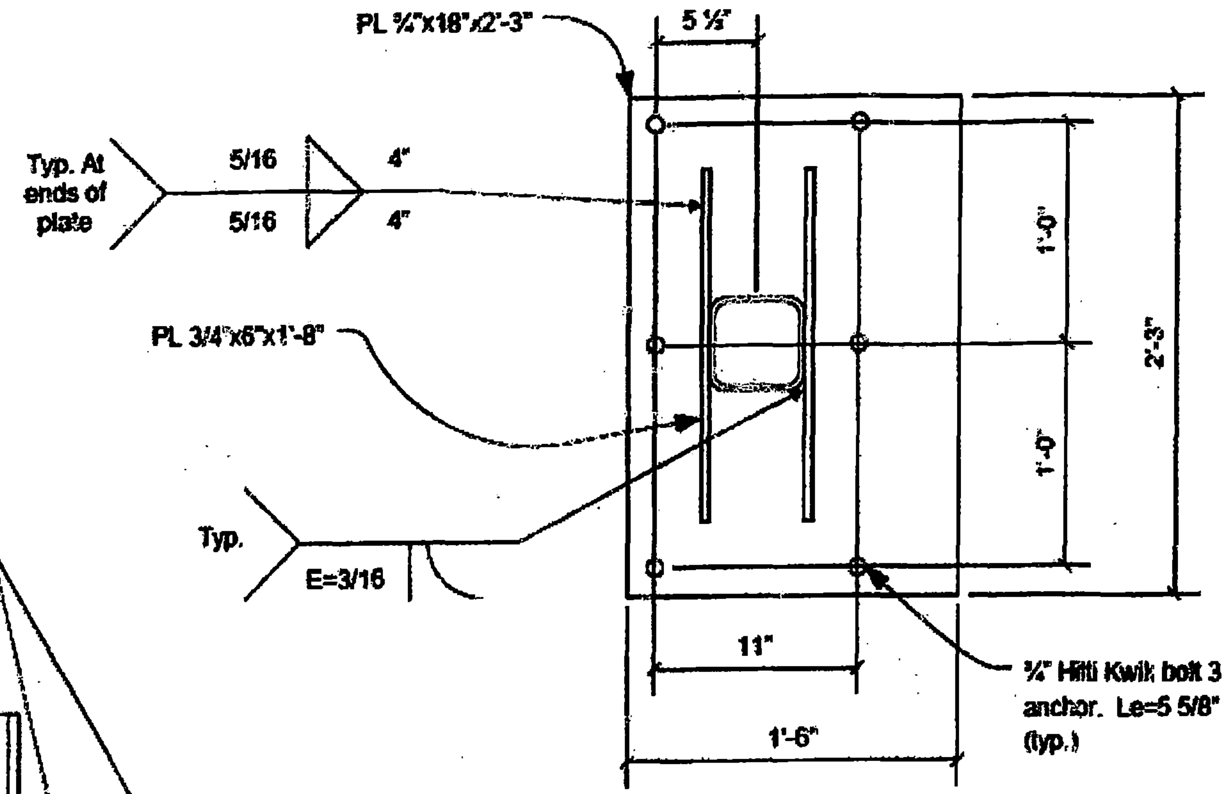
Station: ZION   Affected Unit: 00



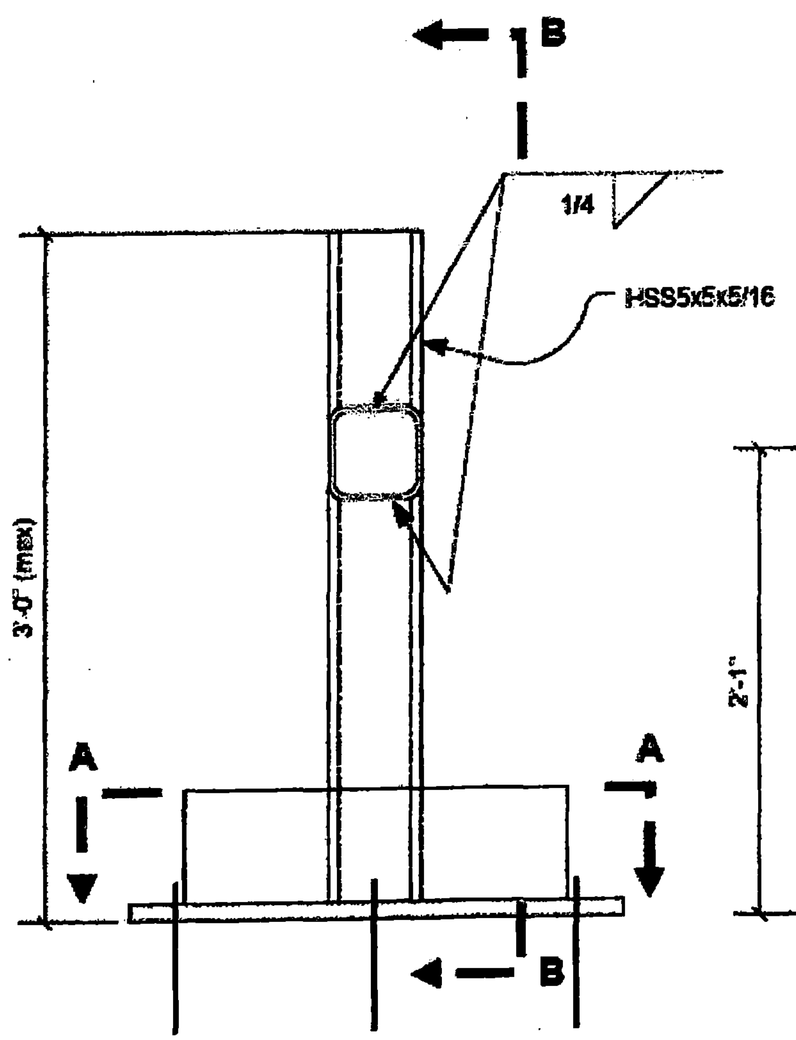
Section A-A

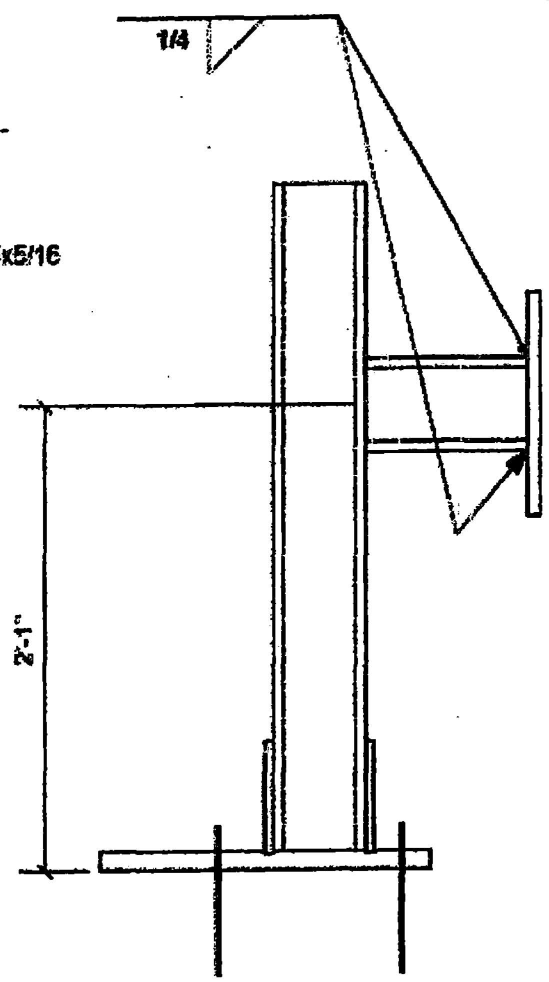
Prepared By: [signature]   Date: 3-12-15
Reviewed By: [signature]   Date: 3-17-15

PART 4



Detail 1





Sketch 7
On pump platform on pump side of flex joint

Section B-B

Section C-C

Prepared By: [signature] Date: 3-17-15

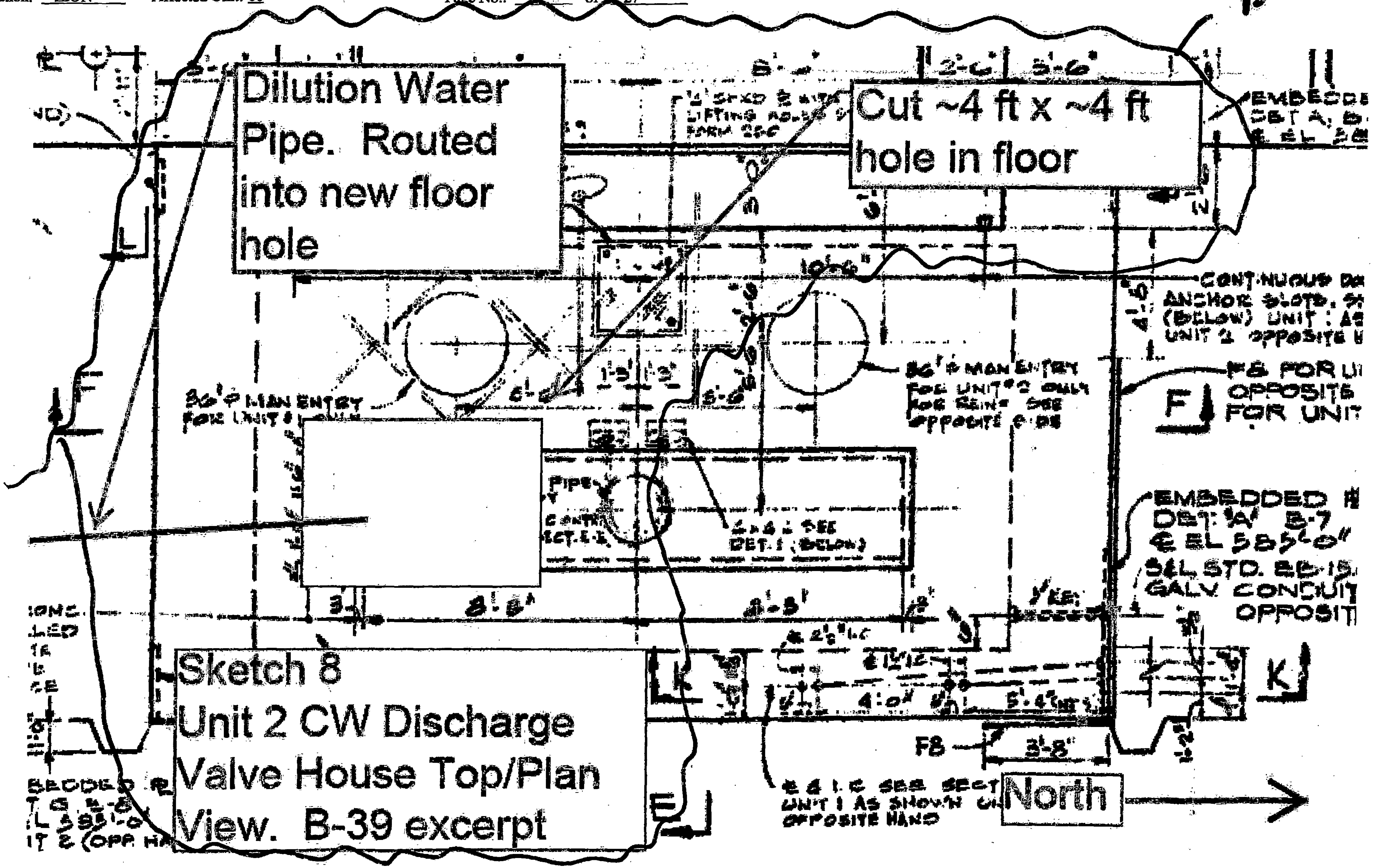
Reviewed By: [signature] Date: 3-17-15

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Station: ZION   Affected Unit: 00

PART 4

EC 400 786



Prepared By: Lee D[illegible]   Date: 3-17-15

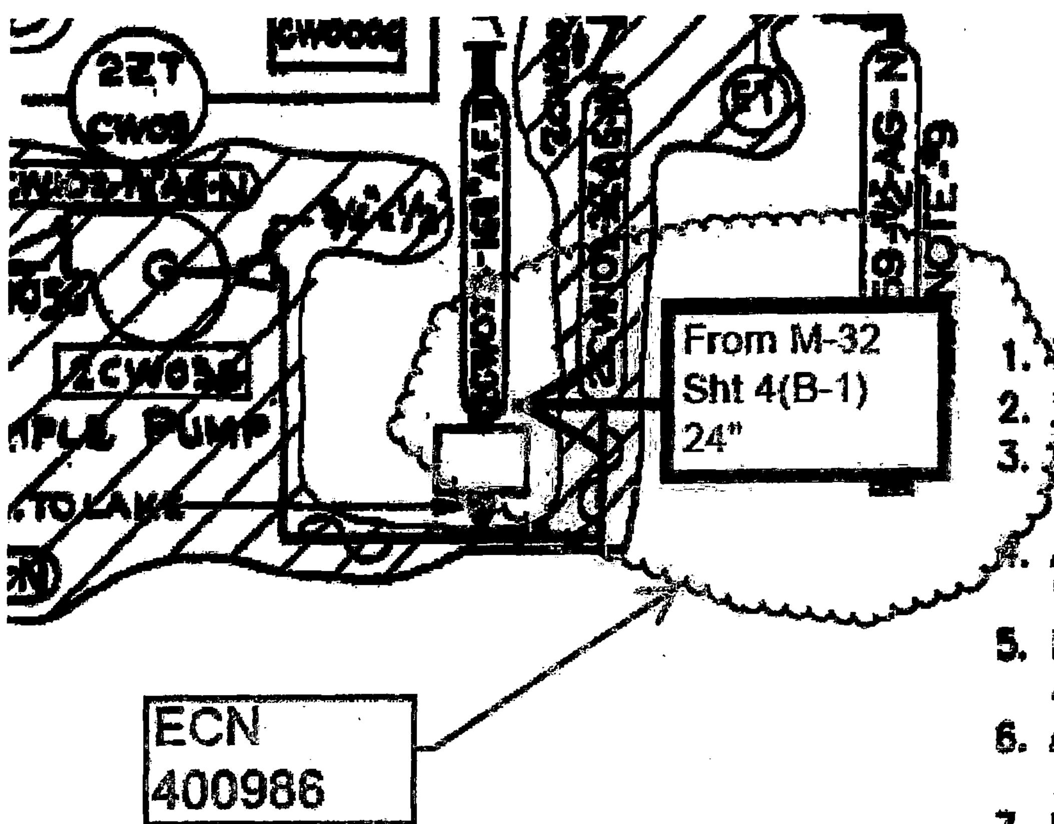
Reviewed By: [illegible]   Date: 3/18/15

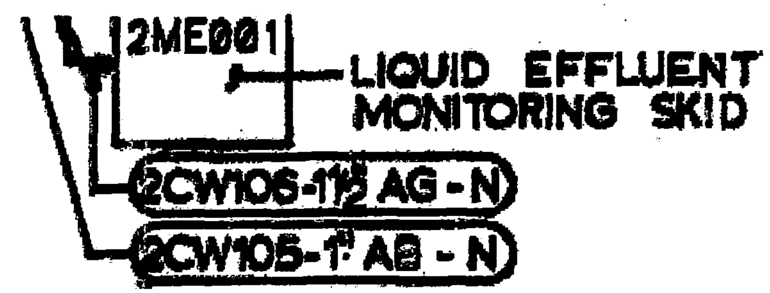
Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Page No.: 25 of 27

Station: ZION Affected Unit: 00

Part 5





NOTES:
1. TO PURCHASERS FOREBAY BUBBLER TUBES
2. TO PURCHASERS SUCTION-BAY SIPHON TUBES
3. ALL PIPING TO AND INCLUDING 30 ICH. O.D. SHALL BE IN ACCORDANCE WITH TABLE (ASF)
4. ALL PIPING LARGER THAN 30 INCH. O.D. SHALL BE INS WITH CORK FILLED MASTIC AS INDICATED IN THE SPEC
5. PIPING 10" O.D. AND SMALLER SHALL BE INSULATED IN ACCORDANCE WITH TABLE (ACF)
6. ALL OTHER PIPING SHALL BE INSULATED WITH "VIMASC INDICATED IN THE SPECIFICATION.
7. FOR DETAILS OF MISC. PIPING SEE (D-2) OF THIS DR

ATE	DESCRIPTION	PREP.	REVR.	APPR.
02/97	FOR RECORD PER DCR# 970247, "AS BUILT", (COMED REVISION)	OVO	JCM	JRO
17/97	FOR RECORD PER T/O# 0000000485 EC# E22-2-97-288, ECN# 001406M	RFD	JCM	JRO
--	(COMED REVISION)	--	--	--

ComEd
A Unicom Company
Chicago, Illinois

DIGRAM OF CIRCULATIN
WATER PIPING

SCALE :NONE
DATE :
DRAWN BY:

M-31

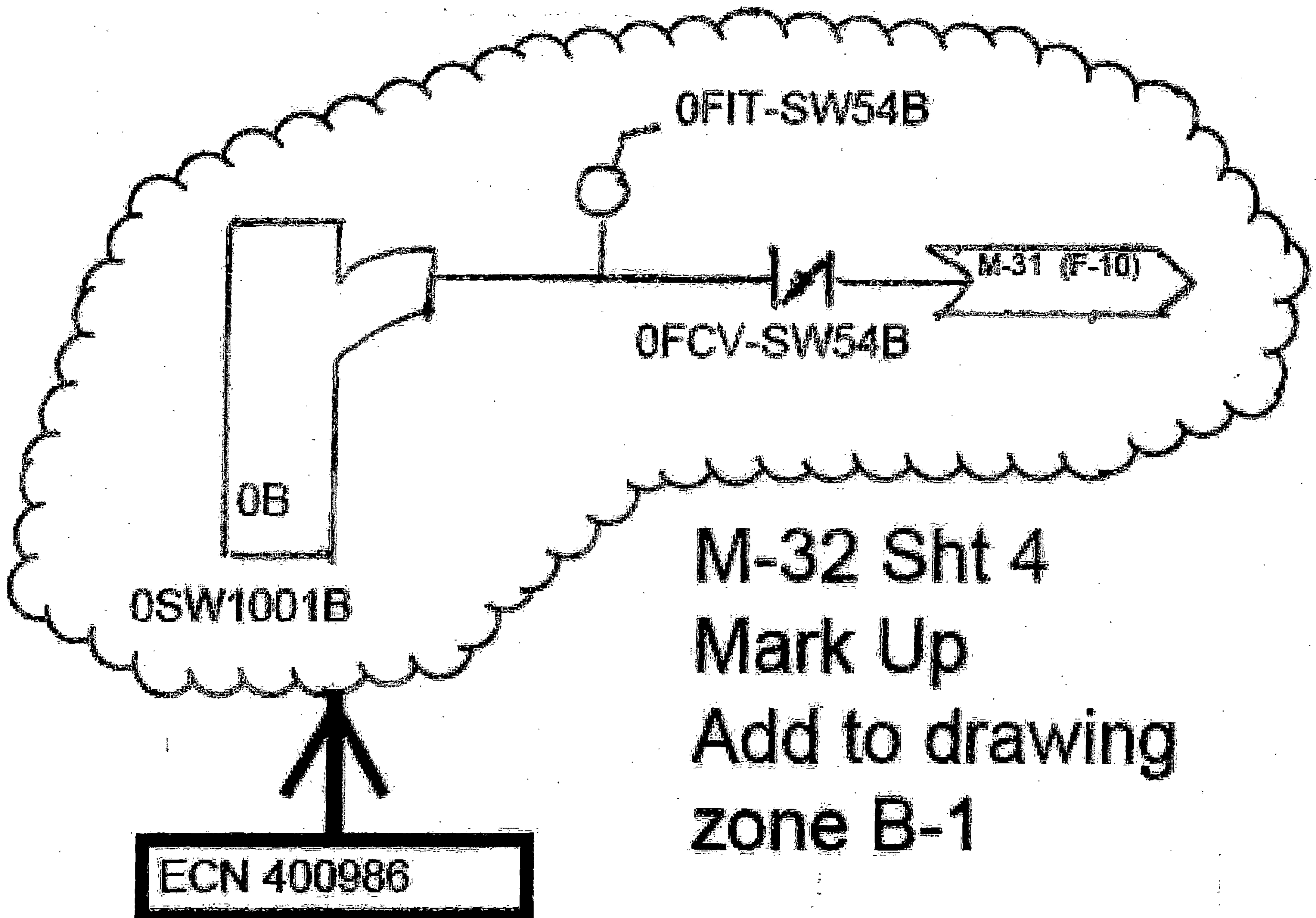
Prepared By: Zee DiBa Date: 3-17-15

Reviewed By: Paul Da Date: 3/18/15

Commonwealth Edison Company
Engineering Change Notice

ECN No.: 400986
Design Change No.: 400985
Station: ZION Affected Unit: 00 Page No.: 26 of 27

Part 5



M-32 Sht 4
Mark Up
Add to drawing
zone B-1

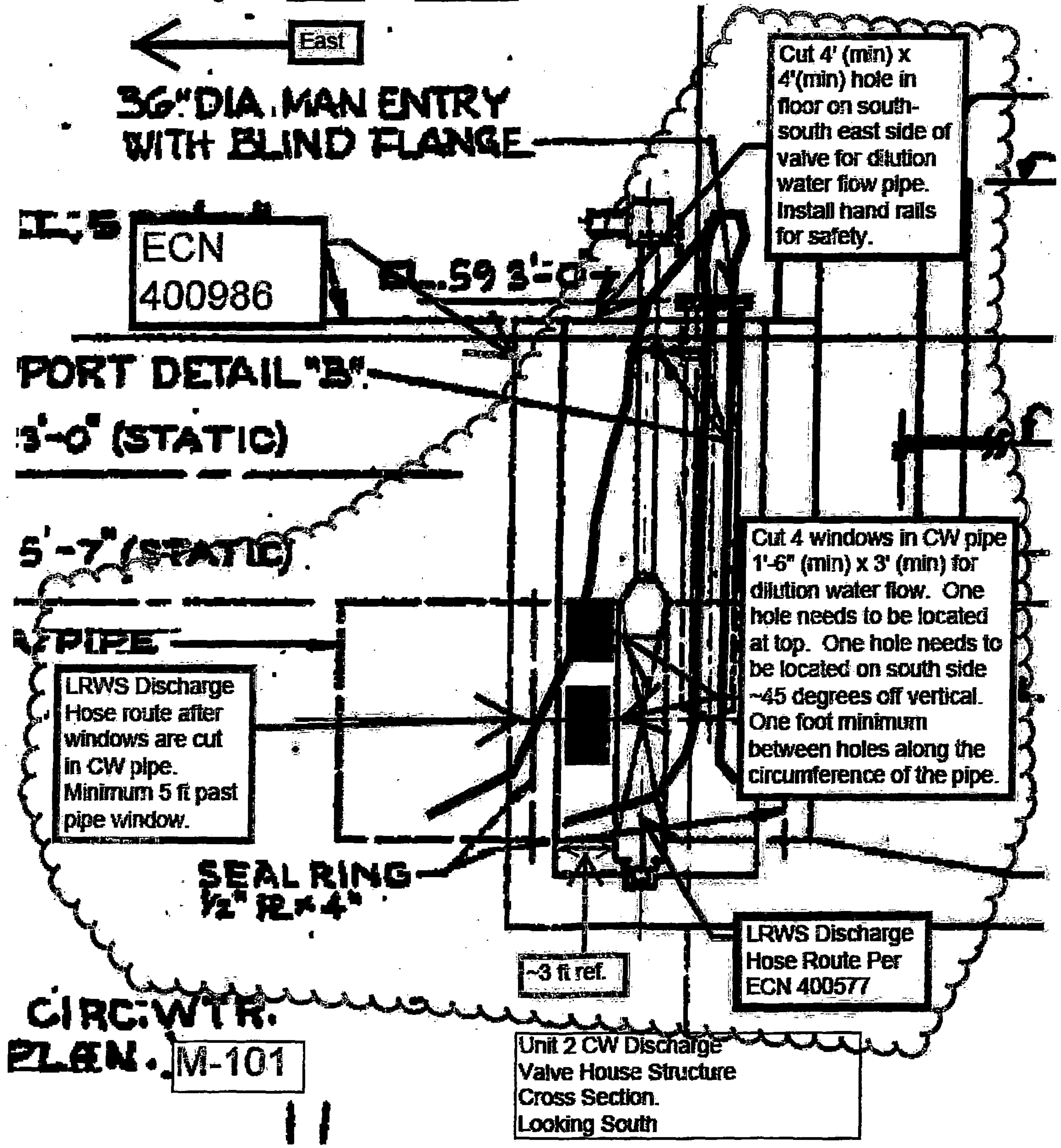
Prepared By: *[signature]* Date: 3-?-15
Reviewed By: *[signature]* Date: 3/12/15

Commonwealth Edison Company
Engineering Change Notice

PART 5

ECN No.: 400986
Design Change No.: 400985

Station: ZION Affected Unit: 00



Prepared By: [signature] Date: 3-17-15

Reviewed By: [signature] Date: 3/18/15

March 17, 2014
In reply refer to
CZE-15-005

To: Tony Orawiec

Subject: Zion Station, Unit 0 and 2
Exempt Change No. 400985
0B Dilution Water Pump

The Engineering Department has reviewed the subject Exempt Change in accordance with ZAP 510-02C and the applicable Zion Solutions Quality Requirements. The applicable Design Input Requirements are discussed in this letter.

System Code: SW, CW

<u>Description of Change</u>:

This activity will add an additional SW dilution water pump (0B) in the Forebay and the flow will run in parallel to the 0A SW dilution water pump to the discharge tunnel. This activity will also abandon (cap inputs to) the Unit 1 and Unit 2 Storm Drain Oil Separators.

<u>Exempt Change Design Package</u>:

The design for this exempt change will be contained in ECNs 400986 and 400987 are issued "For Construction" by this letter.

<u>10 CFR 50.59 Evaluation / Decommissioning Impact Evaluation</u>:

SCREENING DPL 3/18/2015

A 10 CFR 50.59 ~~Evaluation~~ was performed in accordance with ZAP 100-06 and is being transmitted along with this letter. This activity can be implemented without prior NRC approval. A Decommissioning Impact Evaluation was performed and it was concluded that the proposed activity is not restricted by 10 CFR 50.82.

<u>DSAR / ODCM Impact Review</u>:

There is no impact to the DSAR or the ODCM as a result of this Exempt change.

Applicable Codes and Standards:

This exempt change shall be installed in accordance with Zion Specification X-3646, which is the general work specification for mechanical, structural and electrical work as well as applicable site, vendor and corporate procedures. Installation requirements identified in ECN 400896 and 400897 supersede X-3646 specifications.

Installation Schedule / Outage Requirements:

Installation of this exempt change does NOT require an outage and therefore will be scheduled via the site work schedule process.

Technical Specification Changes:

The existing Technical Specifications do not require revisions as a result of this exempt change.

ALARA / Fire Protection Review:

This exempt change is NOT being performed in a radiological area. Therefore, an ALARA review will NOT be performed as a part of the work package preparation.

There are minor additional combustibles being added. These combustibles (cable and motor oil) will not be near any critical equipment.

Construction Drawings:

Construction is authorized to proceed in accordance with ECN 400896 and 400897.

Identification of the Installer:

D & D will perform this exempt change.

Procurement Requirements:

Procurement is the responsibility of the installing organization other than the pump/motor which will be procured by Engineering.

Procedures:

Operations, Chemistry, Radiation Protection and Environmental have identified affected procedures and are responsible for updating the required procedures prior to declaring this modification Operable.

Training Requirements:

There are no training requirements as a result of this exempt change.

Testing Requirements:

There are no testing requirements as a direct result of this exempt change. However, the new valve, flange and piping should be checked for no visible leakage and any leakage identified should be evaluated by engineering as acceptable.

Operating Requirements:

None required.

Technical Review:

The SW system is mentioned in the DSAR; therefore this modification is subject to a Technical Review in accordance with the requirements of ZAP 500-08 and the ZNPS. A Technical Review was completed under the ECNs and found to be acceptable.

Other Considerations

Engineering considerations are documented in ECN engineering document files. They are found to be acceptable.

Environmental Considerations

The removal of the Oil Separators was evaluated. As part of this activity the site will be transitioning to the Storm Water Pollution Protection Plan for storm water management. Roof drains from major buildings (Fuel Building, Auxiliary Building and Turbine Building) will now be discharged to the ground through the existing yard man ways. Oil and Grease storage will be at the guidance of the Environmental Manager.

If there are any questions regarding this exempt change, please contact Lee DuBois at 224-789-4065.

Prepared By: Lee DuBois
L. J. DuBois
Design Engineering

Approved By: Donald F. Roth
Don Roth
Design Engineering Supervisor

cc:

	MAL	ECN	50.59
Central File	1	1	1
Tara Pratt	originals		
Dennis Grub/James Gaskill	2	2	2
Tony Orawiec	1	1	1

TECHNICAL REVIEW LETTER

TR-010-2015

To: Anthony Orawiec
Decommissioning Plant Manager
Zion Station

Subject: Installing an additional Service Water (SW) Dilution Pump (Pp) with increased flow rates.

The purpose of this letter is to document the Technical Review of the Design Change Package for Exempt Change EC # 400985 and associated ECNs 400986 and 400987.

Our conclusion, the proposed exempt change does not impact the operation of any system which may be credited in any DSAR evaluation, the methodology used to establish the design bases or in the safety analyses as described in DSAR Chapters 3 or 5 in support of the safe storage of nuclear fuel.

In conclusion, the proposed Exempt Change does not affect the design or the design function of the SW System; as well, the proposed Exempt Change does not affect the ability of SW to perform that design function.

Prepared By: Lee DuBois Lee DuBois Date: 03/11/2015

Required Review Disciplines: A, B, D, G Donald F. Roth
Engineering Supervisor

Qualified Technical Reviews

Signature	Discipline	Date
Roger W Boyce	A, D, F	3-17-15
[signature]	A, B, D, E	3/18/15

I Concur and Approve: [signature] 3/18/15
Decommissioning Plant Manager Date

Distribution:
Decommissioning Plant Manager
Operations Supervisor
Engineering Supervisor
SRC Coordinator
Master File

ATTACHMENT D: 50.59 REVIEW COVERSHEET FORM

Station: ZION

Activity/Document Number: Design Change 400986 **Revision Number: 0**

Title: Increase the SW Pump Capacity and Elimination of the U1 & U2 Storm Drain Oil Separators

NOTE: For 50.59 Evaluations, information on this form will provide the basis for preparing the biennial summary report submitted to the NRC in accordance with the requirements of 10 CFR 50.59(d)(2).

Description of Activity:
(Provide a brief, concise description of what the proposed activity involves.)

Design Change 400985 adds a higher capacity SW pump and eliminates the U1 & U2 Oil Separators.

Reason for Activity:
(Discuss why the proposed activity is being performed.)

Increased capacity is needed to support RCA dewatering efforts and decommissioning schedules.

Effect of Activity:
(Discuss how the activity impacts plant operations, design bases, or safety analyses described in the UFSAR.)

activity merely increases the capacity of the SW system so as to allow for quicker removal of LRW. Removal of the oil separators is a management discretion activity and under the control of the Environmental Manager.

Summary of Conclusion for the Activity's 50.59 Review:
(Provide justification for the conclusion, including sufficient detail to recognize and understand the essential arguments leading to the conclusion. Provide more than a simple statement that a 50.59 Screening, 50.59 Evaluation, or a License Amendment Request, as applicable, is not required.)

The SW system and the Oil Separators are not credited for any design function nor are they credited for any accident mitigation in the DSAR. Additionally, this activity merely adds capacity and does not change the design function of the SW system. The Oil Separator function is being transition to the Storm Water Pollution Protection Plan.

Attachments:
Attach all 50.59 Review forms completed, as appropriate.
(NOTE: if both a Screening and Evaluation are completed, no Screening No. is required.)

Forms Attached: (Check all that apply.)

X	**Applicability Review**				
X	**50.59 Screening**	**50.59 Screening No.**	**2015-041**	**Rev.**	**0**
	50.59 Evaluation	**50.59 Evaluation No.**		**Rev.**	

WORK ON THIS 50.59 SCREENING BEGAN BEFORE 3/16/15, SO IT UTILIZES OLD FORMS. THE REVISED FORMS DO NOT TECHNICALLY OR FUNCTIONALLY AFFECT THE WORK.

Donald F. Roth 3/18/2015

ATTACHMENT E: 50.59 APPLICABILITY REVIEW FORM

Activity/Document Number: EC 400985 and ECN 400986 ECN 400987 **Revision Number:** 0

Address the questions below for all aspects of the Activity. If the answer is yes for any portion of the Activity, apply the identified process(es) to that portion of the Activity. Note that it is not unusual to have more than one process apply to a given Activity. See Section 4 of the Resource Manual (RM) for additional guidance.

I.	Does the proposed Activity involve a change:		
	1. Technical Specifications or Operating License (10CFR50.90)?	_X_ NO __ YES	See Section 4.2.1.1 of the RM
	2. Conditions of License Quality Assurance program (10CFR50.54(a))? Security Plan (10CFR50.54(p))? Emergency Plan (10CFR50.54(q))?	 _X_ NO __ YES _X_ NO __ YES _X_ NO __ YES	See Section 4.2.1.2 of the RM
	3. Specific Exemptions (10CFR50.12)?	_X_ NO __ YES	See Section 4.2.1.5 of the RM
	4. Radiation Protection Program (10CFR20)?	_X_ NO __ YES	See Section 4.2.1.6 of the RM
	5. Fire Protection Program (applicable UFSAR or operating license condition)?	_X_ NO __ YES	See Section 4.2.1.7 of the RM
	6. Programs controlled by the Operating License or the Technical Specifications (such as the ODCM).	_X_ NO __ YES	See Section 4.2.1.7 of the RM
	7. Environmental Protection Program	_X_ NO __ YES	See Section 4.2.1.7 of the RM
	8. Other programs controlled by other regulations.	_X_ NO __ YES	See Section 4.2.1 of the RM
II.	Does the proposed Activity involve maintenance which restores SSCs to their original condition or involve a temporary alteration supporting maintenance that will be in effect during at-power operations for 90 days or less?	_X_ NO __ YES	See Section 4.2.2 of the RM
III.	Does the proposed Activity involve a change to the:		
	1. UFSAR (including documents incorporated by reference) that is excluded from the requirement to perform a 50.59 Review by NEI 96-07 or NEI 98-03?	_X_ NO __ YES	See Section 4.2.3 of the RM
	2. Managerial or administrative procedures governing the conduct of facility operations	_X_ NO __ YES	See Section 4.2.4 of the RM
	3. Procedures for performing maintenance activities (subject to 10 CFR 50.65(a)(4))?	_X_ NO __ YES	See Section 4.2.4 of the RM
	4. Regulatory commitment not covered by another regulation based change process (see NEI 99-04)?	_X_ NO __ YES	See Section 4.2.3/4.2.4 of the RM
IV.	Does the proposed Activity involve a change to the Independent Spent Fuel Storage Installation (ISFSI) (subject to control by 10 CFR 72.48)	_X_ NO __ YES	See Section 4.2.6 of the RM
V.	Does the proposed Activity involve a change to the Packaging & Transportation of Radioactive Material? (subject to control by 10CFR71)	_X_ NO __ YES	
VI.	Is the proposed activity a Decommissioning Activity that does NOT require a 50.59 Screening, as described in Attachment 1 of ZS-EG-100?	_X_ NO __ YES	

Check one of the following:

☐ **If all aspects of the Activity are controlled by one or more of the above processes, then a 50.59 Screening is not required and the Activity may be implemented in accordance with its governing procedure.**

X **If any portion of the Activity is not controlled by one or more of the above processes, then process a 50.59 Screening for the portion not covered by any of the above processes. The remaining portion of the activity should be implemented in accordance with its governing procedure.**

This Exempt Change affects systems discussed in the DSAR that are Important to Defueled Condition. **Signoff:**

50.59 Screener/50.59 Evaluator: PAUL J. BONECKE Sign: [signature] Date: 3/18/15
(Circle One) (Print name) (Signature)

ZAP 100-06 ATTACHMENT F: 50.59 SCREENING FORM

50.59 Screening No: 2015-041 Rev No: 0

Activity/Document No: Design Change 400985 Revision No: 0

I. 50.59 Screening Questions (Check correct response and provide separate written response providing the basis for the answer to each question) (See Section 5 of the Resource Manual (RM) for additional guidance):

1.	**Does the proposed Activity involve a change to an SSC that adversely affects an UFSAR described design function? (See Section 5.2.2.1 of the RM)** Neither the SW system nor the Storm Drain Oil Separators are required SSC per the DSAR. There are no described design functions for these systems.	__ YES	_X_ NO
2.	**Does the proposed Activity involve a change to a procedure that adversely affects how UFSAR described SSC design functions are performed or controlled? (See Section 5.2.2.2 of the RM)** Procedure changes associated with this design acticity will be reviewed under a separate 50.59.	__ YES	_X_ NO
3.	**Does the proposed Activity involve an adverse change to an element of a UFSAR described evaluation methodology, or use of an alternative evaluation methodology, that is used in establishing the design bases or used in the safety analyses? (See Section 5.2.2.3 of the RM)** This activity does not involve a change to an element of a DSAR described evaluation methodology, or use of an alternative evaluation methodology, that is used in establishing the design bases or used in the safety analyses.	__ YES	_X_ NO
4.	**Does the proposed Activity involve a test or experiment not described in the UFSAR, where an SSC is utilized or controlled in a manner that is outside the reference bounds of the design for that SSC or is inconsistent with analyses or descriptions in the UFSAR? (See Section 5.2.2.4 of the RM)** The change activity is not a test or experiment.	__ YES	_X_ NO
5.	**Does the proposed Activity require a change in the Technical Specifications or Operating License? (See Section 5.2.2.5 of the RM)** No changes are required to the Zion Technical Specifications.	__ YES	_X_ NO

II. List the documents (e.g., UFSAR, Technical Specifications, other licensing basis, technical, commitments, etc.) reviewed, including sections numbers where relevant information was found (if not identified in the response to each question).

ZAP 100-06 ATTACHMENT F: 50.59 SCREENING FORM

50.59 Screening No: 2015-041 Rev No: 0

Activity/Document No: Design Change 400985 Revision No: 0

Zion DSAR 3, 4.6, ODCM, FPR

III. Select the appropriate conditions:

X	**If** all questions are answered NO, **then** complete the 50.59 Screening and implement the Activity per the applicable governing procedure.
	If question 1, 2, 3, or 4 is answered YES and question 5 is answered NO, **then** a 50.59 Evaluation shall be performed.
	If questions 1, 2, 3, and 4 are answered NO and question 5 is answered YES, **then** a License Amendment is required prior to implementation of the Activity.
	If question 5 is answered YES for any portion of an Activity, **then** a License Amendment is required prior to implementation of that portion of the Activity. In addition, **if** question 1, 2, 3, or 4 is answered YES for the remaining portions of the Activity, **then** a 50.59 Evaluation shall be performed for the remaining portions of the Activity.

IV. Screening Signoffs:

50.59 Screener: Paul J. Beinecke Sign: [signature] Date: 3 / 17 /2015
2015

(Print name) (Signature)

50.59 Reviewer: DONALD F. ROTH Sign: [signature] Date: 3 / 8 /2015
(Print name) (Signature)

ATTACHMENT 5

ECN# 2015-04

Installation of new liquid effluent radiation monitor for 0RT-PR04 and dilution flow permissive for lake discharge valve 0SOV-WD010

Attachment 4 Design Changes – DCPs, ECNs, FCRs, and DCRs	ZS-WC-100 Revision 10 Information Use

Exhibit A
(page A1)
ENGINEERING CHANGE NOTICE
(Part 1)

ECN No. 2015-04

ISSUANCE: [ ] FOR CONSTRUCTION [ ] FOR COMMENT Page: 1 of 17

Station: Zion Affected Unit: 0 Changes to a previously Approved ECN [ ]	[ ] Safety Related [X] Non-Safety Related [ ] Regulatory	Design Change No. 2015-04 Project No.(if appl.) Supp ID No. (if appl.) System: IS

Description of Design Change Request:
Install new radiation monitor for 0RT-PR04 and add a dilution flow permissive for lake discharge valve 0SOV-WD010.

Reason for Design Change: Change and action required (Provide reason for change, specific actions required, attach supporting documents, as applicable).
The existing sensor for 0RT-PR04 has failed and compatible parts are unavailable. The dilution flow permissive is an enhancement to the existing system to ensure adequate dilution flow is maintained for lake releases.

INTERFACING COMMENTS by

Design Group or Discipline	Name of Commenter (Printed)	Signature of Commenter	Date	C or NC
Elect./I&C				
Mechanical				
Structural				
D&D Operations				
Others				

Prepared by: Jerome C. Hansen Date: 6/17/15	Reviewed by: [signature] C or NC Date: 6-17-15	Approved by: Donald F. Pach Date: 6/17/2015

All affected design documents revised by (date):

Verified by: Date:

Exhibit A
(page A2)
DESIGN CHANGE DOCUMENT - AFFECTED DOCUMENT LIST
(Part 2)

Associated With:

_ ECN - Comment

X ECN - Construction

_ FCR

_ Other:________

DCP Number: 2015-04

Part 1 - General Information - Optional for FCR

Date Prepared: 16 June 2015

Originator: James Hausser

W.O. Number: 2015-031

Description: Install new radiation monitor for 0RT-PR04 and add a dilution flow permissive for lake discharge valve 0SOV-WD010

Part 2 - Related Design Change Documents (i.e., ECN,FCR)

Ref. No.	Type	Number	Ref. No.	Type	Number
1.	DCP	2015-04	5.		
2.	ECN	2015-04	6.		
3.			7.		
4.			8.		

Prepared By: Jon C Haus Date 6/17/15
Reviewed By: [signature] Date 6-17-15

Attachment 4 Design Changes – DCPs, ECNs, FCRs, and DCRs	ZS-WC-100 Revision 10 Information Use

Part 2 - Affected Design Documents

DESIGN DOCUMENT (DD)					C/R*	F/D**	Related DCDs (Ref # from Part 2	Incorp. Rev. or Date (Optional)
Type Code (1-Dwg 2-Calc 3-Other)	Number	Sheet /Page	Rev. No.	Rev Date				
ECN Drawings Part 4								

*'C' for Construction or 'R' for Record **'F' for Functional or 'D' for Detailed

Prepared By: Jane C Ham Date 6/17/15
Reviewed By: [signature] Date 6-17-15

Exhibit A
(page A3)
Back-up Calculation Listing
(Part 2)

Calculation/Analysis No	Rev. No.	Description
None		

Prepared By: Jams C Haus Date 6/17/15
Reviewed By: [signature] Date 6-17-15

Exhibit A
(page A4)
CERTIFICATION PAGE
(Part 3)

ECN No: 2015-04
Design Change No.: 2015-04

Station: Zion Affected Unit: 0 Page 5 of 17

CERTIFICATION OF ECN NO. N/A

I certify that this Engineering Change Notice was prepared by me or under my supervision and that I am a registered Professional Engineer under the laws of the State of Illinois.

Certified by: N/A Date:

Seal

Prepared By: James L Hays Date 6/17/15
Reviewed By: [signature] Date 6-17-15

Part 4 – Construction Support Information

1. 0RT-PR04/0SOV-WD010 Control Panel Construction

Note:
Steps in Section 1 can be performed in any logical order at the discretion of the responsible work group.

1.a. Install components and wire according to Sketch 7

1.b. Obtain PR04 electronics module from Engineering and mount on right side of control panel as shown on Sketch 1.

1.c. Request Engineering to program the Pico control relay.

1.d. With Engineering assistance, apply power to the control panel and verify proper operation of the control relay, control switches, and indicating lights.

2. Field Installation

Note:
The steps of section 2 can be performed in any logical order at the discretion of the responsible work group.

2.a. At unit 2 boric acid tank room, determinate and remove the test cart associated with 0RT-PR04.

2.b. At unit 2 boric acid tank room, install new PR04/WD010 control panel on wall.

2.c. At unit 2 boric acid tank room, determinate and remove cables from 120 Vac junction box.

2.d. At unit 2 boric acid tank room, install new 120 Vac junction box and terminal strip as depicted in Sketch 1.

2.e. At unit 2 boric acid tank room, terminate cable 04264 at terminal strip in new junction box as shown in Sketch 1.

2.f. At unit 2 boric acid tank room, field route and terminate Cable C at new 120 Vac junction box and PR04/WD010 control panel as shown on Sketches 1 and 7.

2.g. At unit 2 boric acid tank room, terminate cable "B" in PR04/WD010 control panel as shown in Sketch 7.

2.h. At unit 2 boric acid tank room, plug UPS into wall outlet supplied by 120 Vac junction box.

2.i. At unit 2 boric acid tank room, plug cable "B" into UPS as depicted in Sketch 1.

2.j. Above 480 V SWGR 232, connect cables 75316 and 75323 as shown on Sketch 9.

Prepared By: James C Hann Date 6/17/15
Reviewed By: [signature] Date 6-17-15

2.k. At Unit 2 valve house, field route cable 0SW005 from 0SW1001A starter to flow transmitter 0FIT-SW054B.

2.l. Terminate cable 0SW005 at 0SW1001A starter and flow transmitter 0FIT-SW054B as shown on Sketch 9.

2.m. At new PR04/WD010 control panel, terminate the following cables as shown on Sketch 7:

- Cable "B" from PR04 UPS
- Cable "C" from 120 Vac Junction Box
- Cable 75323
- Wire pair associated with ADS Alarm Zone 505
- Wire pair associated with ADS Alarm Zone 506
- Wire pair associated with ADS Alarm Zone 512
- Wire pair associated with ADS Alarm Zone 513

3. Functional Testing

Note:
Engineering and RP Technician assistance are required for the following steps.

Note:
The steps in Section 3 can be performed in any logical order at the direction of Engineering and RP Instrument Technician.

3.a. Isolate 0SOV-WD010 to allow cycling of the valve for testing purposes.

3.b. Verify Dilution Pumps 0SW1001A and 0SW1001B are shut off.

3.c. At PR04/WD010 control panel, verify all five fuses are pulled out.

3.d. At PR04/WD010 control panel, insert Fuse F1 and verify 24 Vdc power supply and PR04 electronics module are both energized.

3.e. At PR04/WD010 control panel, insert Fuse F5 and verify all four (4) red lights on the control panel illuminate.

3.f. At PR04/WD010 control panel, PRESS PR04 Alarm Reset Push Button and VERIFY relays PR04-RLY01 and PR04-RL02 energize and remain energized (Ref. Sketch 3).

3.g. At PR04/WD010 control panel, insert Fuse F2 and verify Pico relay energizes.

3.h. At PR04/WD010 control panel, insert Fuses F3 and F4.

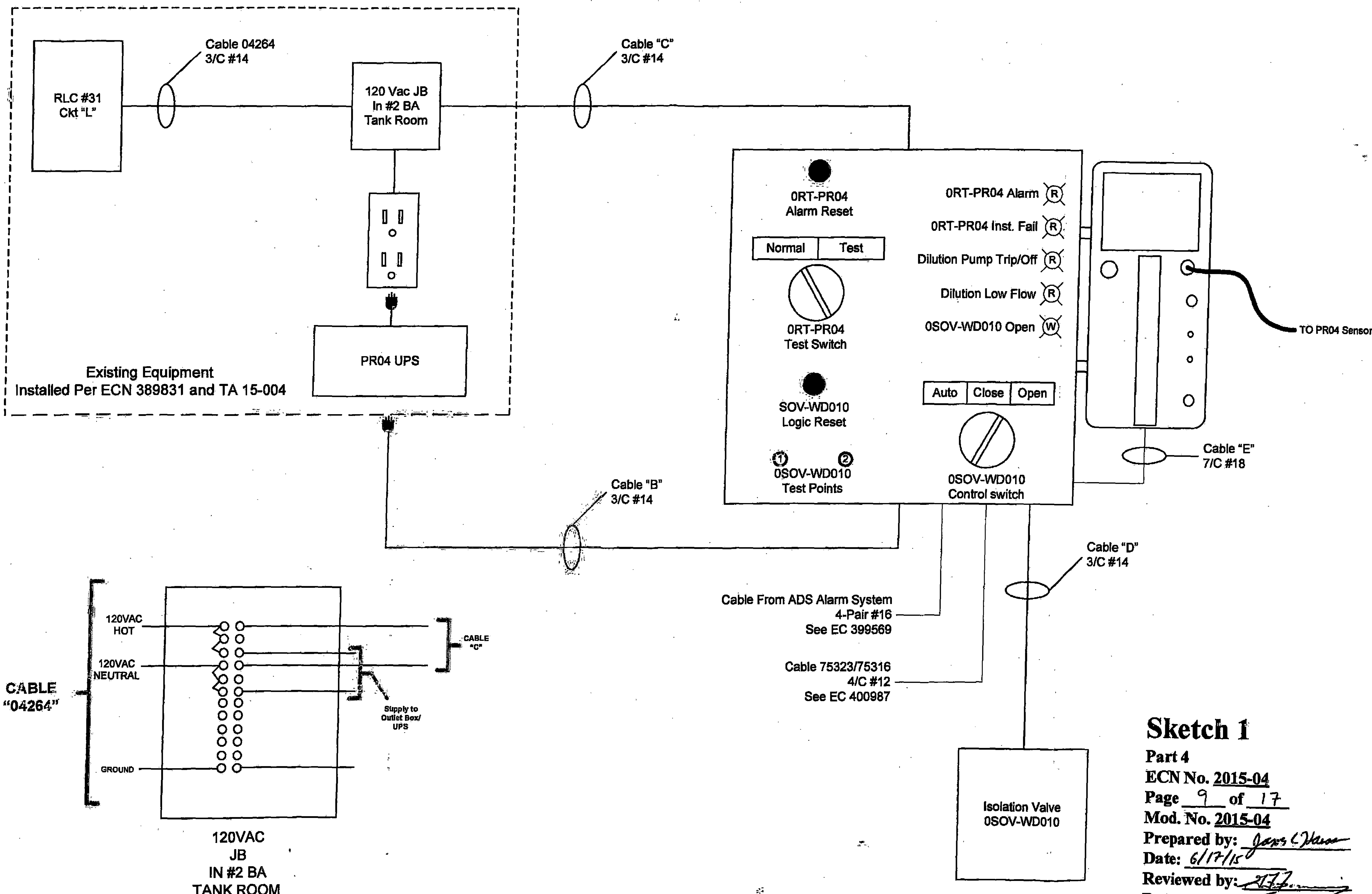
3.i. At Engineering and RP Instrument Tech direction, verify the following (Lift Leads and install jumpers as necessary to simulate normal/alarm conditions. Reset logic and alarms as necessary).

- Open Fuse F1 and verify light indication and ADS alarms are received for both PR04 Inst. Alarm and Inst. Fail.
- Induce PR04 high radiation alarm and verify proper light indication and ADS alarm.
- Using a jumper, CYCLE Dilution Pump Running/Trip alarm and verify proper light indication and ADS alarm.
- Using a jumper, CYCLE low dilution pump flow alarm and verify proper light indication and ADS Alarm.
- With 0RT-PR04 Test Switch in TEST, verify valve cycles with receipt of either PR04 radiation or instrument fail alarm. Verify this operates independently of control switch for 0SOV-WD010 position as well as other alarm conditions.
- With 0SOV-WD010 control switch in AUTO, verify 0SOV-WD010 closes upon receipt of any of the individual alarms. Also verify that the valve will NOT open until the appropriate reset button is actuated.
- With 0SOV-WD010 control switch in OPEN, verify 0SOV-WD010 remains open regardless of 0RT-PR04 alarm status. Also verify valve closes upon receipt of any alarm other than 0RT-PR04.

4. **Post Installation Calibration**

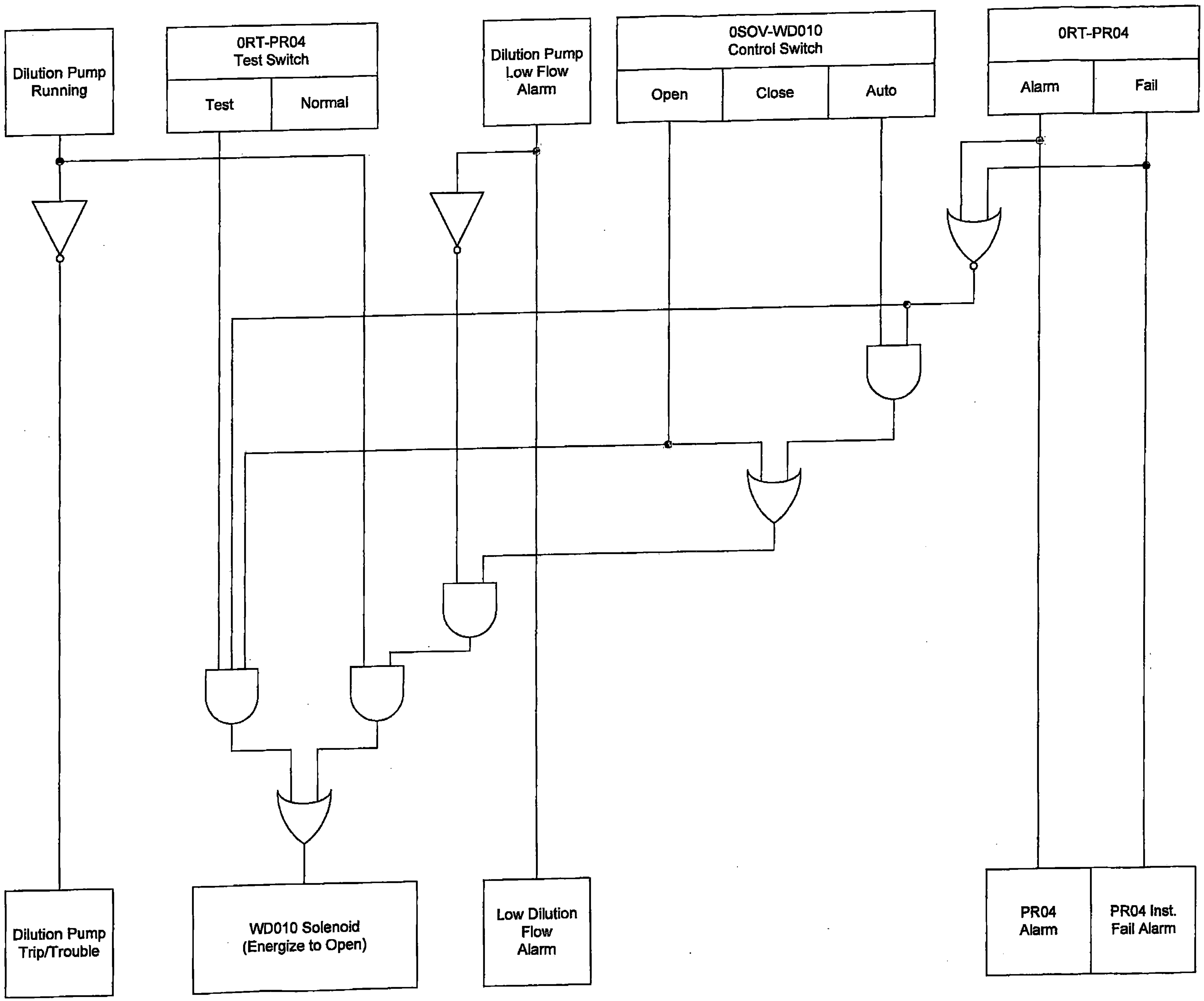
4.a. Request RP perform the appropriate calibration surveillances to enable placing 0RT-PR04 in service.

Prepared By: James C Hay Date 6/17/15
Reviewed By: [signature] Date 6-17-15



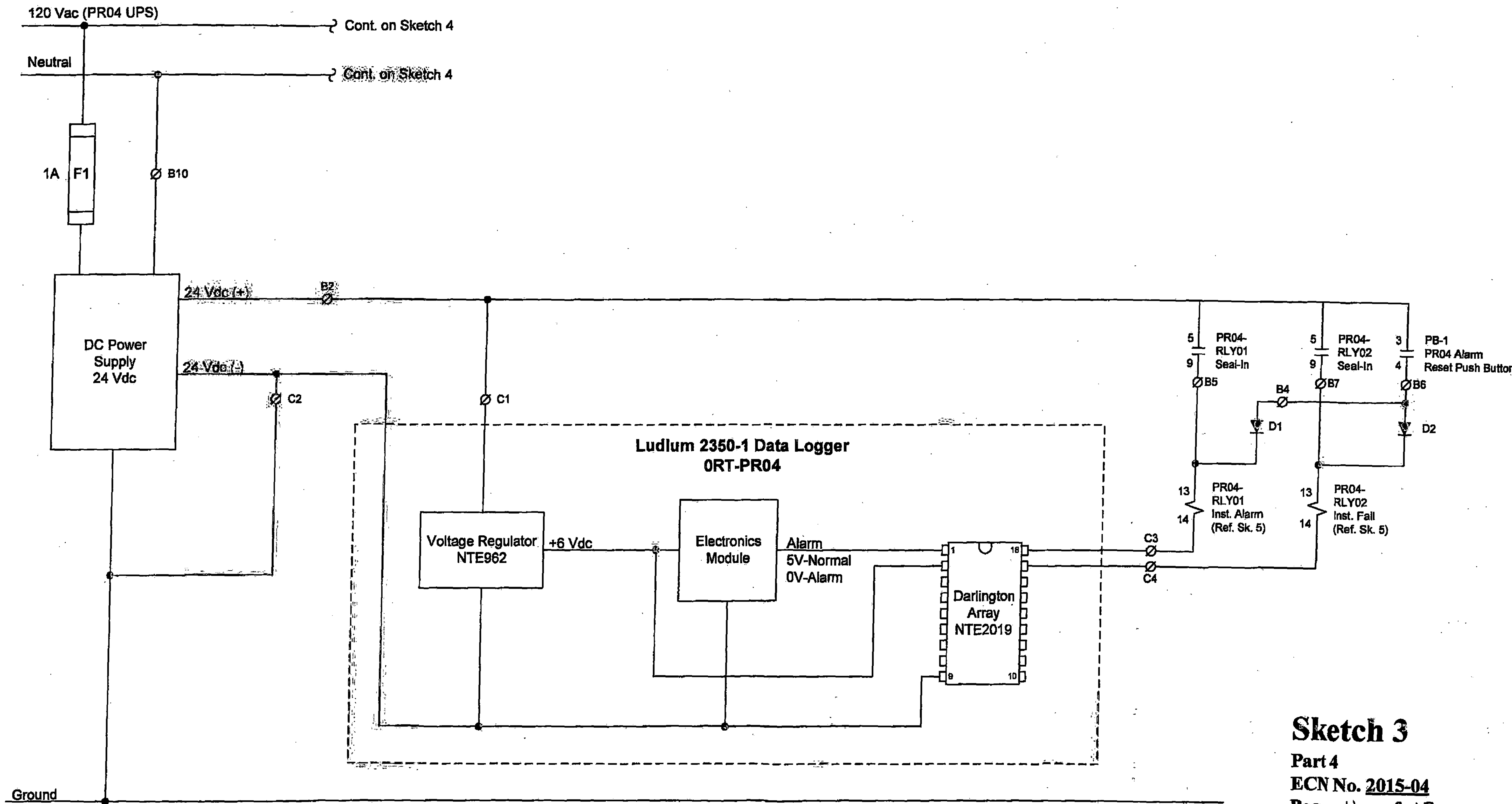
Sketch 1

Part 4
ECN No. 2015-04
Page 9 **of** 17
Mod. No. 2015-04
Prepared by: Jayes C. Vaughn
Date: 6/17/15
Reviewed by: [illegible]
Date: 6-17-15



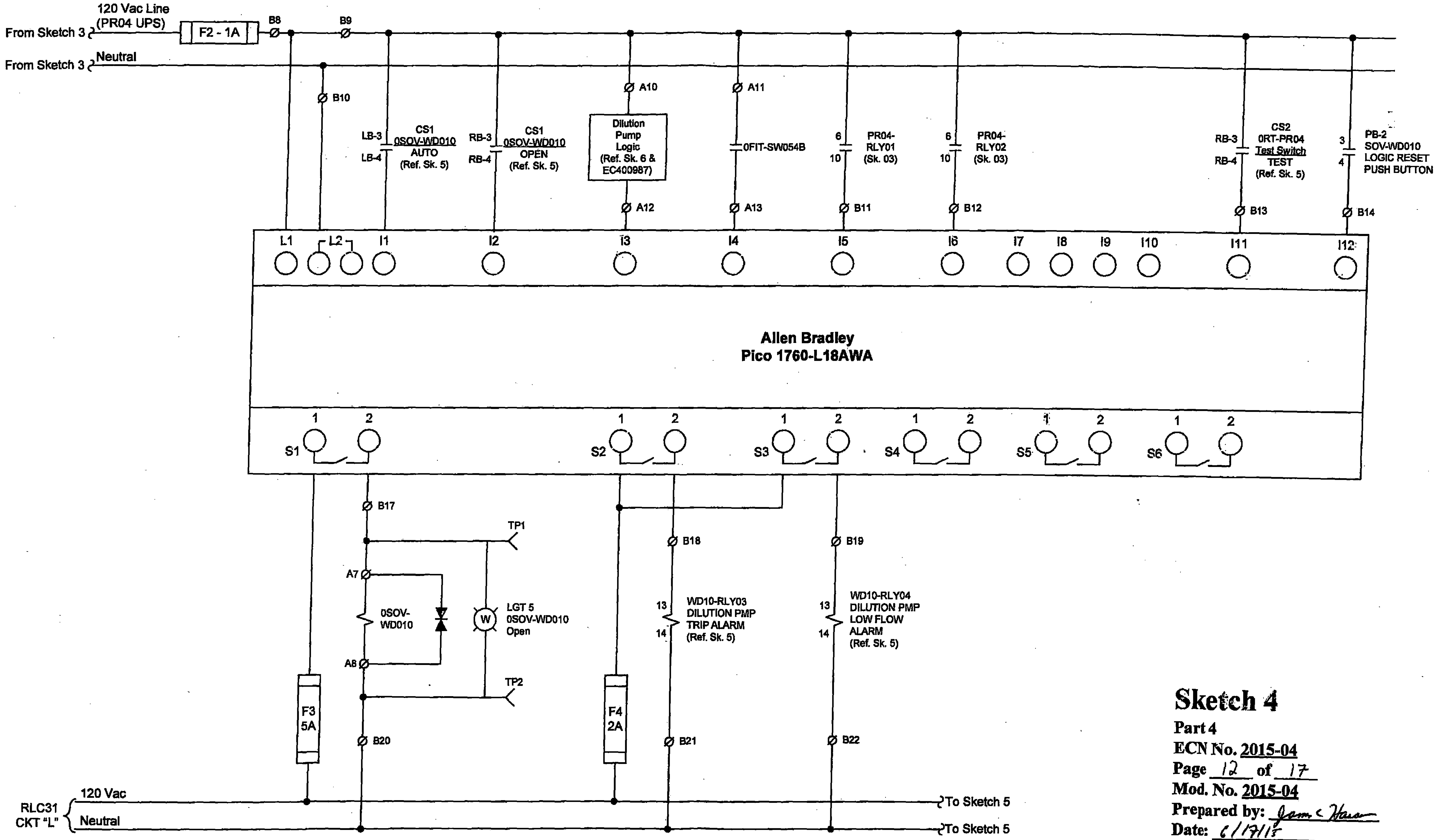
Sketch 2

Part 4
ECN No. 2015-04
Page 10 **of** 17
Mod. No. 2015-04
Prepared by: James C Hawe
Date: 6/17/15
Reviewed by: [signature]
Date: 6-17-15



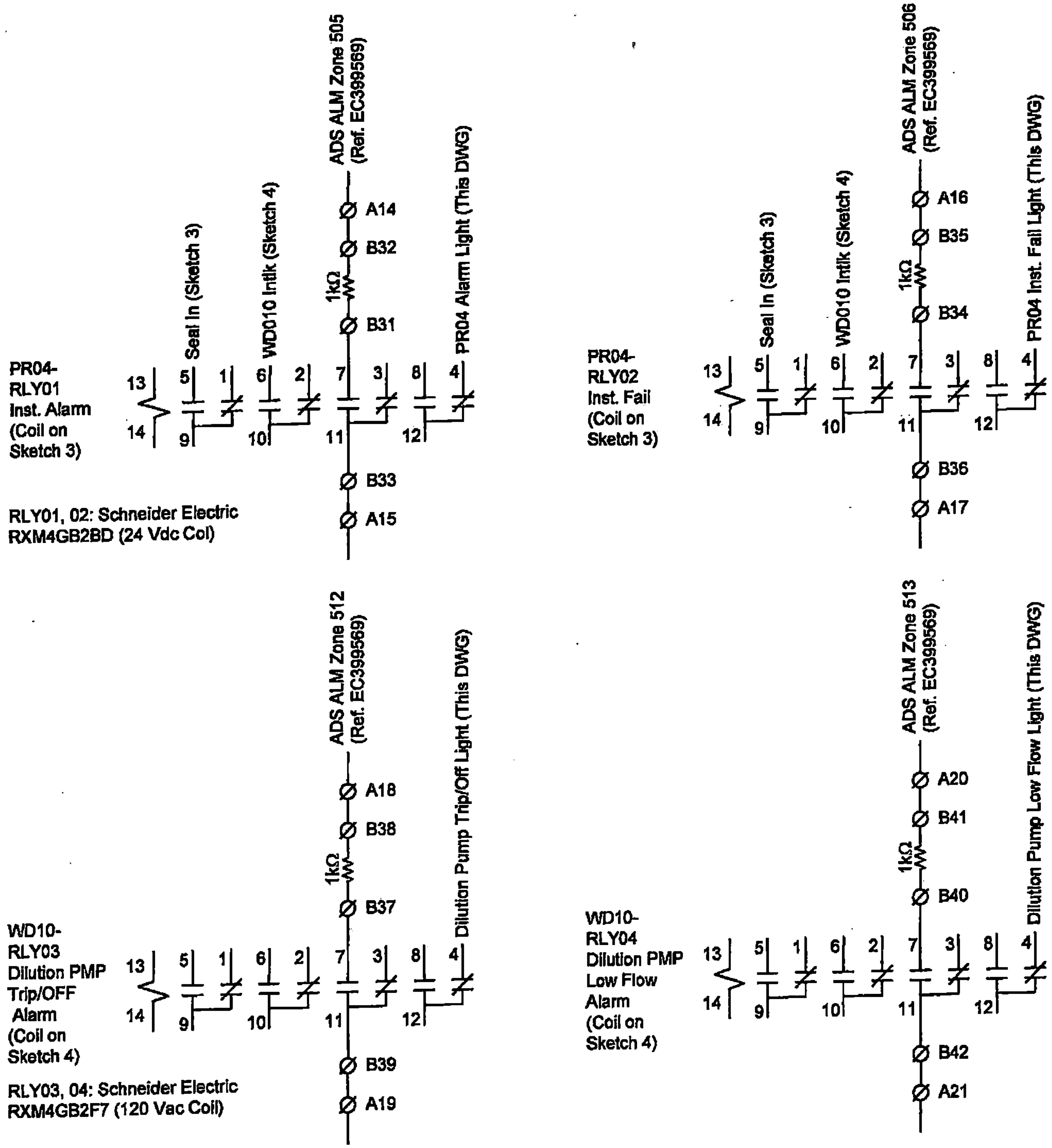
Sketch 3

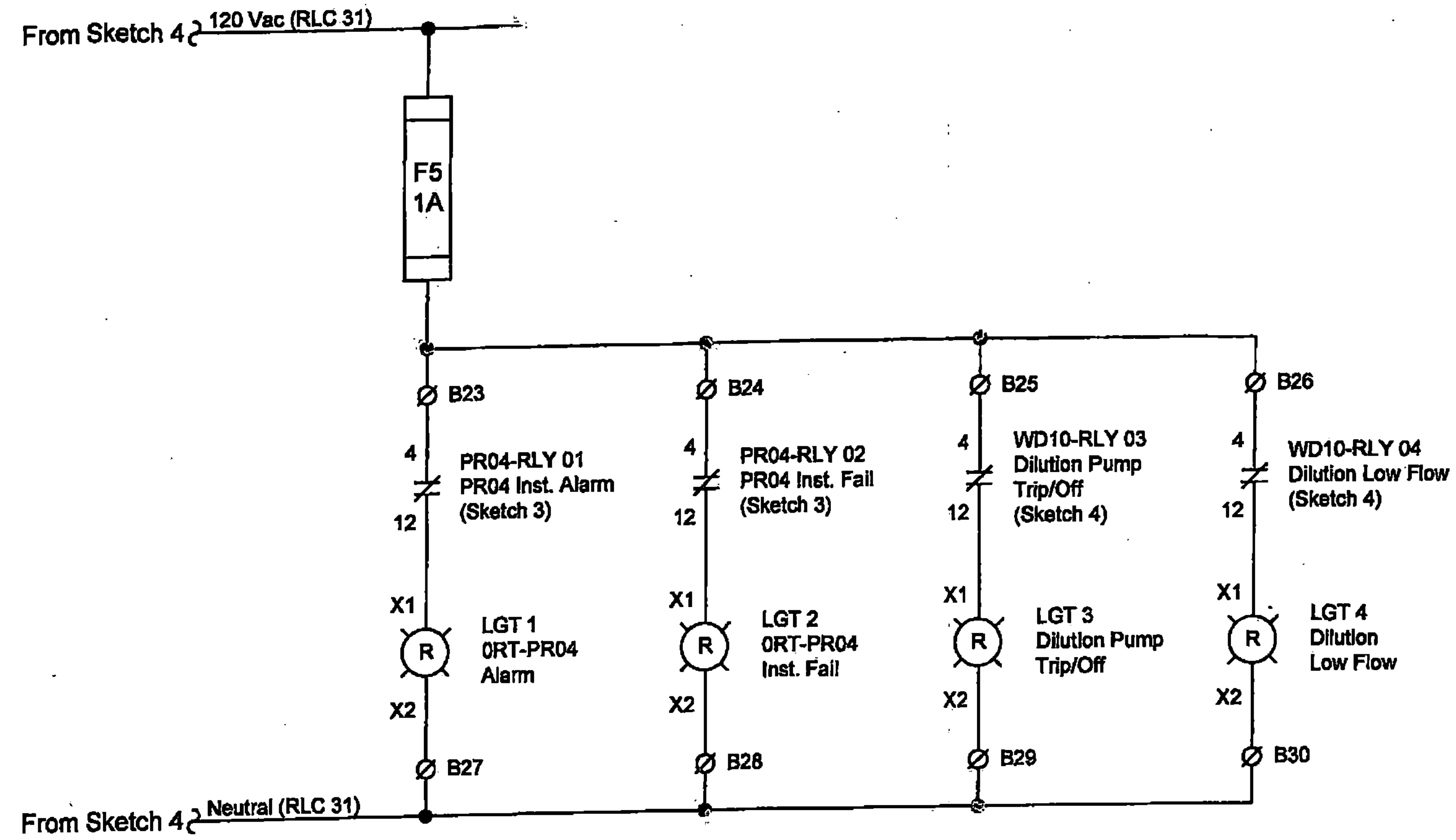
Part 4
ECN No. 2015-04
Page 11 **of** 17
Mod. No. 2015-04
Prepared by: [signature]
Date: 6/17/15
Reviewed by: [signature]
Date: 6-17-15



Sketch 4

Part 4
ECN No. 2015-04
Page 12 **of** 17
Mod. No. 2015-04
Prepared by: Jam c Haas
Date: 6/17/15
Reviewed by: [signature]
Date: 6-17-15





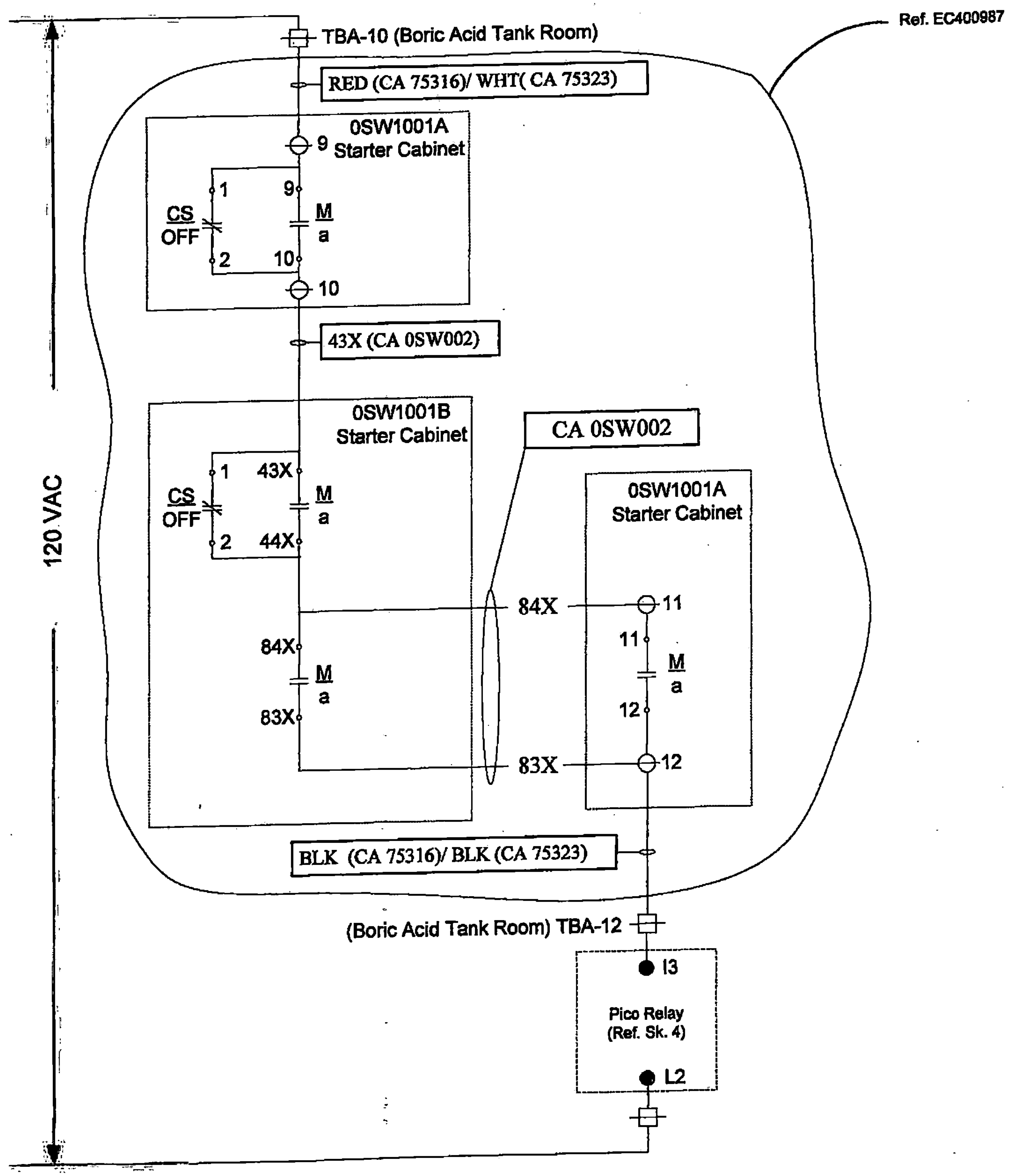
CS 0SOV-WD010			
Contacts	Auto	Close	Open
LB 3–4	X		
RB 3–4			X

0RT-PR04 Test Switch		
Contacts	Normal	Test
LB 3–4	X	
RB 3–4		X

Sketch 5

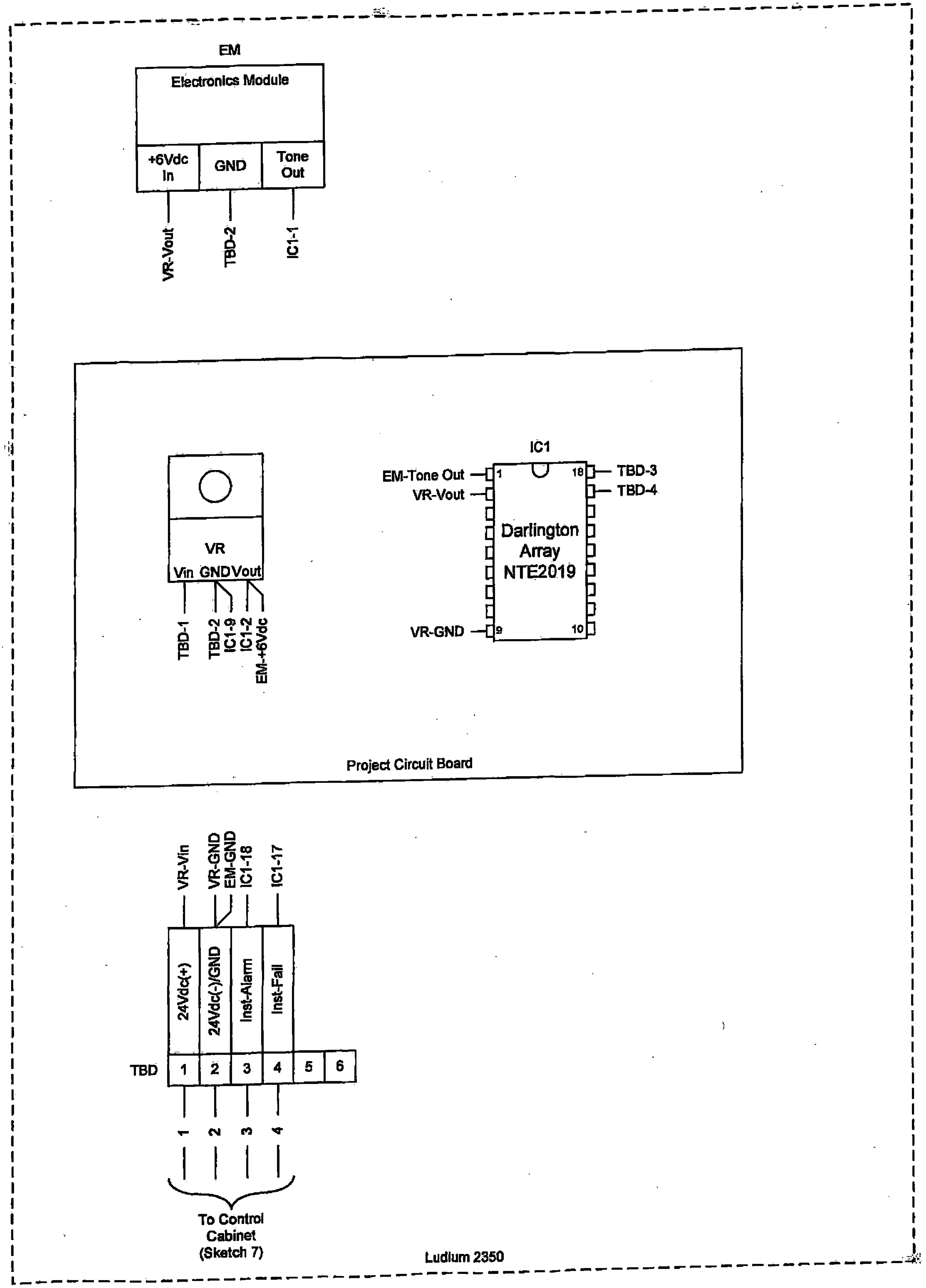
Part 4
ECN No. 2015-04
Page 13 **of** 17
Mod. No. 2015-04
Prepared by: [signature]
Date: 6/17/15
Reviewed by: [signature]
Date: 6-17-15

0SW1001A & 0SW1001B



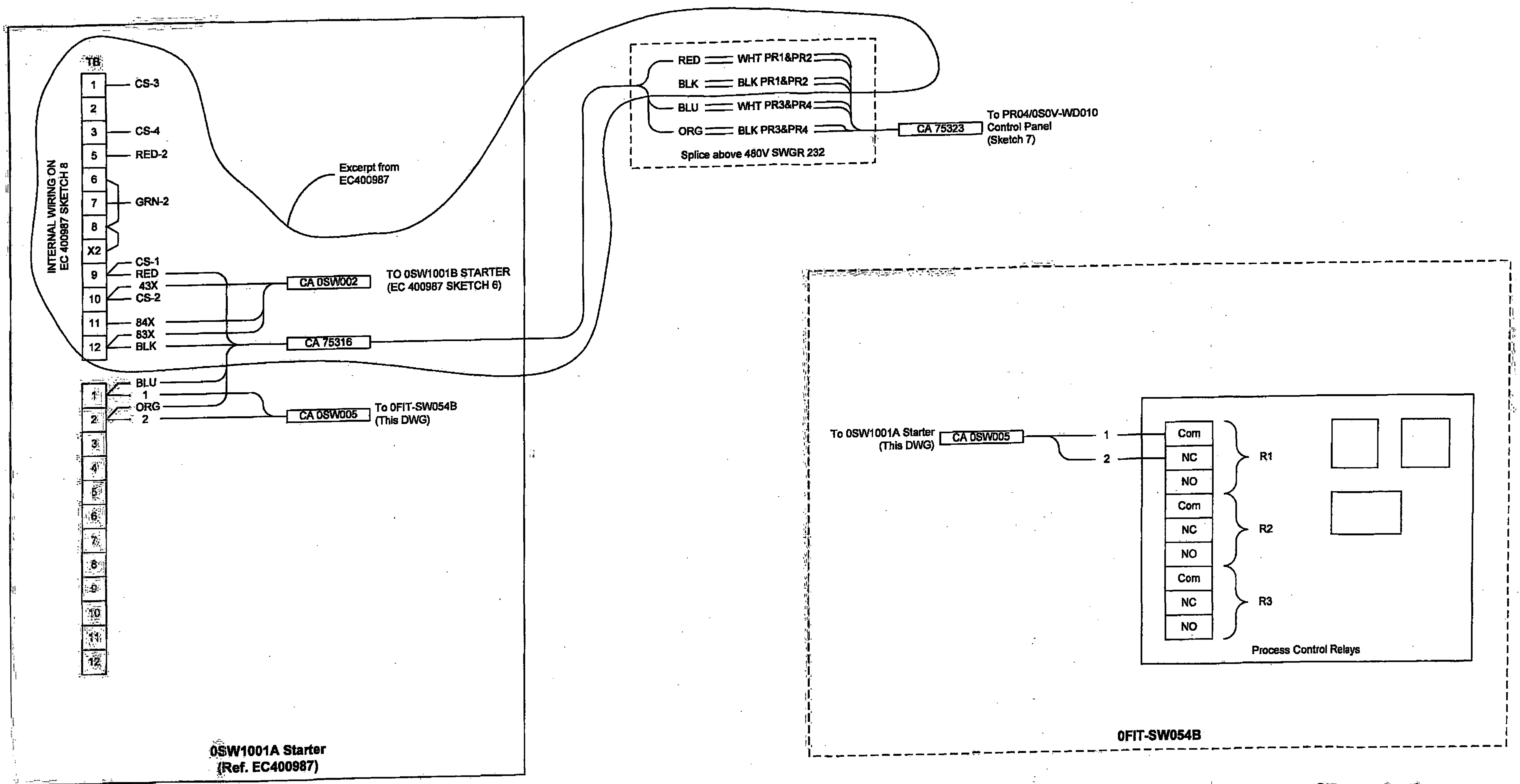
Sketch 6

Part 4
ECN No. 2015-04
Page 14 **of** 17
Mod. No. 2015-04
Prepared by: [signature]
Date: 6/17/15
Reviewed by: [signature]
Date: 6-17-15



Sketch 8

Part 4
ECN No. 2015-04
Page 16 **of** 17
Mod. No. 2015-04
Prepared by: James C Haus
Date: 6/17/15
Reviewed by: [signature]
Date: 6-17-15



Sketch 9

Part 4
ECN No. 2015-04
Page 17 **of** 17
Mod. No. 2015-04
Prepared by: [signature]
Date: 6/17/15
Reviewed by: [signature]
Date: 6-17-15

June 17, 2015
CZE-15-010

To: A. Orawiec

Subject: Zion Station, Unit 1 & 2
Design Change No. 2015-004

System Codes: PR

The Engineering Department has reviewed the subject design change in accordance with ZS-WC-100. Applicable design input requirements are included in the design change approval letter as applicable.

Description of Change:

This design change addresses the design issues required to replace 0RT-PR04 with a new detector unit and electronics module. The functionality of the original equipment will be maintained. This design change also adds an interlock to ensure closure of 0SOV-WD010 due to inadequate dilution flow as measured by flow transmitter 0FIT-SW054B. The logic for discharge valve 0SOV-WD010 will be configured such that the valve will automatically close upon receipt of any of the following signals:

- 0RT-PR04 Alarm or Instrument Fail
- Trip of a dilution pump or no dilution pump running
- Low dilution flow from 0FIT-SW054B

Design Change Package:

The design for this Design Change is contained in ECN 2015-04 which is issued "For Construction" by this letter.

10 CFR 50.59 Evaluation / Decommissioning Impact Evaluation:

10CFR 50.59 screening 2015-066 was performed in accordance with AD-11 and is being transmitted along with this letter. This activity can be implemented without prior NRC approval.

A Decommissioning Impact Evaluation was performed and it was concluded that the proposed activity is not restricted by 10 CFR 50.82. The evaluation is also being transmitted along with this letter.

DSAR / ODCM Impact Review:

DSAR Chapters 1 through 6 were reviewed for this design change. No DSAR changes are required as a result of this design change. Additionally, a review of the ODCM was conducted. No ODCM changes are planned as a result of this design change.

Applicable Codes and Standards:

This design change shall be installed in accordance with Zion Specification X-3646, which is the general work specification for mechanical, structural and electrical work as well as applicable site and Zion Solutions procedures. Installation requirements identified in ECN 2015-04 supersede X-3646 guidance.

Basic Functions:

0RT-PR04 monitors the liquid radiation waste release point to the service water system and ultimately Lake Michigan. An alarm signal from 0RT-PR04 will result in automatic closure of discharge valve 0SOV-WD010. The valve will also receive automatic closure signals due to either low dilution flow or trip of a running dilution pump.

Industrial Safety:

There are no industrial safety concerns associated with this design change.

Installation Schedule / Outage Requirements:

Installation of this design change will require that valve 0SOV-WD010 be out of service.

Technical Specification Changes:

The existing Technical Specifications do not require revision as a result of this design change.

ALARA / Fire Protection Review:

An ALARA review was performed for this exempt change. The bulk of the work is being performed in the Unit 2 boric acid tank room. Any additional cable adds minimal combustibles and will not contribute significantly to the combustible loading.

Impact of Pending Modifications or Temporary Alterations:

A review of pending design changes has been completed. This design change does not impact any pending modifications. This Design Change Package (DCP) is being issued to document the installation of a new detector and electronics module for 0RT-PR04 and to add an automatic closure of 0SOV-WD010 due to low flow in the dilution system.

Identification of the Installer:

This Design Change will be performed by Zion Solutions or an approved contractor.

Procurement Requirements:

None

Training Requirements:

None

Security Requirements:

None

Technical Review:

This design change is subject to a Technical Review in accordance with the requirements of AD-1. A Technical Review has been performed and submitted with this design package (TR-017-2015).

If there are any questions regarding this design change, please contact Jim Hausser at 224-789-4285.

Prepared By: James C Hausser
Jim Hausser
Zion Solutions Engineering

Approved By: Donald F. Roth
D. Roth
Director of Engineering

cc:

	MAL	ECN	50.59	50.82
Central File	1	1	1	1
D. Roth	1	1	1	1
J. Hausser	1	1	1	1
T. Lukken	1	1	1	1

ATTACHMENT B-1

50.59 Review Coversheet Form

Station: **Zion**

Activity/Document Number: DCP 2015-04 **Revision Number: 0**

Title: Install New Radiation Monitor for 0RT-PR04

NOTE: For 50.59 Evaluations, information on this form will provide the basis for preparing the biennial summary report submitted to the NRC in accordance with the requirements of 10 CFR 50.59(d)(2).

Description of Activity:
(Provide a brief, concise description of what the proposed activity involves.)

This modification will replace the sensor and rate counting module for liquid radiation monitor 0RT-PR04. A permissive signal requiring adequate dilution system flow to allow opening of lake discharge valve 0SOV-WD010 will also be added by this change.

Reason for Activity:
(Discuss why the proposed activity is being performed.)

The sensor for the existing radiation monitor has failed and compatible replacement parts are unavailable. The addition of the dilution flow permissive is a system enhancement.

Effect of Activity:
(Discuss how the activity impacts plant operations, design bases, or safety analyses described in the UFSAR.)

The radiation monitor will generate a signal to automatically close lake discharge valve 0SOV-WD010 upon detection of a high radiation level. Likewise, the dilution flow permissive will cause an automatic closure of the lake discharge valve should dilution flow drop below prescribed levels. These automatic actions are enhancements to sampling and periodic monitoring to ensure compliance with the ODCM.

The modification does not affect the accident evaluated in the DSAR.

Summary of Conclusion for the Activity's 50.59 Review:
(Provide justification for the conclusion, including sufficient detail to recognize and understand the essential arguments leading to the conclusion. Provide more than a simple statement that a 50.59 Screening, 50.59 Evaluation, or a License Amendment Request, as applicable, is not required.)

The modification only changes the specific devices used to monitor the liquid radiation waste discharge. The function of the devices remains unchanged. This modification does not represent a change to the facility as described in the DSAR and it may be installed under 10CFR50.59 without prior NRC approval.

Attachments:
Attach all 50.59 Review forms completed, as appropriate.
(NOTE: if both a Screening and Evaluation are completed, no Screening No. is required.)

Forms Attached: (Check all that apply.)

	Applicability Review				
x	50.59 Screening	50.59 Screening No.	2015-066	Rev.	0
	50.59 Evaluation	50.59 Evaluation No.		Rev.	

ATTACHMENT C-1
50.59 APPLICABILITY REVIEW FORM

Activity/Document Number:_ DCP 2015-04______________________________ Revision Number:_0__________

Address the questions below for all aspects of the Activity. If the answer is yes for any portion of the Activity, apply the identified process(es) to that portion of the Activity. Note that it is not unusual to have more than one process apply to a given Activity.

See Section 4 of the Resource Manual (RM) for additional guidance.

I.	Does the proposed Activity involve a change:		
	1. Technical Specifications or Operating License (10 CFR 50.90)?	_x NO __ YES	See Section 4.2.1.1 of the RM
	2. Conditions of License Quality Assurance program (10 CFR 50.54(a))? Security Plan (10 CFR 50.54(p))? Emergency Plan (10 CFR 50.54(q))?	_x NO __ YES _x NO __ YES _x NO __ YES	See Section 4.2.1.2 of the RM
	3. Specific Exemptions (10 CFR 50.12)?	_x NO __ YES	See Section 4.2.1.5 of the RM
	4. Radiation Protection Program (10 CFR 20)?	_x NO __ YES	See Section 4.2.1.6 of the RM
	5. Fire Protection Program (applicable UFSAR or operating license condition)?	_x NO __ YES	See Section 4.2.1.7 of the RM
	6. Programs controlled by the Operating License or the Technical Specifications (such as the ODCM).	_x NO __ YES	See Section 4.2.1.7 of the RM
	7. Environmental Protection Program	_x NO __ YES	See Section 4.2.1.7 of the RM
	8. Other programs controlled by other regulations.	_x NO __ YES	See Section 4.2.1 of the RM 10 CFR50.37
II.	Does the proposed Activity involve maintenance which restores SSCs to their original condition or involve a temporary alteration supporting maintenance that will be in effect during at-power operations for 90 days or less?	_x NO __ YES	See Section 4.2.2 of the RM
III.	Does the proposed Activity involve a change to the:		
	1. UFSAR (including documents incorporated by reference) that is excluded from the requirement to perform a 50.59 Review by NEI 96-07 or NEI 98-03?	_x NO __ YES	See Section 4.2.3 of the RM
	2. Managerial or administrative procedures governing the conduct of facility operations	_x NO __ YES	See Section 4.2.4 of the RM
	3. Procedures for performing maintenance activities (subject to 10 CFR 50.65(a)(4))?	_x NO __ YES	See Section 4.2.4 of the RM
	4. Regulatory commitment not covered by another regulation based change process (see NEI 99-04)?	_x NO __ YES	See Section 4.2.3/4.2.4 of the RM
IV.	Does the proposed Activity involve a change to the Independent Spent Fuel Storage Installation (ISFSI) (subject to control by 10 CFR 72.48)	_x NO __ YES	See Section 4.2.6 of the RM
V.	Does the proposed Activity involve a change to the Packaging & Transportation of Radioactive Material? (subject to control by 10 CFR 71)	_x NO __ YES	
VI.	Is the proposed activity a Decommissioning Activity that requires a change to DSAR Chapter 3, 4 or 5 thereby requiring a 50.59 Screening.	_x NO __ YES	

Check one of the following:

☐ If all aspects of the Activity are controlled by one or more of the above processes, then a 50.59 Screening is not required and the Activity may be implemented in accordance with its governing procedure.

X If any portion of the Activity is not controlled by one or more of the above processes, then process a 50.59 Screening for the portion not covered by any of the above processes. The remaining portion of the activity should be implemented in accordance with its governing procedure.

Signoff: 50.59 Screener/50.59 Evaluator Gary F. Fanning Sign: [signature] Date: 6-17-5
(Circle One) (Print name) (Signature)

ATTACHMENT D-1

50.59 Screening Form

50.59 Screening No. _2015-066__ Rev. No. __0_____

Activity/Document Number:_DCP 2015-04______________________ **Revision Number:____0_______**

I. **50.59 Screening Questions** (Check correct response and provide separate written response providing the basis for the answer to each question) (See Section 5 of the Resource Manual (RM) for additional guidance):

1. Does the proposed Activity involve a change to an SSC that adversely affects an UFSAR described design function? (See Section 5.2.2.1 of the RM) ___YES _x_ NO

   The function of liquid radiation monitor 0RT-PR04 is unchanged by this modification. The only change is to the actual equipment used to perform the design function. The addition of the dilution flow permissive for the lake discharge valve is a system enhancement.

2. Does the proposed Activity involve a change to a procedure that adversely affects how UFSAR described SSC design functions are performed or controlled? (See Section 5.2.2.2 of the RM) ____YES _x_ NO

   The only procedures affected by this change are those directly related to the physical device installed. The function of the radiation monitor and responses to alarm conditions are not altered by this design change.

3. Does the proposed Activity involve an adverse change to an element of a UFSAR described evaluation methodology, or use of an alternative evaluation methodology, that is used in establishing the design bases or used in the safety analyses? (See Section 5.2.2.3 of the RM) ___ YES _x_ NO

   There are no evaluation methods altered by this change. This change will only alter the equipment used to monitor lake releases. Methods for determining the alarm setpoints are not affected by this change.

4. Does the proposed Activity involve a test or experiment not described in the UFSAR, where an SSC is utilized or controlled in a manner that is outside the reference bounds of the design for that SSC or is inconsistent with analyses or descriptions in the UFSAR? (See Section 5.2.2.4 of the RM) ___ YES _x_ NO

   The replacement of the radiation monitor and addition of the flow interlock do not represent a test or experiment not described in the UFSAR. The function of the radiation monitor is not altered by this change.

5. Does the proposed Activity require a change in the Technical Specifications or Operating License? (See Section 5.2.2.5 of the RM) ___YES _x_ NO

   The new radiation monitor equipment will support operation of the liquid waste system as described in DSAR sections 4.5 and 4.6. The new monitoring equipment will also support plant operations as described in ODCM section 10.2.2.1 and tables 12.2-1 and 12.2-2. No changes to any plant licensing documents are required for this design change.

II. List the documents (e.g., UFSAR, Technical Specifications, other licensing basis, technical, commitments, etc.) reviewed, including sections numbers where relevant information was found (if not identified in the response to each question).

DSAR Change 2013-010
DSAR Chapters 1 through 6
Zion Station Offsite Dose Calculation Manual (ODCM)
Permanently Defueled Technical Specifications (PDTS)
Zion Station Unit 1 and 2 Composite Licenses

III. Select the appropriate conditions:

X	**If** all questions are answered NO, **then** complete the 50.59 Screening and implement the Activity per the applicable governing procedure.
	If question 1, 2, 3, or 4 is answered YES and question 5 is answered NO, **then** a 50.59 Evaluation shall be performed.
	If questions 1, 2, 3, and 4 are answered NO and question 5 is answered YES, **then** a License Amendment is required prior to implementation of the Activity.
	If question 5 is answered YES for any portion of an Activity, **then** a License Amendment is required prior to implementation of that portion of the Activity. In addition, **if** question 1, 2, 3, or 4 is answered YES for the remaining portions of the Activity, **then** a 50.59 Evaluation shall be performed for the remaining portions of the Activity.

IV. Screening Signoffs:

50.59 Screener: Gary F. Fanning (Print name) Sign: [signature] (Signature) Date: 6/17/15

50.59 Reviewer: DONALD F. ROTH (Print name) Sign: Donald F. Roth (Signature) Date: 6/17/2015

TECHNICAL REVIEW LETTER

TR/017/2015

To: T. Orawiec
Decommissioning Plant Manager
Zion Station

Subject: DCP 2015-004, Replace 0RT-PR04

Summary:

The purpose of this Technical Review is to provide basis and justification for replacing the original 0RT-PR04 detector and electronics unit with new equipment. This design change package will also add logic to automatically close 0SOV-WD010 due to low dilution flow measured by flow transmitter 0FIT-SW054B.

Prepared By: James C. Hausser — 6/17/15 Date

Required review Disciplines: A, E, G — Donald F. Roth, Engineering Supervisor

Qualified Technical Reviewers

Signature	Discipline	Date
[signature]	AEG	6-17-15
[signature]	A, D, F	6-18-15

I Concur and Approve: [signature] Decommissioning Plant Manager — 6/18/15 Date

Distribution:
Decommissioning Plant Manager
Operations Manager
Engineering Manager
SRC Coordinator
Master File

ATTACHMENT 6
Zion Station ODCM, Rev. 5

Zion Station

Offsite

Dose

Calculation

Manual

Docket Numbers:
50-295, 50-304 and 72-1037

OFFSITE DOSE CALCULATION MANUAL

TABLE OF CONTENTS **PAGE**

CHAPTER 1
INTRODUCTION

1.0 INTRODUCTION

The Offsite Dose Calculation Manual (ODCM) presents a discussion of the following:

- The basic concepts applied in calculating offsite doses from Zion Station effluents.
- The regulations and requirements for the ODCM and related programs.
- The methodology and parameters for the offsite dose calculations used to assess impact on the environment and compliance with regulations.

The methodology detailed in this manual is intended for the calculation of radiation doses during routine (i.e., non-accident) conditions. The calculations are normally performed using a computer program. Manual calculations may be performed in lieu of the computer program.

The dose effects of airborne radioactivity releases predominately depend on meteorological conditions (wind speed, wind direction, and atmospheric stability). For airborne effluents, the dose calculations prescribed in this manual are based on historical average atmospheric conditions. This methodology is appropriate for estimating annual average dose effects and is stipulated in the Bases Section of the Radiological Effluent Technical Standards (RETS).

1.1 STRUCTURE OF THIS MANUAL

Chapters 1 thru 7 provide a brief introduction and overview of Zion Stations offsite dose calculation methodology and parameters. Chapters 10 thru 12 provide specific requirements for the treatment and monitoring of radioactive effluents covered by the Radiological Environmental Monitoring Program (REMP) and the Radiological Effluent Technical Standards (RETS). Appendices A and B provide detailed information on specific aspects of the methodology. Appendix C contains tables of values of the generic parameters used in offsite dose equations. Appendix F contains tables of values for the parameters used in the offsite dose equations. Appendix O provides description of the bases for the methodology and parameters discussed in the ODCM.

CHAPTER 2

REGULATIONS AND GUIDELINES

2.0 INTRODUCTION

This chapter of the ODCM serves to illustrate the regulations and requirements that define and are applicable to the ODCM. Any information provided in the ODCM concerning specific regulations are not a substitute for the regulations as found in the Code of Federal Regulations (CFR) or Quality Assurance Project Plan (QAPP).

2.1 CODE OF FEDERAL REGULATIONS

Various sections of the Code of Federal Regulations (CFR) require nuclear power stations to be designed and operated in a manner that limits the radiation exposure to members of the public. These sections specify limits on offsite radiation doses and on effluent radioactivity concentrations and they also require releases of radioactivity to be "As Low As Reasonably Achievable". These requirements are contained in 10CFR20, 10CFR50, 10CFR72 and 40CFR190. In addition, 40CFR141 imposes limits on the concentration of radioactivity in drinking water provided by the operators of public water systems.

2.1.1 10CFR20, Standards for Protection Against Radiation

The 10CFR20 dose limits are summarized in Table 2-1.

2.1.2 Design Criteria (Appendix A of 10CFR50)

Section 50.36 of 10CFR50 requires that an application for an operating license include proposed Technical Specifications. Final Technical Specifications are developed through negotiation between the applicant and the NRC. The Technical Specifications are then issued as a part of the operating license, and the licensee is required to operate the facility in accordance with them. The remaining Defueled Technical Specification requirements have been relocated to the QAPP.

Section 50.34 of 10CFR50 states that an application for a license must state the principal design criteria of the facility. Minimum requirements are contained in Appendix A of 10CFR50.

2.1.3 ALARA Provisions (Appendix I of 10CFR50)

Sections 50.34a and 50.36a of 10CFR50 require that the nuclear plant design and the station RETS have provisions to keep levels of radioactive materials in effluents to unrestricted areas "As Low As Reasonably Achievable" (ALARA). Although 10CFR50 does not impose specific limits on releases, Appendix I of 10CFR50 does provide numerical design objectives and suggested limiting conditions for operation. According to Section I of Appendix I of 10CFR50, design objectives and limiting conditions for operation, conforming to the guidelines of Appendix I "shall be deemed a conclusive showing of compliance with the "As Low As Reasonably Achievable" requirements of 10CFR50.34a and 50.36a."

An applicant must use calculations to demonstrate conformance with the design objective dose limits of Appendix I. The calculations are to be based on models and data such that the actual radiation exposure of an individual is "unlikely to be substantially underestimated" (see 10CFR50 Appendix I, Section III.A.1).

The guidelines in Appendix I call for an investigation, corrective action and a report to the NRC whenever the calculated dose due to the radioactivity released in a calendar quarter exceeds one-half of an annual design objective. The guidelines also require a surveillance program to monitor releases, monitor the environment and identify changes in land use.

2.1.3 10CFR72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste

During normal operations and anticipated occurrences, the annual dose equivalent to any real individual who is located beyond the Controlled Area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid and 25 mrem to any other critical organ as a result of exposure to:

- Planned discharges of radioactive materials, radon and its decay products excepted, to the general environment,
- Direct radiation from ISFSI or MRS operations, and
- Any other radiation from uranium fuel cycle operations within the region.

2.1.4 40CFR190, Environmental Radiation Protection Standards for Nuclear Power Operations

Under an agreement between the NRC and the EPA, the NRC stipulated to its licensees in Generic Letter 79-041 that "Compliance with Radiological Effluent Technical Specifications (RETS), NUREG-0472 (Rev.2) for PWR's or NUREG-0473 (Rev.2) for BWR's, implements the LWR provisions to meet 40CFR190". (See reference 103 and 49.)

The regulations of 40CFR190 limit radiation doses received by members of the public as a result of operations that are part of the uranium fuel cycle. Operations must be conducted in such a manner as to provide reasonable assurance that the annual dose equivalent to any member of the public due to radiation and to planned discharges of radioactive materials does not exceed the following limits:

- 25 mrem to the total body
- 75 mrem to the thyroid
- 25 mrem to any other organ

An important difference between the design objectives of 10CFR50 and the limits of 40CFR190 is that 10CFR50 addresses only doses due to radioactive effluents. 40CFR190 limits doses due to effluents and also to radiation sources maintained on site. See Section 2.4 for further discussion of the differences between the requirements of 10CFR50 Appendix I and 40CFR190.

2.1.5 40CFR141, National Primary Drinking Water Regulations

The following radioactivity limits for community water systems were established in the July, 1976 Edition of 40CFR141:

- Combined Ra-226 and Ra-228: $\leq$ 5 pCi/L.
- Gross alpha (particle activity including Ra-226 but excluding radon and uranium): $\leq$ 15 pCi/L.
- The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 mrem/yr.

The regulations specify procedures for determining the values of annual average radionuclide concentration which produce an annual dose equivalent of 4 mrem. Radiochemical analysis methods are also specified. The responsibility for monitoring radioactivity in a community water system falls on the supplier of the water. However, Zion Station has requirements related to 40CFR141 in their specific RETS. For calculation methodology, see Section A.6 of Appendix A.

2.2 RADIOLOGICAL EFFLUENT TECHNICAL STANDARDS

The Radiological Effluent Technical Standards (RETS) were formerly a subset of the Technical Specifications. They implement provisions of the Code of Federal Regulations aimed at limiting offsite radiation dose. The NRC published Standard Radiological Effluent Technical Specifications for PWRs (Reference 2) as guidance to assist in the development of technical specifications. These documents have undergone frequent minor revisions to reflect changes in plant design and evolving regulatory concerns. The Radiological Effluent Technical Specifications have been removed from the Technical Specifications and placed in the ODCM as the Radiological Effluent Technical Standards (RETS) (see Reference 90). The Zion Station RETS are similar, but not identical to the guidance of the Standard Radiological Effluent Technical Specifications.

2.2.1 Categories

The major categories found in the RETS are the following:

- **Definitions**
  A glossary of terms (not limited to the ODCM).

- **Instrumentation**
  This section states the Operability Requirements (OR) for instrumentation performance as well as the associated Surveillance Requirements. The conservative alarm/trip setpoints ensure regulatory compliance for both liquid and gaseous effluents. Surveillance requirements are listed to ensure ORs are met through testing, calibration, inspection and calculation. Also included are the bases for interpreting the requirements. The Operability Requirement (OR) is the ODCM equivalent of a Limiting Condition for Operation (LCO) as defined in both the NRC published Standard Radiological Effluent Technical Specifications and the stations' Technical Specifications.

- **Liquid Effluents**
  This section addresses the limits, special reports and liquid waste treatment systems required to substantiate the dose due to liquid radioactivity concentrations to unrestricted areas. Surveillance Requirements and Bases are included for liquid effluents.

- **Gaseous Effluents**
  This section addresses the limits, special reports and gaseous radwaste and ventilation exhaust treatment systems necessary for adequate documentation of the instantaneous offsite radiation dose rates and doses to a member of the public. Surveillance Requirements and Bases are included for gaseous effluents.

- **Radiological Environmental Monitoring Program**
  This section details the Radiological Environmental Monitoring Program (REMP) involving sample collection and measurements to verify that the radiation levels released are minimal. This section describes the annual land use census and participation in an interlaboratory comparison program. Surveillance Requirements and Bases are included for environmental monitoring.

- **Reports and Records**
  This section serves as an administrative guide to maintain an appropriate record tracking system. The management of procedures, record retention, review/audit and reporting are discussed.

2.3 OFFSITE DOSE CALCULATION MANUAL

The NRC in Generic Letter 89-01 defines the ODCM as follows (not verbatim) (see Reference 90):

The Offsite Dose Calculation Manual (ODCM) shall contain the methodology and parameters used in the calculation of offsite doses resulting from radioactive gaseous and liquid effluents, in the calculation of gaseous and liquid effluent monitoring Alarm/Trip Setpoints, and in the conduct of the Radiological Environmental Monitoring Program. The ODCM shall also contain (1) the Radioactive Effluent Controls and Radiological Environmental Monitoring Programs and (2) descriptions of the Information that should be included in the Annual Radiological Environmental Operating and Annual Radioactive Effluent Release Reports.

Additional requirements for the content of the ODCM are contained throughout the text of the RETS.

2.4 OVERLAPPING REQUIREMENTS

In 10CFR20, 10CFR50, 10CFR72 and 40CFR190, there are overlapping requirements regarding offsite radiation dose and dose commitment to the total body.
In 10CFR20.1301 the total effective dose equivalent (or TEDE) to a member of the public is limited to 100 mrem per calendar year. In addition, Appendix I to 10CFR50 establishes design objectives on annual total body dose or dose commitment of 3 mrem per reactor for liquid effluents and 5 mrem per reactor for gaseous effluents (see 10CFR50 Appendix I, Sections II.A and II.B.2(a)). Per 10CFR72, the annual dose equivalent to a real individual beyond the controlled area boundary is limited to 25 mrem whole body from both effluents and direct radiation combined. Finally, 40CFR190 limits annual total body dose or dose commitment to a member of the public to 25 mrem due to all uranium fuel cycle operations.

While these dose limits/design objectives appear to overlap, they are different and each is addressed separately by the RETS. Calculations are made and reports are generated to demonstrate compliance to all regulations. Refer to Tables 2-1, 2-2 and 2-3 for additional information regarding instantaneous effluent limits, design objectives and regulatory compliance.

2.5 DOSE RECEIVER METHODOLOGY

Table 2-2 lists the location of the dose recipient and occupancy factors, if applicable. Dose is assessed at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposures with the exception of dose from contained sources. The dose calculation methodology is consistent with the methodology of Regulatory Guide 1.109 (Reference 6), NUREG 0133 (Reference 14) and NRC ISG-13 Rev. 0, Spent Fuel Project Office Interim Staff Guidance – 13 Real Individual, May 17, 2000 (Reference 108). The "maximum individual" is characterized as "maximum" with regard to food consumption, occupancy and other usage of the area in the vicinity of the plant site. Occupancy of a "maximum individual" is not used in dose assessments from contained sources. Such a "maximum individual" represents reasonable deviation from the average for the population in general. In all physiological and metabolic respects the maximum individual is assumed to have those characteristics that represent averages for their corresponding age group. When calculating dose attributed to contained sources for the "maximum individual" dose receptor location, occupancy is defined as a habit for a "real individual" at that location. 100% occupancy is not assumed when calculating dose from contained sources.

Finally Table 2-3 relates the dose component (or pathway) to specific ODCM equations and the appropriate regulation.

Table 2-1

Regulatory Dose Limit Matrix

REGULATION	DOSE TYPE	DOSE LIMIT(s)		ODCM EQUATION
Airborne Releases:		(quarterly)	(annual)	
10CFR50 App. I[3]	Gamma Dose to Air due to Noble Gas Radionuclides (per reactor unit)	5 mrad	10 mrad	A-1
	Beta Dose to Air Due to Noble Gas Radionuclides (per reactor unit)	10 mrad	20 mrad	A-2
	Organ Dose Due to Specified Non-Noble Gas Radionuclides (per reactor unit)	7.5 mrem	15 mrem	A-7
	Total Body and Skin Dose (if air dose is exceeded) – Total Body	2.5 mrem	5 mrem	A-3
	Total Body and Skin Dose (if air dose is exceeded) – Skin	7.5 mrem	15 mrem	A-4
QAPP	Organ Dose Rate Due to Specified Non-Noble Gas Radionuclides (instantaneous limit, per site)	1,500 mrem/yr		A-16
Liquid Releases:		(quarterly)	(annual)	
10CFR50 App. I[3]	Whole (Total) Body Dose (per reactor unit)	1.5 mrem	3 mrem	A-17
	Organ Dose (per reactor unit)	5 mrem	10 mrem	A-17
QAPP	The concentration of radioactivity in liquid effluents released to unrestricted areas	Ten (10) times the concentration values listed in 10CFR20 Appendix B; Table 2, Column 2		A-21
Total Doses [1]:				
10CFR20.1301 (a)(1)	Total Effective Dose Equivalent [4]	100 mrem/yr		A-25
10CFR20.1301 (d), 10CFR72.104 (a) and 40CFR190	Total Body Dose	25 mrem/yr		A-25
	Thyroid Dose	75 mrem/yr		A-25
	Other Organ Dose	25 mrem/yr		A-25
Other Limits [2]:				
40CFR141	Total Body Dose Due to Drinking Water From Public Water Systems	4 mrem/yr		A-17
	Organ Dose Due to Drinking Water From Public Water Systems	4 mrem/yr		A-17

1 These doses are calculated considering all sources of radiation and radioactivity in effluents.
2 These limits are not directly applicable to nuclear power stations. They are applicable to the owners or operators of public water systems. However, the Zion Station RETS requires assessment of compliance with these limits. For additional information, see Section A.6 of Appendix A.
3 Note that 10CFR50 provides design objectives not limits.
4 Compliance with 10CFR20.1301(a)(1) is demonstrated by compliance with 40CFR190. Note that it may be necessary to address dose from on-site activity by members of the public as well.

TABLE 2-2

DOSE ASSESSMENT RECEIVERS

Dose Component or Pathway	Location; Occupancy if Different than 100%
"Instantaneous" concentration limits in liquid effluents	Point where liquid effluents enter the unrestricted area
Annual average concentration limits for liquid effluents	Point where liquid effluents enter the unrestricted area
Direct dose from contained sources	Dose receptor location and occupancy with respect to the habits of a real individual as described in EH&S TSD 13-009, "Member of the Public Dose from all Onsite Sources."
Direct dose from airborne plume	Receiver is at the unrestricted area boundary location that results in the maximum dose.
Dose due to tritium and particulates with half-lives greater than 8 days for inhalation, ingestion of vegetation, milk and meat, and ground plane exposure pathways.	Receiver is at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the highest potential exposures.
Ingestion dose from drinking water	The drinking water pathway is considered as an additive dose component in this assessment only if the public water supply serves the community immediately adjacent to the plant.
Ingestion dose from eating fish	The receiver eats fish from the receiving body of water (lake)
Total Organ Doses	Summation of ingestion/inhalation doses
Total Dose	Summation of above data (Note it may also be necessary to address dose from on-site activity by members of the public.)

TABLE 2-3

DOSE COMPONENT/REGULATION MATRIX

		Regulation in which dose component is utilized			
Dose Component or Pathway	**Reference equation; Comments**	**10CFR20**	**10CFR72**	**40CFR190**	**10CFR50 App. I**
"Instantaneous" concentration limits in liquid effluents	A-21: Ten times the limits of Table 2, Col. 2,10CFR20, Appendix B to §§20.1001 – 20.2402	X(2)			
Annual average concentration limits for liquid effluents	10CFR20, Appendix B to §§20.1001 – 20.2402(2)	X(3)			
Direct dose from contained sources	Section A.3.1	X	X	X	
Direct dose from radioactivity deposited on the ground	A-7 and A-8	X	X	X	X
Inhalation dose from airborne effluents	A-7 and A-9 (1)	X	X	X	X
Ingestion dose from vegetables	A-7, A10 and A-11 (1)	X	X	X	X
Ingestion dose from milk	A-7, A-12 and A-13 (1)	X	X	X	X
Ingestion dose from meat	A-7, A-14 and A-15 (1)	X	X	X	X
Ingestion dose from drinking water	A-17, A-18 and A-19 (1)	X	X	X	X
Ingestion dose from eating fish	A-17, A-18 and A-20 (1)	X	X	X	X
Total Organ Doses	A-25		X	X	X
Total Effective Dose Equivalent	A-25(4)	X			

1 Ingestion/inhalation dose assessment is evaluated for adult/teen/child and infant for 10CFR50 Appendix I compliance and for 10CFR20/40CFR190 compliance. Ingestion/inhalation dose factors are taken from Reg. Guide 1.109 (Reference 6).
2 With the relocation of fuel to the ISFSI, noble gas releases can no longer occur.
3 Optional for 10CFR20 compliance.
4 Compliance with the Total Effective Dose Equivalent limits of 10CFR20 is demonstrated by compliance with 40CFR190. It may also be necessary to address dose from on-site activity by members of the public.

Figure 2-1

Simplified Chart of Offsite Dose Calculations[2]

Category	Radionuclides	Pathway	Text Section	Receptor	Code and Limits	Frequency of Calculation[1]
Airborne Releases:	Non-Noble Gases:	Inhalation[b]	A.1.5	Child (Any Organ)	RETS: 1500 mrem/yr Instantaneous	As required by Station Procedure
	Non-Noble Gases:	Ground Deposition[c]	A.1.4.1	Total Body	10CFR50[3]: 7.5 mrem/qtr, 15 mrem/yr	Monthly and Annually
		Inhalation[c]	A.1.4.2	Four Age Groups (All Organs)		
		Vegetation[d]	A.1.4.3.1			
		Milk[d]	A.1.4.3.2			
		Meat[d]	A.1.4.3.3			
Liquid Releases:	All	Water	A.2.2	Not Applicable	RETS, 10 times 10CFR20 Appendix B; Table 2; Col. 2	As Required by Station Procedure
	Non-Noble Gases	Water[e] and Fish[f]	A.2.1	Total Body	10CFR50[3]: 1.5 mrem/qtr 3 mrem/yr	Monthly
	Non-Noble Gases	Water[e] and Fish[f]	A.2.1	All Organs (4 Age Groups)	10CFR50[3]: 5 mrem/qtr 10 mrem/yr	
	Non-Noble Gases	Water[e]	A.6	Total Body and All Organs (Adult)	40CFR141: 4 mrem/yr	When Required by RETS
Uranium Fuel Cycle:	All	All releases plus direct radiation from contained sources	A.4.2	Total Body	40CFR190: 25 mrem/yr	Annually
				Thyroid (Adult)	40CFR190: 75 mrem/yr	
				Any Other Organ (Adult)	40CFR190: 25 mrem/yr	
ISFSI and Uranium Fuel Cycle:	All	All releases plus direct radiation from ISFSI plus any other radiations	A.4.2	Total Body	10CFR72: 25 mrem/yr	Annually
				Thyroid (Adult)	10CFR72: 75 mrem/yr	
				Any Other Critical Organ (Adult)	10CFR72: 25 mrem/yr	
All Licensed Operations:	All	Total Effective Dose Equivalent	A.5	Total Body and All Organs (Adult)	10CFR20: 100 mrem/yr	Annually

Figure 2-1 (Cont'd)

Notes for Figure 2-1:

1. Definition: Monthly means at least once per 31 days or once per month. See station RETS for exact requirements.

2. Additional Calculations: In addition to the calculations shown in this figure, monthly projections of doses due to radioactive materials are required for gaseous and liquid effluents. See Sections A.1.6 and A.2.5 of Appendix A.

3. 10 CFR 50 prescribes design objectives not limits.

4. If the air dose is exceeded, doses to the total body and skin are calculated. Total body objectives are 2.5 mrem/qtr and 5.0 mrem/year; the skin dose objectives are 7.5 mrem/qtr and 15 mrem/year.

a Evaluated at the unrestricted area boundary.

b Evaluated at the location of maximum offsite X/Q.

c Ground plane and inhalation pathways are considered to be present at all offsite locations.

d Evaluated at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposures. If no real pathway exists then a hypothetical cow-milk producer is evaluated at 5 miles in the highest D/Q sector.

e Evaluated for the nearest downstream community water supply as specified in Table A-3 of Appendix A. The flow and dilution factors specified in Table F-1 of Appendix F are used.

f Evaluated for fish caught in the near-field region downstream of plant using the flow and dilution factors specified in Table F-1 of Appendix F.

CHAPTER 3

EXPOSURE PATHWAYS

3.0 INTRODUCTION

Figure 3-1 illustrates some of the potential radiation exposure pathways to humans due to routine nuclear power station activities. These exposure pathways may be grouped into three categories:

1. **Airborne Releases** - Exposures resulting from radioactive materials released with gaseous effluents to the atmosphere.

2. **Liquid Releases** - Exposures resulting from radioactive materials released with liquid discharges to bodies of water.

3. **Radiation from Contained Sources** - Exposures to radiation from contained radioactive sources.

When performing radiation dose calculations, only exposure pathways that significantly contribute (≥ 10%) to the total dose of interest need to be evaluated. The radiation dose from air and water exposure pathways is routinely evaluated. (See Regulatory Guide 1.109, Reference 6.)

3.1 AIRBORNE RELEASES

For airborne releases of radioactivity, the NRC considers the following pathways of radiation exposure of persons:

- External radiation from radioactivity airborne in the effluent plume.
- External radiation from radioactivity deposited by the plume on the ground.
- Ingestion of radioactivity on, or in, edible vegetation (from direct plume deposition).
- Ingestion of radioactivity that entered an animal food product (milk or meat) because the animal ingested contaminated feed, with the contamination due to direct deposition on foliage.
- Inhalation of radioactivity in the plume.

Dose for airborne releases is assessed at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposures.

3.2 LIQUID RELEASES

For liquid releases of radioactivity (Figure 3-1), the NRC considers the following pathways of radiation exposure of persons:

- Ingestion of aquatic food (e.g., fish or invertebrate) obtained from the body of water to which radioactive station effluents are discharged.
- Ingestion (drinking) of potable water contaminated by radioactive liquid effluents discharged from the station.

For the aquatic food pathway, only fish is considered since it is the only significant locally produced aquatic food consumed by humans.

Zion Station omits the pathways involving irrigation and animal consumption of contaminated water because these pathways were determined to be insignificant. Zion Station also omits the pathway of radiation exposure from shoreline sediment because this pathway was also found to be insignificant (see Appendix O, Section O.3.2).

Zion Station has also verified that the dose contribution to people participating in water recreational activities (swimming and boating) is negligible. (See Appendix O, Table O-3.) This pathway was not addressed explicitly in Regulatory Guide 1.109. Thus, Zion Station also omits dose assessments for the water recreational activities pathway.

Periodically, the Illinois Army Corps of Engineers dredges silt and debris from the river beds near Zion Station. As a part of the land use census, Zion Station will determine if the Corps performed dredging within one mile of the discharge point. If so, Zion Station will obtain spoils samples, through its REMP vendor, for analysis. The impact to the offsite dose will be evaluated on a case by case basis and added to the ODCM when applicable.

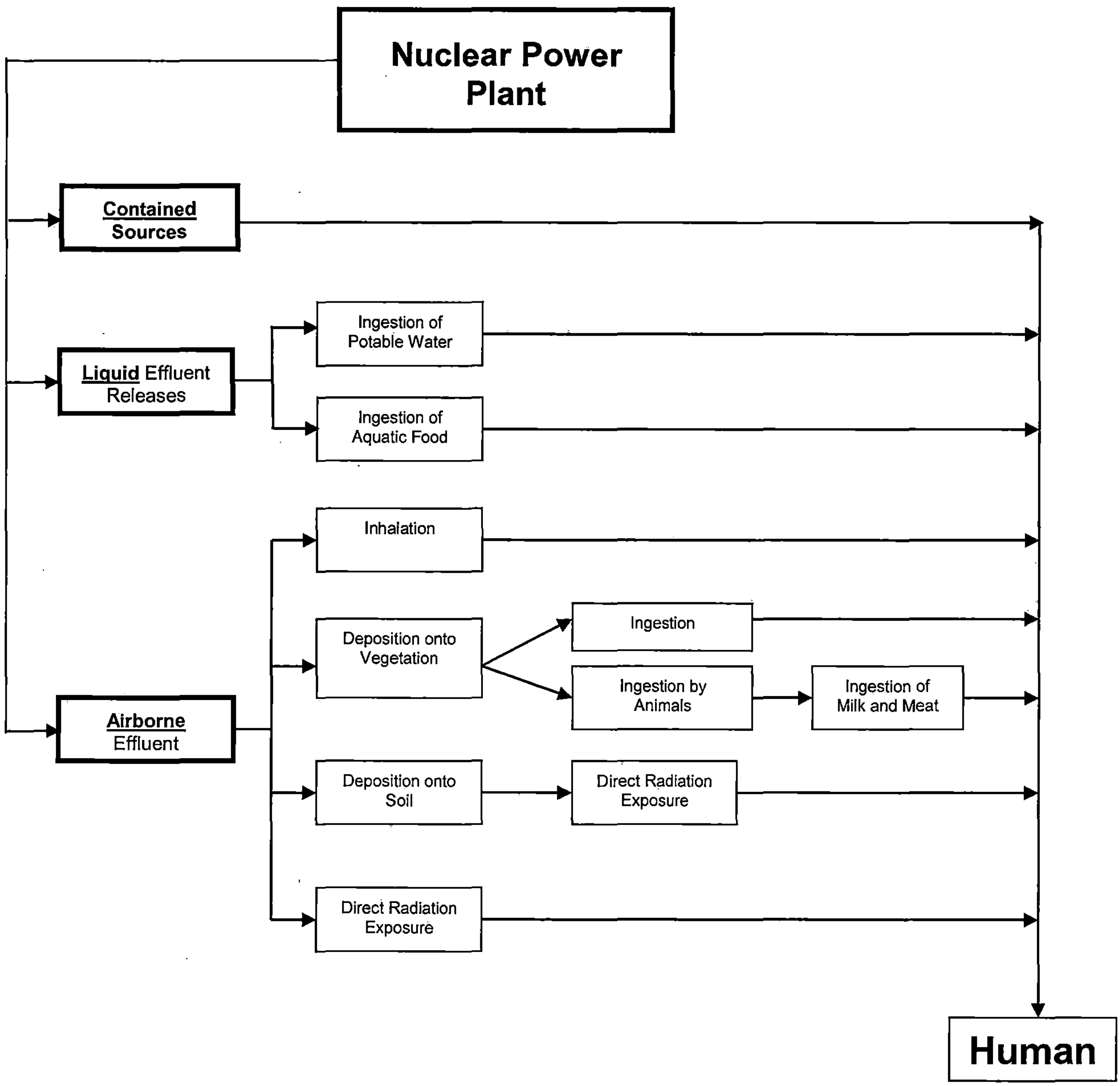
In addition, to assure that doses due to radioactivity in liquid effluents will be ALARA, concentrations will be limited to ten times (10x) the values given in 10CFR20 Appendix B, Table 2; Column 2.

3.3 RADIATION FROM CONTAINED SOURCES

Radioactivity contained within waste containers, including those present at the ISFSI, can produce radiation at offsite locations. Annual offsite radiation doses near Zion Station due to such sources have the potential to challenge annual dose limits to members of the public due to direct radiations. Additions or rearrangements of waste storage locations that may impact the offsite dose through increases to the direct radiation levels are monitored through site administrative processes and procedures.

Figure 3-1

Radiation Exposure Pathways to Humans



CHAPTER 4

METHODOLOGY

4.0 INTRODUCTION

This chapter provides an introduction to the methodology used at the Zion Station to calculate offsite radiation doses. Additional explanation and details of the methodology are provided in Appendices A and B. Appendix A discusses each dose limit in the RETS and provides the associated assessment equations. Appendix B describes methods used to determine values of parameters included in the equations.

4.1 IMPORTANT CONCEPTS AND PARAMETERS

4.1.1 Dose

The dose calculation equations contained in the ODCM are based on two types of exposure to radiation; external and internal exposure. The first type of exposure is that resulting from radioactive sources external to the body (including radiation emanating from an effluent plume, radiation emanating from radioactivity deposited on the ground and radiation emanating from contained sources (also referred to as direct radiation)). Exposure to radiation external to the body only occurs while the source of the radioactivity is present. It should be noted that with the relocation of the fuel from the Spent Fuel Pool to the ISFSI there is no longer an exposure pathway from noble gases which affects the dose impacts at the Zion Station. Although noble gases are no longer included as an effluent from Zion Station activities, the associated information included in this chapter of the ODCM will remain at this time for historical purposes.

Internal exposure occurs when the source of radioactivity is inside the body. Radiation can enter the body by breathing air containing the radioactivity, or by consumption of food or drinking water containing radioactivity. Once radioactivity enters the body and becomes internal radiation, a person will continue to receive radiation dose until the radioactivity has decayed or is eliminated by biological processes. The dose from this type of exposure is also termed dose commitment, meaning that the person will continue to receive dose even-though the plume containing the radioactivity has passed by the individual, or even-though the individual is no longer drinking water containing radioactivity.

The regulations addressed by the ODCM may require assessment of either type of exposure to radiation or of both types in summation.

The term dose is used instead of the term "dose equivalent," as defined by the International Commission on Radiological Units and Measurements (ICRU). When applied to the evaluation of internal deposition of radioactivity, the term "dose," as used in the ODCM, includes the prospective dose component arising from retention in the body beyond the period of environmental exposure, i.e. the dose commitment. The dose commitment is evaluated over a period of 50 years.

4.1.2 Exposure Pathways

All of the exposure pathways are discussed in Chapter 3. This section presents the exposure pathways addressed by Zion Station in the ODCM and associated software.

For releases of radioactivity in airborne effluents the primary pathways are the following:

- Direct radiation from an effluent plume.
- Direct radiation from radioactivity deposited on the ground by a plume.
- Inhalation of radioactivity in a plume.
- Ingestion of radioactivity that entered the food chain from a plume that deposited radioactivity on vegetation.

For releases of radioactivity in liquid effluents, the exposure pathways considered are human consumption of water and fish.

When determining total doses, as required by 10CFR20, 10CFR72 and 40CFR190, Zion Station considers exposure to radiation emanating from onsite radioactive waste.

4.1.3 Categories of Radioactivity

Radionuclide content of effluent releases from Zion Station can be categorized according to the characteristics of the radionuclides. In evaluating doses associated with a particular pathway, only those categories of radionuclides that significantly contribute to the dose need to be included in the dose calculations (See Section 3.0). The categories of radionuclides considered by Zion Station for each of the airborne pathways are summarized in Table 4-1. Selection of the significant airborne pathways was based on the following:

- The requirements in the RETS (see discussion in Appendix A),
- Applicable regulatory guidance (References 6 and 14), and
- A study of the potential radiological implications of nuclear facilities in the upper Mississippi River basin (Reference 20).

4.1.4 Atmospheric Release Point Classifications

The dose impact from airborne release of radioactivity is determined by the height of the release of the effluent plume relative to the ground and by the location of the dose recipient.

The height an effluent plume maintains as it travels above the ground is related to the elevation of the release point and to the height of structures immediately adjacent as follows:

- If the elevation of the release point is sufficiently above the height of any adjacent structures, the plume will remain elevated for considerable distances.

- If the elevation of the release point is at or below the heights of adjacent structures, the plume is likely to be caught in the turbulence of the wakes created by wind passing over the buildings. The plume elevation would then drop to ground level.

- If the elevation of the release point is not significantly above the heights of adjacent structures, then the plume may be elevated or at ground level.

For the calculations of this manual, each established release point has been designated as belonging to one of three release point classifications:

Stack (or Elevated) Release Points (denoted by the letter S or subscript s)

These are release points approximately twice the height of adjacent solid structures. Releases are treated as elevated releases unaffected by the presence of the adjacent structures.

Ground Level Release Points (denoted by the letter G or subscript g)

These are release points at ground level or lower than adjacent solid structures. Releases are considered drawn into the downwind wake of these structures and are treated as ground level releases.

Vent (or Mixed Mode) Release Points (denoted by the letter V or subscript v)

These are release points as high or higher than adjacent solid structures but lower than twice the structure's heights. These releases are treated as a mixture of elevated and ground level releases. The proportion of the release attributed to either elevated or ground level in a vent release is determined by the ratio of stack exit velocity to the wind speed (see Section B.1.2.4 of Appendix B).

The definitions of these classifications are based on Regulatory Guide 1.111 (Reference 7). Zion Station has no Stack (Elevated) or Vent (Mixed Mode) release points, therefore; all releases at Zion Station are considered Ground Level.

4.1.5 Historical Average Atmospheric Conditions

The dispersion characteristics of airborne effluents from a nuclear power station are dependent on weather conditions. Meteorological factors that directly affect the concentration of airborne radioactivity in a plume include the following:

- Wind Direction

  The concentration of radioactivity is highest in the direction toward which the wind is blowing.

- Wind Speed

  Greater wind speeds produce more dispersion and consequently lower concentrations of radioactivity.

- Atmospheric Turbulence

  The greater the atmospheric turbulence, the more a plume spreads both vertically and horizontally. For calculations in this manual, the degree of turbulence is classified by use of seven atmospheric stability classes, designated A (extremely unstable) through G (extremely stable). The seven classes and some of their characteristics are listed in Table C-4 of Appendix C.

Meteorological conditions strongly impact the values of various parameters applied in the dose calculations of this manual. These include:

- The Relative Concentration Factors χ/Q and gamma-χ/Q (Section 4.1.6)
- The Relative Deposition Factor D/Q (Section 4.1.7)

The bases sections of the Standard Radiological Effluent Technical Specifications (guidance documents NUREGs 0472, 0473, 1301 and 1302) and the RETS specify that dose calculations be based on "historical average atmospheric conditions". Therefore, this manual provides values for the above parameters that are based on Zion Station historical average meteorological conditions. These values were obtained by averaging hourly values of the parameters over a long-term, several-year period of record. The averaging period was based on calendar years in order to avoid any bias from weather conditions associated with any one season. The period of record is identified in each of the tables providing the values (see Appendix F).

4.1.6 Relative Concentration Factors χ/Q and Gamma-χ/Q

A person immersed in a plume of airborne radioactivity is exposed to radiation from the plume and may also inhale some of the radioactivity from the plume. The concentration of radioactivity in air near the exposed person must be calculated to adequately evaluate doses resulting from any inhalation. The relative concentration factor χ/Q (referred to as "chi over Q") is used to simplify these calculations. χ/Q is the concentration of radioactivity in air, at a specified location, divided by the radioactivity release rate. χ/Q has the following units:

Units of χ/Q = (μCi/m^3) / (μCi/sec) = sec/m^3

Zion Station values of χ/Q are provided in Table F-5 of Appendix F. These values are based on historical average atmospheric conditions (see Section 4.1.5). For each of the release point classifications (eg. stack, vent and ground level) and for the 16 compass-direction sectors (N, NNE, etc.), Table F-5 provides the maximum value of χ/Q for locations at or beyond the unrestricted area boundary.

The value of χ/Q for each sector reflects the fraction of time that the wind blew into that sector and the distribution of wind speeds and atmospheric stability classes during that time. Note that the value would be zero if the wind never blew into the sector.

The gamma-χ/Q provides a simplified method of calculating gamma air dose and dose rates for a finite and/or elevated plume. It is used in place of the semi-infinite plume model that tends to underestimate gamma air dose for elevated plumes. Use of the gamma-X/Q also corrects for the tendency of the semi-infinite plume model to overestimate gamma air dose for mixed mode and ground level releases.

The methodologies for determining χ/Q and gamma-χ/Q are discussed in detail in Section B.3 of Appendix B.

4.1.7 Relative Deposition Factor D/Q

As a plume travels away from its release point, portions of the plume may touch the ground and deposit radioactivity on the ground and/or on vegetation. Occurrences of such deposition are important to model since any radioactivity deposited on the ground or on vegetation may directly expose people and/or may be absorbed into food products which can ultimately be ingested by people. The relative deposition factor is used to simplify the dose calculations for these pathways.

The relative deposition factor D/Q is the rate of deposition of radioactivity on the ground divided by the radioactivity release rate. Its value was determined for specific conditions. In this manual it has the following units:

Units of D/Q = [(pCi/sec)/m^2] / (pCi/sec) = 1/m^2

The values of D/Q are affected by the same parameters that affect the values of χ/Q: release characteristics, meteorological conditions and location (see Section 4.1.6). Zion Station values of D/Q are provided in Appendix F Tables F-5 and F-6. These values are based on historical average atmospheric conditions (see Section 4.1.5).

For each release point classification and for each of the 16 compass-direction sectors (N, NNE, etc.), Table F-5 provides the maximum value of D/Q for locations at or beyond the unrestricted area boundary. In Table F-6, values of D/Q are given for the locations of the nearest milk and meat producers within 5 miles of Zion Station. The methodology for determining D/Q is discussed in Section B.4 of Appendix B.

4.1.8 Dose Factors

Various dose factors are used in this manual to simplify the calculation of radiation doses. These factors are listed in Table 4-2. Definitions of these factors are given in the remainder of this chapter. Methods of determining their values are addressed in Appendix B.

4.2 AIRBORNE RELEASES

4.2.1 Gamma Air Dose

The term 'gamma air dose' refers to the component of dose absorbed by air resulting from the absorption of energy from photons emitted during nuclear and atomic transformations, including gamma rays, x-rays, annihilation radiation, and Bremsstrahlung radiation (see footnote on page 1.109-19 of Regulatory Guide 1.109).

The noble gas dose factors of Reg. Guide 1.109, Table B-1 are based upon assumption of immersion in a semi-infinite cloud. For ground level and mixed mode releases this tends to overestimate the gamma air dose arising from a plume that is actually finite in nature.

For elevated releases, the Reg. Guide 1.109 noble gas dose factors will underestimate exposure as they consider only immersion and not that portion of exposure arising from sky shine.
At distances close in to the point of elevated release, the ground level concentration as predicted by **χ/Q** will be essentially zero. In such a case, the sky shine component of the exposure becomes significant and must be considered.

The **gamma-χ/Q** provides a simplified method of calculating gamma air dose and dose rates for a finite and/or elevated plume. The methodology of Reg. Guide 1.109, Section C.2 and Appendix B provide the methodology for calculating finite cloud gamma air dose factors from which the **gamma-χ/Q** values can be derived. Section B.5 addresses the calculation of these dose factors.

Three **gamma-χ/Q** values are defined: **$(\chi/Q)_s^\gamma$, $(\chi/Q)_v^\gamma$ and $(\chi/Q)_g^\gamma$** for stack, vent and ground level releases, respectively. Section B.3.5 addresses the calculation of the **gamma-χ/Q** values.

4.2.1.1 Finite Cloud Gamma Air Dose Factor

The finite cloud gamma air dose factor is determined by calculating the gamma dose rate to air (at a specific location and corresponding to a given release rate) and dividing that dose rate by the corresponding release rate:

Finite Cloud Gamma Air Dose Factor = [(mrad/yr)/(μCi/sec)]

The methodology for this calculation is discussed in Section B.5 of Appendix B. The calculation is complex because the dose rate at any given point is affected by the radioactivity concentration and distance. Calculation of the finite cloud gamma air dose factor takes into consideration release characteristics, meteorological conditions and location (see Section 4.1.6). Additionally, the value is affected by radiological parameters: the distribution of energies and intensities for gamma emissions from each specific radionuclide and the photon attenuation characteristics of air.

In the ODCM, station-specific values of gamma dose factors are provided for Zion Station in Appendix F, Table F-7. These values are based on historical average atmospheric conditions (see Section 4.1.5). For the release point classification and for each of the 16 compass-direction sectors, Table F-7 provides the maximum value of the gamma air dose factor for noble gas radionuclides at the unrestricted area boundary. The value includes a correction for radioactive decay during transport of the radionuclide from the release point to the dose calculation location.

4.2.1.2 Semi-Infinite Cloud Gamma Air Dose Factor

The semi-infinite cloud gamma dose factor is the gamma air dose rate divided by the concentration of radioactivity in air at the dose calculation location. Values of these gamma dose factors are radionuclide specific and are provided in Appendix C, Table C-9.

The semi-infinite cloud gamma dose factor is used in conjunction with **gamma-χ/Q** to calculate noble gas gamma air dose and dose rate for elevated and finite noble gas plumes. The **gamma-χ/Q** is defined such that for a given finite cloud the semi-infinite cloud methodology will yield the same gamma air dose as the finite cloud methodology.

4.2.2 Beta Air Dose

The term 'beta air dose' refers to the component of dose absorbed by air resulting from the absorption of energy from emissions of beta particles, mono-energetic electrons and positrons during nuclear and atomic transformations (see the footnote on Page 1.109-20 of Regulatory Guide 1.109).

The Beta Air Dose Factor

The beta air dose factor is the beta air dose rate divided by the concentration of radioactivity in air at the dose calculation location. Values of the beta air dose factor are radionuclide specific and are provided in Appendix C Table C-9.

4.2.3 Total Body Dose and Dose Rate

Total Body Dose

Equation A-3 of Appendix A is used to calculate dose to the total body from noble gas radionuclides released in gaseous effluents. The total body dose equation is similar to that used to calculate gamma air dose (Equation A-1 of Appendix A).

Total Body Dose Rate

Equation A-5 of Appendix A is used to calculate dose rate to the total body. The assumptions used for this equation are the same as those used in the calculation of total body dose (Equation A-3 of Appendix A) except that any shielding benefit (dose attenuation) provided by residential structures is not applied. Since the calculation is for the maximum instantaneous dose rate, the dose recipient may be out of doors when exposed and would not be shielded from the exposure by any structural material.

The Total Body Dose Factor

The total body dose factor is the total body dose rate divided by the radioactive release rate. Values for the total body dose factor are site specific and are provided in Table C-9 of Appendix C.

4.2.4 Skin Dose and Dose Rate

Skin Dose

Equation A-4 of Appendix A is used to calculate dose to skin from noble gas radionuclides released in gaseous effluents. The skin dose is the summation of dose to the skin from beta and gamma radiation.

The equation for beta dose to skin is similar to that used to calculate beta dose to air (Equation A-2 of Appendix A) except that beta skin dose factors are used instead of beta air dose factors. The beta skin dose factor differs from the beta air dose factor by accounting for the attenuation of beta radiation by the dead layer of skin. The dead layer of skin is not susceptible to radiation damage and therefore is not of concern. The beta dose to the skin from non-noble gases is insignificant and is not calculated for the reason described in Section 4.1.3. When calculating the beta contribution to skin dose, no reduction is included in the calculations due to shielding provided by occupancy of residential structures.

The equation for gamma dose to skin is similar to that used to calculate gamma dose to air except for the following:

- Equation A-4 of Appendix A includes a unit's conversion factor 1.11 rem/rad to convert from units of gamma air dose (rad) to units of tissue dose equivalent (rem).
- Equation A-4 of Appendix A includes a dimensionless factor of 0.7 to account for the shielding due to occupancy of residential structures.

Equation A-4 of Appendix A uses gamma air dose factors not gamma total body dose factors. When calculating gamma dose to skin, no reduction is applied for the attenuation of radiation due to passage through body tissue (dead layer of skin).

Skin Dose Rate

Equation A-6 of Appendix A is used to calculate dose rate to skin. The assumptions are the same as those used in the calculation of skin dose (Equation A-4 of Appendix A) except that no credit is taken for shielding of gamma radiation by residential structures. The dose recipient may be outdoors when exposed and the maximum instantaneous dose rate is of concern.

The Skin Dose Factor

Values of the beta air dose factors and skin dose factors are nuclide specific and are provided in Table C-9 of Appendix C for 15 noble gas radionuclides.

4.2.5 Ground Radiation

Equations A-7 and A-8 of Appendix A are used to calculate the total body dose due to non-noble gas radionuclides released in gaseous effluents and deposited on the ground.

Comment
Note that if there is no release of radionuclide **i** during a given time period, then the deposition rate is zero, the ground plane concentration is zero and the resulting dose due to ground deposition is zero. If there is a release of radionuclide **i**, the ground concentration is computed as if that release had been occurring at a constant rate for the ground deposition time period.

The Ground Plane Dose Conversion Factor

The ground plane dose conversion factor is the dose rate to the total body per unit of radioactivity concentration on the ground. Values of the ground plane dose conversion factor that are calculated by assuming constant concentration over an infinite plane are provided for various radionuclides in Table C-10 of Appendix C.

4.2.6 Inhalation

Dose

Radioactivity from airborne releases of particulate and tritium can enter the body through inhalation. Equations A-7 and A-9 of Appendix A are used to calculate dose commitment to the total body or organs due to inhalation of non-noble gas radionuclides released in gaseous effluents.

The Inhalation Dose Factor

Values for the inhalation dose commitment factor are nuclide specific and are taken from Reg. Guide 1.109 (Reference 6) Tables E-7, 8, 9 and 10. These tables include data for four age groups (adult, teenager, child and infant) and seven body organs.

Dose Rate

The inhalation dose rate is the rate at which dose is accrued by an individual breathing contaminated air. Equation A-16 of Appendix A is used to calculate dose commitment rate to an organ due to inhalation of non-noble gas radionuclides. The assumptions are the same as used in the calculation of inhalation dose. The dose rate is determined for the child age group in accordance with the guidance found in NUREGs 0472, 0473, 1301 and 1302 (References 2, 3, 105 and 106).

4.2.7 Ingestion

Airborne releases of particulate and tritium can enter the food chain through deposition on vegetation. The radioactivity can be ingested by humans who consume the vegetation or who consume products (e.g., milk or meat) of animals who have fed on the contaminated vegetation. Zion Station may consider the following ingestion pathways:

- Vegetables
- Milk
- Meat

Equations A-7 and A-10 through A-15 of Appendix A are used to calculate the dose due to ingestion of food containing non-noble gas radionuclides released in gaseous effluents. Dose is assessed at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposures.

Values of the ingestion dose commitment factors are taken from Reg. Guide 1.109 Tables E-11, 12, 13 and 14. These tables include data for four age groups and seven organs.

The equations used for radioactivity concentration on vegetation and in milk, and meat are discussed in Appendix A.

4.3 LIQUID RELEASES

The evaluation of dose due to releases of radioactivity in liquid effluents is required to confirm compliance with the provisions of RETS related to 10CFR50 Appendix I. The ODCM, Section 3.2 and Figure 3-1 list some of the pathways by which radioactivity in liquid effluents can impact man. The pathways used by Zion Station to calculate dose from liquid effluents are ingestion by drinking water and by eating fish from the body of water receiving station liquid discharges. Zion Station obtains the dose commitment due to radioactivity in liquid effluent releases by summing the dose commitments from the drinking water and fish pathways depending upon their presence.

Equations A-17 through A-20 of Appendix A are used to calculate dose for the member of the public due to consumption of drinking water and fish.

The radioactivity concentration in water is obtained by dividing the quantity of radioactivity released by the volume of water in which the release is diluted. The result can be modified by a factor to represent any additional dilution that might occur.

The radioactivity concentration in fish is the product of the radioactivity concentration in water and a bioaccumulation factor. The dilution factors for fish may be different from those for water. (The fish may be caught at a location different from where drinking water is drawn.)

The bioaccumulation factor accounts for the fact that the quantity of radioactivity in fish can build up with time to a higher value relative to the concentration of the radioactivity in the water they consume. The bioaccumulation factor is the equilibrium ratio of the concentration of radionuclide **i** in fish to its concentration in water. The same values are used for the bio-accumulation factor at Zion Station. These values are provided in Appendix C, Table C-8.

4.4 CONTAINED SOURCES OF RADIOACTIVITY

In addition to the total body, skin and single organ dose assessments previously described, an additional assessment is required. The additional assessment addresses radiation dose due to radioactivity contained within the nuclear power station and its structures.

4.4.1 Deleted

4.4.2 Onsite Radioactive Waste and Radioactive Material Storage Facilities

Low-level radioactive waste and radioactive material may be stored at Zion Station in the following types of locations:

- Concrete Rad Vaults
- Miscellaneous Shipping Containers
- Existing and temporary support structures

Spent Fuel is stored at the Independent Spent Fuel Storage Installation. Administrative controls are implemented by Zion Station to ensure compliance to applicable regulations. The impact to the offsite dose from contained sources shall be documented in site Technical Support Documents. In addition, a 10CFR50.59 analysis may be required for selected radwaste storage facilities.

4.5 TOTAL DOSE REQUIREMENTS

4.5.1 Total Effective Dose Equivalent Limits; 10CFR20 and 40CFR190

10CFR20 requires compliance to dose limits expressed as "Total Effective Dose Equivalent" (TEDE). Although annual dose limits in 10CFR20 are now expressed in terms of TEDEs, 40CFR190 limits remain stated as organ dose. The NRC continues to require 10CFR50 Appendix I and 40CFR190 doses to be reported in terms of organ dose and not TEDE. Due to the fact that organ dose limits set forth in 40CFR190 are substantially lower than those of 10CFR20 (25 mrem/yr vs. 100 mrem/yr), the NRC has stated that demonstration of compliance with the dose limits in 40CFR190 will be deemed as demonstration of compliance with the dose limits of 10CFR20 for most facilities (Reference 104).

In addition to compliance with 40CFR190, it may be necessary for a nuclear power plant to address dose from on-site activity by members of the public.

4.5.2 Total Dose For Uranium Fuel Cycle

Zion Station is required to determine the total dose to a member of the public due to all uranium fuel cycle sources in order to assess compliance with 40CFR190 as part of demonstrating compliance with 10CFR20.

The total dose for the uranium fuel cycle is the sum of doses due to radioactivity in airborne and liquid effluents and the doses due to direct radiation from contained sources at the Zion Station. When the evaluation of total dose is required for the Zion Station, the following contributions are summed:

- Doses due to airborne and liquid effluents.
- Doses due to liquid effluents from nuclear power stations upstream
- Doses due to any onsite radioactive waste storage facilities; if applicable.

Section A.5.2 of Appendix A discusses the details of evaluations.

Table 4-1

Radionuclide Types Considered For Airborne Effluent Exposure Pathways

	External Radiation		Internal Radiation	
Category	Plume	Ground	Inhalation	Ingestion
Noble Gases	X			
Tritium (H-3)			X	X
Particulate[a]		X	X	X

[a] Only particulates with half-life greater than 8 days need be considered. For details, see Generic Letter 89-01 and the RETS.

Table 4-2
Radiation Dose Factors

Name and Symbol	Units	Definition	Table
Gamma Air Dose Factor M_i	mrad/yr per $\mu Ci/m^3$	Gamma air dose rate per unit of radioactivity concentration for radionuclide **i**.	RG 1.109 Table B-1, Column 4
Total Body Dose Factor: K_i	mrem/yr per $\mu Ci/m^3$	Total body dose rate per unit of radioactivity concentration for radionuclide **i**.	RG 1.109 Table B-1, Column 5
Beta Air Dose Factor N_i	mrad/yr per $\mu Ci/m^3$	Beta air dose rate per unit of radioactivity concentration for radionuclide **i**.	RG 1.109 Table B-1, Column 2
Beta Skin Dose Factor L_i	mrem/yr per $\mu Ci/m^3$	Beta skin dose rate per unit of radioactivity concentration for radionuclide **i**.	RG 1.109 Table B-1, Column 3
Ground Plane Dose Conversion Factor DFG_i	mrem/hr per pCi/m^2	Dose rate per unit of ground radioactivity concentration for radionuclide **i**.	RG 1.109 Table E-6, Column 2
Inhalation Dose Commitment Factor DFA_{ija}	mrem per pCi	Dose to organ **j** of age group **a** per unit of radioactivity inhaled for radionuclide **i**. (see Note 1)	RG 1.109 Tables; E-7, E-8, E-9, E-10
Ingestion Dose Commitment Factor DFI_{ija}	mrem per pCi	Dose to organ **j** of age group **a** per unit of radioactivity ingested for radionuclide **i**. (see Note 1)	RG 1.109 Tables; E-11, E-12, E-13, E-14

Note 1: Dose assessments for 10CFR20, 10CFR72 and 40CFR190 compliance are made for an adult only.

Dose assessments for 10CFR50 Appendix I are made using dose factors of Regulatory Guide 1.109 (Reference 6) for all age groups.

CHAPTER 5

MEASUREMENT

5.0 INTRODUCTION

Zion Station has two measurement programs associated with offsite dose assessment:

- Measurement of releases of radioactivity at the site.
- Measurement of levels of radiation and radioactivity in the environs surrounding the site.

5.1 EFFLUENT AND PROCESS MONITORING

Radioactivity in liquid and gaseous effluents is measured in order to provide data for calculating radiation doses and radioactivity concentrations in the environment. Measurement of effluent radioactivity is required by 10CFR20.1302 and 10CFR50. The RETS provides detailed requirements for monitoring the effluents from the Zion Station. Relevant Regulatory Guides are 1.21 (Reference 4) and 4.15 (Reference 13). Chapter 10 of the ODCM includes brief descriptions of the systems. The RETS requires submission to the NRC of reports of effluent radioactivity releases and environmental measurements.

5.2 METEOROLOGICAL MONITORING

A historical average of meteorological measurements is used at the Zion Station in lieu of real time monitoring.

5.3 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM (REMP)

Zion Station has a REMP that provides representative measurements of radiation and radioactive material in the environment. The program provides verification that measurable radiological impacts from the station on the environment are within expectations derived from effluent measurements and calculations. The REMP is required by 10CFR50 (see Appendix I, Sections IV.B.2 and IV.B.3). General requirements of the program are prescribed in Zion Stations RETS and more precise details (such as specific monitoring locations) are specified in the ODCM Chapter 11.

5.3.1 Interlaboratory Comparison Program

The laboratory which performs the REMP analyses is required by the RETS to participate in an interlaboratory comparison program. The purpose is to provide an independent check on the laboratory's analytical procedures and to alert it to potential problems (e.g. accuracy). In order to assess the measurements of radioactivity in environmental media, an independent agency supplies participating laboratories with samples of environmental media containing unspecified amounts of radioactivity. The laboratories measure the radioactivity concentrations and report the results to the agency. At a later time, the agency informs the participating laboratories of the actual concentrations and associated uncertainties. Any significant discrepancies are investigated by the participating laboratories. A similar process is used to assess measurements of environmental radiation by passive thermoluminescent dosimeters.

CHAPTER 6

IMPLEMENTATION OF OFFSITE DOSE ASSESSMENT PROGRAM

6.1 NUCLEAR POWER STATION

Zion Station staff is responsible for effluent monitoring. The staff determines effluent radioactivity concentration and flow rate. These data are used to determine the radioactivity release information required for the Radioactive Effluent Release Report and to perform monthly calculations and projections of offsite radiation dose.

Zion Station staff is also responsible for control of effluent radioactivity. Procedures are implemented for determining, calculating and implementing monitor setpoints. Liquid and gaseous radwaste treatment systems and ventilation exhaust treatment systems are utilized when appropriate. Zion Station staff implements the Process Control Program (PCP) for solid radwaste and measures tank radioactivity.

Zion Station staff maintains instrumentation associated with these activities and demonstrates operability of the instrumentation in accordance with the surveillance requirements of the RETS. In the event that any RETS requirements are violated, Zion Station staff is responsible for taking one of the actions allowed by the RETS and issuing any required reports to the NRC.

Zion Station assembles and distributes the Annual Radioactive Effluent Release Report.

6.2 REMP CONTRACTOR

The radiological environmental contractor collects environmental samples and performs radiological analyses as specified in the Zion Station REMP (see ODCM Chapters 11 and 12). The contractor issues reports of results to appropriate points of contact. The contractor participates in an interlaboratory comparison program and reports results in the Annual Radiological Environmental Operating Report. The contractor performs the annual land use census and assembles the Annual Radiological Environmental Operating Report.

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CHAPTER 8

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CHAPTER 9

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CHAPTER 10

RADIOACTIVE EFFLUENT TREATMENT SYSTEM AND MONITORING

10.1 AIRBORNE RELEASES

10.1.1 System Description

During operation of the ventilation systems, the principal release points for potentially radioactive airborne effluents are the two auxiliary building ventilation stacks (Unit 1 and Unit 2). Each is classified as a ground level release.

These ventilation systems maintain acceptable ambient air temperatures for equipment operation and personnel habitability, they provide air flow as needed for contamination control purposes, from lesser contamination potential to areas of greater contamination potential, and they provide bulk exhaust flow for ease of effluent control, sampling, and quantification.

The Unit 2 Aux Bldg (AB) ventilation stack provides the release point for airborne effluent from the Aux Bldg, Fuel Building, and the Containments (when the Containment Purge Fans are not in operation). Operation of the AB ventilation system is administratively controlled to ensure that at least one (of 3) exhaust fan is operating when a supply fan is running.

During times when the Containment Purge Fans are operating; the Unit 1 AB ventilation stack provides the release point for airborne effluent from the Unit 1 Containment, and the Unit 2 AB ventilation stack provides the release point for airborne effluent from the Unit 2 Containment.

Gaseous effluent system and ventilation systems are described in the Defueled Safety Analysis Report (DSAR) and Section 10.4.

10.1.1.1 Ventilation Exhaust Treatment System

Ventilation exhaust treatment systems are designed and installed to reduce radioactive material in particulate form in gaseous effluents by passing ventilation through HEPA and/or pre-filters prior to release to the environment for ALARA reasons.

10.1.2 Radiation Monitors

Pertinent information is provided in the DSAR and Section 10.4.

10.1.2.1 Auxiliary Building Ventilation Stack Effluent Monitors

2RIA-PR49 (Unit 2) continuously monitors the final effluent from the Aux Bldg, Fuel Bldg, and Unit 2 containment for beta, particulate and provides an alarm function.

10.1.2.2 Containment Purge Effluent Monitors

1RIA-PR49 (Unit 1) continuously monitors the final effluent from the Unit 1 containment when the associated Purge Fan is in operation for beta particulate and provides an alarm function.

2RIA-PR49 (Unit 2) continuously monitors the final effluent from the Unit 2 containment when the associated Purge Fan is in operation for beta particulate and provides an alarm function.

10.1.3 to 10.1.3.4 Deleted

10.1.3.5 HVAC Flow Rates

Flow rates for aux vent stack release are provided by flow measuring instrumentation. However, flow rates out of the vent stack can be calculated based on the number of operating fans in the monitored flow path.

F_M = $\Sigma F_{ip} \times N_i$ (10-4)

F_M = Total Flow In Monitored Flow Path [cc/sec]

F_{ip} = Flow from fan i in path p. [cc/sec]

N_i = Number of fans, in operation

The maximum flow for each fan is used for setpoint calculations because this maximizes the flow, establishing a conservative, "worst case" release rate/concentration for setpoint determination.

Pertinent data for the fans is provided in Table 10-2.

HVAC flows for the remaining monitors are conservatively fixed at upper bound values.

10.2 LIQUID RELEASES

10.2.1 System Description

The liquid waste system description is provided in the DSAR and Section 10.4.

The liquid radwaste treatment system is designed and installed to allow for a reduction if needed, in the concentration of radioactive liquid effluents by filtration, providing for retention or holdup and/or providing for treatment by demineralizers. The overall purpose is to ensure releases to the lake do not exceed any concentration release limit and liquid effluent releases to the public are ALARA.

10.2.1.1 Lake Release Tanks

There are two Lake Release Tanks which receive processed liquid waste before discharge to Lake Michigan.

10.2.1.2 Holdup Tanks

There are three Holdup Tanks (120,000-gallon capacity each) which receive and store liquid waste from the Containments, AB and FB. The Holdup Tanks (HUTS) will store the liquid waste water until it can be processed for release to Lake Michigan or removed from the site.

10.2.2 Radiation Monitors

10.2.2.1 Lake Release Tank Monitors

If the option is used, 0RT-PR04 monitors releases from the Lake Release Tanks. On high alarm, the monitor automatically initiates closure of a valve to prevent further releases. The monitor and valve are located in an arrangement that allows closure prior to exceeding release limits. The monitor setpoints are found by solving Equation 10-5 for release setpoint P.

Available information is provided in the DSAR and Section 10.4.

10.2.3 Alarm and Trip Setpoints

10.2.3.1 Setpoint Calculation

Alarm and trip setpoint of liquid effluent monitor at the principal release points is established to ensure that the concentration limits of the QAPP and 10 CFR 20 are not exceeded in the unrestricted area. The monitor setpoint is found by solving Equation 10-5 for a conservative mixture of radionuclides found in liquid effluents.

$$P \leq K \times (C_{mpc})(F^d/F^r) \qquad (10\text{-}5)$$

P Release Setpoint [μCi/mL]

The alarm setpoint for radioactivity to be released in liquid effluents.

C_{mpc} Maximum Permissible Concentration [μCi/mL]

F^d Dilution Flow Rate [gpm]

The flow rate of the radwaste dilution stream.

F^r Discharge Flow Rate [gpm]

The flow rate from the Lake Release Tank.

K Factor of conservatism
K = 0.5 for Lake Release Tank

10.2.3.2 Discharge Flow Rates

10.2.3.2.1 Lake Release Tank Discharge Flow Rate

Prior to each batch release, the water is recirculated, sampled, and analyzed.

(1) The results of the analysis of the waste sample determine the discharge rate of each batch as follows:

$$F^r_{max} = (C_{mpc})(F^d_{act}/C) \qquad (10\text{-}6)$$

F^r_{max} Maximum Permitted Discharge Flow Rate [gpm]

The maximum permitted flow rate from the Lake Release Tank.
[gpm]

F^d_{act} Actual Dilution Flow Rate [gpm]

The actual flow rate of the radwaste dilution stream.

(1) C Sample Radioactivity Concentration [μCi/mL]

The concentration of radioactivity in the Lake Release Tank, based on measurements of a sample drawn from the tank.

C_{mpc} has the same definition as in Equation 10-5.

10.2.3.2 Release Limits

Release limits are determined from 10 CFR 20.

10.2.3.3 Release Mixture

The release mixture used for setpoint determination is based on a composition of 100% of a nuclide with a conservative concentration discharge limit to the lake (e.g. Sr90)

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(1) A more conservative discharge rate may be calculated based on concentration limits for NPDES constituents (e.g., boron concentration). In either case, discharge procedures verify that all discharge limits to the lake are below applicable limits.

10.2.4 Allocation of Effluents from Common Release Points

Radioactive liquid effluents released from the Lake Release Tanks are comprised of contributions from both units. Under normal site conditions, it is difficult to apportion the radioactivity between the units. Consequently, allocation is based on the unit discharge canal used for dilution.

10.3 SOLIDIFICATION OF WASTE/PROCESS CONTROL PROGRAM

The process control program (PCP) contains the sampling, analysis, and formulation determination by which solidification of radioactive wastes from liquid systems is ensured.

10.4 Radioactive Effluent Radiation Monitoring Systems

10.4.1 Design Bases

The Radiation Monitoring System is designed to detect, indicate and alarm based on the radiation levels at selected locations in the facility. The system consists of the process radiation monitoring system, which includes the effluent monitors which are designed to provide early warning of increasing radiation activity due to a malfunction of plant equipment, and to monitor radioactive discharges to the environment to ensure concentrations do not exceed specified limits.

In the decommissioning state, radioactive material exists in the form of particulates. As such, the instrument channels in the radiation monitoring system monitor only particulates.

None of the radiation monitors are relied upon to initiate an accident mitigation function for the radioactive waste handling event described in Chapter 5.0 of the DSAR. In the decommissioning configuration, the source term continues to be reduced as the buildings are prepared for decontamination and demolition. Based on this, potential radiological events of concern are limited, but will focus on major structures with radioactive material and liquid releases to the lake. The process radiation monitoring system provides general radiological monitoring, as well as specific information on the concentration of radioactivity in the event of a radiological event or an abnormal liquid release to the lake. This enables personnel to evaluate and respond to an event accordingly.

10.4.2 System Description

The Process Radiation Monitoring System consists of several channels which primarily give early warning of an unexpected elevated release. Effluent Radiation Monitors are controlled in accordance with Chapter 12 to ensure an "as low as reasonably achievable" site boundary dose is obtained.
This is consistent with the design characteristics of the monitoring equipment, and acceptable operating considerations. The Process Radiation Monitoring System provides radiological monitoring of key areas and activities at the station. The primary areas of focus for the current radiation monitoring system are: Gaseous effluents through the vent stacks and the liquid effluent pathways. As decommissioning progresses, these monitors will no longer be needed and will be removed from service.

10.4.3 Containment Purge System Effluent Monitoring

Unit 1 Containment Purge Exhaust is monitored for radiation by the Unit 1 Auxiliary Building vent stack particulate Air Monitor.

Unit 2 Containment Purge Exhaust is monitored for radiation by the Unit 2 Auxiliary Building vent stack particulate Air Monitor.

10.4.4 Fuel Building Exhaust Air Monitor

The Fuel Building Ventilation exhaust is monitored via the Unit 2 Auxiliary Building ventilation stack effluent monitor.

10.4.5 Waste Disposal System Liquid Effluent Monitor

The liquid radiation monitor PR-04 remains an option for lake water discharges. It is a self-contained monitor and is used to measure radioactivity levels in liquid effluent being discharge to site effluent discharge point. Detector outputs are transmitted to the Radiation Monitoring alarms. High radioactivity-alarms are communicated so that actions can be implemented in accordance with approved procedures.

The accuracy of these monitors will be maintained to provide a highly reliable backup to the multiple sample analyses prior to discharge. A single monitor is provided on each discharge line and is considered adequate since the tank sample analyses are the primary method for determination of allowable discharge volume and flow. The release of liquid waste is performed under administrative control and these channels provide continuous monitoring during the release. An additional option exists to complete lake water radioactive effluent discharges to alternate controls as described in Chapter 12.

10.4.6 Calibration and Testing

Each channel employs a check source for channel testing. Check source testing is performed as defined in Chapter 12.

All radiation monitors are calibrated by exposing the detectors to an isotope(s) of known activity. By changing the distance or placing filters between detector and the standard isotope, the field intensity is varied thereby allowing for a multi-point calibration. The waste disposal system liquid effluent monitors are calibrated by the use of two (2) isotopic standards of different intermediate activity levels. The standards are monitored during calibration in a configuration similar to that of the monitored sample during normal operation. This method allows for an accurate isotopic calibration without contamination of the system.

The method of calibration of laboratory radiation counting instrumentation is in accordance with the vendor's manual. Complete documentation of calibration checks is maintained.

10.4.7 Effluent Monitoring and Sampling

The methods used in quantifying routine effluent releases to the environment consist of continuous Radiation Monitoring Systems and/or laboratory analyses. Laboratory analyses are conducted on either grab samples or composite samples.

All liquid and gaseous effluents sample results are recorded/saved in some form to provide a complete history of abnormal occurrences for evaluation; high radiation level alarms are sent to an on-shift individual when effluent releases are in progress. The high radiation alarm setpoints are based upon a value of activity which is sufficiently low to be in conformance with the concentration limit requirements.

Laboratory instrumentation used for radiation analysis of effluent grab samples are as described in the Chapter 12. The calibration of counting equipment will be maintained by the use of sources certified against the National Institute of Standards and Technology (NIST) certificates.

Effluent monitors will be calibrated at frequencies established in the Chapter 12. The multi-channel gamma analyzer will be performance checked when in use. Sources are used to verify against known energy lines and activity. Geometry factors will be checked in accordance with approved procedures. The liquid scintillation counter will be checked in accordance with approved procedures when in use.

Complete documentation of all calibration checks will be maintained.

Effluent discharge line waste monitors will be checked against laboratory analyzed or established known portable sources.

TABLE 10-1

DELETED

TABLE 10-2
HVAC EXHAUST FAN CAPACITIES

FAN	CC/SEC	CFM	CFH
#2 Aux. Bldg.			
0D Exh. Fan	3.16×10^7	6.70×10^4	4,020,000
0E Exh. Fan	3.16×10^7	6.70×10^4	4,020,000
0F Exh. Fan	3.16×10^7	6.70×10^4	4,020,000
#1 Purge Exh.			
1A Purge Fan	2.12×10^7	4.50×10^4	2,700,000
1B Purge Fan	2.12×10^7	4.50×10^4	2,700,000
U1 Mini-Purge Fan	1.42×10^6	3.00×10^3	180,000
H^2 Purge Fan 1A	1.70×10^5	3.60×10^2	21,600
H_2 Purge Fan 1B	1.75×10^5	3.40×10^2	22,200
#2 Purge Exh.			
2A Purge Fan	1.65×10^7	3.50×10^4	2,102,400
2B Purge Fan	1.72×10^7	3.65×10^4	2,188,800
U2 Mini-Purge Fan	1.42×10^6	3.00×10^3	180,000
H_2 Purge Fan 2A	1.82×10^5	3.85×10^2	23,100
H_2 Purge Fan 2B	1.75×10^5	3.71×10^2	22,260
Hot Lab Exh. 0A	1.50×10^6	3.18×10^3	191,000
Hot Lab Exh. 0B	1.18×10^6	2.51×10^3	150,600

CHAPTER 11

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

The parameters of the radiological environmental monitoring program for the environs around Zion Station are given in Table 11-1.

Figures 11-1a, 11-1b and 11-2 show sampling and monitoring locations.

Table 11-1

Radiological Environmental Monitoring Program

Exposure Pathway And/or Sample	Sampling or Monitoring Locations	Sampling or Collection Frequency	Type and Frequency of Analysis
1. Airborne	a. Indicators – Near Field Z-01 Onsite No. 1 South side, 0.2 mi S (0.3 km J) Z-02 Onsite No. 2 West side, 0.2 mi W (0.3 km N) Z-03 Onsite No. 3 North side, 0.20 mi NNE (0.3 km B) b. Control– Far Field Z-13 Pleasant Prairie Wisconsin 10 mi NW (15 km Q)	Continuous sampler operation with particulate filter collection weekly or more frequently if required by dust loading.	Particulate Sampler: Gross beta analysis following weekly filter change[2] and gamma isotopic analysis[3] quarterly on composite filters by location.

Table 11-1

Radiological Environmental Monitoring Program – Cont.

Exposure Pathway And/or Sample	Sampling or Monitoring Locations	Sampling or Collection Frequency	Type and Frequency of Analysis
2. Direct Radiation	a. Indicators – Inner Ring[5] Z-101-1 and 2 0.2 mi N (0.3 km A) Z-102-1 and 2 0.2 mi NNE (0.3 km B) Z-103-1 and 2 0.15 mi NE (0.25 km C) Z-104-1 and 2 0.13 mi ENE (0.2 km D) Z-105-1 and 2 0.1 mi E (0.15 km E) Z-106-1 and 2 0.1 mi ESE (0.15 km F) Z-107-1 and 2 0.1 mi SE (0.15 km G) Z-108-1 and 2 0.13 mi SSE (0.2 km H) Z-109-1 and 2 0.2 mi SSE (0.3 km H) Z-112-1 and 2 0.7 mi WSW (1.1 km M) Z-113-1 and 2 0.6 mi W (1.0 km N) Z-114-1 and 2 0.6 mi WNW (1.0 km P) Z-115-1 and 2 0.4 mi NW (0.6 km Q) Z-121-1 and 2 0.2 mi NNW (0.3 km R) Z-124-1 and 2 0.5 mi SW (0.8 km L) Z-125-1 and 2 0.4 mi SSW (0.6 km K) Z-129-1 and 2 0.2 mi NW (0.3 km P) Z-130-1 and 2 0.2 mi WNW (0.3 km N) Z-131-1 and 2 0.2 mi WSW (0.3 km L)	Quarterly	Gamma dose on each TLD quarterly
	b. Other One at each airborne location given in 1.a. Z01-1 and 2 0.2 mi S (0.3 km J) Z02-1 and 2 0.2 mi E (0.3 km N) Z03-1 and 2 0.2 mi NNE (.3 km B) One control at control airborne location Z13-1 thru 6 10 mi NW (15 km Q)	Quarterly	Gamma dose on each TLD quarterly

Table 11-1
Radiological Environmental Monitoring Program – Cont.

Exposure Pathway And/or Sample	Sampling or Monitoring Locations	Sampling or Collection Frequency	Type and Frequency of Analysis
2. Direct Radiation – Cont.	d. Indicators – Outer Ring Z-209-1 and 2 5.1 mi S (8.2 km K) Z-211-1 and 2 4.7 mi SW (7.6 km L) Z-212-1 and 2 5.1 mi WSW (8.2 km M) Z-213-1 and 2 5.1 mi W (8.2 km N) Z-214-1 and 2 4.6 mi WNW (7.4 km P) Z-215-1 and 2 4.0 mi NW (6.4 km Q) Z-216-1 and 2 3.0 mi NNW (4.8 km R)	Quarterly	Gamma dose on each TLD quarterly Gamma dose on each TLD quarterly

Table 11-1

Radiological Environmental Monitoring Program – Cont.

Exposure Pathway And/or Sample	Sampling or Monitoring Locations	Sampling or Collection Frequency	Type and Frequency of Analysis
3. Waterborne			
	a. Drinking Water Indicator[6]		
	Z-15 Lake County Water Works, 1.4 mi NNW (2.2 km R) Z-16 Waukegan Water Works, 6.1 mi S (9.8 km J)	Weekly grab samples.	Gross beta and gamma isotopic[3] analysis on monthly composite; tritium analysis on quarterly composite.
	b. Control[6]		
	Z-14 Kenosha Water Works, 10.0 mi N (1.60 km A) Z-18 Lake Forest Water Works, 12.9 mi S (20.8 km J)	Weekly grab samples.	Gross beta and gamma isotopic[3] analysis on monthly composite; tritium analysis on quarterly composite.
	c. Sediments		
	Z-25 Lake Michigan, Illinois Beach State Park, 2.0 mi S (3.2 km J)	Semiannually	Gamma isotopic[3] analysis semiannually.

Table 11-1

Radiological Environmental Monitoring Program – Cont.

Exposure Pathway And/or Sample	Sampling or Monitoring Locations	Sampling or Collection Frequency	Type and Frequency of Analysis
4. Ingestion	a. Fish Indicator Z-26, Lake Michigan in vicinity of station Discharge b. Fish Control Z-27, Lake Michigan, 10.0 mi N (16.0 km A)	Semiannually	Gamma isotopic[3] analysis on edible portions.
5. Vegetation	a. Vegetation Indicator Z-QUAD 3, Pleasant Prairie market, 4 mi NNW (6.4 km R) Z-QUAD 4, Sheridan Road Zion Farmers market, 1.1 mi W (1.7 km N) b. Vegetation Control Z-Control, Kenosha Farmers Market, 11 mi NNW (18 km R)	Annual (during growing season)	Gamma isotopic[3] analysis on edible portions.

Table 11-1
Radiological Environmental Monitoring Program – Cont.

1. Deleted – No longer applicable.

2. Airborne particulate sample filters shall be analyzed for gross beta radioactivity 24 hours or more after sampling to allow for radon and thoron daughter decay. If gross beta activity in any individual air particulate sample is greater than 10 times the 1999 mean of control samples, then, a gamma isotopic analysis shall be performed on that elevated individual sample.

3. Gamma isotopic analysis means the identification and quantification of gamma-emitting radionuclides that may be attributable to the effluents from the station.

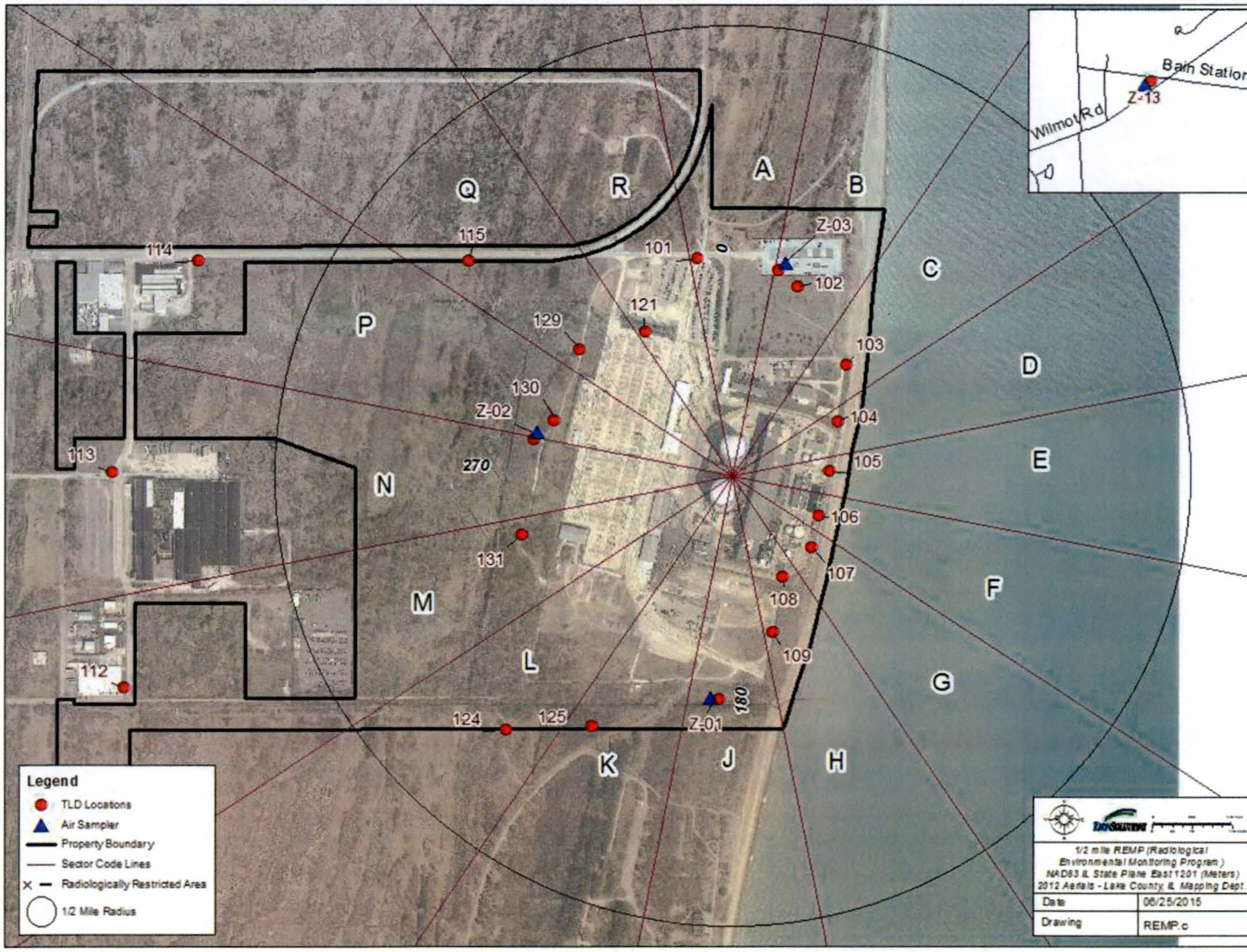
4. Deleted – No longer applicable.

5. Limited TLD placements due to Lake Michigan and location of air samplers.

6. The closest drinking water locations (North/South) chosen for drinking water indicators; two other locations beyond 6.2 miles (North/South) chosen for control samples.

Figure 11-1a

Airborne and Direct Radiation Sample Locations – Inner Ring



- ● TLD Monitoring Location
- ▲ Air Sampling Location

Figure 11-1b

Direct Radiation Sample Locations – Outer Ring

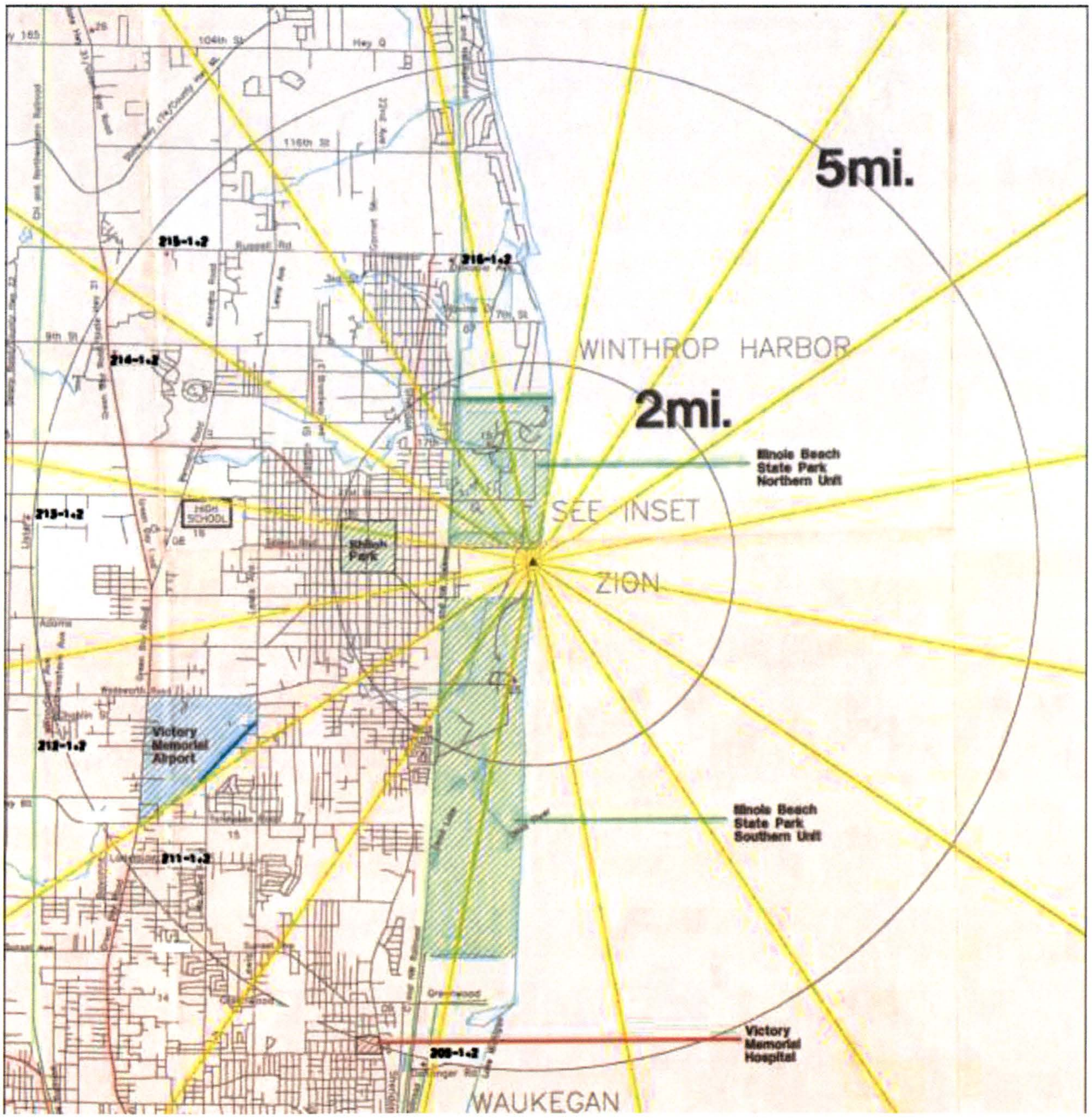
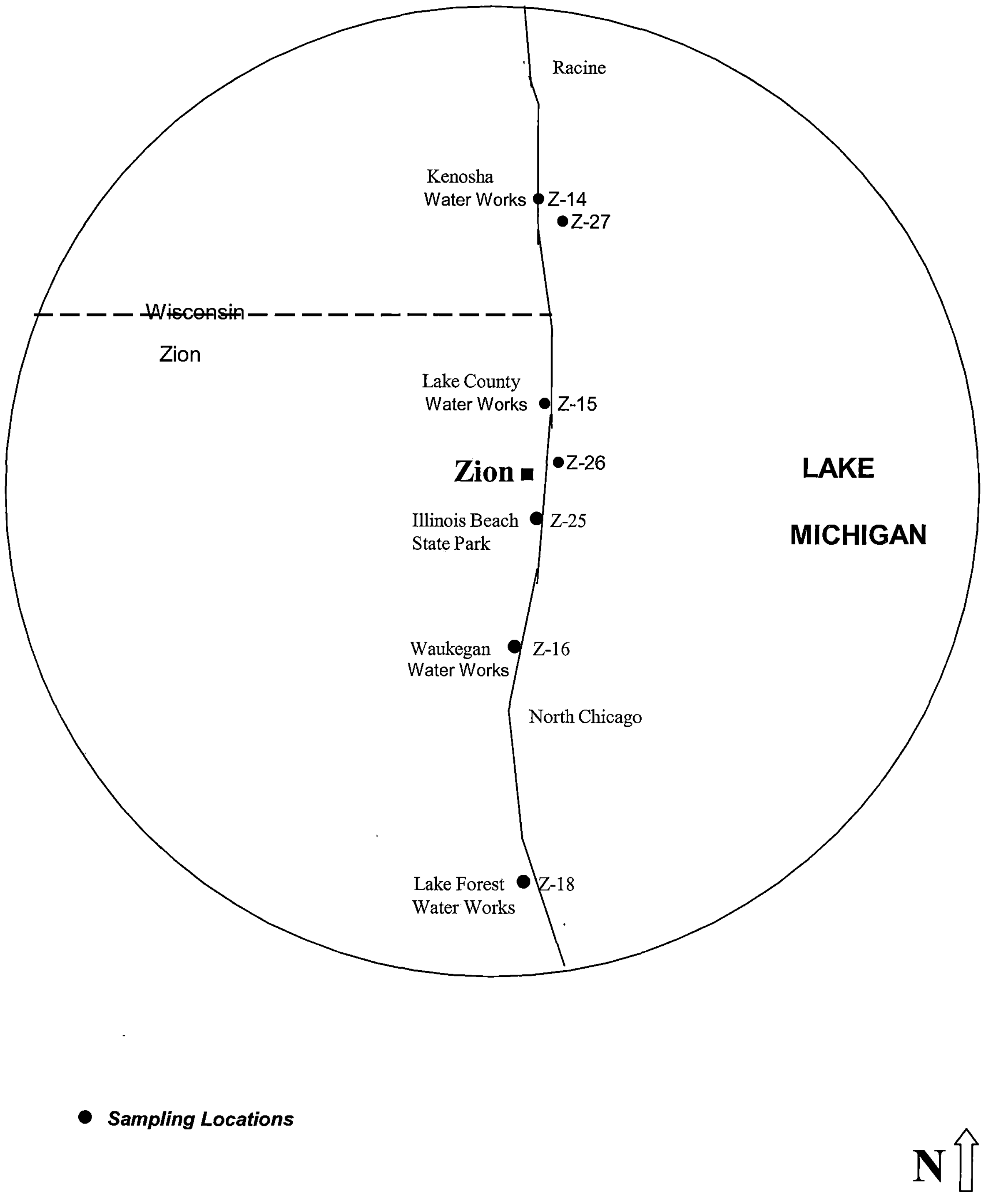


Figure 11-2

Location of Waterborne and Ingestion Sampling Sites



CHAPTER 12

Radiological Effluent Technical Standards (RETS)

SPECIAL NOTE

The requirements of Quality Assurance Project Plan (QAPP) Appendix B shall take precedence over this chapter, should any differences occur.

12.1 DEFINITIONS

12.1.1 A BATCH RELEASE is the discharge of liquid wastes of a discrete volume. Prior to sampling for analyses, each batch shall be isolated and then thoroughly mixed to assure representative sampling.

12.1.2 A CHANNEL CALIBRATION shall be the adjustment, as necessary, of the channel such that it responds with the necessary range and accuracy to known values of input. The CHANNEL CALIBRATION shall encompass the entire channel including the sensors (where possible), alarm interlock and/or trip functions (if applicable) and shall include the CHANNEL FUNCTIONAL TEST. The CHANNEL CALIBRATION may be performed by any series of sequential, overlapping, or total channel steps such that the entire channel is calibrated.

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

12.1.4 A CHANNEL FUNCTIONAL CHECK shall be:

a. Instruments-The injection of a simulated signal(s) into the channel as close to the primary sensor(s) as practicable to verify OPERABILITY, including all channel outputs, as appropriate.

b. Logics-The application of input signals, or the operation of relays or switch contacts, in all the combinations required to produce the required decision outputs including the operation of all ACTUATION DEVICES. Where practicable, the test shall include the operation of the ACTUATED EQUIPMENT as well (i.e. pumps will be started, valves operated, etc.).

12.1.5 A COMPOSITE SAMPLE is one in which the quantity of liquid sample is proportional to the quantity of liquid waste discharged and in which the method of sampling employed results in a specimen which is representative of the liquids released.

12.1.6 A CONTINUOUS RELEASE is the discharge of liquid or gaseous wastes of a nondiscrete volume (e.g. from a volume or system that has an input flow during the release).

12.1.7 CONTINUOUS SAMPLING is uninterrupted sampling with the exception of sampling interruptions of short duration for routine activities (e.g. filter replacements).

12.1.8 MEMBER OF THE PUBLIC means any individual except when that individual is receiving an occupational dose.

12.1.9 OCCUPATIONAL DOSE means the dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation and/or radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the public.

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

12.1.11 OPERATING is defined as performing the intended function in the intended manner.

12.1.12 The PROCESS CONTROL PROGRAM (PCP) shall contain the current formulas, sampling, analyses, test, and determinations to be made to ensure that processing and packaging of solid radioactive wastes based on demonstrated processing of actual or simulated wet solid wastes will be accomplished in such a way as to assure compliance with 10CFR Parts 20, 61, and 71, State regulations, burial ground requirements, and other requirements governing the disposal of solid radioactive waste.

12.1.13 PURGE OR PURGING is the controlled process of discharging air from a confinement to maintain temperature, pressure, humidity, concentration or other operating condition, in such a manner, that replacement air or gas is required to purify the confinement.

12.1.14 The SITE BOUNDARY shall be that line beyond which the land is not owned, leased or otherwise controlled by the licensee.

12.1.15 SOLIDIFICATION shall be the conversion of radioactive liquid, resin and sludge wastes from liquid systems into a form that meets shipping and burial site requirements.

12.1.16 A SOURCE CHECK shall be the qualitative assessment of channel response when the channel sensor is exposed to a radioactive source.

12.1.17 SURVEILLANCE shall be those parts of the sections which prescribe remedial measures required under designated conditions, activities required to demonstrate instrument operability, and activities performed to ensure applicable offsite dose limits are not exceeded.

12.1.18 The SURVEILLANCE FREQUENCY NOTATION specified for the performance of Surveillance Requirements shall correspond to the intervals defined in Table 12.1-1.

12.1.19 UNRESTRICTED AREA means an area, access to which is neither limited nor controlled by the licensee.

12.1.20 UNVENTILATED BUILDING RELEASE means A building that is not negative pressure controlled with presence of radioactive that could potentially become airborne that has a pathway to be released to the environment.

12.1.21 GASEOUS EFFLUENT TREATMENT SYSTEM shall be any system designed and installed to reduce radioactive material in particulate form in effluents by passing ventilation through HEPA filters for the purpose of removing particulates from the gaseous exhaust stream prior to the release to the environment

12.1.22 VENTING is the controlled process of discharging air or gas from a confinement to maintain temperature, pressure, humidity, concentration or other operating condition, in such a manner that replacement air is not provided or required during venting. Vent, used in system names, does not imply a venting process.

TABLE 12.1-1

SURVEILLANCE FREQUENCY NOTATIONS

NOTATION		FREQUENCY *
S	(Shiftly)	At least once per 12 hours
D	(Daily)	At least once per 24 hours
W	(Weekly)	At least once per 7 days
M	(Monthly)	At least once per 31 days
Q	(Quarterly)	At least once per 92 days
SA	(Semiannually)	At least once per 184 days
A	(Annually)	At least once per 366 days
R		At least once per 18 months
P	(Prior)	Complete prior to start of release
N/A		Not Applicable

* Each Surveillance Requirement shall be performed within the specified time interval with a maximum allowable extension not to exceed 25% of the surveillance interval.

12.2 INSTRUMENTATION

12.2.1 Radioactive Liquid Plant Monitoring Instrumentation

Operability Requirements

12.2.1.A The radioactive liquid plant monitoring instrumentation channels shown in Table 12.2-1 shall be OPERABLE AND, the radioactive liquid effluent monitoring instrumentation channels shall have their alarm/trip setpoints set to ensure that the limits of Section 12.3.1.A are met.

Applicability: As indicated in Table 12.2-3.

Action

1. With a radioactive liquid effluent monitoring instrument channel trip setpoint less conservative than the value necessary to prevent violating the limits of Section 12.3.1.A, immediately suspend the release of radioactive liquid effluents monitored by the affected channel or declare the channel inoperable.

2. With one or more radioactive liquid plant monitoring instrumentation channels inoperable, initiate the SURVEILLANCE requirement delineated in Table 12.2-1.

3. Restore the inoperable effluent monitor to OPERABLE status within 30 days, if unsuccessful, explain in the next Annual Radioactive Effluent Release Report the reasons as detailed in Section 12.7.2 and perform a review to determine course of action to restore to OPERABLE status.

Surveillance Requirements

12.2.1.B.1 The liquid effluent monitor setpoints shall be determined in accordance with procedures as described in the ODCM.

12.2.1.B.2 Each radioactive liquid plant monitoring instrumentation channel shall be demonstrated OPERABLE by performance of a CHANNEL CHECK, SOURCE CHECK, CHANNEL CALIBRATION and CHANNEL FUNCTIONAL TEST at the frequencies shown in Table 12.2-2.

Bases

12.2.1.C The radioactive liquid plant monitoring instrumentation is provided to indicate abnormal radiological conditions, AND,

The radioactive liquid effluent instrumentation is provided to monitor and control, as applicable, the release of radioactive materials in liquid effluents. The alarm/trip setpoints for these instruments shall be calculated in accordance with the procedures in the ODCM to ensure that the alarm/trip will occur prior to exceeding the limits of RETS. The OPERABILITY and use of this instrumentation is consistent with the requirements of Appendix A to 10CFR Part 50.

TABLE 12.2-1

RADIOACTIVE LIQUID PLANT MONITORING INSTRUMENTATION

INSTRUMENT	MINIMUM CHANNELS OPERABLE	SURVEILLANCE #	APPLICABLE CONDITION
1. Liquid Effluent Monitors Providing Automatic Termination of Release			
A. Lake Release Tanks			
1. 0R-PR04	1	1*	Liquid Release through this Pathway
2. Effluent Continuous Composite Sampler			
A. WWTF	1	4	During Release via this pathway
3. Effluent Flow Rate Monitor			
A. Lake Release Tank #1			
1. 0FI-WD005	1	3	Liquid Release through this Pathway
2. 0FI-WD005A	1	3	Liquid Release through this Pathway
B. Lake Release Tank #2			
1. 0FI-WD006	1	3	Liquid Release through this Pathway
2. 0FI-WD006A	1	3	Liquid Release through this Pathway
C. Common discharge pathway			
1. 0FI-WD007	1	3	Liquid Release from Either LRT #1 or #2
4. Plant System Monitors			
A. Dilution Flow Pressure Indication			
1. 0PI-SW01A	1**	3	Liquid Release from Either LRT #1 or #2
2. 0PI-SW01	1**	3	Liquid Release from Either LRT #1 or #2

* - The Surveillance 1 may be used as an equivalent alternative to the use of 0R-PR04.
**- Minimum Channels Operable for Dilution Flow Pressure Indication is one channel from 0PI-SW01 OR one channel from 0PI-SW01A during LRT releases.

TABLE 12.2-1

RADIOACTIVE LIQUID PLANT MONITORING INSTRUMENTATION
(Cont'd)

SURVEILLANCE 1

If the monitor is inoperable, effluent releases from the tank may continue provided that prior to initiating the release:

1. At least two independent samples of the tank's contents are analyzed, in accordance with Section 12.3.1.B.1, and

2. At least two technically qualified members of the facility staff independently verify the release-rate calculations and discharge flow path valving; and

3. Approval by the Plant Manager.

4. Restore the inoperable effluent monitor to OPERABLE status within 30 days, if unsuccessful, explain in the next Annual Radioactive Effluent Release Report the reasons as detailed in Section 12.7.2 and perform a review to determine course of action to restore to OPERABLE status.

Otherwise, suspend release of radioactive effluents via this pathway.

SURVEILLANCE 2

Deleted .

SURVEILLANCE 3

For the applicable flowpath at least one of the listed flowmeters within the flowpath must be operable to monitor flow provided the monitored flowrate falls within the calibration range of the flowmeter. With the no flow channels OPERABLE within the flowpath, effluent releases via this pathway may continue provided the flow rate is estimated at least once per 4 hours during actual releases. Pump curves may be used to estimate flow.

SURVEILLANCE 4

If the composite sampler is inoperable, effluent releases via this pathway may continue, provided that at least once per day grab samples are taken. The samples shall be analyzed in accordance with Section 12.3.1.B.3.

TABLE 12.2-2

RADIOACTIVE LIQUID PLANT MONITORING INSTRUMENTATION SURVEILLANCE

INSTRUMENT	CHANNEL CHECK	SOURCE CHECK	CHANNEL CALIBRATION (1)	CHANNEL FUNCTIONAL TEST (2)
1. Liquid Effluent Monitors Providing Automatic Termination Of Release				
A. Lake Release Tanks				
1. 0R-PR04	P	P	R	Q
2. Effluent Continuous Composite Sampler				
A. WWTF	N/A	N/A	N/A	N/A
3. Effluent Flow Rate Monitor				
A. Lake Release Tank #1				
1. 0FI-WD005	D(3)	N/A	R	N/A
2. 0FI-WD005A	D(3)	N/A	R	N/A
B. Lake Release Tank #2				
1. 0FI-WD006	D(3)	N/A	R	N/A
2. 0FI-WD006A	D(3)	N/A	R	N/A
C. Common Discharge pathway				
1. 0FI-WD007	D(3)	N/A	R	N/A
4. Plant System Monitors				
A. Dilution Flow Pressure Indication				
1. 0PI-SW01A	D(4)	N/A	R	N/A
2. 0PI-SW01	D(4)	N/A	R	N/A

(1) CHANNEL CALIBRATION shall include performance of a CHANNEL FUNCTIONAL TEST.
(2) The CHANNEL FUNCTIONAL TEST shall also demonstrate that any automatic isolation of this pathway occurs and that control room alarm annunciation occurs if any of the following conditions exist. (if the capability is installed):
a) Instrument indicates levels above the alarm setpoints.
b) Circuit failure.
c) Instrument indicates a downscale failure.
d) Instrument controls not set in operate mode.
(3) CHANNEL CHECK shall consist of verifying indications of flow during periods of release. CHANNEL CHECK shall be made at least once daily on any day on which continuous, periodic, or BATCH RELEASES are made.
(4) Dilution Flow Pressure Gauge 0PI-SW01A OR 0PI-SW01 may be used. The pressure gauge being used shall be verified operating at least daily during Lake Release Tank Batch discharge And pump curves used to estimate flow once per day based on the readings.

12.2.2 Radioactive Plant Monitoring Instrumentation

Operability Requirements

12.2.2.A The radioactive plant monitoring instrumentation channels shown in Table 12.2-3 shall be OPERABLE, AND, the radioactive gaseous effluent monitoring instrumentation shall have their alarm/trip setpoints set in accordance with the method prescribed in the ODCM to ensure that the limits of Section 12.4.1.A are met.

Applicability: As indicated in Table 12.2-3.

Action

1. With a radioactive gaseous effluent monitoring instrumentation channel alarm/trip setpoint less conservative than required by the above Section, immediately suspend the release of radioactive gaseous effluents monitored by the affected channel or declare the channel inoperable.

2. With one or more radioactive plant monitoring instrumentation channels inoperable, initiate the SURVEILLANCE requirement as delineated in Table 12.2-3.

3. Restore the inoperable effluent monitor to OPERABLE status within 30 days, if unsuccessful, explain in the next Annual Radioactive Effluent Release Report the reasons as detailed in Section 12.7.2 and perform a review to determine course of action to restore to OPERABLE status.

Surveillance Requirements

12.2.2.B.1 The effluent monitor setpoints shall be determined in accordance with procedures as described in the ODCM.

12.2.2.B.2 Each radioactive plant monitoring instrumentation channel shall be demonstrated OPERABLE, when in its APPLICABLE CONDITION, by performance of a CHANNEL CHECK, SOURCE CHECK, CHANNEL CALIBRATION and CHANNEL FUNCTIONAL TEST at the frequencies shown in Table 12.2-4.

Bases

12.2.2.C The radioactive plant monitoring instrumentation is provided to indicate abnormal radiological conditions.

The radioactive gaseous effluent instrumentation is provided to monitor and control, as applicable, the release of radioactive materials in gaseous effluents during actual or potential releases. The alarm/trip setpoints for these instruments shall be calculated in accordance with the ODCM to ensure that the alarm/trip will occur prior to exceeding the limits of 10CFR Part 20.

TABLE 12.2-3

RADIOACTIVE PLANT MONITORING INSTRUMENTATION

INSTRUMENT	MINIMUM CHANNELS OPERABLE	SURVEILLANCE	APPLICABLE CONDITION
1. Effluent Containment Purge or Vent			
A. Particulate Monitor			
1. 1R-PR49	1	11	Gaseous Release through this Pathway
2. 2R-PR49	1	11	Gaseous Release through this Pathway
B. Flow Rate Monitor			
1. 1LP-084	1	8	Gaseous Release through this Pathway
2. 2LP-084	1	8	Gaseous Release through this Pathway
2. Aux Building Effluent Monitoring			
A. DELETED			
B. Particulate Monitor			
1. 2R-PR49	1	11	Gaseous Release through this Pathway
C. Flow Rate Monitor			
1. 2LP-084	1	8	Gaseous Release through this Pathway

TABLE 12.2-3

RADIOACTIVE PLANT MONITORING INSTRUMENTATION - (Cont'd)

TABLE NOTATIONS

SURVEILLANCE 6 DELETED

SURVEILLANCE 7 DELETED

SURVEILLANCE 8 Effluent releases via this pathway may continue provided:

1. The effluent flow rate is estimated at least once per day while a release is in progress.
2. Continuous sampling is maintained with either inline sample pump or air sampling at locations that input into the gaseous effluent system.
3. A Channel Check is performed daily
4. Restore the inoperable effluent monitor to OPERABLE status within 30 days, if unsuccessful, explain in the next Annual Radioactive Effluent Release Report the reasons as detailed in Section 12.7.2 and perform a review to determine course of action to restore to OPERABLE status.

SURVEILLANCE 9 DELETED

SURVEILLANCE 10 DELETED

SURVEILLANCE 11 With the number of OPERABLE channels less than the minimum number required:

1. Effluent releases via this pathway may continue provided samples are continuously collected as required in Table 12.4-1.
2. Restore the channel to OPERABLE status within 30 days or conduct a review to determine a plan of action to restore the channel to OPERABLE status.

Compensatory sampling does not return the monitor to an OPERABLE status.

SURVEILLANCE 12 DELETED.

SURVEILLANCE 13 DELETED

SURVEILLANCE 14 DELETED

TABLE 12.2-4

RADIOACTIVE PLANT MONITORING INSTRUMENTATION SURVEILLANCE

	CHANNEL CHECK	CHANNEL SOURCE CHECK	CHANNEL CALIBRATION (1)	FUNCTIONAL TEST (2)
1. Effluent Containment Purge or Vent				
A. Particulate Monitor				
1. 1R-PR49	D	M	R	Q
2. 2R-PR49	D	M	R	Q
B. Flow Rate Monitor				
1. 1LP-084	D	N/A	R	Q
2. 2LP-084	D	N/A	R	Q
2. Aux Building Effluent Monitoring				
A. DELETED				
B. Particulate Monitor				
1. 2R-PR49	D	M	R	Q
C. Flow Rate Monitor				
1. 2LP-084	D	N/A	R	Q

Table 12.2-4

RADIOACTIVE PLANT MONITORING INSTRUMENTATION SURVEILLANCE
(Cont'd)

TABLE NOTATIONS

(1) CHANNEL CALIBRATION shall include performance of a CHANNEL FUNCTIONAL TEST.

(2) The CHANNEL FUNCTIONAL TEST shall also demonstrate that any automatic isolation occurs; and that alarms occur if any of the following conditions exist (if the capability is installed):

a) Instrument indicates measured levels above the alarm setpoint.
b) Circuit failure.
c) Instrument indicates a downscale failure.
d) Instrument controls not set in "operate" mode.

12.3 LIQUID EFFLUENTS

12.3.1 Concentration

Operability Requirements

12.3.1.A.1 The concentration of radioactive material released from the site to UNRESTRICTED AREAS (see Appendix F, Figure F-1) shall be limited to 10 times the concentrations specified in Appendix B, Table 2, Column 2 to 10CFR20.1001-20.2402

12.3.1.A.2 During the release of radioactive liquid wastes, the combination of dilution water flow and waste water discharge flow shall be established to ensure the discharge concentration limits of 12.3.1.A.1 are not exceeded.

Applicability: At all times.

Action

1. With the concentration of radioactive materials released from the site to UNRESTRICTED AREAS exceeding the limits specified in Section 12.3.1.A.1 immediately decrease the release rate of radioactive materials and/or increase the dilution flow rate to restore the concentration to within the above limits.

Surveillance Requirements

12.3.1.B.1 The radioactivity content of each batch of radioactive liquid waste shall be determined prior to release by sampling and analysis in accordance with Table 12.3-2. The results of pre-release analyses shall be used with the calculational methods in the ODCM to assure that the concentration at the point of release is maintained within the limits of Section 12.3.1.A.1.

12.3.1.B.2 Post-release analyses of samples composited from BATCH RELEASES shall be performed in accordance with Table 12.3-2. The results of the previous post-release analyses shall be used with the calculational methods in the ODCM to assure that the concentrations at the point of release were maintained within the limits of Section 12.3.1.A.1.

12.3.1.B.3 The radioactivity concentration of liquids discharged from continuous release points shall be determined by collection and analysis of samples in accordance with Table 12.3-2. The results of the analysis shall be used with the calculational methods in the ODCM to assure that the concentrations at the point of release were maintained within the limits of Section 12.3.1.A.1.

12.3.1.B.4 Appropriate discharge and dilutions flows for each batch radioactive liquid release shall be determined with the calculational methods in the ODCM to assure that the concentration at the point of release is maintained within the limits of Section 12.3.1.A.1.

Bases

12.3.1.C This Section is provided to ensure that the concentration of radioactive materials released in liquid waste effluents from the site to UNRESTRICTED AREAS will be less than ten (10) times the concentration levels specified in Appendix B, Table 2, Column 2 to 10CFR 20.1001-20.2402. This limitation provides additional assurance that the levels of radioactive materials in bodies of water outside the site will result in exposures within (1) the Section II.A design objectives of Appendix I, 10 CFR 50, to a MEMBER OF THE PUBLIC, and (2) the limits of 10CFR20.1301.

TABLE 12.3-1

DELETED

TABLE 12.3-2

RADIOACTIVE LIQUID EFFLUENT SAMPLING AND ANALYSIS SURVEILLANCE

LIQUID RELEASE TYPE	SAMPLING FREQUENCY	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LOWER LIMIT OF DETECTION (LLD) (μCi/ml) (a,e)
A. Lake Release	Prior to Each Release (c)	Prior to Each Release	Principal Gamma Emitters (e)	5E-7
	P Each Batch (c)	M Composite (b)	Tritium	1E-5
			Gross Alpha	1E-7
	P Each Batch (c)	Q Composite (b)	Sr-90	5E-8
			Fe-55, Ni-63	1E-6
B. WWTF (f)	Continuous During Release (d)	W when discharging	Principal Gamma Emitters(e)	5E-7
	Continuous During Release(d)	M Composite (b)	Tritium	1E-5
			Gross Alpha	1E-7
	Continuous During Release (d)	Q Composite (b)	Sr-90	5E-8
			Fe-55, Ni-63	1E-6
C. Waste Neutralizing Tank	Prior to each Release	Prior to each Release	Principal Gamma Emitters (e)	5E-7
	P Each Batch (c)	M Composite (b)	Tritium	1E-5
			Gross Alpha	1E-7
D. Groundwater	Prior to each Release	Prior to each Release	Principal Gamma Emitters (e)	5E-7
	P Each Batch (c)	M Composite (b)	Tritium	1E-5
E. Groundwater (f)	Continuous During Release (d)	W	Principal Gamma Emitters(e)	5E-7
	Continuous (d)	M Composite (b)	Tritium	1E-5

TABLE 12.3-2

RADIOACTIVE LIQUID EFFLUENT SAMPLING AND ANALYSIS SURVEILLANCE
(Cont'd)

TABLE NOTATIONS

a. The LLD is the smallest concentration of radioactive material in a sample that will be detected with 95% probability with 5% probability of falsely concluding that a blank observation represents a "real" signal.

For a particular measurement system (which may include radiochemical separation):

$$LLD = \frac{4.66\, s_b}{A \cdot E \cdot V \cdot 2.22 \cdot Y \cdot \exp(-\lambda \Delta t)}$$

Where:

LLD is the lower limit of detection as defined above in picocuries (pCi) per unit mass or volume,

s_b is the square root of the background counting rate or of the counting rate of a blank sample as appropriate (as counts per minute),

A is the number of gamma rays emitted per disintegration for gamma ray radionuclide analysis (A = 1.0) for gross alpha, strontium, and tritium measurement.

E is the counting efficiency (as counts per gamma),

V is the sample size (in units of mass or volume),

2.22 is the number of disintegrations per minute per picocurie,

Y is the fractional radiochemical yield when applicable (otherwise Y = 1.0)

λ is the radioactive decay constant for the particular radionuclide, and

Δt is the elapsed time between midpoint of sample collection and time of counting (for plant effluents, not environmental sample).

The value of s_b used in the calculation of the LLD for a detection system shall be based on the actual observed variance of the background counting rate or of the counting rate of the blank samples (as appropriate) rather than on an unverified theoretically predicted variance. In calculating the LLD for a radionuclide determined by gamma ray spectrometry, the background shall include the typical contributions of other radionuclides normally present in the samples. Typical values of E, V, Y, and Δt shall be used in the calculation. The background count rate is calculated from the background counts that are determined to be within $\pm$ one FWHM (Full Width at Half Maximum) energy band about the energy of the gamma ray peak used for the quantitative analysis for that radionuclide.

TABLE 12.3-2

RADIOACTIVE LIQUID EFFLUENT SAMPLING AND ANALYSIS SURVEILLANCE
(Cont'd)

TABLE NOTATIONS

For certain mixtures of gamma emitters, it may not be possible to measure radionuclides in concentrations near their sensitivity limits when other nuclides are present in the sample in much greater concentrations. Under these circumstances, it will be more appropriate to calculate the concentrations of such radionuclides using observed ratios with those radionuclides which are measurable.

b. A COMPOSITE SAMPLE is one in which the quantity of liquid sampled is proportional to the quantity of liquid waste discharged and in which the method of sampling employed results in a specimen which is representative of the liquids released.

   1) To be representative of the quantities and concentrations of radioactive materials in liquid effluents, all samples taken for the composite shall be thoroughly mixed in order for the composite sample to be representative of the effluent release.

   2) The weekly and monthly Proportional Composite samples are not required provided that (1) the analysis required for each of these composite samples has been run on each batch discharged, and (2) a monthly record of radionuclides discharged (isotope and quantity) is maintained.

c. A BATCH RELEASE is the discharge of liquid wastes of a discrete volume. Prior to sampling for analyses, each batch shall be isolated, and then thoroughly mixed to assure representative sampling.

d. A CONTINUOUS RELEASE is the discharge of liquid wastes of a nondiscrete volume; e.g., from a volume of system that has an input flow during the continuous release.

e. The principal gamma emitters for which the LLD specification applies exclusively are the following radionuclides: Nb-94, Co-60, Cs-137 and Sb-125. This list does not mean that only these nuclides are to be detected and reported. Other peaks which are measurable and identifiable, together with the above nuclides, shall also be identified and reported. Nuclides which are below the LLD for the analyses shall be reported as "less than" the nuclide's LLD, and shall not be reported as being present at the LLD level for that nuclide. The "less than" values shall not be used in the required dose calculations.

f. If the composite sampler is inoperable, grab samples shall be taken from the discharge stream once per day during system operation.

12.3.2 Dose

Operability Requirements

12.3.2.A The dose or dose commitment to a MEMBER OF THE PUBLIC above background from radioactive materials in liquid effluents released from each unit to UNRESTRICTED AREAS (see Appendix F, Figure F-1) shall be limited:

1. During any calendar quarter to less than or equal to 1.5 mrem to the total body and to less than or equal to 5 mrem to any organ, and

2. During any calendar year to less than or equal to 3 mrem to the total body and to less than or equal to 10 mrem to any organ.

Applicability: At all times.

Action

1. With the calculated dose from the release of radioactive materials in liquid effluents exceeding twice the limits specified in Section 12.3.2.A, limit the subsequent releases such that the dose or dose commitment to a MEMBER OF THE PUBLIC from all uranium fuel cycle sources is limited to less than or equal 25 mrem to the total body or any organ (except thyroid, which is limited to less than or equal to 75 mrem) over 12 consecutive months. Demonstrate that radiation exposures to all MEMBERS OF THE PUBLIC from all uranium fuel cycle sources (including all effluent pathways and direct radiation) are less than the 40CFR Part 190 and 40CFR Part 141 Standard, otherwise obtain a variance from the Commission to permit releases which exceed the 40CFR Part 141 or 190 Standard. The radiation exposure analysis shall use methods prescribed in the ODCM.

Surveillance Requirements

12.3.2.B Cumulative dose contributions from liquid effluents for the current calendar quarter and the current calendar year shall be determined in accordance with the methodologies and parameters of the ODCM at least once per 31 days.

Bases

12.3.2.C This Section is provided to implement the requirements of Sections II.A, III.A and IV.A of Appendix I, 10CFR Part 50. The limiting Condition of Operation implements the guides set forth in Section II.A of Appendix I. The ACTION statements provide the required OPERATING flexibility and at the same time implement the guides set forth in Section IV.A of Appendix I to assure that the releases of radioactive material in liquid effluents will be kept "as low as is reasonably achievable." Also, for fresh water sites with drinking water supplies, which can be potentially affected by plant operations, there is reasonable assurance that the operation of the facility will not result in radionuclide concentrations in the finished drinking water that are excess of the requirements of 40CFR 141. The dose calculations in the ODCM implement the requirements in Section III.A of Appendix I that conformance with the guides of Appendix I be shown by calculational procedures based on models and data, such that the actual exposure of an individual through appropriate pathways is unlikely to be substantially underestimated. The equations specified in the ODCM for calculating the dose due to the actual release rate of radioactive materials in liquid effluents are consistent with the methodology provided in Regulatory Guide 1.109; Calculation of Annual Doses to Man from Routine Releases of Radioactive Effluents for the Purpose of Evaluating Compliance with 10CFR Part 50, Appendix I, Revision 1, October 1977 and Regulatory Guides 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," April 1977.

This Section applies to the release of liquid effluents from each unit at the site. For shared radwaste treatment systems, the liquid effluents from the shared systems are proportioned among the units sharing the system.

12.3.3 Liquid Radwaste Treatment System

Operability Requirements

12.3.3.A The Liquid Radwaste Treatment System shall be OPERABLE* and appropriate portions of the system shall be used to reduce the radioactive materials in liquid effluents prior to discharge when the projected doses due to liquid effluent, from each unit, to UNRESTRICTED AREAS (see Appendix F, Figure F-1) would exceed 0.06 mrem to the total body or 0.20 to any organ in a 31-day period.

* The liquid Radwaste Treatment System shall be considered OPERABLE, if liquid waste can be held up and/or discharged within applicable limits.

Applicability: At all times.

Action: With the Liquid Radwaste Treatment System inoperable for more than 30 days or with radioactive liquid waste being discharged without treatment and in excess of the above limits, return the system to OPERABLE status and place the appropriate portions of the system in use.

Surveillance Requirements

12.3.3.B Doses due to liquid releases from the site to UNRESTRICTED AREAS, shall be projected at least once per 31 days in accordance with the methodologies and parameters of the ODCM when the Liquid Radwaste Treatment System is not being fully utilized.

Bases

12.3.3.C The OPERABILITY of the Liquid Radwaste Treatment System ensures that the system will be available for use whenever liquid effluents require treatment prior to release to the environment. The requirement that the appropriate portions of this system be used when specified, provides assurance that the releases of radioactive materials in liquid effluents will be kept "as low as is reasonably achievable." This Section implements the requirements of 10CFR Part 50.36a, General Design Criterion of Appendix A to 10CFR Part 50 and the design objective given in Section II.D of Appendix I to 10CFR Part 50. The specified limits governing the use of appropriate portions of the Liquid Radwaste Treatment System were specified as a 2% fraction of the dose design objectives set forth in Section II.A of Appendix I, 10CFR Part 50, for liquid effluents.

12.4 GASEOUS EFFLUENTS

12.4.1 Dose Rate

Operating Requirements

12.4.1.A The dose rate due to radioactive materials released in gaseous effluents from the site to areas at or beyond the SITE BOUNDARY (see Appendix F, Figure F-1), shall be limited to the following:

1. DELETED
2. For tritium and all radionuclides in particulate form with half-lives greater than 8 days the limit is less than or equal to 1500 mrem/yr to any organ.

Applicability: At all times.

Action

With a release exceeding the above limits, immediately reduce the release rate to within the above limits.

Surveillance Requirements

12.4.1.B The dose rate due to radioactive materials in gaseous effluents shall be determined to be within the prescribed limits in accordance with the methods and procedures of the ODCM by obtaining representative samples and performing analyses in accordance with the sampling and analysis program specified in Table 12.4-1.

Bases

12.4.1.C This Section is provided to ensure that radioactive material discharged in gaseous effluents will not result in the exposure of a Member of the Public in an Unrestricted Area, either at or beyond the Site Boundary in excess of the design objectives of appendix I to 10 CFR part 50. This section is provided to ensure that gaseous effluents from all units on the site will be appropriately controlled. It provides operational flexibility for releasing gaseous effluents to satisfy the Section II.A and II design objectives of appendix I to 10 CFR part 50. These release-rate limits also restrict, at all times, the corresponding organ dose rate above background to a child via the inhalation pathway to less than or equal to 1500 mrem/year. For purposes of calculating dose resulting from airborne releases, the stack is considered a ground-level release.

The Sampling and Analysis Program requirements prescribed in Table 12.4-1 are established to provide representative and appropriate sampling of the radiologically controlled areas. The method and frequency of sampling is based on the effluent flowrate. Continuous Releases are defined for areas with forced ventilation release points. Unventilated Building Releases are defined for areas with no specific release point.

TABLE 12.4-1

RADIOACTIVE GASEOUS EFFLUENT SAMPLING AND ANALYSIS PROGRAM

GASEOUS RELEASE TYPE	SAMPLING METHOD	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LOWER LIMIT OF DETECTION (LLD) (µCi/cc) (f)
A. Deleted				
B. Continuous Releases (1) Containment Vent and Purge	Continuous (b)(h)	Weekly(c) Daily(a)	Particulate Principal Gamma Emitters (e)	1E-11
C. Continuous Releases (1)				
Aux Building Unit 2 Ventilation Stack Unit 1 Vent Stack,	Composite	Quarterly	Sr-90 Particulate	1E-11
Modular HEPA Ventilation discharge (if applicable)			Fe-55 Particulate	3E-11
			Ni-63 Particulate	1E-11
			Gross Alpha	1E-11

(1) The requirements listed in this table for Continuous Releases are applicable for release paths that are available.

TABLE 12.4-1

RADIOACTIVE GASEOUS EFFLUENT SAMPLING AND ANALYSIS PROGRAM
(Cont'd)

GASEOUS RELEASE TYPE	SAMPLING METHOD	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LOWER LIMIT OF DETECTION (LLD) (μCi/cc) (f)
D. Unventilated Building Releases(1)				
	Continuous (h)	Daily(c)	Particulate Principal Gamma Emitters (e)	1E-11
	Composite	Quarterly	Sr-90 Particulate	1E-11
			Fe-55 Particulate	3E-11
			Ni-63 Particulate	1E-11
			Gross Alpha	1E-11

[1]This requirement sampling point may be used for any release point that is unventilated and will be tracked as an abnormal gaseous discharge point.TABLE 12.4-1

RADIOACTIVE GASEOUS EFFLUENT SAMPLING AND ANALYSIS PROGRAM
(Cont'd)

TABLE NOTATIONS

a. The daily sampling requirement is applicable when 1RIA-PR49 or 2R-PR49A is inoperable AND decommissioning activities that can create airborne radioactivity are in progress in the associated building (Containment and/or AB).

b. The ratio of the sample flow rate to the sampled stream flow rate shall be known for the time period in Section 12.4.1.

c. The particulate filter(s) shall be saved for a quarterly composite analysis for Sr-90, Ni-63, Fe-55 and gross alpha.

d. DELETED

e. For particulate emissions, the principal gamma emitters for which the LLD specification applies exclusively are the following radionuclides: Nb-94, Co-60, Cs-137 and Sb-125. Other peaks which are measurable and identifiable by gamma-ray spectrometry, together with the above nuclides, shall also be identified and reported when an actual analysis is performed on a sample. Nuclides which are below the LLD for the analyses shall not be reported as being at the LLD level for that nuclide.

f. The LLD is defined in Notation a. of Table 12.3-2.

g. DELETED

h. Sampling interruptions of short duration for routine activities, e.g. filter replacement or opening/closing of the construction door, do not constitute a deviation from the requirements for continuous sampling.

i. DELETED

12.4.2 DELETED

12.4.3 Dose – Tritium and Radioactive Material in Particulate Form

Operability Requirements

12.4.3.A The dose to a MEMBER OF THE PUBLIC from tritium and all radionuclides in particulate form with half-lives greater than 8 days in gaseous effluents released from each unit to areas at or beyond the SITE BOUNDARY (see Appendix F, Figure F-1) shall be limited to the following:

1. During any calendar quarter: Less than or equal to 7.5 mrem to any organ, and

2. During any calendar year: Less than or equal to 15 mrem to any organ.

Applicability: At all times.

Action

With the calculated dose from the release of tritium and all radionuclides in particulate form with half-lives greater than 8 days in gaseous effluents exceeding twice the limits of Section 12.4.3.A:

1. Limit subsequent releases such that the dose or dose commitment to a MEMBER OF THE PUBLIC from all uranium fuel cycle sources to less than or equal to 25 mrem to the total body or organ (except the thyroid which is limited to less than or equal to 75 mrem) over 12 consecutive months.

2. Prepare an analysis which demonstrates that radiation exposures to all MEMBERS OF THE PUBLIC from all uranium fuel cycle sources (including all effluent pathways and direct radiation) are less than the 40CFR Part 190 Standard. Otherwise, request a variance from the Commission to permit release which exceeds the 40CFR Part 190 Standard. The radiation exposure analysis shall use the methods prescribed in the ODCM.

Surveillance Requirements

12.4.3.B Cumulative dose contribution for the current calendar quarter and current calendar year for tritium, and all radionuclides in particulate form with half-lives greater than 8 days shall be determined in accordance with the methodologies and parameters in the ODCM at least once per 31 days.

Bases

12.4.3.C This Section implements the requirements of Sections II.C, III.A and IV.A of Appendix I, 10CFR Part 50. The Operability Requirements are the guides set forth in Section II.C of Appendix I. The ACTION statements provide the required operating flexibility and at the same time, implement the guides set forth in Section IV.A of Appendix I to assure that the releases of radioactive materials in gaseous effluents will be kept "as low as is reasonably achievable." The ODCM calculation methods specified in the Surveillance Requirements implement the requirements in Section III.A of Appendix I that conformance with the guides of Appendix I is to be shown by calculational procedures based on models and data such that the actual exposure of an individual through appropriate pathways is unlikely to be substantially underestimated. The release-rate specifications for radioactive material in particulate form are dependent on the existing radionuclide pathways to man, at or beyond the SITE BOUNDARY. The pathways which are examined in the development of these calculations are: 1) individual inhalation of airborne radionuclides, 2) disposition of radionuclides onto green leafy vegetation with subsequent consumption by man, 3) deposition onto grassy areas where milk animals and meat producing animals graze with consumption of the milk and meat by man.

12.4.4 Gaseous Effluent Treatment System

Operability Requirements

12.4.4.A The GASEOUS EFFLUENT TREATMENT SYSTEM shall be OPERABLE* and appropriate portions of these systems shall be used to reduce radioactive materials in gaseous effluents when the projected doses in 31 days due to gaseous effluent releases, from each unit, to areas at or beyond the SITE BOUNDARY (see Appendix F, Figure F-1) would exceed 0.3 mrem to any organ.

* The GASEOUS EFFLUENT TREATMENT SYSTEM shall be considered OPERABLE by meeting Sections 12.4.1 and/or 12.4.3, as applicable.

Applicability: At all times.

Action: With the Gaseous Effluent Treatment System inoperable for more than 30 days or with radioactive gaseous waste being discharged without treatment and in excess of the above limits, return the system to OPERABLE status and place the appropriate portions of the system in use.

Surveillance Requirements

12.4.4.B Doses due to gaseous releases from each unit to areas at or beyond the SITE BOUNDARY shall be projected at least once per 31 days in accordance with the methodologies and parameters in the ODCM when the Gaseous Effluent Treatment Systems are not being fully utilized.

Bases

12.4.4.C The OPERABILITY of the GASEOUS EFFLUENT TREATMENT SYSTEM ensures that the system will be available for use whenever gaseous effluents require treatment prior to the release to the environment.

he requirement that the appropriate portions of this system be used when specified provides reasonable assurance that the releases of radioactive materials in gaseous effluents will be kept "as low as is reasonably achievable." This section implements the requirement of 10CFR50.36a, General Design Criterion 60 of Appendix A to 10CFR50 and the design objective given in Section II.D of Appendix I to 10CFR50. The specified limits governing the use of appropriate portions of the Gaseous Effluent Treatment System were specified as a 2% fraction of the dose design objectives set forth in Section II.B and II.C of Appendix I, 10CFR50, for gaseous effluents.

12.5 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

12.5.1 Monitoring Program

Operability Requirements

12.5.1.A The Radiological Environmental Monitoring Program shall be conducted as specified in Table 12.5-1.

Applicability: At all times.

Action

1. With the Radiological Environmental Monitoring Program not being conducted as specified in Table 12.5-1, prepare and submit to the Commission, in the Annual Radiological Environmental Operating Report, a description of the reasons for not conducting a program as required and the plans for preventing a recurrence.

   Deviations are permitted from the required sampling schedule if specimens are unobtainable due to hazardous conditions, seasonal unavailability, malfunction of sampling equipment, if a person who participates in the program goes out of business or no longer can provide sample, or contractor omission which is corrected as soon as discovered. If the equipment malfunctions, corrective actions shall be completed as soon as practical. If a person/business supplying samples goes out of business, a replacement supplier shall be found as soon as possible. All deviations from the sampling schedule shall be described in the Annual Radiological Environmental Operating Report.

2. With the level of radioactivity as a result of plant effluents in an environmental sampling medium at a specified location exceeding the reporting levels of Table 12.5-2 when averaged over any calendar quarter, prepare and submit to the Commission within 30 days a Special Report which identifies the cause(s) for exceeding the limit(s) and defines the corrective actions to be taken to reduce radioactive effluents so that the potential annual dose* to a MEMBER OF THE PUBLIC is less than the calendar year limits of Section 12.3.2 or 12.4.3. When more than one of the radionuclides in Table 12.5.2 are detected in the sampling medium, this report shall be submitted if:

$$\frac{\text{concentration (1)}}{\text{reporting level (1)}} + \frac{\text{concentration (2)}}{\text{reporting level (2)}} + \ldots \geq 1.0$$

   When radionuclides other than those in Table 12.5-2 are detected and are the result of plant effluents, this report shall be submitted if the potential annual dose to a MEMBER OF THE PUBLIC from all radionuclides is equal to or greater than the calendar year limits of Section 12.3.2 or 12.4.3. This report is not required if the measured level of radioactivity was not the result of plant effluents; however, in such an event, the condition shall be reported and described in the Annual Radiological Environmental Operating Report.

*The methodology and parameters used to estimate the potential dose to a MEMBER OF THE PUBLIC shall be indicated in the report.

3. If the sample type or sampling location(s) required by Table 12.5-1 become(s) permanently unavailable, identify suitable alternative sampling media for the pathway of interest and/or specific locations for obtaining replacement samples and add them to the Radiological Environmental Monitoring Program as soon as practicable. The specific locations from which samples were unavailable may then be deleted from the program.

   Prepare and submit a controlled version of the ODCM within 180 days including a revised figure(s) and table reflecting the new location(s) with supporting information identifying the cause of the unavailability of samples and justifying the selection of new location(s) for obtaining samples.

<u>Surveillance Requirements</u>

12.5.1.B.1 The Radiological Environmental Monitoring samples shall be collected from the locations specified in the ODCM and analyzed pursuant to Table 12.5-1 and the detection capabilities required by Table 12.5-3.

<u>Bases</u>

12.5.1.C The Radiological Environmental Monitoring Program required by this section provides representative measurements of radiation and of radioactive materials in those exposure pathways and for those radionuclides that lead to the highest potential radiation exposures of MEMBERS OF THE PUBLIC resulting from the station operation. This monitoring program implements Section IV.B.2 of Appendix I to 10CFR50 and thereby supplements the radiological effluent monitoring program by verifying that the measurable concentrations of radioactive materials and levels of radiation are not higher than expected on the basis of the effluent measurements and modeling of the environmental exposure pathways. Guidance for this monitoring program is provided by the Radiological Assessment Branch Technical Position on Environmental Monitoring. The specified monitoring program is based on baseline/historical conditions for direct radiation measurements, soil, biota, and sediments established over years of operational experience and current site conditions/operating activities. The REMP need only be re-evaluated for major changes to site conditions/configuration (e.g., prior to site decommissioning, if a significant release occurs, changing baseline data...). Program changes may be initiated at any time based on operational experience.

The required detection capabilities for environmental sample analyses are tabulated in terms of the lower limits of detection (LLD). The LLDs required by Table 12.5-3 are considered optimum for routine environmental measurements in industrial laboratories. It should be recognized that the LLD is defined as a before the fact limit representing the capability of a measurement system and not as an after the fact limit for a particular measurement.

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

<u>Interpretations</u>

12.5.1.D Table 12.5-1 requires "one sample of each community drinking water supply downstream of the plant within 10 kilometers (6.2 miles)." Drinking water supply is defined as water taken from river, lakes, or reservoirs (not well water) which is used for drinking. Since Lake Michigan has no designated downstream or upstream direction, two drinking water locations (one north/one south) within 10 kilometers shall be sampled as drinking water indicator locations, and two other locations (one north/one south) beyond 10 kilometers shall be sampled as control locations.

TABLE 12.5-1

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

EXPOSURE PATHWAY AND/ OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS(1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
1. Airborne	Samples from a total of three locations: a. Indicator- Near Field Three samples from locations within 4 km (2.5 mi) in different sectors. b. Control- Far Field One sample from location 15-25 km (10-17 mi) in minimal D/Q sector.	Continuous sampler operation with particulate sample collection weekly (or more frequently if required due to dust loading).	Particulate Sampler: Gross beta analysis following weekly filter change(3) and gamma isotopic analysis(4) quarterly on composite filters by location on near field samples.

TABLE 12.5-1 (Continued)
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

EXPOSURE PATHWAY AND/ OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS[1]	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
2. Direct Radiation[5]	Thirty-one routine monitoring stations with thermoluminescent dosimeters (TLD), placed with at least one monitoring location in each meteorological sector, as follows: a. Indicator- Inner Ring (100 Series TLD) in the general area of the SITE BOUNDARY (0.1 to 1.5 mi); b. Other- One at each Airborne location given in part 1.a. Including 1 control TLD location located at control air sample station given in part 1.b. c. Indicator- Outer Ring (100 Series TLD) in the general area of the 5 mile ring. (2.0 to 10 mi); Other TLDs may be placed at special interest locations beyond the Restricted Area where either a MEMBER OF THE PUBLIC or Commonwealth Edison employees have routine access.	Quarterly	Gamma dose on each TLD quarterly.

TABLE 12.5-1 (Continued)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

EXPOSURE PATHWAY AND/ OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS(1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
3. Waterborne	a. Drinking Water Indicator(6)		
	One Sample from each community drinking water supply that could be affected by the station discharge within 10 km (6.2 mi) of discharge (north/south).	Weekly grab samples.	Gross beta and gamma isotopic analyses(4) on monthly composite; tritium analysis on quarterly composite.
	b. Control(6)		
	One sample upstream and downstream (north/south) of discharge.	Weekly grab samples.	Gross beta and gamma isotopic analyses(4) on monthly composite; tritium analysis on quarterly composite.
	c. Sediments		
	At least one sample within 10 km (6.2 mi) of discharge	Semiannually.	Gamma isotopic analysis (4) semiannually.

TABLE 12.5-1 (Continued)
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

EXPOSURE PATHWAY AND/ OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS(1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
4. Ingestion	a. Fish Indicator Representative samples of commercially and recreationally important species in discharge area.	Semiannually	Gamma isotopic analysis(4) on edible portions.
	b. Control Representative samples of commercially and recreationally important species not influenced by plant discharge.	Semiannually	Gamma isotopic analysis on edible portions.
5. Vegetation	a. Vegetation Indicator 3 Different types of broadleaf vegetation grown in the local area at publicly available vegetable markets. 2 Different types of root vegetables grown in the local area at publicly available vegetable markets.	Annual (during growing season)	Gamma isotopic analysis(4) on edible portions.
	b. Vegetation Control 3 Different types of broadleaf vegetation grown in the local area at publicly available vegetable markets. 2 Different types of root vegetables grown in an area >8 mi (12 km) from publicly available vegetable markets.	Annual (during growing season)	Gamma isotopic analysis(4) on edible portions.

TABLE 12.5-1 (Continued)
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM
TABLE NOTATIONS

(1) Specific parameters of distance and direction from the centerline of the midpoint of the two units and additional description where pertinent, shall be provided for each and every sample location in Table 11-1 of the ODCM Station Annexes. Refer to NUREG-0133, "Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants," October 1978, and to Radiological Assessment Branch Technical Position, Revision 1, November 1979.

(2) Deleted – No longer applicable.

(3) Airborne particulate sample filters shall be analyzed for gross beta radioactivity 24 hours or more after sampling to allow for radon and thorium daughter decay. If gross beta activity in any individual air particulate sample is greater than 10 times the 1999 mean of control samples, then, a gamma isotopic analysis shall be performed on that elevated individual sample.

(4) Gamma isotopic analysis means the identification and quantification of gamma emitting radionuclides that may be attributable to the effluents from the station. or identification of nuclides that are same type but <u>not</u> attributable to station effluents in the case of 'control' samples

(5) One or more instruments, such as a pressurized ion chamber, for measuring and recording dose rate continuously may be used in place of, or in addition to, integrating dosimeters. Film badges shall not be used as dosimeters for measuring direct radiation. The number of locations is not an absolute number. The number of direct radiation monitoring stations may be reduced according to geographical limitations; e.g., If a station is adjacent to a lake (i.e. Zion), some sectors may be over water thereby reducing the number of dosimeters which could be placed at the indicated distances. The frequency of analysis or readout for TLD systems will depend upon the characteristics of the specific system used and should be selected to obtain optimum dose information with minimal fading.

(6) Refer to Section 12.5.1.D for interpretation on the applicability of "downstream" and "upstream". If no community drinking water supply exists within 6.2 miles of the discharge, surface water sampling shall be performed.

TABLE 12.5-2

REPORTING LEVELS FOR RADIOACTIVITY CONCENTRATIONS IN ENVIRONMENTAL SAMPLES*

ANALYSIS	WATER (pCi/L)	AIRBORNE PARTICULATE OR GASES (pCi/m^3)	FISH (pCi/kg, wet)	Vegetation (pCi/kg, wet)
H-3	20,000 (1)			
Mn-54	1,000		30,000	
Fe-59	400		10,000	
Co-58	1,000		30,000	
Co-60	300		10,000	
Zn-65	300		20,000	
Zr-Nb-95	400			
Cs-134	30	10	1,000	
Cs-137	50	20	2,000	2,000
Ba-La-140	200			

(1) For drinking water samples. This is 40 CFR Part 141 value. If no drinking water pathway exists, a value of 30,000 pCi/l may be used.

* This table contains reporting levels for analyses beyond the requirements of Table 12.5-1.

TABLE 12.5-3

DETECTION CAPABILITIES FOR ENVIRONMENTAL SAMPLE ANALYSIS[1]

LOWER LIMIT OF DETECTION (LLD)[2]

ANALYSIS	WATER (pCi/L)	AIRBORNE PARTICULATE OR GASES (pCi/m^3)	FISH (pCi/kg, wet)	Vegetation (pCi/kg, wet)	SEDIMENT (pCi/kg, dry)
Gross Beta	4	0.01	1000		
H-3	2,000[3]				
Mn-54	15		130		
Co-58,60	15		130		
Zn-65	30		260		
Zr-Nb-95	15				
Cs-134	15	0.01	100		150
Cs-137	18	0.01	100	80	180

TABLE 12.5-3 (Continued)
DETECTION CAPABILITIES FOR ENVIRONMENTAL SAMPLE ANALYSIS
TABLE NOTATIONS

(1) This table contains lower limits of detection for analyses beyond the requirements of Table 12.5-1. This table does not imply that only these nuclides are to be detected and reported; other peaks which are measurable and identifiable in the analyses required by Table 12.5-1 shall be reported in the Annual Radiological Environmental Operating Report.

(2) The Lower Limit of Detection (LLD) is defined, for purposes of these specifications, as the smallest concentration of radioactive material in a sample that will yield a net count, above system background, that will be detected with 95% probability with only 5% probability of falsely concluding that a blank observation represents a "real" signal.

For a particular measurement system, which may include radiochemical separation, the LLD is defined as follows:

$$LLD = \frac{4.66\ S_b + 3/t_b}{(E)\ (V)\ (2.22)\ (Y)\ (\exp(-\lambda\Delta t))}$$

$$LLD \sim \frac{4.66\ S_b}{(E)\ (V)\ (2.22)\ (Y)\ (\exp(-\lambda\Delta t))}$$

Where: $4.66\ S_b >> 3/t_b$

LLD = the "a priori" Lower Limit of Detection (picocuries per unit mass or volume),

s_b = the standard deviation of the background counting rate or of the counting rate of a blank sample, as appropriate (counts per minute),

$$= \frac{\sqrt{Total\ Counts}}{t_b}$$

E = the counting efficiency(counts per disintegration),

V = the sample size (units of mass or volume),

2.22 = the number of disintegrations per minute per picocurie,

Y = the fractional radiochemical yield, when applicable,

λ = the radioactive decay constant for the particular radionuclide (sec^{-1}),

t_b = counting time of the background or blank (minutes), and

TABLE 12.5-3 (Continued)
DETECTION CAPABILITIES FOR ENVIRONMENTAL SAMPLE ANALYSIS
TABLE NOTATIONS

Δt = the elapsed time between sample collection, or end of the sample collection period, and the time of counting (sec).

Typical values of E, V, Y, and Δt should be used in the calculation.

It should be recognized that the LLD is defined as a before the fact limit representing the capability of a measurement system and not as an after the fact limit for a particular measurement.

Analyses shall be performed in such a manner that the stated LLDs will be achieved under routine conditions. Occasionally, background fluctuations, unavoidable small sample sizes, the presence of interfering nuclides, or other uncontrollable circumstances may render these LLDs unachievable. In such cases, the contributing factors shall be identified and described in the Annual Radiological Environmental Operating Report.

(3) This is the minimum required LLD; however, environmental samples analyzed off-site will be required to use 200 pCi/l.

12.5.2 LAND USE CENSUS

Operability Requirements

12.5.2.A. A Land Use Census shall be conducted and shall identify within a distance of 10 km (6.2 mi.) the location, in each of the following meteorological sectors, A, J, K, L, M, N, P, Q, and R**, the nearest residence. For dose calculation, a garden will be assumed at the nearest will residence. . For REMP purposes, aerial phographs or equivalent method shall be used to determine the nearest garden/farm >500 sq. ft (50sq meters) in each sector within 10 mi. (15km)

Applicability: At all times.

Action:

With a Land Use Census identifying location(s) that yields a calculated dose or dose commitment, via the same exposure pathway 20% greater than at a location from which samples are currently being obtained in accordance with Section 12.5.1, add the new location(s) within 30 days to the Radiological Environmental Monitoring Program given in Chapter 11 of the ODCM Station Annexes. The sampling location(s), excluding the control location, having the lowest calculated dose or dose commitment(s), via the same exposure pathway, may be deleted from this monitoring program after October 31 of the year in which this Land Use Census was conducted. Submit in the next Annual Radiological Environmental Operating Report documentation for a change in the ODCM including revised figure(s) and table(s) for the ODCM reflecting the new location(s) with information supporting the change in sampling locations.

** The nearest industrial facility shall also be documented if closer than the nearest residence.

Surveillance Requirements

12.5.2.B The Land Use Census shall be conducted, between June 1 and October 1, at least once per calendar year using that information that will provide the best results, such as by a door-to-door survey or aerial survey. The result of the Land Use Census shall be included in the Annual Radiological Environmental Operating Report.

Bases

12.5.2.C This specification is provided to ensure that changes in the use of areas at and beyond the SITE BOUNDARY are identified and that modifications to the Radiological Environmental Monitoring Program given in the ODCM are made if required by the results of this census.

This census satisfies the requirements of Section IV.B.3 of Appendix I to 10 CFR Part 50.

12.5.3 INTERLABORATORY COMPARISON PROGRAM

Operability Requirements

12.5.3.A Analyses shall be performed on radioactive materials supplied as part of an interlaboratory comparison program that correspond to samples required by Table 12.5.1.

Applicability: At all times.

Action:

1. With analyses not being performed as required above, report the corrective actions taken to prevent a recurrence to the Commission in the Annual Radiological Environmental Operating Report.

Surveillance Requirements

12.5.3.B A summary of the results obtained as part of the above required interlaboratory comparison program shall be included in the Annual Radiological Environmental Operating Report.

Bases

12.5.3.C The requirement for participation in an interlaboratory comparison program is provided to ensure that independent checks on the precision and accuracy of the measurements of radioactive material in environmental samples matrices are performed as part of the quality assurance program for environmental monitoring in order to demonstrate that the results are valid for the purposes of Section IV.B.2 of Appendix I to 10 CFR Part 50.

12.6 PROCESS CONTROL PROGRAM (PCP)

12.6.1 PCP Program Requirements

Contains the requirements and methodology for the current formulas, sampling, analyses, tests, and determinations performed to ensure the processing and packaging of solid radioactive wastes based on actual or simulated wet solid wastes is accomplished in compliance with:

- 10CFR Parts 20, 61, and 71
- State Regulations
- Burial Site Requirements
- Other Requirements Governing the Shipping and Burial of Radioactive Waste

12.6.2 Changes to the PCP

Changes to the PCP include those changes that affect the process or methodology, by which wastes are solidified, packaged to meet burial site form requirements, classified, or dewatered.

12.6.2.1. Shall be documented and records of reviews performed shall be retained, and

Shall contain sufficient information to support the change together with the appropriate analyses or evaluations justifying the change(s), and

Shall contain a determination that the change will maintain the overall conformance of the solidified waste product to existing requirements of Federal, State, or other applicable regulations, and

Shall become effective after review and approval by the Decommissioning Plant Manager.

12.7 REPORTING REQUIREMENTS

12.7.1 Annual Radiological Environmental Operating Report*

Routine Annual Radiological Environmental Operating Report covering the operation of the Unit(s) during the previous calendar year shall be submitted according to the Permanently Defueled Technical Specifications. The Annual Radiological Environmental Operating Report shall include summaries, interpretations, and an analysis of trends of the results of the radiological environmental surveillance activities for the report period, including, as found appropriate, a comparison of preoperational studies with operational controls or with previous environmental surveillance reports, and an assessment of the observed impacts of the plant operation on the environment.

The Annual Radiological Environmental Operating Report shall include the results of all radiological environmental samples and of all environmental radiation measurements taken during the period pursuant to the locations specified in the tables and figures in the Chapter 11 of the ODCM Station Annexes, as well as summarized and tabulated results of these analyses and measurements in the format of the table in the Radiological Assessment Branch Technical Position, Revision 1, November 1979. In the event that some individual results are not available for inclusion with the report, the report shall be submitted noting and explaining the reasons for the missing results. The missing data shall be submitted as soon as possible in a supplementary report.

The reports shall also include the following: a summary description of the Radiological Environmental Monitoring Program; legible maps covering all sampling locations keyed to a table giving distances and directions from the midpoint between the two units; reasons for not conducting the Radiological Environmental Monitoring Program as required by Section 12.5.1, and discussion for all deviations from the sampling schedule of Table 11.1-1; a Table of Missed Samples and a Table of Sample Anomalies for all deviations from the sampling schedule of Table 11.1-1; discussion of environmental sample measurements that exceed the reporting levels of Table 12.5-2 but are not the result of plant effluents; discussion of all analyses in which the LLD required by Table 12.5-3 was not achievable; results of the Land Use Census required by Section 12.5.2; and the results of licensee participation in an interlaboratory comparison program and the corrective actions being taken if the specified program is not being performed as required by Section 12.5.3.

The Annual Radiological Environmental Operating Report shall also include an annual summary of hourly meteorological data collected over the applicable year. This annual summary may be either in the form of an hour-by-hour listing on magnetic tape of wind speed, wind direction, atmospheric stability, and precipitation (if measured), or in the form of joint frequency distributions of wind speed, wind direction, and atmospheric stability. In lieu of submission with the Annual Radiological Environmental Operating Report, the licensee has the option of retaining this summary of required meteorological data on site in a file that shall be provided to the NRC upon request.

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* A single submittal may be made for a multiple unit station.

The Annual Radiological Environmental Operating Report shall also include an assessment of the radiation doses due to the radioactive liquid and gaseous effluents released from the Unit or Station during the previous calendar year. This report shall also include an assessment of radiation doses to the most likely exposed MEMBER OF THE PUBLIC from reactor releases and other nearby uranium fuel cycle sources, including doses from primary effluent pathways and direct radiation, for the previous calendar year. The assessment of radiation doses shall be performed in accordance with the methodology and parameters in the ODCM and in compliance with 10 CFR 20 and 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operation."

12.7.2 <u>Annual Radioactive Effluent Release Report</u>**

The Annual Radioactive Effluent Release Reports shall include a summary of the quantities of radioactive liquid and gaseous effluents and solid waste released from the unit as outlined in Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Material in Liquid and Gaseous Effluent from Light-Water-Cooled Nuclear Power Plants," Revision 1, June 1974, with data summarized on a quarterly basis following the format of Appendix B thereof.

The Annual Radioactive Effluent Release Report shall include a list and description of unplanned releases of radioactive material in liquid effluents from the site to UNRESTRICTED AREAS and of unplanned releases of radioactive material in gaseous effluents from the site to areas at or beyond the SITE BOUNDARY during the reporting period.

The Annual Radioactive Effluent Release Report shall include any changes made during the reporting period to the Process Control Program as well as any major changes to Liquid, Gaseous or Solid Radwaste Treatment Systems, pursuant to Section 12.7.4.

The Annual Radioactive Effluent Release Report shall also include the following: an explanation as to why the inoperability of liquid or gaseous effluent monitoring instrumentation was not corrected within the time specified in Section 12.2.1 or 12.2.2, respectively; and description of the events leading to liquid holdup tanks exceeding the limits of the Quality Assurance Project Plan App.B.

12.7.2.1 Exceptions to Regulatory Guide 1.21 Reporting Requirements:

a. All references to "semiannual" are not applicable. The report will be submitted according to Quality Assurance Project Plan (QAPP).

b. Hourly meteorological data is recorded for all periods throughout the year, and quarterly summaries will be reported. Separate meteorological data for periods of batch releases are not required to be included.

c. Total body and significant organ doses to the maximally exposed individual from receiving-water-related exposure pathways will be provided. Associated population dose is not required to be included.

d. Organ doses to the maximally exposed individual in unrestricted areas from radioactive material in particulate form from all exposure pathways will be provided. Associated population dose is not required to be included.

e. Total body doses to the maximally exposed individual in unrestricted areas from direct radiation from the facility should be included in the report. Associated population dose is not required to be included.

f. Total body doses to the population and average doses to individuals in the population from all receiving-water-related pathways are not required to be included.

g. Total body doses to the population and average doses to individuals in the population from gaseous effluents to a distance of 50 miles from the site and beyond will not be included.

** A single submittal may be made for a multiple unit station. The submittal should combine those sections that are common to all units at the station; however, for units with separate radwaste systems, the submittal shall specify the releases of radioactive material from each unit.

12.7.3 Offsite Dose Calculation Manual (ODCM)

12.7.3.1 Changes to the ODCM:

a. Shall be documented and records of reviews performed shall be retained as required by QAPP. This documentation shall contain:

   1. Sufficient Information to support the change together with the appropriate analyses or evaluations justifying the change(s); and

   2. A determination that the change will maintain the level of radioactive effluent control required by 10 CFR 20.1302, 40 CFR Part 190, 10 CFR 50.36a, and Appendix I to 10 CFR Part 50 and not adversely impact the accuracy or reliability of effluent, dose, or setpoint calculations.

   3. Documentation of the fact that the change has been reviewed and found acceptable by a Qualified Technical Review.

b. Shall become effective after the approval of the Decommissioning Plant Manager on the date specified by the Qualified Technical Review.

c. Shall be submitted to the Commission in the form of a complete, legible copy of the entire ODCM as a part of or concurrent with the Annual Radioactive Effluent Release Report for the period of the report in which any change to the ODCM was made effective. Each change shall be identified by markings in the margin of the affected pages, clearly indicating the area of the page that was changed, and shall indicate the date (e.g., month/year) the change was implemented.

12.7.4 Major Changes to Liquid and Gaseous Effluent Treatment Systems***

Licensee-initiated major changes to the Effluent Treatment Systems (liquid and gaseous):

a. Shall be reported to the Commission in the Annual Radioactive Effluent Release Report for the period in which the evaluation was reviewed by a Qualified Technical Review. The discussion of each change shall contain:

   1) A summary of the evaluation that led to the determination that the change could be made in accordance with 10 CFR 50.59;

   2) Sufficient detailed information to totally support the reason for the change without benefit of additional and supplemental information;

   3) A detailed description of the equipment, components, and processes involved and the interfaces with other plant systems.

   4) An evaluation of the change which shows the predicted releases of radioactive materials in liquid and gaseous effluents that differ from those previously predicted in the License application and amendments thereto;

   5) An evaluation of the change, which shows the expected maximum exposures to a MEMBER OF THE PUBLIC and to the general population that differ from those previously estimated in the License application and amendments thereto;

6) A comparison of the predicted releases of radioactive materials, in liquid and gaseous effluents, to the actual releases for the period prior to when the changes are to be made;

7) An estimate of the exposure to plant operating personnel as a result of the change; and

8) Documentation of the fact that the change was reviewed and found acceptable by a Qualified Technical Review.

b. Shall become effective upon review and acceptance by the Qualified Technical Review.

*** Licensees may choose to submit the information called for in this standard as part of the biennial DSAR update.

APPENDIX A

COMPLIANCE METHODOLOGY

APPENDIX A
COMPLIANCE METHODOLOGY

A.0 INTRODUCTION

This appendix reviews the offsite radiological limits applicable to Zion Station' and presents in detail the equations and procedures used to assess compliance with these limits. An introduction to the calculation approach used here is given in Chapter 4. The approach incorporates simplifications such as the following:

- Use of pre-calculated atmospheric transport parameters based on historical average atmospheric conditions (see Section 4.1.5). These atmospheric dispersion and deposition factors are defined in Chapter 4.

The equations and parameters of this appendix are for use in calculating offsite radiation doses during routine operating conditions. They are not for use in calculating doses due to non-routine releases (e.g., accident releases).

This section of the ODCM provides the methodological details for demonstrating compliance with the 10CFR20, 10CFR50 Appendix I, 10CFR72.104 and 40CFR190 radiological limits for liquid and gaseous effluents.

An overview of the required compliance is given in Tables 2-1, 2-2, and 2-3. In Table 2-1, the dose components are itemized and referenced, and an indication of their regulatory application is noted. A more detailed compliance matrix is given in Table 2-3. Additionally, the locations of dose receivers for each dose component are given in Table 2-2.

The following sections detail the required radiological dose calculations.

A.1 AIRBORNE RELEASES

A.1.1 Release Point Classifications

The pattern of dispersion of airborne releases is dependent on the height of the release point relative to adjacent structures. For the equations of this appendix, each release point is classified as one of the following three height-dependent types, which are defined in Section 4.1.4:

- Stack (or Elevated) Release Point (denoted by the letter S or subscript s)

- Ground Level Release Point (denoted by the letter G or subscript g)

- Vent (or Mixed Mode) Release Point (denoted by the letter V or subscript v)

The release point classifications of routine release points at Zion Station are stated in Table A-2.

A.1.2 Dose Due to Noble Gas Radionuclides

A.1.2.1 Gamma Air Dose

Requirement

RETS limit the gamma air dose due to noble gas effluents released from each reactor unit to areas at and beyond the unrestricted area boundary to the following:

- Less than or equal to 5 mrad per calendar quarter.
- Less than or equal to 10 mrad per calendar year.

Equation

The gamma air dose due to noble gases released in gaseous effluents is calculated by the following expression:

$$D_\gamma = (3.17E-8)\sum_i M_i \left\{ (\chi/Q)_s^\gamma A_{is} + (\chi/Q)_v^\gamma A_{iv} + (\chi/Q)_g^\gamma A_{ig} \right\} \qquad \textbf{(A-1)}$$

The summation is over noble gas radionuclides **i**.

D_γ Gamma Air Dose [mrad]

Dose to air due to gamma radiation from noble gas radionuclides released in gaseous effluents.

3.17E-8 Conversion Constant (seconds to years) [yr/sec]

M_i Gamma Air Dose Conversion Factor [(mrad/yr)/(μCi/m^3)]

Gamma air dose rate factor per unit of radioactivity release rate for radionuclide **i**. From Table B-1 of Reg Guide 1.190.

$(\chi/Q)_s^\gamma$, $(\chi/Q)_v^\gamma$, $(\chi/Q)_g^\gamma$ Gamma-χ/Q Factor [sec/m^3]

Radioactivity concentration based on finite cloud methodology at a specific location per unit of radioactivity release rate from a stack, vent or ground level release, respectively. See Section B.3.5 and Table F-5b of appendix F.

A_{is}, A_{iv}, A_{ig} Cumulative Radionuclide Release [μCi]

Measured cumulative release of radionuclide **i** over the time period of interest from a stack, vent, or ground level release point, respectively.

Application

RETS require determination of cumulative and projected gamma air dose contributions due to noble gases for the current calendar quarter and the current calendar year at least once per 31 days (see Sections 12.4 of Zion Station' RETS or Technical Specifications).

Gamma air dose is calculated for the sector with the highest offsite $(\chi/Q)^\gamma$ and is compared with the RETS limits on gamma air dose.

For a release attributable to a processing or effluent system shared by more than one reactor unit, the dose due to an individual unit is obtained by proportioning the effluents among the units sharing the system. The allocation procedure is specified in ODCM Chapter 10.

A.1.2.2 Beta Air Dose

Requirement
RETS limit the beta air dose due to noble gases in gaseous effluents released from each reactor unit to areas at and beyond the unrestricted area boundary to the following:

- Less than or equal to 10 mrad per calendar quarter.
- Less than or equal to 20 mrad per calendar year.

Equation
The beta air dose due to noble gases released in gaseous effluents is calculated by the following expression:

$$D_\beta = (3.17E-8)\sum_i \left\{ N_i \left[(\chi/Q)_s A_{is} + (\chi/Q)_v A_{iv} + (\chi/Q)_g A_{ig} \right] \right\} \quad \textbf{(A-2)}$$

The summation is over noble gas radionuclides **i**.

D_β	Beta Dose	[mrad]
	Dose to air due to beta radiation from noble gas radionuclides released in gaseous effluents.	
3.17E-8	Conversion Constant (seconds to years)	[yr/sec]
N_i	Beta Air Dose Conversion Factor	[(mrad/yr)/(μCi/m^3)]
	Beta air dose rate per unit of radioactivity concentration for radionuclide **i**. Take from Table C-9 of Appendix C.	
$(\chi/Q)_s$ $(\chi/Q)_v$ $(\chi/Q)_g$	Relative Concentration Factor	[sec/m^3]
	Radioactivity concentration based on semi-infinite cloud methodology at a specified location per unit of radioactivity release rate for a stack, vent, or ground level release, respectively. See Section 4.1.6, Section B.3 of Appendix B, and Table F-5 of Appendix F.	
A_{is}, A_{iv}, A_{ig}	Cumulative Radionuclide Release	[μCi]
	Measured cumulative release of radionuclide **i** over the time period of interest from a stack, vent, or ground level release point, respectively.	

Application

RETS require determination of cumulative and projected beta air dose contributions due to noble gases for the current calendar quarter and the current calendar year at least once per 31 days (see Section 12.4 of Zion Station RETS or Technical Specification).

Beta air dose is calculated for the sector with the highest offsite **(χ/Q)** and is compared with the RETS limit on beta air dose.

For a release attributable to a processing or effluent system shared by more than one reactor unit, the dose due to an individual unit is obtained by proportioning the effluents among the units sharing the system. The allocation procedure is specified in ODCM Chapter 10.

A.1.2.3 Total Body Dose

Requirement
The total body dose, to any receiver is due, in part, to gamma radiation emitted from radioactivity in airborne effluents. This component is added to others to demonstrate compliance to the requirements of 40CFR190 and 10CFR20.

Equation

The total body dose component due to gamma radiation from noble gases released in gaseous effluents is calculated by the following expression:

$$D_{TB} = (3.17E-8)\sum_{i} K_i \left\{ (\chi/Q)_s^{\gamma} A_{is} + (\chi/Q)_v^{\gamma} A_{iv} + (\chi/Q)_g^{\gamma} A_{ig} \right\} \qquad \text{(A-3)}$$

The summation is over noble gas radionuclides **i**.

D_{TB}	Total Body Dose	[mrem]
	Dose to the total body due to gamma radiation from noble gas radionuclides released in gaseous effluents.	
3.17E-8	Conversion Constant (seconds to years)	[yr/sec]
K_i	Gamma Total Body Dose Conversion Factor	[(mrem/yr)/(uCi/m3)]
	Gamma total body dose factor due to gamma emissions for noble gas radionuclide **i** released from a stack, vent or ground level release point, respectively. Taken from Table C-9 of Appendix C.	
A_{is}, A_{iv}, A_{ig}	Cumulative Radionuclide Release	[μCi]
	Measured cumulative release of radionuclide **i** over the time period of interest from a stack, vent, or ground level release point, respectively.	

Application

The total body dose is also calculated for the 40CFR190 and 10CFR20 compliance assessments. In some cases, the total body dose may be required in 10CFR50 Appendix I assessments (See Table 2-1).

A.1.2.4 Skin Dose

Requirement
There is no regulatory requirement to evaluate skin dose. However, this component is evaluated for reference as there is skin dose design objective contained in 10CFR50 Appendix I. Note that in the unlikely event that if beta air dose guideline is exceeded, then the skin dose will require evaluation.

Equation
The part of skin dose due to noble gases released in gaseous effluents is calculated by the following expression:

$$\begin{aligned} D_{SK} = (3.17E-8)\sum_{i} \Big\{ & L_i \left[(\chi/Q)_s A_{is} + (\chi/Q)_v A_{iv} + (\chi/Q)_g A_{ig} \right] \\ & + (1.11) M_i \left[(\chi/Q)_s^{\gamma} A_{is} + (\chi/Q)_v^{\gamma} A_{iv} + (\chi/Q)_g^{\gamma} A_{ig} \right] \Big\} \end{aligned} \qquad \text{(A-4)}$$

The summation is over noble gas radionuclides **i**.

D_{SK}	Skin Dose	[mrem]
	Dose to the skin due to beta and gamma radiation from noble gas radionuclides released in gaseous effluents.	
L_i	Beta Skin Dose Conversion Factor	[(mrem/yr)/(μCi/m^3)]
	Beta skin dose rate per unit of radioactivity concentration for radionuclide **i**. Taken from Table C-9 of Appendix C.	
1.11	Conversion Constant (rads in air to rem in tissue)	[mrem/mrad]

All other terms have been previously defined.

Application

The skin dose is calculated for reference only.

A.1.3 Dose Rate Due to Noble Gas Radionuclides

A.1.3.1 Total Body Dose Rate

Requirement
RETS limit the total body dose rate due to noble gases in gaseous effluents released from a site to areas at and beyond the site boundary to less than or equal to 500 mrem/yr at all times. (see Section 12.4 of Zion Station RETS and Technical Specifications)

Equation
The total body dose rate due to noble gases released in gaseous effluents is calculated by the following expression:

$$\dot{D}_{TB} = \sum_i K_i \left\{ (\chi/Q)_s^\gamma Q_{is} + (\chi/Q)_v^\gamma Q_{iv} + (\chi/Q)_g^\gamma Q_{ig} \right\} \quad \textbf{(A-5)}$$

The summation is over noble gas radionuclides **i**.

$\dot{D}_{TB}$	Total Body Dose Rate	[mrem/yr]
	Dose rate to the total body due to gamma radiation from noble gas radionuclides released in gaseous effluents.	
Q_{is}, Q_{iv}, Q_{ig}	Release Rate	[μCi/sec]
	Measured release rate of radionuclide **i** from a stack, vent or ground level release point, respectively.	

All other terms have been previously defined.

Application

RETS require the dose rate due to noble gases in gaseous effluents be determined to be within the above limit in accordance with methodology specified in the ODCM (see Section 12.4 of Zion Stations RETS and Technical Specifications).

To comply with this specification, Zion Station uses an effluent radiation monitor setpoint corresponding to an offsite total body dose rate at or below the limit (see Chapter 10). In addition, Zion Station assesses compliance by calculating offsite total body dose rate on the basis of periodic samples obtained in accordance with station procedures.

A.1.3.2 Skin Dose Rate

Requirement
RETS limit the skin dose rate due to noble gases in gaseous effluents released from a site to areas at and beyond the site boundary to less than or equal to a dose rate of 3000 mrem/yr at all times. (See Section 12.4 of Zion Stations RETS and/or Technical Specifications)

Equation
The skin dose rate due to noble gases released in gaseous effluents is calculated by the following expression:

$$\dot{D}_{SK} = \sum_i \Big\{ L_i \left[(\chi/Q)_s Q_{is} + (\chi/Q)_v Q_{iv} + (\chi/Q)_g Q_{ig} \right] + (1.11)\, M_i \left[(\chi/Q)_s^{\gamma} Q_{is} + (\chi/Q)_v^{\gamma} Q_{iv} + (\chi/Q)_g^{\gamma} Q_{ig} \right] \Big\} \quad \text{(A-6)}$$

The summation is over noble gas radionuclides **i**.

$\dot{D}_{SK}$	Skin Dose Rate	[mrem/yr]
	Dose rate to skin due to beta and gamma radiation from noble gas radionuclides released in gaseous effluents.	
Q_{is}, Q_{iv}, Q_{ig}	Release Rate	[μCi/sec]
	Measured release rate of radionuclide **i** from a stack, vent or ground level release point, respectively.	

All other terms been previously defined.

Application
RETS require the dose rate due to noble gases in gaseous effluents to be determined to be within the above limit in accordance with methodology specified in the ODCM. (See Section 12.4 of Zion*Solutions*' RETS and Technical Specifications.)

To comply with this specification, Zion Station uses an effluent radiation monitor setpoint corresponding to an offsite skin dose rate at or below the limit (see Chapter 10). In addition, Zion*Solutions*' assesses compliance by calculating offsite skin dose rate on the basis of samples obtained periodically in accordance with site procedures.

A.1.4 Dose Due to Non-Noble Gas Radionuclides

Requirement
RETS provide the following limits, based on 10CFR50 Appendix I, on the dose to a member of the public from specified non-noble gas radionuclides in gaseous effluents released from each reactor unit to areas at and beyond the unrestricted area boundary:

- Less than or equal to 7.5 mrem to any organ during any calendar quarter.
- Less than or equal to 15 mrem to any organ during any calendar year.

The individual dose components are also required as part of the 40CFR190 assessments and combined as part of the 10CFR20 assessment (See Section A.4). The dose due to radionuclides deposited on the ground is considered to be a component of the deep dose equivalent for 10CFR20 compliance and an organ (and total body) dose component for 10CFR50 Appendix I and 40CFR190 compliance.

In accordance with the definition of dose in Regulatory Guide 1.109, the term "dose" in this document when applied to individuals, is used instead of the more precise term "dose equivalent," as defined by the International Commission on Radiological Units and Measurements (ICRU). When applied to the evaluation of internal deposition of radioactivity, the term "dose" as used here, includes the prospective dose component arising from retention in the body beyond the period of environmental exposure, i.e., the dose commitment. The dose commitment is evaluated over a period of 50 years. Assessments for 10CFR50 Appendix I compliance are made for 4 age groups (adult/teenager/child/infant) using Regulatory Guide 1.109 (Reference 6) dose conversion factors.

Equation

The dose is calculated for releases in the time period under consideration.

Specifically, the dose is calculated as follows:

$$\mathbf{D_{aj}^{NNG}} = (3.17\mathrm{E}-8)\sum_{p}\sum_{i}\left[W_s R_{aipj} A_{is} + W_v R_{aipj} A_{iv} + W_g R_{aipj} A_{ig}\right] \tag{A-7}$$

The summation is over pathways **p** and non-noble gas radionuclides **i**.

$\mathbf{D_{aj}^{NNG}}$	Dose Due to Non-Noble Gas Radionuclides	[mrem]
	Dose due to non-noble gases (tritium and particulates) to age group **a**, and to organ **j**.	
3.17E-8	Conversion Constant (seconds to years)	[yr/sec]
$\mathbf{W_s, W_v, W_g}$	Relative Concentration Factor	
	Radioactive concentration at a specific location per unit of radioactivity release rate or concentration for stack, vent or ground level release, respectively.	
	W_s, W_v, or W_g = $(\chi/Q)_s$, $(\chi/Q)_v$ or $(\chi/Q)_g$ for immersion, inhalation and all tritium pathways.	
	W_s, W_v, or W_g = $(D/Q)_s$, $(D/Q)_v$ or $(D/Q)_g$ for ground plain and all ingestion pathways.	

$(\chi/Q)_s$, $(\chi/Q)_v$, $(\chi/Q)_g$ Relative Concentration Factor [sec/m^3]

Radioactivity concentration based on semi-infinite cloud model at a specified location per unit of radioactivity release rate for a stack, vent, or ground level release, respectively. See Section 4.1.6, Section B.3 of Appendix B, and Table F-5 of Appendix F.

$(D/Q)_s$, $(D/Q)_v$, $(D/Q)_g$ Relative Deposition Factor [1/m^2]

Radioactivity concentration at a specified location per unit of radioactivity release concentration for a stack, vent, or ground level release, respectively. See Section 4.1.6, Section B.3 of Appendix B, and Table F-6 of Appendix F.

R_{aipj} Site-Specific Dose Factor [(m^2 mrem/yr)/(μCi/sec)] or [(mrem/yr)/(μCi/m^3)]

Site-specific dose factor for age group **a**, nuclide **i**, pathway **p** and organ **j**. Pathway included are ground plane exposure, inhalation, vegetation ingestion, milk ingestion and meat ingestion. Values of R_{aipj} are provided in Appendix F.

A_{is}, A_{iv}, A_{ig} Cumulative Radionuclide Release [μCi]

Measured cumulative release of radionuclide **i** over the time period of interest from a stack, vent, or ground level release point, respectively.

Application

RETS require cumulative and projected dose contributions for the current calendar quarter and the current calendar year for the specified non-noble gas radionuclides in airborne effluents to be determined at least once per 31 days (see Section 12.4 of Zion Stations' RETS and Technical Specifications).

To comply with this specification, Zion Station obtains and analyzes samples in accordance with the radioactive gaseous waste or gaseous effluent sampling and analysis program in its RETS. In accordance with NUREG 0133 (Reference 14), dose due to non-noble gases is assessed at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposure. The inhalation and ground plane exposure pathways are considered to exist at all locations. The food ingestion pathways at a specific location are considered based on their existence as determined by land use census. The values used for (χ/Q) and (D/Q) correspond to the applicable pathway location.

For a release attributable to a processing or effluent system shared by more than one reactor, the dose due to an individual unit is obtained by proportioning the effluents among the units sharing the system. The allocation procedure is specified in ODCM Chapter 10.

The dose evaluated is also included as part of the 10CFR20 and 40CFR190 assessment (See Section A.4).

A.1.4.1 Ground Deposition

The site-specific dose factor for ground deposition of radioactivity is considered to be a total body dose component and is calculated by the following expression:

$$R_{ai(GP)j}[D/Q] = K'K''(0.7)DFG_i\left[\frac{1-e^{-\lambda_i t_b}}{\lambda_i}\right] \quad \textbf{(A-8)}$$

$R_{ai(GP)j}[D/Q]$	Ground Plane Deposition Dose Factor	[(m^2 mrem/yr)/(µCi/sec)]
	Site-specific ground plane dose factor for age group **a**, nuclide **i** and organ **j**. The ground plane dose is calculated using (D/Q).	
K'	Conversion Constant (1E6 pCi per µCi)	[pCi/µCi]
K"	Conversion Constant (8760 hr/yr)	[hr/yr]
0.7	Shielding Factor; a factor which accounts for shielding due to occupancy of structures.	dimensionless
DFG_i	Ground Plane Dose Conversion Factor	[(mrem/hr)/(pCi/m^2)]
	Dose rate to the total body per unit of surface radioactivity concentration due to standing on ground uniformly contaminated with radionuclide **i**. Taken from Table C-10 of Appendix C.	
	Note that ground plane dose factors are only given for the total body and no age group. Doses to other organs are assumed to be equal to the total body dose. All age groups are assumed to receive the same dose.	
λ_i	Radiological Decay Constant	[hr^{-1}]
	Radiological decay constant for radionuclide **i**. See Table C-7 of Appendix C.	
t_b	Time Period of Ground Deposition	[hr]
	Time period during which the radioactivity on the ground is assumed to have been deposited. See Table C-1 of Appendix C.	

Application
The ground plane exposure pathway is considered to exist at all locations.

A.1.4.2 Inhalation

The site-specific dose factor for inhalation is calculated by the following expression:

$$R_{ai(Inhal)j}[\chi/Q] = K'BR_a DFA_{aij} \quad \textbf{(A-9)}$$

$R_{ai(Inhal)j}[\chi/Q]$	Inhalation Pathway Dose Factor	[(mrem/yr)/(µCi/m^3)]
	Site-specific inhalation dose factor for age group **a**, nuclide **i** and organ **j**. The inhalation dose is calculated using (χ/Q).	
K'	Conversion Constant (1E6 pCi per µCi)	[pCi/µCi]
BR_a	Individual Air Inhalation Rate	[m^3/yr]

The air intake rate for individuals in age group **a**. See Table C-2 of Appendix C.

DFA_{aij}	Inhalation Dose Conversion Factor	[mrem/pCi]

Dose commitment to an individual in age group **a** to organ **j** per unit of activity of radionuclide **i** inhaled. Taken from Tables E-7 through E-10 of Regulatory Guide 1.109. The value for H-3 is taken from NUREG 4013 (Reference 107).

Application
The inhalation exposure pathway is considered to exist at all locations.

A.1.4.3 Food Ingestion Pathway Dose Factors

Application
Food ingestion pathway doses are calculated at locations indicated by the land use census survey. If no real pathway exists within 5 miles of the station, the cow-milk pathway is assumed to be located at 5 miles. Food pathway calculations are not made for sectors in which the offsite regions near the station are over bodies of water.

A.1.4.3.1 Vegetation Ingestion Pathway Dose Factor
The dose factor for consumption of vegetables is calculated by the following expression:

$$R_{ai(Veg)j}[D/Q] = K'\left[\frac{(r)}{Y_v(\lambda_i+\lambda_w)}\right](DFL_{aij})\left[U_a^L f_L e^{-\lambda_i t_L} + U_a^S f_g e^{-\lambda_i t_h}\right] \qquad \textbf{(A-10)}$$

$R_{ai(Veg)j}[D/Q]$	Vegetation Ingestion Pathway Dose Factor	[(m^2 mrem/yr)/(µCi/sec)]
	Site-specific vegetation ingestion dose factor for age group **a**, nuclide **i** and organ **j**. With the exception of H-3, the vegetation dose is calculated using (D/Q).	
K'	Conversion Constant (1E6 pCi per µCi)	[pCi/µCi]
r	Vegetation Retention Factor	dimensionless
Y_v	Agricultural Productivity Yield	[kg/ m^2]
λ_i	Radiological Decay Constant	[1/sec]
	Radiological decay constant for radionuclide **i**. See Table C-7 of Appendix C.	
λ_w	Weathering Decay Constant	[1/sec]
	Removal constant for physical loss of activity by weathering. See Table C-1 of Appendix C.	
DFL_{aij}	Ingestion Dose Conversion Factor	[mrem/pCi]
	Ingestion dose conversion factor for age group **a**, nuclide **i** and organ **j**. Converts pCi ingested to mrem. Taken from Tables E-11 though E-14 of	

	Regulatory Guide 1.109. The value for H-3 is taken from NUREG 4013 (Reference 107).	
U_a^L	Consumption Rate for Fresh Leafy Vegetation	[kg/yr]
	Consumption rate for fresh leafy vegetation for age group **a**.	
U_a^S	Consumption Rate for Stored Vegetation	[kg/yr]
	Consumption rate for stored vegetation for age group **a**.	
f_L	Local Leafy Vegetation Fraction	dimensionless
	Fraction of the annual intake of fresh leafy vegetation which is grown locally.	
f_g	Local Stored Vegetation Fraction	dimensionless
	Fraction of the annual intake of stored vegetation which is grown locally.	
t_L	Environmental Transport Time - Fresh Vegetation	[sec]
	Average time between harvest of leafy vegetation and its consumption.	
t_h	Environmental Transport Time - Stored Vegetation	[sec]
	Average time between harvest of stored vegetation and its consumption.	

The tritium dose from the vegetation pathway must be considered separately as the transport mechanism is based on airborne concentration rather than ground deposition. The dose factor for the tritium vegetation pathway is:

$$R_{a(H-3)(Veg)j}[\chi/Q] = K'K'''\left(U_a^L f_L + U_a^S f_g\right) DFL_{a(H-3)j}[0.75(0.5/H)] \quad \textbf{(A-11)}$$

$R_{a(H-3)(Veg)j}[\chi/Q]$	Tritium Vegetation Ingestion Pathway Dose Factor	[(mrem/yr)/(μCi/m^3)]
	Site-specific tritium vegetation ingestion dose factor for age group **a** and organ **j**. The tritium vegetation dose is calculated using χ/Q.	
K'''	Conversion Constant (1E3 gm per Kg)	[gm/Kg]
H	Absolute Atmospheric Humidity	[gm/m^3]
0.75	Water Fraction	dimensionless
	The fraction of total vegetation that is water.	
0.5	Specific Activity Ratio	dimensionless

A.1.4.3.2 Milk Ingestion Pathway Dose Factor

The dose factor for consumption of milk is calculated by the following expressions:

$$R_{ai(Milk)j}[D/Q] = K' \frac{Q_F(U_{am})}{\lambda_i + \lambda_w} F_m(r)(DFL_{aij}) \left[\frac{f_p f_s}{Y_p} + \frac{(1 - f_p f_s) e^{-\lambda_i t_h}}{Y_s} \right] e^{-\lambda_i t_f} \quad \text{(A-12)}$$

$R_{ai(Milk)j}[D/Q]$	Milk Ingestion Pathway Dose Factor	[(m^2 mrem/yr)/(μCi/sec)]
	Site-specific milk ingestion dose factor for age group **a**, nuclide **i** and organ **j**. With the exception of H-3, the milk dose factor is calculated using (D/Q).	
K'	Conversion Constant (1E6 pCi per μCi)	[pCi/μCi]
Q_F	Feed Consumption	[Kg/da]
	Amount of feed consumed by milk animal each day. See Table C-1 of Appendix C.	
U_{am}	Milk Consumption Rate	[l/yr]
	Milk consumption rate for age group **a**.	
F_m	Stable Element Transfer Coefficient for Milk	[da/l]
	Fraction of animal's daily intake of a particular chemical element which appears in each liter of milk (pCi/l in milk per pCi/da ingested by animal). See Table C-3 of Appendix C.	
f_p	Pasture Time Fraction	dimensionless
	Fraction of year that animal is on pasture.	
f_s	Pasture Grass Fraction	dimensionless
	Fraction of animal feed that is pasture grass while animal is on pasture.	
Y_P	Agricultural Productivity Yield - Pasture Grass	[kg/m^2]
	The agricultural productivity by unit area of pasture feed grass.	
Y_S	Agricultural Productivity Yield - Stored Feed	[kg/m^2]
	The agricultural productivity by unit area of stored feed.	
t_h	Environmental Transport Time - Stored Feed	[sec]
	Average time between harvest to consumption of stored feed by milk animal.	

t_f	Environmental Transport Time - Pasture to Consumption	[sec]
	Average time from pasture, to milk animal, to milk, to consumption.	

All other terms have been previously defined.

The tritium dose from the milk pathway must be considered separately as the transport mechanism is based on airborne concentration rather than ground deposition. The dose factor for the tritium milk pathway is:

$$R_{a(H-3)(Milk)j}[\chi/Q] = K'K'''F_m\, Q_F U_{am} DFL_{a(H-3)j}[0.75(0.5/H)] \tag{A-13}$$

$R_{a(H-3)(Milk)j}[\chi/Q]$	Tritium Milk Ingestion Pathway Dose Factor	[(mrem/yr)/(μCi/m^3)]
	Site-specific tritium milk ingestion dose factor for age group **a** and organ **j**. The tritium milk dose is calculated using χ/Q.	
K'''	Conversion Constant (1E3 gm per Kg)	[gm/Kg]
H	Absolute Atmospheric Humidity	[gm/m^3]
0.75	Water Fraction	dimensionless
	The fraction of total vegetation that is water.	
0.5	Specific Activity Ratio	dimensionless

All other terms have been previously defined.

A.1.4.3.3 Meat

The dose factor for consumption of meat is calculated by the following expression:

$$R_{ai(Meat)j}[D/Q] = K'\frac{Q_F(U_{af})}{\lambda_i+\lambda_w}F_f(r)(DFL_{aij})\left[\frac{f_pf_s}{Y_p}+\frac{(1-f_pf_s)e^{-\lambda_i t_h}}{Y_s}\right]e^{-\lambda_i t_f} \tag{A-14}$$

$R_{ai(Meat)j}[D/Q]$	Meat Ingestion Pathway Dose Factor	[(m^2 mrem/yr)/(μCi/sec)]
	Site-specific meat ingestion dose factor for age group **a**, nuclide **i** and organ **j**. With the exception of H-3, the meat dose factor is calculated using (D/Q).	
U_{af}	Meat Consumption Rate	[l/yr]
	Meat consumption rate for age group **a**.	
F_f	Stable Element Transfer Coefficient for Meat	[da/Kg]
	Fraction of animal's daily intake of a particular chemical element which appears in each liter of meat (pCi/Kg in meat per pCi/da ingested by animal). See Table C-3 of Appendix C.	

t_h	Environmental Transport Time - Stored Feed	[sec]
	Average time between harvest to consumption of stored feed by meat animal.	
t_f	Environmental Transport Time - Pasture to Consumption	[sec]
	Average time from pasture, to meat animal, to meat, to consumption.	

All other terms have been previously defined.

The tritium dose from the meat pathway must be considered separately as the transport mechanism is based on airborne concentration rather than ground deposition. The dose factor for the tritium meat pathway is:

$$R_{a(H-3)(Meat)j}[\chi/Q] = K'K'''F_f\,Q_F U_{af} DFL_{a(H-3)j}[0.75(0.5/H)] \qquad \textbf{(A-15)}$$

$R_{a(H-3)(Meat)j}[\chi/Q]$	Tritium Meat Ingestion Pathway Dose Factor	[(mrem/yr)/(μCi/m^3)]
	Site-specific tritium meat ingestion dose factor for age group **a** and organ **j**. The tritium meat dose is calculated using χ/Q.	
K'''	Conversion Constant (1E3 gm per Kg)	[gm/Kg]
H	Absolute Atmospheric Humidity	[gm/m^3]
0.75	Water Fraction	dimensionless
	The fraction of total vegetation that is water.	
0.5	Specific Activity Ratio	dimensionless

All other terms have been previously defined.

A.1.5 Dose Rate Due to Non-Noble Gas Radionuclides

Requirement
RETS limit the dose rate to any organ, due to radioactive materials in gaseous effluents released from a site to areas at and beyond the site boundary, to less than or equal to a dose rate of 1500 mrem/yr (see Section 12.4 of Zion*Solutions*' RETS and Technical Specifications).

Typically the child is considered to be the limiting receptor in calculating dose rate to organs due to inhalation of non-noble gas radionuclides in gaseous effluents.

Equation
The dose rate to any child organ due to inhalation is calculated by the following expression:

$$\dot{D}^{NNG}_{(Child)i(Inhal)j} = \sum_i R_{(Child)i(Inhal)j}\left\{(\chi/Q)_s Q_{is} + (\chi/Q)_v Q_{iv} + (\chi/Q)_g Q_{ig}\right\} \qquad \textbf{(A-16)}$$

The summation is over non-noble gas radionuclides **i**.

$\dot{D}^{NNG}_{(Child)i(Inhal)j}$	Inhalation Dose Rate	[mrem/yr]
	Dose rate to the child age group from radionuclide **i**, via the inhalation pathway to organ **j** due to non-noble gas radionuclides.	
$R_{(Child)i(Inhal)j}$	Inhalation Dose Factor	[(mrem/yr)/(μCi/m^3)]
	Inhalation dose factor for child age group for radionuclide **i**, and organ **j**. This dose factor is defined by Equation A-9.	
Q_{is}, Q_{iv}, Q_{ig}	Radionuclide Release Rate	[μCi/sec]
	Measured release rate of radionuclide **i** from a stack, vent, or ground level release point, respectively.	

All other terms have been previously defined.

Application
RETS require the dose rate due to non-noble gas radioactive materials in airborne effluents be determined to be within the above limit in accordance with a sampling and analysis program specified in the RETS (see Section 12.4 of Zion*Solutions*' RETS and Technical Specifications).

To comply with this specification, Zion*Solutions*' obtains and analyzes samples in accordance with the sampling and analysis program in its RETS. The child organ dose rate due to inhalation is calculated in each sector at the location of the highest offsite χ/Q. The result for the sector with the highest organ inhalation dose rate is compared to the limit.

A.1.6 Operability and Use of Gaseous Effluent Treatment Systems

Requirement
10CFR50 Appendix I and the station RETS require that the ventilation exhaust treatment system and the waste gas holdup system be used when projected offsite doses in 31 days, due to gaseous effluent releases, from each reactor unit, exceed any of the following limits:

- 0.2 mrad to air from gamma radiation.
- 0.4 mrad to air from beta radiation.
- 0.3 mrem to any organ of a member of the public.

Zion*Solutions*' is required to project doses due to gaseous releases from the site at least once per 31 days.

Equation
Offsite doses due to projected releases of radioactive materials in gaseous effluents are calculated using Equations A-1, A-2 and A-7. Projected cumulative radionuclide releases are used in place of measured cumulative releases A_{is}, A_{iv} and A_{ig}.

Application

For a release attributable to a processing or effluent system shared by more than one reactor unit, the dose due to an individual unit is obtained by proportioning the effluents among the units sharing the system. The allocation procedure is specified in Chapter 10 of this manual.

A.2 LIQUID RELEASES

A.2.1 Dose

Requirement
The design objectives of 10CFR50, Appendix I and RETS provide the following limits on the dose to a member of the public from radioactive materials in liquid effluents released from each reactor unit to restricted area boundaries:

- During any calendar quarter, less than or equal to 1.5 mrem to the total body and less than or equal to 5 mrem to any organ.
- During any calendar year, less than or equal to 3 mrem to the total body and less than or equal to 10 mrem to any organ.

The organ doses due to radioactivity in liquid effluents are also used as part of the 40CFR190 compliance and are included in the combination of doses to determine the total dose used to demonstrate 10CFR20 compliance. (See Section A.4)

Dose assessments for 10CFR50 Appendix I compliance are made for four age groups (adult/teenager/child/infant) using NUREG 0133 (Reference 14) methodology and Regulatory Guide 1.109 (Reference 6) dose conversion factors.

Equation
The dose from radioactive materials in liquid effluents considers the contributions for consumption of fish and potable water. All of these pathways are considered in the dose assessment unless demonstrated not to be present. While the adult is normally considered the maximum individual, the methodology provides for dose to be calculated for all four age groups. The dose to each organ (and to the total body) is calculated by the following expression:

$$\mathbf{D_{aj}^{Liq} = F\,\Delta t \sum_{p}\sum_{i} A_{aipj} C_i} \quad \textbf{(A-17)}$$

The summation is over exposure pathways **p** and radionuclides **i**.

$\mathbf{D_{aj}^{Liq}}$	Organ and Total Body Dose Due to Liquid Effluents	[mrem]
	Dose to organ **j** (including total body) of age group **a** due to radioactivity in liquid effluents.	
F	Near Field Average Dilution Factor	dimensionless
	Dilution in the near field averaged over the period of interest. Defined as:	

$$\mathbf{F = \frac{Waste\ Flow}{Dilution\ Flow \times Z}} \quad \textbf{(A-18)}$$

Waste Flow	Liquid Radioactive Waste Flow	[gpm]
	The average flow during disposal from the discharge structure release point into the receiving water body.	
Dilution Flow	Dilution Water Flow During Period of Interest	[gpm]

Z Discharge Structure Mixing Factor — dimensionless

Site-specific factor to account for the mixing effect of the discharge structure. The factor addresses the dilution which occurs in the near field between the discharge structure and the body of water containing the fish in the liquid ingestion pathway. From Table F-1, Appendix F.

Δt Duration of Release — [hrs]

C_i Average Radionuclide Concentration — [µCi/ml]

Average concentration of radionuclide **i**, in the undiluted liquid effluent during time period Δt.

A_{aipj} Site-Specific Liquid Dose Factor — [(mrem/hr)/(µCi/ml)]

Site-specific dose factor for age group **a**, nuclide **i**, liquid pathway **p** and organ **j**. The pathways included are potable water and fish ingestion. A_{aipj} is defined for these pathways in the following sections. Values for A_{aipj} are provided in Appendix F.

A 2.1.1 Potable Water Pathway

The site-specific potable water pathway dose factor is calculated by the following expression:

$$A_{ai(PW)j} = k_o \left\{ \frac{U_a^w}{D^w} \right\} DFL_{aij} \qquad \textbf{(A-19)}$$

Where:

$A_{ai(PW)j}$ Site-Specific Dose Factor for Potable Water Pathway — [(mrem/hr)/(µCi/ml)]

Site-specific potable water ingestion dose factor for age group **a**, nuclide **i** and organ **j**.

k_o Conversion Constant (1.14E05) — [(yr-pCi-ml)/(hr-µCi-l)]

Units constant to convert years to hours, pCi to µCi and liters to ml.

U_a^w Potable Water Consumption Rate — [l/yr]

Potable water consumption rate for age group **a**. Taken from Table E-5 of Regulatory Guide 1.109.

D^w Potable Water Dilution Factor — dimensionless

Dilution factor from the near field area within one-quarter mile of the release point to the potable water intake. From Table F-1, Appendix F.

DFL_{aij} Ingestion Dose Conversion Factor — [mrem/pCi]

Ingestion dose conversion factor for age group **a**, nuclide **i** and organ **j**. Converts pCi ingested to mrem. Taken from Tables E-11 though E-14 of

Regulatory Guide 1.109. The value for H-3 is taken from NUREG 4013 (Reference 107).

A.2.1.2 Fish Ingestion Pathway

The site-specific fish ingestion pathway dose factor is calculated by the following expression:

$$A_{ai(Fish)j} = k_o U_a^F BF_i DFL_{aij} \quad \text{(A-20)}$$

Where:

$A_{ai(Fish)j}$	Site-Specific Dose Factor for Potable Water Pathway Site-specific fish ingestion dose factor for age group **a**, nuclide **i** and organ **j**.	[(mrem/hr)/(μCi/ml)]
U_a^F	Fish Consumption Rate Fish consumption rate for age group **a**. Taken from Table E-5 of Regulatory Guide 1.109.	[kg/yr]
BF_i	Bioaccumulation Factor Bioaccumulation factor for nuclide **i** in fresh water fish. Taken from Table C-8 of Appendix C.	[(pCi/kg)/(pCi/l)]

All other terms have been previously defined.

Application
RETS require determination of cumulative and projected dose contributions from liquid effluents for the current calendar quarter and the current calendar year at least once per 31 days. (see Section 12.3 of Zion*Solutions*' RETS and/or Technical Specifications).

For a release attributable to a processing or effluent system shared by more than one reactor unit, the dose due to an individual unit is obtained by proportioning the effluents among the units sharing the system. The allocation procedure is specified in ODCM Chapter 10.

A.2.2 Liquid Effluent Concentrations Requirement

Requirement
One method of demonstrating compliance to the requirements of 10CFR20.1301 is to demonstrate that the annual average concentrations of radioactive material released in gaseous and liquid effluents do not exceed the values specified in 10CFR20 Appendix B, Table 2, Column 2. (See 10CFR 20.1302(b)(2).) However, as noted in Section A.5.1, this mode of 10CFR20.1301 compliance has not been elected.

As a means of assuring that annual concentration limits will not be exceeded, and as a matter of policy assuring that doses by the liquid pathway will be ALARA; RETS provides the following restriction:

"The concentration of radioactive material released in liquid effluents to unrestricted areas shall be limited to ten times the concentration values in Appendix B, Table 2, Column 2 to 10CFR20.1001-20.2402."

This also meets the requirement of Station Technical Specifications and RETS.

Equation

According to the footnotes to 10CFR20 Appendix B, Table 2, Column 2, if a radionuclide mix of known composition is released, the concentrations must be such that

$$\sum_i \left(\frac{C_i}{10\,ECL_i} \right) \leq 1 \qquad \textbf{(A-21)}$$

where the summation is over radionuclide **i**.

C_i	Radioactivity Concentration in Liquid Effluents to the Unrestricted Area	[μCi/ml]
	Concentration of radionuclide **i** in liquid released to the unrestricted area.	
ECL_i	Effluent Concentration Limit in Liquid Effluents Released to the Unrestricted Area	[μCi/ml]
	The allowable annual average concentration of radionuclide **i** in liquid effluents released to the unrestricted area. This concentration is specified in 10CFR20 Appendix B, Table 2; Column 2. Concentrations for noble gases are different and are specified in the stations' Technical Specifications/RETS.	
10	Multiplier to meet the requirements of Technical Specifications.	

If either the identity or concentration of any radionuclide in the mixture is not known, special rules apply. These are given in the footnotes in 10CFR20 Appendix B, Table 2, Column 2.

Application

The RETS and Technical Specifications require a specified sampling and analysis program to assure that liquid radioactivity concentrations at the point of release are maintained within the required limits.

To comply with this provision, Zion*Solutions*' obtains and analyzes samples in accordance with the radioactive liquid waste (or effluent) sampling and analysis program in its RETS. Radioactivity concentrations in tank effluents are determined in accordance with Equation A-22 in the next section. Comparison with the Effluent Concentration Limit is made using Equation A-21.

A.2.3 Tank Discharges

When radioactivity is released to the unrestricted area with liquid discharge from a tank (e.g., a radwaste discharge tank), the concentration of a radionuclide in the effluent is calculated as follows:

$$C_i = C_i^t \frac{\textbf{Waste Flow}}{\textbf{Dilution Flow}} \qquad \textbf{(A-22)}$$

C_i	Concentration in Liquid effluent to the unrestricted area.	[μCi/ml]
	Concentration of radionuclide **i** in liquid released to the unrestricted area.	
C_i^t	Concentration in the Discharge Tank	[μCi/ml]
	Measured concentration of radionuclide **i** in the discharge tank.	

All other terms have been previously defined.

A.2.4 Tank Overflow

Requirement
To limit the consequences of tank overflow, the quantity of radioactivity that may be stored in unprotected outdoor tanks is limited. Unprotected tanks are tanks that are not surrounded by liners, dikes, or walls capable of holding the tank contents and that do not have tank overflows and surrounding area drains connected to the liquid radwaste treatment system. The specific objective is to provide assurance that in the event of an uncontrolled release of a tank's contents, the resulting radioactivity concentrations beyond the unrestricted area boundary, at the nearest potable water supply and at the nearest surface water supply, will be less than the limits of 10CFR20 Appendix B, Table 2, Column 2.

Application
Table F-1 of Appendix F provides information on the limits for Zion Station.

A.2.5 Operability and Use of the Liquid Radwaste Treatment System

Requirement
The design objectives of 10CFR50, Appendix I and RETS/Technical Specifications require that the liquid radwaste treatment system be operable and that appropriate portions be used to reduce releases of radioactivity when projected doses due to the liquid effluent from each reactor unit to restricted area boundaries exceed either of the following (see Section 12.3 of Zion*Solutions*' RETS or Technical Specifications);

- 0.06 mrem to the total body in a 31 day period.
- 0.2 mrem to any organ in a 31 day period.

Equation
Offsite doses due to projected releases of radioactive materials in liquid effluents are calculated using Equation A-17. Projected radionuclide release concentrations are used in place of measured concentrations, C_i.

A.2.6 Drinking Water

Zion*Solutions*' has requirements for calculation of drinking water dose that are related to 40CFR141, the Environmental Protection Agency National Primary Drinking Water Regulations. These are discussed in Section A.6.

A.2.7 Non-routine Liquid Release Pathways

Cases in which normally non-radioactive liquid streams (such as the Service Water) are found to contain radioactive material are non-routine will be treated on a case specific basis if and when this occurs. Since Zion Station has sufficient capacity to delay a liquid release for reasonable periods of time, it is expected that planned releases will not take place under these circumstances. Therefore, the liquid release setpoint calculations need not and do not contain provisions for treating multiple simultaneous release pathways.

A.3 DOSE DUE TO CONTAINED SOURCES

There are multiple types of contained sources of radioactivity which contribute to Zion*Solutions*' offsite radiological dose assessments. When the ISFSI if fully loaded it will contain 61 Vertical Concrete Casks (VCCs) containing Spent Nuclear Fuel and 4 VCCs containing Greater Than Class C (GTCC) Waste. The GTCC waste is composed primarily of reactor internals segments from both Unit 1 and Unit 2. There is a waste staging area in the Southern region of the Radiological Restricted Area for 8-120 liners containing Waste Class A, B and C.

This waste is composed primarily of reactor internals segments from both Unit 1 and 2. These 8-120s are stored inside of concrete Rad Vaults then surrounded by several feet of soil above ground level. At various times throughout D&D, there will be various rail cars, Intermodals, Sealands, and various other waste containers staged onsite prior to shipment to a disposal facility. All of these various sources contribute to offsite dose from both directly emitted radiations and radiations due to skyshine from directly emitted radiations.

A.3.1 Dose from Onsite Radioactive Waste Storage

Low-level radioactive waste may be stored at Zion in the following types of containers and storage areas:

- Concrete vaults
- Butler buildings/warehouses
- Shipping containers while awaiting shipment
- Independent Spent Fuel Storage Installation (ISFSI) Facilities

The dose rates resulting from these containers and storage areas will be monitored frequently as they are being utilized, and if necessary, a dose calculation performed to assess projected dose rates from such containers and storage areas. Dose calculations shall be documented in site specific Technical Support Documents and referenced in the ODCM.

A.4 Total Dose Limits (10CFR20, 10CFR72 and 40CFR190)

The regulatory requirements of 10CFR20, 10CFR72 and 40CFR190 each limit total dose to individual members of the public without regard to specific pathways. The only significant exposure pathways for light water reactors included in 10CFR20, 10CFR72 and 40CFR190 not addressed by 10CFR50 Appendix I are the direct radiation pathway and exposure from on-site activity by members of the public. Sections A.1 and A.2 considered organ doses from the gaseous and liquid effluent streams for purposes of compliance with 10CFR50 Appendix I. Section A.3 addresses the direct radiation component that must be considered for 10CFR20, 10CFR72 and 40CFR190 compliance. The following sections will describe the methodology of assessing direct radiation dose and then the manner in which the various doses are combined to obtain the appropriate "total" for regulatory compliance purposes.

Although annual dose limits in 10CFR20 are now expressed in terms of Total Effective Dose Equivalent (TEDE) 40CFR190 limits are still stated as organ dose. The NRC continues to require 10CFR50 Appendix I, 10CFR72 and 40CFR190 doses to be reported in terms of organ dose. Due to the fact that organ dose limits set forth in 40CFR190 are substantially lower than those of 10CFR20 (25 mrem/yr vs 100 mrem/yr), the NRC has stated that demonstration of compliance with the dose limits in 40CFR190 will be deemed as demonstration of compliance with the dose limits of 10CFR20 for most facilities (Reference 104). In addition to compliance with 40CFR190 it may be necessary for a nuclear power plant to address dose from on-site activity by members of the public.

A.4.1 External Total Body Dose

The external total body dose is comprised of the following parts:

1) Total body dose due to noble gas radionuclides in gaseous effluents (Section A.1.2),
2) Dose due to radioactive waste and the ISFSI (Section A.3.1) and
3) Total body dose due to radioactivity deposited on the ground (Section A.1.4.1).

The external total body dose due to radioactivity deposited on the ground is accounted for in the determination of the non-noble gas dose (See Equations A-7 and A-8) and is not considered here.

The total external total body dose, D^{Ex}, is given by:

$$D^{Ex} = D^{TB} + D^{OSF} \quad \textbf{(A-23)}$$

D^{Ex}	Total External Total Body Dose	[mrem]
	Total external total body dose due to irradiation by external sources at the location of interest.	
D^{TB}	Noble Gas Total Body Dose	[mrem]
	External total body dose due to gamma radiation from noble gas radionuclides released in gaseous effluents at the location of interest. See Equation A-3.	
D^{OSF}	Dose From On-Site Storage Facilities	[mrem]
	External total body dose due to gamma radiation from on-site storage facilities at the location of interest. See Section A.3.1.	

A.4.2 Total Dose

The total dose, D^{Tot}, in the unrestricted area to a member of the public due to plant operations is given by:

$$D^{Tot} = D^{Ex} + D^{Liq}_{aj} + D^{NNG}_{aj} \quad \textbf{(A-24)}$$

where:

D^{Tot}	Total Dose To Member of Public	[mrem]
	Total off-site dose to a member of public due to plant operations.	
D^{Ex}	Total External Total Body Dose	[mrem]
	Total body dose due to external exposure to noble gases and on-site radioactive waste storage.	
D^{Liq}_{aj}	Liquid Effluent Dose	[mrem]
	Dose due to liquid effluents to age group **a** and organ **j**. The age group and organ with the highest dose from liquid effluents is used.	
D^{NNG}_{aj}	Non-Noble Gaseous Effluent Dose	[mrem]
	Dose due to non-noble gaseous effluents to age group **a** and organ **j**. The age group and organ with the highest dose from non-noble gas effluents is used.	

A.5 COMPLIANCE TO TOTAL DOSE LIMITS

A.5.1 Total Effective Dose Equivalent Limit - 10CFR20 Compliance

Requirement
Zion*Solutions*' RETS limits the Total Effective Dose Equivalent (TEDE) to an annual limit of 100 mrem, as required by 10CFR20.1301 (a)(1). Demonstration of compliance with the limits of 40CFR190 (per Section 4.5.2) will be considered to demonstrate compliance with the 100 mrem/year limit.

A.5.1.1 Dose to a Member of the Public in the Unrestricted Area

The NRC has stated that demonstration of compliance with the limits of 40CFR190 or with the design objectives of Appendix I to 10CFR50 will be deemed to demonstrate compliance with the limits of 10CFR20.1301(a)(1). Power reactors that comply with 10CFR50 Appendix I may also have to demonstrate that they are within the 25 mrem limit of 40CFR190 (See Reference 104). Zion Station ISFSI pad operations are required to demonstrate compliance with 10CFR72.104 limits.

A.5.1.2. Dose to a Member of the Public in the Restricted Area

In August of 1995, a revision to 10CFR20 was implemented that changed the definition of a member of the public. NUREG/CR-5569, "Health Physics Positions Database" Question 26(a) clarifies dose to a member of the public while inside the Restricted Area. "By definition, and with the exceptions given in the definitions of "occupational dose", any dose received by any individual in a "restricted area" is an "occupational dose." No one in a restricted area is a "member of the public.""

Non-trained radiation workers are administratively restricted to less than 160 total hours on site property per year.

Application
Evaluation of the 40CFR190 dose is used to demonstrate compliance to 10CFR20, 10CFR72 and satisfy station RETS and Technical Specifications (see Chapter 12).

A.5.2 Total Dose due to the Uranium Fuel Cycle (40CFR190)

Requirement

RETS, 40CFR190 and 10CFR72.104 limit the annual (calendar year) dose or dose commitment to any member of the public due to releases of radioactivity and to radiation from uranium fuel cycle sources to the following:

- Less than or equal to 25 mrem to the total body.
- Less than or equal to 25 mrem to any organ except the thyroid.
- Less than or equal to 75 mrem to the thyroid.

Total Dose Components
This requirement includes the total dose from operations at the nuclear power station. This includes doses due to radioactive effluents (airborne and liquid) and dose due to direct radiation from non-effluent sources (e.g., sources contained in systems on site such as the ISFSI).

The operations comprising the uranium fuel cycle are specified in 40CFR190.02(b). The following are included to the extent that they directly support the production of electrical power for public use utilizing nuclear energy:

- Milling of uranium ore.
- Chemical conversion of uranium.

- Isotopic enrichment of uranium.
- Fabrication of uranium fuel.
- Generation of electricity by a light-watered-cooled nuclear power plant using uranium fuel.
- Reprocessing of spent uranium fuel.

Excluded are:

- Mining operations.
- Operations at waste disposal sites.
- Transportation of any radioactive material in support of these operations.
- The re-use of recovered non-uranium special nuclear and by-product materials from the cycle.

The different methods of Decommissioning, SAFSTOR, ENTOMB and DECON, are not mentioned in 40CFR190. Zion was previously a light-water-cooled nuclear power plant that used uranium fuel to generate electricity, therefore, 40CFR190 is applied to the different methods of Decommissioning at Zion.

When Compliance Assessment is Required

Compliance with the 40CFR190 regulations is now required as part of demonstration of compliance to 10CFR20 regulations per 10CFR20.1301(d), and 10CFR72 regulations per 10CFR72.104.

Equation

The dose due to the uranium fuel cycle is determined by equation A-24.

A.5.3 Summary of Compliance Methodology

The required compliance is given in Tables 2-1, 2-2 and 2-3. In Table 2-1, the dose components are itemized and referenced, and an indication of their regulatory application is noted. A more detailed compliance matrix is given in Table 2-3. The locations of dose receivers for each dose component are given in Table 2-2.

Further, Table 2-2 states the location of the receiver and occupancy factors, if applicable. In general, the receiver spends time in locations that result in maximum direct dose exposure and inhales and ingests radioactivity from sites that yield maximum pathway doses. Thus, the dose calculated is a very conservative one compared to the "average" receiver who does not go out of his way to maximize radioactivity uptakes. Occupancy as a habit of a "real individual" is applied to doses received from contained sources. Finally, the connection between regulations, the ODCM equations and the station RETS and Technical Specifications is given in Table 12-0.

ISFSI

10CFR72.104 dose limits are the same as those specified by 40CFR190. ISFSI dose contribution is in the form of direct radiation as no liquid or gas releases are expected to occur. The report prepared in accordance with 10CFR72.212 requirements assumes a certain array of vertical concrete casks exists on the ISFSI. The dose contribution from this array of casks was analyzed to be within the 40CFR190 and 10CFR72.104 limits, and is documented in NAC International Calculation 630073-5501 ZION Site Boundary Skyshine Evaluation, Zion Technical Support Document TSD 13-008 "Evaluation of Independent Spent Fuel Storage Installation and Associated processes Dose Rates" and TSD 13-009 "Member of the Public Dose From All Onsite Sources".

If the dose limits of 40CFR190 or 10CFR72.104 are exceeded, a special report to the NRC as well as an appropriate request for exemption/variance is required to be submitted to the NRC.

The requirement that the dose limits of 10CFR72.104 apply to any "real individual" is controlled for ISFSI activities in the ISFSI 72.212 report. Therefore, for the purposes of analyzing dose from the ISFSI, the member of the public as defined in 40CFR190 is the same as the "real individual" identified in the ES&H TSD 13-008 "Evaluation of Independent Spent Fuel Storage Installation and Associated processes Dose Rates" and TSD 13-009 "Member of the Public Dose From All Onsite Sources".

A.6 DOSE DUE TO DRINKING WATER (40CFR141)

The National Primary Drinking Water Regulations, 40CFR141, contain the requirements of the Environmental Protection Agency applicable to public water systems. Included are limits on radioactivity concentration. Although these regulations are directed at the owners and operators of public water systems, Zion Station has requirements in their Technical Specifications related to 40CFR141.

A.6.1 40CFR141 Restrictions on Manmade Radionuclides

Section 141.16 states the following (not verbatim):

(a) The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year.

(b) Except for the radionuclides listed in Table A-0, the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of drinking 2 liter of water per day. (Using the 168 hour data listed in "Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, "NBSHandbook 69 as amended August 1963, U.S. Department of Commerce.). If two or more radionuclides are present, the sum of their annual dose equivalents to the total body or any organ shall not exceed 4 millirem/year.

TABLE A-0

AVERAGE ANNUAL CONCENTRATIONS ASSUMED TO
PRODUCE A TOTAL BODY OR ORGAN DOSE OF 4 MREM/YR

Radionuclide	Critical Organ	pCi/Liter
Tritium	Total Body	20,000
Strontium-90	Bone Marrow	8

A.6.2 Application

The projection or calculation of dose due to the drinking water pathway is made using Equations A-17 and A-19. Projections are made using projected radionuclide releases in place of measured releases A_i. Doses calculated using Equations A-17 and A-19 may differ from doses determined by the methodology prescribed in 40CFR141.16.

When required, Zion Station prepares a special report on radiological impact at the nearest community water system. This system is taken as the one listed in Table A-3 of this appendix. The report should include the following:

- The doses calculated by Equations A-17 and A-19.
- A statement identifying the dose calculation methodology (e.g., a reference to this manual).
- A statement that the doses calculated by the ODCM methodology are not necessarily the same as doses calculated by the methodology prescribed in 40CFR141.16.
- The data used to calculate the doses. This information includes the amounts of radioactivity released and the flow rate and dilution values used (see Table F-1). This information is provided to assist the operator of the community water system in performing its own dose assessment.

Table A-1

COMPLIANCE MATRIX

Regulation	Dose to be compared to limit
10CFR50 Appendix I	• Gamma air dose and beta air dose due to airborne radioactivity in effluent plume. • Total body and skin dose due to airborne radioactivity in effluent plume are reported only if certain gamma and beta air dose criteria are exceeded. • Dose for all organs and all four age groups due to particulate in effluent plume. Existing pathways are considered. • Dose for all organs and all four age groups due to radioactivity in liquid effluents.
10CFR20	• Adherence determined by compliance with dose limits of 40CFR190.
40CFR190	• Total body dose due to direct radiation, ground and plume exposure from all sources at a station. • Organ doses to an adult due to all pathways.
RETS/ODCM	• "Instantaneous" noble gas total body and skin dose rates and tritium and particulate inhalation dose rates to a child due to radioactivity in airborne effluents. • "Instantaneous" concentration limits for liquid effluents.
10CFR72.104(a)	• During normal operations and anticipated occurrences.

Table A-2

Release Point Classifications

Station	Release Point	Release Point Classification[a]
Zion 1 & 2	Vent Stacks	Ground Level

[a]The definitions of release point classifications (stack, vent and ground level) are given in Section 4.1.4.

Table A-3

Nearest Downstream Community Water Systems

Station	Characteristics of Nearest Affected Downstream Community Water Supply: Location and Distance[a]
Zion	Lake County Intake, 1.4 miles

[a] Appendix O Table O-2 provides the basis of the location and distance data.

Table A-4

40CFR190, 10CFR72.104(a) Compliance

40CFR190 Dose 10CFR72.104(a) Dose	Annual Limit (mrem)	ODCM Dose and Equation Number
Total Body	25	Total Body Dose; A-24 evaluated for total body
Thyroid	75	Thyroid Dose; A-24 evaluated for thyroid
Other Organs	25	Organ Dose; A-24 evaluated for all organs except thyroid

Notes:

1. The evaluation is made considering the following sources:
   a. Radioactivity in contained sources within the station;
   b. Radioactivity in station gaseous and liquid effluents;

APPENDIX B

MODELS AND PARAMETERS FOR AIRBORNE AND LIQUID EFFLUENT CALCULATIONS

APPENDIX B
MODELS AND PARAMETERS FOR AIRBORNE EFFLUENT CALCULATIONS

B.0 INTRODUCTION

The equations used for calculation of doses due to radioactive airborne effluents are given in Section A.1 of Appendix A. The equations involve the following types of parameters:

- **Meteorological Parameters**
  These include **χ/Q, gamma-χ/Q, D/Q** and wind speed. Their values are based on historical average atmospheric conditions at a site for a selected multi-year historical period (see Section 4.1.5).
- **Dose Factors**
  These parameters are used to provide a simple way to calculate doses and dose rates due to gamma and beta radiation. These parameters are independent of meteorological conditions and therefore generic (i.e., not station-specific).
- **Measured Release Parameters**
  These are measured values of radioactivity releases and release rates.
- **Radiological Decay Constants**
  These are used to account for the radioactive decay between the release of radioactivity to the environment and the exposure of persons to it.
- **Production/Exposure Parameters**
  These are parameters characterizing agricultural production (e.g., length of growing season, transport times) and human exposure patterns (e.g., exposure period, breathing rate, food consumption rates). These parameters affect the quantities of radioactivity to which persons may be exposed.

This appendix discusses the methodology used to determine values of these parameters. Section B.1 addresses how the historical meteorology of a site is characterized by use of a function called the joint frequency distribution. Section B.1 and Sections B.3 through B.5 present equations that use the joint frequency distribution to obtain values for site-specific meteorological parameters. These equations involve a mathematical model of a plume known as the Gaussian plume model. This model is developed in Section B.2. Various generic dose factors are discussed in Sections B.6 through B.10. The other parameters are discussed in the remaining sections.

B.1 METEOROLOGICAL DATA AND PARAMETERS

Predicting where airborne effluent will travel requires information on the following:

- Wind speed
- Wind direction
- Atmospheric turbulence

The greater the atmospheric turbulence, the more an effluent plume will tend to broaden and the more dilute the concentration will be. Atmospheric turbulence is affected by the general condition of the atmosphere (e.g., the vertical temperature distribution) and by local features (e.g., objects that protrude into the wind stream). A commonly used classification scheme for the degree of atmospheric turbulence associated with the general condition of the atmosphere involves seven stability classes:

A Extremely Unstable
B Moderately Unstable
C Slightly Unstable
D Neutral
E Slightly Stable

F Moderately Stable
G Extremely Stable

This classification scheme is based on Reference 5, Table 1. Each class is associated with a particular range of wind direction fluctuations and of vertical temperature gradients in the atmosphere. These are specified in Table C-4 of Appendix C.

B.1.1 Data

Historical atmospheric conditions at Zion Station were recorded by an instrumented meteorological tower that measured wind speed, wind direction, and temperature at various heights. Hourly average values of wind speed, wind direction, and stability class were determined. The difference in temperature between two heights was used to assign an atmospheric stability class based on the correlation between temperature gradient and stability class in Table C-4 of Appendix C.

In obtaining the data, quality assurance checks and corrections were made. Also, corrections were applied to compensate for the limitations of wind sensors at low speeds. A calm was said to exist if the wind speed was less than that of the threshold of either the anemometer (wind speed meter) or the wind direction vane. For calm conditions, a wind speed equal to one-half of the higher threshold was assigned. For each stability class, the wind directions during calm conditions were assumed to be distributed in proportion to the observed wind direction distribution of the lowest non-calm wind speed class.

B.1.2 Joint Frequency Distribution

The data for a particular historical period are summarized by developing a joint frequency distribution (JFD). Each such distribution specifies the fraction of time during the historical period that the following jointly occur:

- Wind speed within a particular range (wind speed class).
- Downwind direction in one of the 16 sectors corresponding to the 16 principal compass directions (N, NNE, etc.).
- Atmospheric conditions corresponding to one of the seven atmospheric stability classes discussed in Section B.1. Table B-1 of this appendix displays a portion of an example JFD.

Different JFDs are associated with the different release classifications defined in Section 4.1.4. One JFD is defined for stack releases, and another JFD is defined for ground level releases. Two JFDs are associated with vent (mixed mode) releases, one for the portion of the time the release is treated as elevated and the other for the portion of the time the release is treated as ground level.

B.1.2.1 Downwind Direction Versus Upwind Direction

Unless otherwise noted, any reference to wind direction in this document represents downwind direction, i.e., the direction in which the wind is blowing toward. This is because the parameters developed in this document are used to calculate radioactivity concentration and radiation dose downwind of a release point. In contrast, it is conventional for meteorologists to provide JFDs based on upwind direction, the direction from which the wind is blowing. For example, the JFDs presented in the annual operating report of Zion Station are obtained from a meteorological contractor and the directions specified in the reports are upwind directions. Users of JFDs should always be careful to ascertain whether the directions specified are upwind or downwind.

B.1.2.2 Stack JFD

For a stack release, the JFD is defined as follows:

$\Sigma f_S(n,\theta,c)$ Joint Frequency Distribution, Stack Release

The fraction of hours during a period of observation that all of the following hold:

- The average wind speed is within wind speed class **n**.
- The downwind direction is within the sector denoted by **θ**.
- The atmospheric stability class is **c**.

This function is defined for application to a stack release point (see Section 4.1.4). Its value is based on hourly average wind data obtained at a height representative of the release point height.

The stack JFD is normalized to 1:

$$\Sigma f_S(n,\theta,c) = 1 \qquad \textbf{(B-25)}$$

The summation is over all wind speed classes **n**, all compass direction sectors **θ**, and all stability classes **c**.

B.1.2.3 Ground Level JFD

For a ground level release, the JFD **$f_g(n, \theta,c)$** is defined in the same way as for a stack release except that the wind data are obtained at a height representative of a ground level release point. This height is taken as about 10 meters.

The ground level JFD is normalized to 1:

$$\Sigma f_g(n,\theta,c) = 1 \qquad \textbf{(B-26)}$$

The summation is over all wind speed classes **n**, all compass direction sectors, and all stability classes **c**.

B.1.2.4 Vent JFDs

In accordance with the approach recommended in Regulatory Guide 1.111 (Reference 7), the plume from a vent release is treated as elevated part of the time and as ground level the rest of the time. Two JFDs are determined:

- **$f_{v,elev}(n,\theta,c)$** characterizes the plume during the part of the time that it is considered elevated;
- **$f_{v,gnd}(n,\theta,c)$** characterizes the plume during the part of the time that it is considered ground level.

Their definitions are as follows:

$f_{v,elev}(n,\theta,c)$ Joint Frequency Distribution, Elevated Portion of a Vent Release

The fraction of hours during a period of observation that the plume is considered elevated and that all of the following hold:

- The average wind speed is within wind speed class **n**.
- The downwind direction is within the sector denoted by **θ**.
- The atmospheric stability class is **c**.

$f_{v,gnd}(n,\theta,c)$ Joint Frequency Distribution,

Ground Level Portion of a Vent Release

The fraction of hours during a period of observation that the plume is considered ground level and that all of the following hold:

- The average wind speed is within wind speed class **n**.
- The downwind direction is within the sector denoted by θ.
- The atmospheric stability class is **c**.

The value of $f_{v,elev}(n, \theta,c)$ is based on hourly average wind data at a height representative of the vent release point. Where the measurement height differed considerably from the release height, wind speed data for the release height was obtained by extrapolation. The value of $f_{v,gnd}(n, \theta,c)$ is based on hourly average wind data obtained at a height representative of a ground level release point. This is taken as about 10 meters.

The sum of these two JFDs is normalized to 1:

$$\Sigma\{ f_{v,elev}(n, \theta,c) + f_{v,gnd}(n, \theta,c) \} = 1 \qquad \textbf{(B-27)}$$

The summation is over all wind speed classes **n**, all compass direction sectors θ, and all stability classes **c**.

The prescription of Regulatory Guide 1.111 is used in determining the fraction of time that the plume is considered elevated and the fraction of time that it is considered ground level. The fractions are obtained from the ratio of stack exit velocity W_o to hourly average wind speed **u** at the height of the vent release point as follows:

· If $W_o/u > 5$, then the plume is considered elevated for the hour.

· If $W_o/u \le 1$, then the plume is considered ground level for the hour.

· If $1 < W_o/u \le 5$, the plume is considered to be a ground level release for a fraction G_t of the hour and an elevated release for a fraction $(1 - G_t)$ of the hour where G_t is defined as follows:

$$G_t = 2.58 - 1.58(W_o/u) \quad \text{for } 1.0 < W_o/u \le 1.5 \qquad \textbf{(B-28)}$$

$$G_t = 0.30 - 0.06(W_o/u) \quad \text{for } 1.5 < W_o/u \le 5.0 \qquad \textbf{(B-29)}$$

B.1.3 Average Wind Speed

Using the joint frequency distribution, average wind speeds are obtained for Zion Station. Values are obtained for each downwind direction (N, NNE, etc.) and for various release point classifications (stack, vent, and ground level).

B.1.3.1 Stack Release

For a stack release, the following formula is used:

$$u_s(\theta) = \Sigma\{ f_s(n, \theta,c)u_n \} / \Sigma\{ f_s(n, \theta,c) \} \qquad \textbf{(B-30)}$$

where the summations are over wind speed classes **n** and stability classes **c**.

$u_s(\theta)$ Average Wind Speed, Stack Release [m/sec]

The average wind speed in downwind direction θ for a stack release.

$\mathbf{u_n}$ Wind Speed for Class **n** [m/sec]

A wind speed representative of wind speed class **n**. For each wind speed class except the highest, $\mathbf{u_n}$ is the average of the upper and lower limits of the wind speed range for the class. For the highest wind speed class, $\mathbf{u_n}$ is the lower limit of the wind speed range for the class.

The parameter $\mathbf{f_s}$ is defined in Section B.1.2.2.

B.1.3.2 Ground Level Release

For a ground level release, the following formula is used:

$$u_g(\theta) = \Sigma\{ f_g(n, \theta,c)u_n \} / \Sigma\{ f_g(n, \theta,c) \} \qquad \textbf{(B-31)}$$

where the summations are over wind speed classes **n** and stability classes **c**.

$\mathbf{u_g(\theta)}$ Average Wind Speed, Ground Level Release [m/sec]
The average wind speed in downwind direction θ for a ground level release.

The parameter $\mathbf{f_g}$ is defined in Section B.1.2.3.

B.1.3.3 Vent Release

For a vent release, the following formula is used:

$$u_v(\theta) = \Sigma \{ [f_{v,elev}(n, \theta,c) + f_{v,gnd}(n, \theta,c)]u_n \} / \Sigma\{ f_{v,elev}(n,\theta,c) + f_{v,gnd}(n,\theta,c) \} \qquad \textbf{(B-32)}$$

where the summations are over wind speed classes **n** and stability classes **c**.

$\mathbf{u_v(\theta)}$ Average Wind Speed, Vent Release [m/sec]

The average wind speed in downwind direction θ for a vent release.

The parameters $\mathbf{f_{v,elev}}$ and $\mathbf{f_{v,gnd}}$ are defined in Section B.1.2.4.

B.2 GAUSSIAN PLUME MODELS

As a plume of airborne effluents moves away from an elevated release point, the plume both broadens and meanders. It has been found that the time-averaged distribution of material in an effluent plume can be well represented mathematically by a Gaussian function.

B.2.1 Mathematical Representation

In a widely used form of the Gaussian plume model, the distribution of radioactivity in a plume is represented mathematically by the equation below:

$$\chi(x,y,z) = [Q/(2\pi\,\sigma_y\,\sigma_z u)]\exp(-y^2/2\sigma^2_y) \times \{\exp[-(z-h_e)^2/2\sigma^2_z] + \exp[-(z+h_e)^2/2\sigma^2_z]\} \qquad \text{(B-33)}$$

χ(x,y,z) Radioactivity Concentration [µCi/m³]

The concentration of radioactivity at point **(x,y,z)**. The **x**, **y**, and **z** axis are defined as follows:

x Downwind Distance [m]

Distance from the stack along an axis parallel to the wind direction.

y Crosswind Distance [m]

Distance from the plume centerline along an axis parallel to the crosswind direction.

z Vertical Distance [m]

Distance from the ground (grade level at the stack) along an axis parallel to the vertical direction.

Q Release Rate [µCi/sec]

Release rate of radioactivity.

σ_y, σ_z Horizontal and Vertical Dispersion Coefficients [m]

Standard deviations of the Gaussian distributions describing the plume cross-sections in the **y** and **z** directions, respectively. The values of σ_y and σ_z depend on several parameters:

- Downwind distance **x**.

  Because a plume broadens and meanders as it travels away from its release point, the values of σ_y and σ_z increase as **x** increases.

- Atmospheric stability class.

The plume is broadest for extremely unstable atmospheric conditions (Class A) and narrowest for extremely stable conditions (Class G).

- Time period of averaging plume concentration.

  The values of σ_y and σ_z increase as the averaging period increases.

u Average Wind Speed [m/sec]

The average wind speed. The average speed of travel of the plume in the **x** direction.

h_e Effective Release Height [m]

The effective height of effluent release above grade elevation. This may be greater than the actual release height (see Section B.3.1.1.1).

The two exponential functions of **z** in the curly brackets of Equation B-9 represent the emitted and reflected components of the plume. The reflected component (represented by the exponential with **($z + h_e$)** in its argument) arises from the assumption that all material in a portion of the plume that touches ground is reflected upward. This assumption is conservative if one is calculating airborne radioactivity concentration.

B.2.2 Sector-Averaged Concentration

Sometimes, it is desired to determine the average concentration of radioactivity in a sector due to release at a constant rate over an extended period of time (e.g., a year). For such a case, it is reasonable to assume that the wind blows with equal likelihood toward all directions within the sector. From Equation B-9, the following equation for ground level radioactivity concentration can be derived:

$$\chi_{sector} = [2.032\ f\ Q/(\sigma_z\ u\ x)]\exp(-h^2_e/2\sigma^2_z) \qquad \textbf{(B-34)}$$

χ_{sector} Sector-Averaged Ground Level Concentration [µCi/m^3]

The time-averaged concentration of airborne radioactivity in a sector at ground level at a distance **x** from the release point.

2.032 A dimensionless constant.

f Sector Fraction

The fraction of time that the wind blows into the sector.

Q Release rate of radioactivity. [µCi/sec]

The other parameter definitions are the same as for Equation B-9.

B.3 RELATIVE CONCENTRATION FACTOR χ/Q

The relative concentration factor χ/**Q** (called "chi over Q") provides a simplified method of calculating the radioactivity concentration at a given point in an effluent plume when the release rate is known:

$$\chi = Q\ (\chi/Q) \qquad \text{(B-35)}$$

χ Concentration of Radioactivity [µCi/m³]
Concentration of radioactivity at point **(x,y,z)** in the atmosphere.

Q Release Rate [µCi/sec]

Release rate of radioactivity.

χ/**Q** Relative Concentration Factor [sec/m³]
Relative concentration factor for point **(x,y,z)**. The airborne radioactivity concentration at **(x,y,z)** per unit release rate.

Expressions for χ/**Q** based on Gaussian plume models can be obtained from the equations for concentration χ in Section B.2 simply by dividing both sides of each equation by the release rate **Q**. For example, from Equation B-10, we obtain the following expression for the sector-averaged χ/**Q**:

$$(\chi_{sector}/Q) = [2.032\ f/(\sigma_Z\ u\ x)]\exp(-h^2{}_e/2\sigma^2{}_Z) \qquad \text{(B-36)}$$

The values of χ/**Q** used in ODCM calculations are both sector-averaged and time-averaged. The time averaging is based on the historical average atmospheric conditions of a specified multi-year time period (see Section 4.1.5) and is accomplished by use of the joint frequency distribution discussed in Section B.1.2. The formulas used to obtain the time- and sector-averaged χ/**Q** are based on Equation B-12, but vary depending on whether the release is a stack, ground level, or vent release. The three cases are discussed below.

B.3.1 Stack Release

For a stack release, the relative concentration factor is designated $(\chi/Q)_S$. Its value is obtained by the following formula:

$$(\chi/Q)_S = (2.032/R)\ \Sigma\{\ f_S(n,\theta,c) \times [\exp\ (-h^2{}_e/2\sigma^2 z)]/(u_n\ \sigma_Z)\ \} \qquad \text{(B-37)}$$

The summation is over wind speed classes **n** and atmospheric stability classes **c**.

$(\chi/Q)_S$ Relative Concentration Factor, Stack Release [sec/m³]

The time- and sector-averaged relative concentration factor due to a stack release for a point at ground level at distance **R** in downwind direction θ.

2.032 Constant

A dimensionless constant.

R Downwind Distance [m]

The downwind distance from the release point to the point of interest.

$\mathbf{f_s(n,\theta,c)}$ Joint Frequency Distribution, Stack Release

This function is defined in Section B.1.2.2.

$\mathbf{h_e}$ Effective Release Height [m]

The effective height of an effluent release above grade elevation. For a stack release, $\mathbf{h_e}$ is obtained by correcting the actual height of the release point for plume rise, terrain effects, and downwash as described in Section B.3.1.1, below.

σ_z Standard Vertical Dispersion Coefficient [m]

A coefficient characterizing vertical plume spread in the Gaussian model for stability class **c** at distance **R** (see Table C-5 of Appendix C).

$\mathbf{u_n}$ Wind Speed [m/sec]

A wind speed representative of wind speed class **n**. For each wind speed class except the highest, $\mathbf{u_n}$ is the average of the upper and lower limits of the wind speed range for the class. For the highest wind speed class, $\mathbf{u_n}$ is the lower limit of the wind speed range for the class.

This expression is recommended by the NRC in Regulatory Guide 1.111 (Reference 7) and is based on a model designated there as the "constant mean wind direction model." In this model it is assumed that the mean wind speed, the mean wind direction, and the atmospheric stability class determined at the release point also apply at all points within the region in which airborne concentration is being evaluated.

B.3.1.1 Effective Release Height

For a stack release, the effective height of an effluent plume is the height of the release point corrected for plume rise and terrain effects:

If $\mathbf{(h_s + h_{pr} - h_t) < 100}$ **meters**, then

$$\mathbf{h_e = h_s + h_{pr} - h_t} \tag{B-38}$$

If $\mathbf{(h_s + h_{pr} - h_t) \geq 100}$ **meters**, then;

$$\mathbf{h_e = 100\ meters} \tag{B-39}$$

$\mathbf{h_e}$ Effective Release Height [m]

The effective height of an effluent release above grade elevation.

$\mathbf{h_s}$ Actual Release Height [m]

The actual height of the release above grade elevation.

h_{pr} Plume Rise [m]

The rise of the plume due to its momentum and buoyancy. (See Section B.3.1.1.1.)

h_t Terrain Correction Parameter [m]

A parameter to account for the effect of terrain elevation on the effective height of a plume. Taken as zero (see Section B.3.1.1.2).

B.3.1.1.1 Plume Rise

Because nuclear power stations generally have plumes that are not significantly warmer than room temperature, plume rise due to buoyancy is neglected. The formulas used to calculate plume rise due to momentum are given below.

Stability Classes A, B, C, and D

For these stability classes (corresponding to unstable and neutral conditions), **h_{pr}** is taken as the lesser of two quantities:

$$h_{pr} = \text{Minimum of } [(h_{pr})_1, (h_{pr})_2] \quad \text{(B-40)}$$

$$(h_{pr})_1 = (1.44)(W_o/u)^{2/3}(R/d)^{1/3}(d) - h_d \quad \text{(B-41)}$$

$$(h_{pr})_2 = (3)(W_o/u)(d) \quad \text{(B-42)}$$

W_o Stack Exit Velocity [m/sec]

The effluent stream velocity at the discharge point.

u Wind Speed [m/sec]

R Downwind Distance [m]

The downwind distance from the release point to the point of interest.

d Internal Stack Diameter [m]

The internal diameter of the stack from which the effluent is released.

h_d Downwash Correction [m]

A parameter to account for downwash at low exit velocities.

The parameter **h_d** is calculated by the following equations:

$$h_d = (3)(1.5 - W_o/u)(d) \text{ if } W_o < 1.5u \quad \text{(B-43)}$$

$$h_d = 0 \text{ if } W_o \geq 1.5u \quad \text{(B-44)}$$

Note that **$(h_{pr})_1$** can increase without limit as **R** increases; thus, the effect of **$(h_{pr})_2$** is to limit calculated plume rise at large distances from the nuclear power station.

Stability Classes E, F, and G

For these stability classes (corresponding to stable conditions), $\mathbf{h_{pr}}$ is taken as the minimum of four quantities:

$$h_{pr} = \text{Minimum of } [(h_{pr})_1, (h_{pr})_2, (h_{pr})_3, (h_{pr})_4] \quad \text{(B-45)}$$

$$(h_{pr})_3 = (4)(F/S)^{1/4} \quad \text{(B-46)}$$

$$(h_{pr})_4 = (1.5)(F/u)^{1/3}(S)^{-1/6} \quad \text{(B-47)}$$

F Momentum Flux Parameter [m^4/sec^2]

A parameter defined as:

$$F = W_o^2(d/2)^2 \quad \text{(B-48)}$$

S Stability Parameter [$1/sec^2$]

A parameter defined as follows:

Stability Class	S
E	8.70E-4
F	1.75E-3
G	2.45E-3

The quantities $\mathbf{(h_{pr})_1}$ and $\mathbf{(h_{pr})_2}$ are as defined by Equations B-17 and B-18.

B.3.1.1.2 Terrain Effects

Due to general flatness of the terrain in the vicinity of the Zion site, the terrain correction parameter $\mathbf{h_t}$ was taken as zero in all calculations of meteorological dispersion and dose parameters for this Manual.

B.3.2 Ground Level Release

For a ground level release, the relative concentration factor is designated $\mathbf{(\chi/Q)_g}$. Its value is obtained by the following formula:

$$(\chi/Q)_g = (2.032/R)\, \Sigma\{ f_g(n,\theta,c)/(u_n S_z) \} \quad \text{(B-49)}$$

The summation is over wind speed classes **n** and atmospheric stability classes **c**.

$\mathbf{(\chi/Q)_g}$ Relative Concentration Factor, Ground Level Release [sec/m^3]

The time- and sector-averaged relative concentration factor due to a ground level release for a point at ground level at distance **R** in downwind direction θ.

$\mathbf{f_g(n,\theta,c)}$ Joint Frequency Distribution, Ground Level Release

This function is defined in Section B.1.2.3.

S_z Wake-Corrected Vertical Dispersion Coefficient [m]

The vertical dispersion coefficient corrected for building wake effects. The correction is made as described below.

The remaining parameters are defined in Section B.3.1.

Wake-Corrected Vertical Dispersion Coefficient

The wake-corrected vertical dispersion coefficient **S_z** in Equation B-25 is taken as the lesser of two quantities:

$$S_z = \text{Minimum of } [(S_z)_1, (S_z)_2] \quad \textbf{(B-50)}$$

$$(S_z)_1 = [\sigma^2_z + D^2/(2\pi)]^{1/2} \quad \textbf{(B-51)}$$

$$(S_z)_2 = (\sigma_z)(3^{1/2}) \quad \textbf{(B-52)}$$

S_z Wake-Corrected Vertical Dispersion Coefficient [m]

The vertical dispersion coefficient corrected for building wake effects.

σ_z Standard Vertical Dispersion Coefficient [m]

The coefficient characterizing vertical plume spread in the Gaussian model for stability class **c** at distance **R** (see Table C-5 of Appendix C).

D Maximum Height of Neighboring Structure [m]

The maximum height of any neighboring structure causing building wake effects (see Table F-2 of Appendix F).

B.3.3 Vent Release

For a vent release, the relative concentration factor is designated **$(\chi/Q)_V$**. Its value is obtained by the following formula:

$$(\chi/Q)_V = (2.032/R)\,\Sigma\{ f_{V,elev}(n,\theta,c) \times [\exp(-h^2_e/2\sigma^2_z)]/(u_n\,\sigma_z) + f_{V,gnd}(n,\theta,c)/(u_n S_z) \} \quad \textbf{(B-53)}$$

The summation is over wind speed classes **n** and atmospheric stability classes **c**.

$(\chi/Q)_V$ Relative Concentration Factor, Vent Release [sec/m^3]

The time and sector averaged relative concentration factor due to a vent release for a point at ground level at distance **R** in downwind direction **θ**.

The parameters **$f_{V,elev}(n,\theta,c)$** and **$f_{V,gnd}(n,\theta,c)$** are defined in Section B.1.2.4. The parameter **S_z** is defined in Section B.3.2. The remaining parameters are defined in Section B.3.1.

B.3.4 Removal Mechanisms

In Regulatory Guide 1.111, the NRC allows various removal mechanisms to be considered in evaluating the radiological impact of airborne effluents. These include radioactive decay, dry deposition, wet deposition, and deposition over water. For simplicity, these removal mechanisms cited by the NRC are not accounted for in the evaluation or use of **χ/Q** in this manual. This represents a conservative approximation as ignoring removal mechanisms increases the value of **χ/Q**.

B.3.5 Gamma-χ/Q

The noble gas dose factors of Reg. Guide 1.109, Table B-1 are based upon assumption of immersion in a semi-infinite cloud. For ground level and mixed mode releases this tends to overestimate the gamma air dose arising from a plume that is actually finite in nature.

For elevated releases, the Reg. Guide 1.109 noble gas dose factors will underestimate exposure as they consider only immersion and not that portion of exposure arising from sky shine. At distances close in to the point of elevated release, the ground level concentration as predicted by **χ/Q** will be essentially zero. In such a case, the sky shine component of the exposure becomes significant and must be considered.

The **gamma-χ/Q** provides a simplified method of calculating gamma air dose and dose rates for a finite and/or elevated plume. The methodology of Reg. Guide 1.109, Section C.2 and Appendix B provides the methodology for calculating finite cloud gamma air dose factors from which the **gamma-χ/Q** values can be derived. Section B.5 addresses the calculation of these dose factors.

The **gamma-χ/Q** is defined such that for a given finite cloud the semi-infinite cloud methodology will yield the same gamma air dose as the finite cloud methodology.

Three **gamma-χ/Q** values are defined: **$(\chi/Q)_s^\gamma$, $(\chi/Q)_v^\gamma$ and $(\chi/Q)_g^\gamma$** for stack, vent and ground level releases, respectively. These **gamma-χ/Q** values are calculated as follows:

For stack releases:

$$(\chi/Q)_s^\gamma = \frac{\sum_i f_i S_i}{\sum_i f_i M_i} \qquad \textbf{(B-54)}$$

The summation is over all noble gas radionuclides **i**.

$(\chi/Q)_s^\gamma$	**Gamma-γ/Q** for Stack Releases	[sec/m3]
f_i	Noble Gas Nuclide Fraction	dimensionless
	Fraction of total noble gas release that is due to radionuclide **i**. Values for **f_i** are listed in Table B-0.	
S_i	Stack Release Gamma Air Dose Factor	[(mrad/yr)/(μCi/sec)]
	Gamma air dose factor for radionuclide **i** for stack releases as defined in Section B.5.1. Taken from Appendix F, Table 7.	
M_i	Semi-Infinite Cloud Dose Factor	[(mrad/yr)/(μCi/m^3)]
	Dose factor for immersion exposure to a semi-infinite cloud of noble gas. Taken from Reg. Guide 1.109, Table B-1, Col 4. (Note that the units in Reg. Guide 1.109 must be multiplied by 1E6 to convert pCi to μCi.)	

For vent releases:

$$(\chi/Q)_v^\gamma = \frac{\sum_i f_i V_i}{\sum_i f_i M_i} \qquad \textbf{(B-55)}$$

The summation is over all noble gas radionuclides **i**.

$(\chi/Q)_v^\gamma$	**Gamma-γ/Q** for Vent Releases	[sec/m3]
V_i	Vent Release Gamma Air Dose Factor	[(mrad/yr)/(µCi/sec)]
	Gamma air dose factor for radionuclide **i** for stack releases as defined in Section B.5.3. Taken from Appendix F, Table 7.	

All other terms have been previously defined.

For ground level releases:

$$(\chi/Q)_g^\gamma = \frac{\sum_i f_i G_i}{\sum_i f_i M_i} \qquad \textbf{(B-56)}$$

The summation is over all noble gas radionuclides **i**.

$(\chi/Q)_g^\gamma$	**Gamma-γ/Q** for Ground Releases	[sec/m3]
G_i	Ground Level Release Gamma Air Dose Factor	[(mrad/yr)/(µCi/sec)]
	Gamma air dose factor for radionuclide **i** for ground level releases as defined in Section B.5.2. Taken from Appendix F, Table 7.	

All other terms have been previously defined.

The Noble Gas Nuclide Fraction, $\mathbf{f_i}$ is determined from historical release data and defined as:

$$f_i = \frac{A_i}{\sum_i A_i} \qquad \textbf{(B-57)}$$

The summation is over all noble gas radionuclides **i**.

A_i	Cumulative Radionuclide Release	units of activity
	Cumulative release of noble gas radionuclide **i** over a period of time.	

B.4 RELATIVE DEPOSITION FACTOR D/Q

The quantity **D/Q** (called "D over Q") is defined to provide the following simple way of calculating the rate of deposition of radioactivity at a given point on the ground when the release rate is known.

$$\mathbf{d = Q\ (D/Q)} \qquad \textbf{(B-58)}$$

d Deposition Rate [(μCi/m^2)/sec]

Rate of deposition of radioactivity at a specified point on the ground.

Q Release Rate of radioactivity. [μCi/sec]

D/Q Relative Deposition Factor [1/m^2]

Relative deposition factor for a specified point on the ground. The deposition rate per unit release rate.

The values of **D/Q** used in this manual are time-averaged. The time averaging is based on the historical average atmospheric conditions of a specified multi-year time period (see Section 4.1.5) and is accomplished by use of the joint frequency distribution described in Section B.1.2. The formulas used to obtain **D/Q** vary depending on whether the release is a stack, ground level, or vent release. The three cases are discussed below.

B.4.1 Stack Release

For a stack release, the relative deposition factor is designated $(D/Q)_s$. Its value is obtained by the following formula:

$$(D/Q)_s = [1/(2\pi R/16)]\ \Sigma\{f_s(n,\theta,c)\ D_r(c,R,h_e)\} \quad \textbf{(B-59)}$$

The summation is over wind speed classes **n** and stability classes **c**.

$(D/Q)_s$ Relative Deposition Factor, Stack Release [1/m^2]

The time-averaged relative deposition factor due to a stack release for a point at distance **R** in the direction θ.

2π/16 Sector Width [radians]

The width of a sector over which the plume direction is assumed to be uniformly distributed (as in the model of Section B.2.2). Taken as 1/16 of a circle.

R Downwind Distance [m]

The downwind distance from the release point to the point of interest.

$f_s(n,\theta,c)$ Joint Frequency Distribution, Stack Release

This function is defined in Section B.1.2.2.

$D_r(c,R,h_e)$ Relative Deposition Rate, Stack Release [m^{-1}]

The deposition rate per unit downwind distance [μCi/(sec-m)] divided by the source strength [μCi/sec] due to a stack release for stability class **c**, downwind distance **R**, and effective release height h_e.

The value is based on Figures 7 to 9 of Regulatory Guide 1.111, which apply, respectively, to release heights of 30, 60, and 100 m. Linear interpolation is used to obtain values at intermediate release heights. If the

effective release height is greater than 100 meters, then the data for 100 meters are used.

h_e Effective Release Height [m]

The effective height of the release above grade elevation. See Section B.3.1.1.

B.4.2 Ground Level Release

For ground level release, the relative deposition factor is designated **$(D/Q)_g$**. Its value is obtained by the following formula:

$$(D/Q)_g = [1/(2\pi R/16)]\ D_r(R)\ \Sigma\{ f_g(n,\theta,c) \} \qquad \textbf{(B-60)}$$

The summation is over wind speed classes **n** and stability classes **c**.

$(D/Q)_g$ Relative Deposition Factor, Ground Level Release [$1/m^2$]

The time-averaged relative deposition factor due to a ground level release for a point at distance **R** in the direction θ.

$f_g(n,\theta,c)$ Joint Frequency Distribution, Ground Level Release

This function is defined in Section B.1.2.3.

$D_r(R)$ Relative Deposition Rate, Ground Level [m^{-1}]

The deposition rate per unit downwind distance [µCi/(sec-m)] divided by the source strength [µCi/sec] due to a ground level release for downwind distance **R**. The value is taken from Figure 6 of Regulatory Guide 1.111 and is the same for all atmospheric stability classes.

The remaining parameters are defined in Section B.4.1.

B.4.3 Vent Release

For a vent release, the relative deposition factor is designated **$(D/Q)_V$**. Its value is obtained by the following formula:

$$(D/Q)_V = [1/(2\pi R/16)] \times [\Sigma\{ f_{V,elev}(n,\theta,c)\ D_r(c,R,h_e) \} + D_r(R)\ \Sigma\{ f_{V,gnd}(n,\theta,c) \}] \qquad \textbf{(B-61)}$$

The summation is over wind speed classes **n** and stability classes **c**.

$(D/Q)_V$ Relative Deposition Factor, Vent Release [$1/m^2$]

The time-averaged relative deposition factor due to a ground level release for a point at distance **R** in the direction θ.

The parameters **$f_{V,elev}(n,\theta,c)$** and **$f_{V,gnd}(n,\theta,c)$** are defined in Section B.1.2.4. The remaining parameters are defined in Sections B.4.1 and B.4.2.

B.5 GAMMA AIR DOSE FACTORS (S_i, V_i, G_i)

The gamma air dose factors provide a simple way of calculating doses and dose rates to air due to gamma radiation. For example, using a dose factor $\mathbf{DF_i}$, gamma air dose rate may be calculated as follows:

$$\dot{D} = \Sigma \dot{D}_i \qquad \textbf{(B-62)}$$

$$\dot{D}_i = \Sigma\{Q_i DF_i\} \qquad \textbf{(B-63)}$$

The summations are over **i** radionuclides.

$\dot{D}$ Gamma Air Dose Rate [mrad/yr]

The gamma air dose rate due to all radionuclides released.

$\dot{D}_i$ Gamma Air Dose Rate Due to Radionuclide **i**
[mrad/yr]

Q_i Release Rate of Radionuclide **i** [µCi/sec]

DF_i Gamma Air Dose Factor for Radionuclide **i** [(mrad/yr)/ (µCi/sec)]

A factor used to calculate gamma air dose or dose rate due to release of radionuclide **i**. Gamma air dose rate at a particular location per unit release rate.

Three gamma air dose factors are defined: $\mathbf{S_i}$, $\mathbf{V_i}$, and $\mathbf{G_i}$. They are used for stack, vent, and ground level releases, respectively. These three release point classifications are defined in Section 4.1.4. The calculation of the three dose factors is discussed below.

B.5.1 Stack Release

For a stack release, the gamma air dose factor $\mathbf{S_i}$ is obtained by a model similar to that of Equation 6 of Regulatory Guide 1.109 (Reference 6). A sector-averaged Gaussian plume is assumed and the dose factor is evaluated on the basis of historical average atmospheric conditions. The value of $\mathbf{S_i}$ depends on distance **R** from the release point and on downwind sector **θ**.

The following equation is used:

$$S_i = [260/(2\pi R/16)] \times \Sigma\{f_s(n,\theta,c)[\exp(-\lambda_i R/3600u_n)] \times E_k\, \mu_a(E_k) A_{Ki}\, I(h_e,u_n,c,\sigma_z,E_k)/u_n\} \qquad \textbf{(B-64)}$$

The summation is over wind speed classes **n**, atmospheric stability classes **c**, and photon group indices **k**.

S_i Gamma Air Dose Factor, Stack Release [(mrad/yr)/ (µCi/sec)]

The gamma air dose factor at ground level for a stack release for radionuclide **i**, downwind sector **θ**, downwind distance **R** from the release point, and the average atmospheric conditions of a specified historical time period.

260 Conversion factor [(mrad-radians-m^3-disintegrations)/(sec-MeV-Ci)]

Reconciles units of Equation B-36.

2π/16 Sector Width [radians]

The width of a sector over which the plume direction is assumed to be uniformly distributed (as in the model of Section B.2.2). Taken as 1/16 of a circle.

$f_s(n,\theta,c)$ Joint Frequency Distribution, Stack Release

This function is defined in Section B.1.2.2.

λ_i Radiological Decay Constant [hr^{-1}]

Radiological Decay Constant for radionuclide **i** (see Table C-7 of Appendix C).

3600 Conversion Factor [sec/hr]

The number of seconds per hour. Used to convert wind speed in meters/sec to meters/hr.

E_k Photon Group Energy [MeV/photon]

An energy representative of photon energy group **k**. The photons emitted by each radionuclide are grouped into energy groups in order to facilitate analysis. All photons with energy in energy group **k** are assumed to have energy **E_k**.

$\mu_a(E_k)$ Air Energy Absorption Coefficient [m^{-1}]

The linear energy absorption coefficient for air for photon energy group **k**. The fraction of energy absorbed in air per unit of distance traveled for a beam of photons of energy **E_k**. Distance is measured in units of linear thickness (meters).

A_{ki} Effective Photon Yield [photons/disintegration]

The effective number of photons emitted with energy in energy group **k** per decay of nuclide **i**. On the basis of Section B.1 of Regulatory Guide 1.109 (Reference 6), the parameter **A_{ki}** is calculated as follows:

$$A_{ki} = [\Sigma\{A_m E_m \mu_a(E_m)\}]/[E_k \mu_a(E_k)] \quad \textbf{(B-65)}$$

The summation in the numerator is over the index **m**.

A_m True Photon Yield [photons per disintegration]

The actual number of photons emitted with energy **E_m** per decay of nuclide **i**.

E_m Photon Energy [MeV/photon]

The energy of the m^{th} photon within photon energy group **k**.

$\mu_a(E_m)$ Air Energy Absorption Coefficient [m^{-1}]

The linear energy absorption coefficient for air for photon energy E_m.

I(...) I Function

A dimensionless parameter obtained by numerical evaluation of integrals that arise in the plume gamma dose problem. The value of **I** depends on the arguments **(...)** listed in Equation B-40. A specific definition for **I** is given by Equation F-13 of Regulatory Guide 1.109.

The integrals involved in calculating **I** arise from conceptually dividing up the radioactive plume into small elements of radioactivity and adding up the doses produced at the point of interest by all of the small elements. The distribution of radioactivity in the plume is represented by a sector-averaged Gaussian plume model like that discussed in Section B.2.2.

The parameters **R**, h_e, u_n, and σ_z are defined in Section B.3.1.

B.5.2 Ground Level Release

The gamma air dose factor G_i for a ground level release is defined as follows:

G_i Gamma Air Dose Factor, Ground Level Release [(mrad/yr)/(µCi/sec)]

The gamma air dose factor at ground level for a ground level release for radionuclide **i**, downwind sector θ, downwind distance **R** from the release point, and the average atmospheric conditions of a specified historical time period.

The value of G_i is obtained by the same equation as used for a stack release, Equation B-36 of Section B.5.1, with the following modifications:

- The joint frequency distribution for a ground level release (f_g of Section B.1.2.3) is used in place of the one for a stack release (f_s).
- In evaluating the **I** function, the effective release height h_e is taken as zero.

This corresponds to use of a finite plume model.

B.5.3 Vent Release

For a vent release, the gamma air dose factor is calculated as follows:

$$V_i = [260/(2\pi R/16)] \times \Sigma\{f_{v,elev}(n,\theta,c)[\exp(-\lambda_i R/3600u_n)] \times A_{ki}E_k\mu_a(E_k)\, I(h_e,u_n,c,\sigma_z,E_k)/u_n + f_{v,gnd}(n,\theta,c)[\exp(-\lambda_i R/3600u_n)] \times A_{ki}E_k\mu_a(E_k)\, I(0,u_n,c,\sigma_z,E_k)/u_n\} \quad \text{(B-66)}$$

The summation is over wind speed classes **n**, atmospheric stability classes **c**, and photon group indices **k**.

V_i Gamma Air Dose Factor, Vent Release [(mrad/yr)/(µCi/sec)]

The gamma air dose factor at ground level for a vent release for radionuclide **i**, downwind sector **θ**, downwind distance **R** from the release point, and the average atmospheric conditions of a specified historical time period.

The parameters $\mathbf{f_{v,elev}(n,\theta,c)}$ and $\mathbf{f_{v,gnd}(n,\theta,c)}$ are defined in Section B.1.2.4. The parameter σ_z is defined in Section B.3.2. The remaining parameters are discussed in Section B.5.1.

B.6 Gamma Total Body Dose Conversion Factor (K_i)

The gamma total body dose conversion factors (K_i) are used to calculate doses and dose rates due to gamma irradiation of the whole body. The gamma total body dose conversion factors are taken from Reg. Guide 1.109, Table B-1, Column 5. The gamma total body dose conversion factors in Table B-1 of Reg. Guide 1.109 are based upon the semi-infinite cloud model.

B.7 BETA AIR AND BETA SKIN DOSE CONVERSION FACTORS (N_i,L_i)

The beta air (N_i) and beta skin (L_i) dose conversion factors are used to calculate doses and dose rates due to noble gas beta exposure. The beta air dose conversion factors are taken from Reg, Guide 1.109, Table B-1, Column 2. The beta skin dose conversion factors are taken from Column 5 of that same table. The values are based on a semi-infinite cloud model.

B.8 GROUND PLANE DOSE CONVERSION FACTOR DFG_i

The ground plane dose conversion factor $\mathbf{DFG_i}$ is used to calculate dose due to standing on ground contaminated with radionuclide **i** (see Equation A-8 of Appendix A). The units of $\mathbf{DFG_i}$ are (mrem/hr) per (pCi/m^2).

Values are provided (see Table C-10 of Appendix C) for dose to the whole body. The values are taken from Regulatory Guide 1.109 and are based on a model that assumes a uniformly contaminated ground plane.

B.9 INHALATION DOSE COMMITMENT FACTOR DFA_{ija}

The inhalation dose commitment factor $\mathbf{DFA_{ija}}$ is used to calculate dose and dose rate to organ **j** of an individual of age group **a** due to inhalation of radionuclide **i** (see Equations A-7 and A-9 of Appendix A).

Values of $\mathbf{DFA_{ija}}$ for 10CFR50 compliance are taken from Regulatory Guide 1.109 (Reference 6). The units of $\mathbf{DFA_{ija}}$ are mrem per pCi inhaled. Values are provided for seven organs, with the whole body considered as an organ (see Tables E-7, E-8, E-9 and E-10 in Reg. Guide 1.109).

B.10 INGESTION DOSE COMMITMENT FACTOR DFL_{ija}

The ingestion dose commitment factor $\mathbf{DFL_{ija}}$ is used to calculate dose to organ **j** of an individual of age group **a** due to ingestion of radionuclide **i** (see Equations A-7 and A10 through A20 of Appendix A).

Values of $\mathbf{DFL_{ija}}$ for 10CFR50 compliance are taken from Regulatory Guide 1.109 (Reference 6). The units of $\mathbf{DFL_{ija}}$ are mrem per pCi ingested. In Tables E-11, E-12, E-13 and E-14 of Reg. Guide 1.109, values are provided for seven organs, with the whole body considered as an organ.

B.11 MEASURED RELEASE PARAMETERS

Input parameters required for calculations of dose or dose rate due to airborne effluents include measured values of radioactivity release ($\mathbf{A_{is}}$, $\mathbf{A_{iv}}$, and $\mathbf{A_{ig}}$) or release rate ($\mathbf{Q_{is}}$, $\mathbf{Q_{iv}}$, and $\mathbf{Q_{ig}}$) (see Section A.1 of Appendix A). These are obtained per Zion station procedures.

B.12 RADIOLOGICAL DECAY CONSTANTS

Values used for these are obtained from the literature and are specified in Table C-7 of Appendix C.

B.13 PRODUCTION/EXPOSURE PARAMETERS

These parameters characterize various aspects of agricultural production and human exposure. Values used for generic (site-independent) parameters are specified in Appendix C.

Values of site-specific parameters are given in Appendix F. Many of the values are based on Reg. Guide 1.109, while others are based on site-specific considerations.

SECTION 2:

MODELS AND PARAMETERS FOR LIQUID EFFLUENT CALCULATIONS

B.14 INTRODUCTION

Equations for radiation dose and radioactivity concentration due to liquid effluents are given in Section A.2 of Appendix A. The equations involve the following types of parameters:

- Flow and Dilution Parameters.
- Dose Factors.
- Measured Release Parameters.
- Transport/Consumption Parameters.

This section discusses the methodology used to determine these parameters. Section B.15 addresses dose calculations and Section B.16 addresses concentration calculations for tank discharges. For dose calculations, flow and dilution parameters are discussed for the Lake Michigan Model, which is used for Zion.

B.15 DOSE

B.15.1 Drinking Water

The radiation dose due to consumption of drinking water containing released radioactivity is calculated by Equations A-17, A-18 and A-19 of Appendix A:

$$D_{aj}^{Liq} = F\ \Delta t \sum_{p}\sum_{i} A_{aipj} C_i \qquad \textbf{(A-17)}$$

$$F = \frac{\text{Waste Flow}}{\text{Dilution Flow} \times Z} \qquad \textbf{(A-18)}$$

$$A_{ai(PW)j} = k_o \left\{ \frac{U_a^w}{D^w} \right\} DFL_{aij} \qquad \textbf{(A-19)}$$

The summation is over index **i** (radionuclides) and **p** (pathways). The parameters are defined in Section A.2.1 of Appendix A.

This methodology addresses the following considerations:

- The duration of the release, Δt.
- The concentration of the activity released, C_i.
- The dilution that takes place in the environment is represented by the parameters **F** and **Z**.
- Receptor consumption rate, U_a^W.
- Dilution which occurs from the near field discharge area to potable water intake as represented by D^w.
- The dose commitment per unit of ingested radioactivity is $\mathbf{DFL_{aij}}$.

B.15.2 Aquatic Foods (Fish)

Near Zion station, the only aquatic food of significance for human consumption is fish. The liquid dose due to consumption of fish containing released radioactivity is calculated by Equations A-17, A-18 and A-20 of Appendix A.

$$A_{ai(Fish)j} = k_o U_a^F BF_i DFL_{aij} \qquad \textbf{(A-20)}$$

The parameters are defined in Section A.2.1 of Appendix A.

This is similar to the methodolgy used for calculating the dose due to drinking water except for the addition of the bioaccumulation factor, $\mathbf{BF_i}$. This factor is the equilibrium ratio of the concentration of radionuclide **i** in fish (pCi/kg) to its concentration in water (pCi/L). It accounts for the fact that radioactivity ingested by fish can accumulate in their bodies to a higher concentration than in the waters in which the fish live.

B.15.3 Parameters

B.15.3.1 Flow and Dilution

The values of dilution can differ for potable water and fish. The dilution for potable water will depends on where water is drawn, while that for fish will depends on where the fish are caught. Models used to determine these parameters are discussed below. The values used for Zion Station are summarized in Table F-1 of Appendix F.

B.15.3.1.1 Lake Michigan Model

Only (Zion) discharges liquid effluents into Lake Michigan. For Zion station, it is assumed that the dilution in the near-field (**Z**) is dictated by the initial entrainment dilution is a factor of 10. The potable water pathway dilution factor of 6 ($\mathbf{D^w}$) is derived from the plume dilution (a factor of 3 over approximately 1 mile) and the current direction frequency (annual average factor of 2).

B.15.3.2 Dose Factors

Equations A-17 through A-20 of Appendix A determine dose due to ingested radioactivity using the same ingestion dose factor $\mathbf{DFL_{ija}}$ as used in the evaluation of airborne radioactivity which is ingested with foods. The units of $\mathbf{DFL_{ija}}$ are:

(mrem) per (pCi ingested)

For 10CFR50 Appendix I compliance, the data of Tables E-1, E-12, E-13 and E-14 of Reg. Guide 1.109, are used for four age groups and for seven organs, with the whole body considered as an organ.

B.15.3.3 Measured Releases

Calculations of dose due to liquid effluents require measured values of radioactivity concentration release ($\mathbf{C_i}$) for input. These release values are obtained per Zion*Solutions*' procedures.

B.15.3.4 Consumption

Equations A-19 and A-20 of Appendix A involve consumption rates for water and fish ($\mathbf{U_a^w}$ and $\mathbf{U_a^F}$). The values used are specified for Zion Station in Table F-1 of Appendix F.

B.16 CONCENTRATION IN TANK DISCHARGES

The concentration of radioactivity in a release to the unrestricted area due to a tank discharge is calculated by Equation A-22 of Appendix A:

$$\mathbf{C_i = C_i^t \frac{Waste\ Flow}{Dilution\ Flow}} \qquad \textbf{(A-22)}$$

The parameters are defined in Section A.2.3 of Appendix A.

The radioactivity concentration released from the tank ($\mathbf{C^t}_i$ at flow rate $\mathbf{F^r}$) is diluted by mixing with the initial dilution stream (with flow rate $\mathbf{F^d}$) to yield a lower concentration ($\mathbf{C}_i$) in the combined streams.

Table B-0
Noble Gas Nuclide Fractions

Nuclide	Zion[1]
Ar-41	0.00E+00
Kr-83m	0.00E+00
Kr-85	1.00E+00
Kr-85m	0.00E+00
Kr-87	0.00E+00
Kr-88	0.00E+00
Kr-89	0.00E+00
Kr-90	0.00E+00
Xe-131m	0.00E+00
Xe-133	0.00E+00
Xe-133m	0.00E+00
Xe-135	0.00E+00
Xe-135m	0.00E+00
Xe-137	0.00E+00
Xe-138	0.00E+00

Notes:
(1) From Table 10-1.

Table B-1

Portion of an Example Joint Frequency Distribution

Summary Table of Percent by Direction and Class

Class	N	NNE	NE	ENE	E	ESE	SE	SSE	S
A	.289	.317	.301	.244	.249	.190	.198	.197	.335
B	.190	.187	.178	.158	.125	.065	.079	.130	.193
C	.269	.226	.252	.218	.190	.118	.152	.189	.302
D	3.298	2.327	2.338	2.684	1.992	1.334	1.365	2.172	3.012
E	1.466	1.198	.988	1.331	1.661	1.226	1.472	2.553	3.628
F	.504	.318	.185	.276	.699	.648	.803	1.293	1.732
G	.202	.091	.061	.099	.253	.250	.355	.400	.624
Total	6.217	4.663	4.304	5.011	5.169	3.830	4.424	6.933	9.826

Summary Table of Percent by Direction and Speed

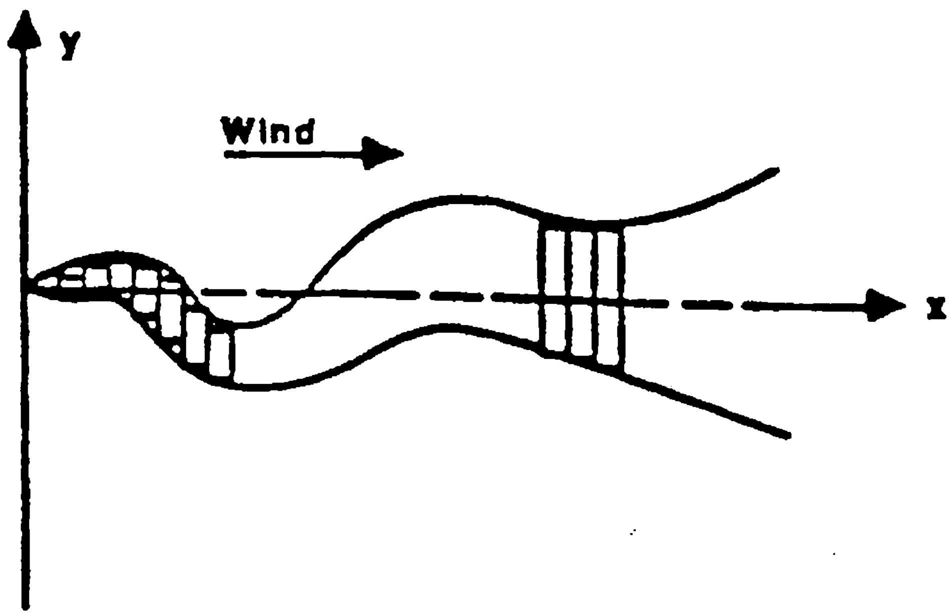
Speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S
.45	.098	.099	.078	.030	.009	.000	.014	.032	.046
1.05	.308	.154	.125	.137	.121	.093	.090	.090	.127
2.05	.939	.602	.458	.594	.843	.606	.598	.605	1.008
3.05	1.164	1.030	.779	.981	1.468	1.075	1.093	1.478	1.982
4.05	1.179	1.024	.878	.995	1.243	.831	1.027	1.727	2.110
5.05	.839	.631	.658	.798	.724	.474	.652	1.254	1.636
6.05	.612	.467	.496	.589	.417	.313	.418	.803	1.153
8.05	.755	.437	.612	.695	.310	.313	.405	.735	1.319
10.05	.253	.157	.183	.165	.032	.093	.103	.180	.374
13.05	.053	.061	.034	.027	.001	.031	.025	.028	.072
18.00	.016	.001	.004	.000	.000	.001	.001	.002	.000
99.00	.000	.000	.000	.000	.000	.000	.000	.000	.000
Total	6.217	4.663	4.304	5.011	5.169	3.830	4.424	6.933	9.826

Summary Table of Percent by Speed and Class

Class Speed	A	B	C	D	E	F	G
.45	.004	.001	.000	.095	.257	.275	.346
1.05	.018	.012	.027	.508	1.035	1.080	.780
2.05	.286	.171	.246	3.256	5.028	3.228	1.419
3.05	.744	.428	.616	6.258	7.173	3.272	.985
4.05	.992	.581	.781	8.165	6.404	1.902	.460
5.05	.909	.506	.808	7.302	4.357	.607	.077
6.05	.712	.388	.613	6.167	2.938	.164	.013
8.05	.819	.500	.755	7.616	2.734	.081	.011
10.05	.230	.150	.196	2.606	.667	.009	.000
13.05	.075	.032	.055	.755	.161	.001	.000
18.00	.004	.000	.018	.117	.012	.000	.000
99.00	.000	.000	.001	.001	.000	.000	.000

Figure B-1

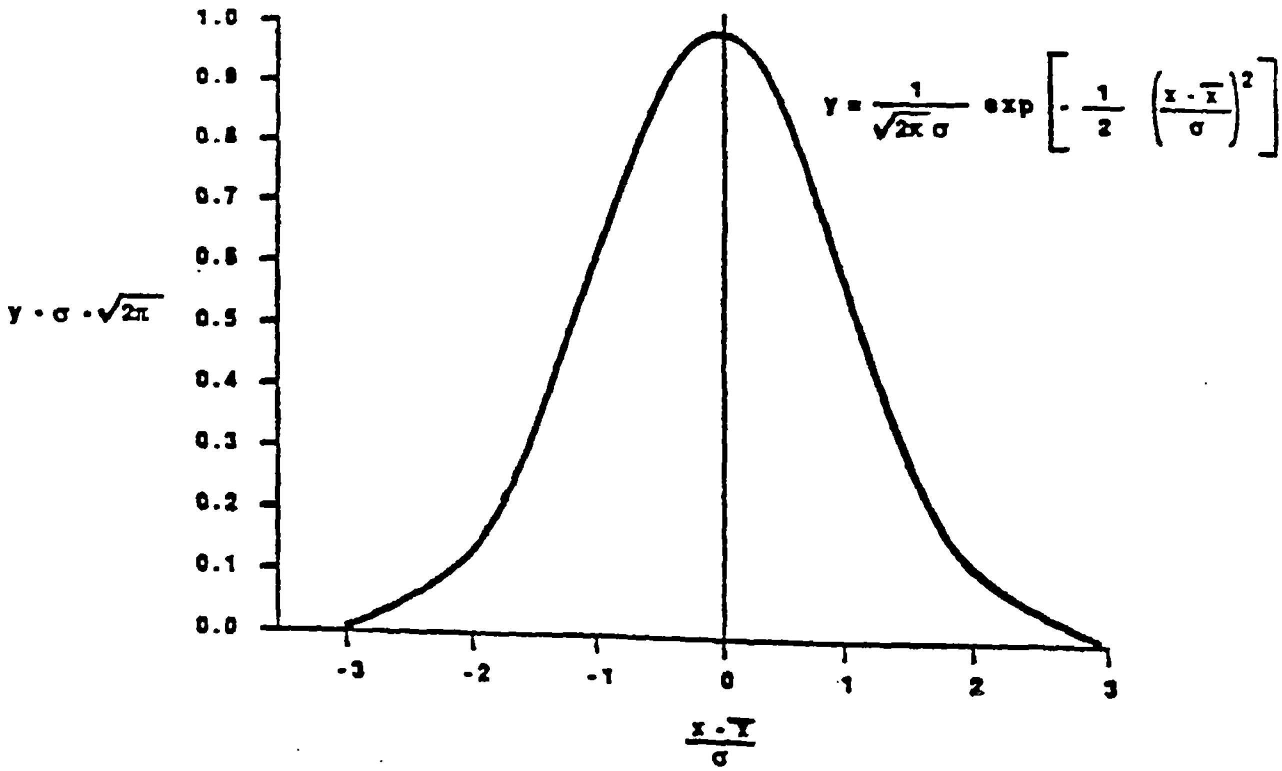
Instantaneous View of Plume



This figure represents a snapshot of a projection of a plume on the horizontal plane. As it moves downwind, the plume meanders about the average wind direction and broadens (adapted from Reference 18).

Figure B-2

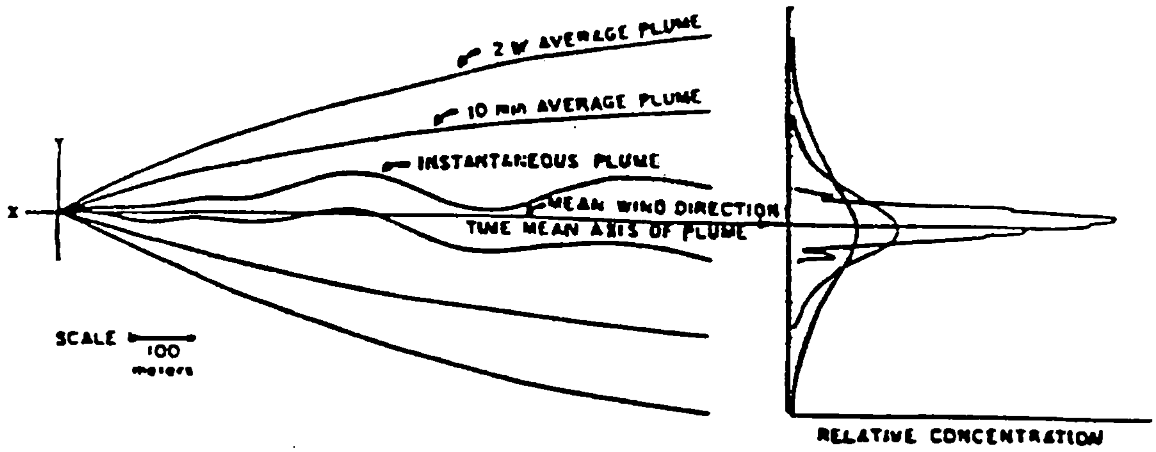
A Gaussian Curve



(Adapted from Reference 24 of Chapter 9, Page 61.)

Figure B-3

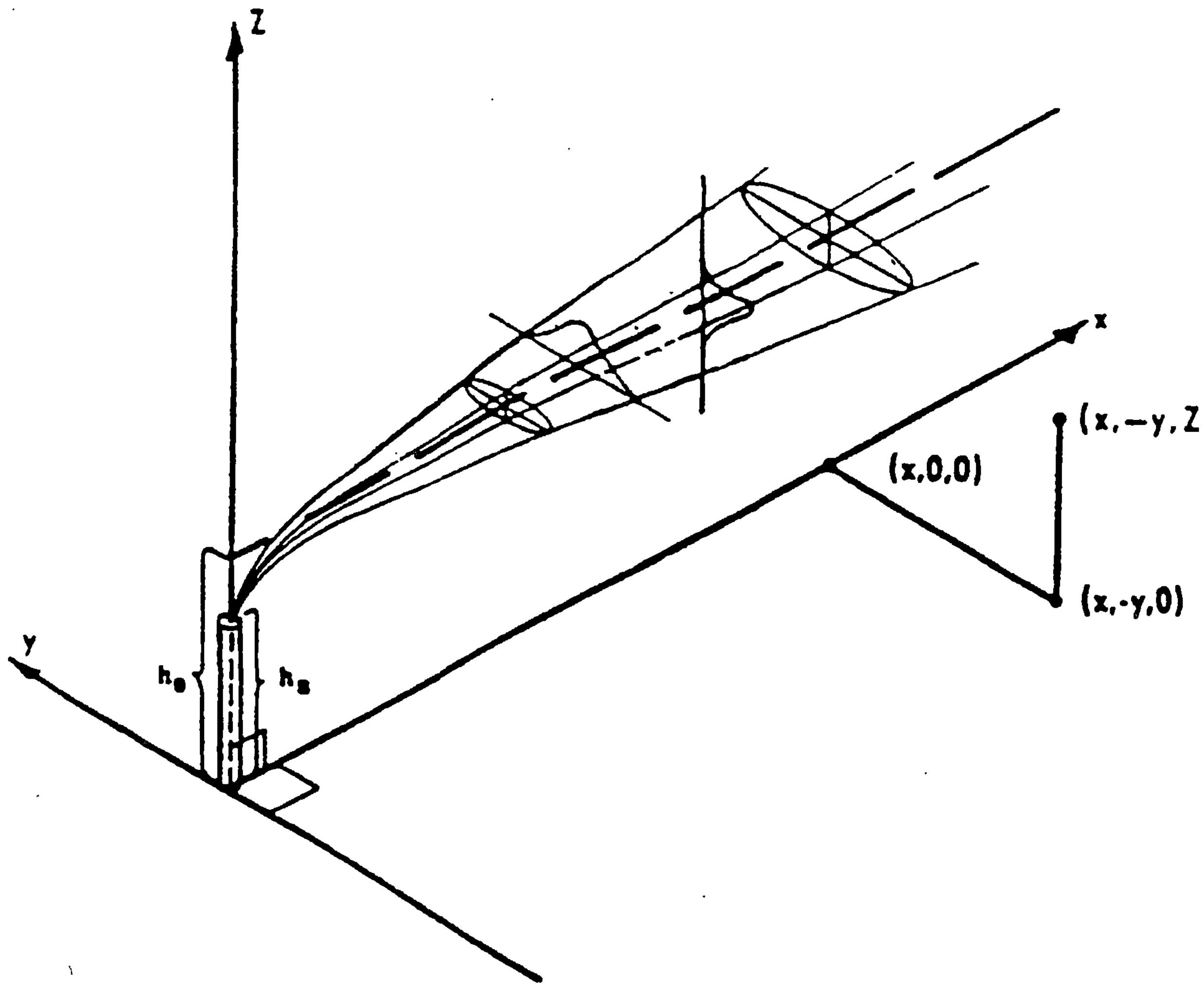
Effect of Observation Period on Plume Shape



This sketch represents the approximate outlines of a smoke plume observed instataneously and averaged over periods of 10 minutes and 2 hours. The diagram on the right shows the corresponding cross plume distribution patterns. The plume width increases as the period of observation increases (from Reference 18).

Figure B-4

A Gaussian Plume



This sketch illsutrates a plume characterized by Equation B-9. The plume is moving downwind in the x direction. Both the horizontal dispersion parameter sz increases as x increases. The reflected component has been omitted in this illustration (adapted from Reference 24).

APPENDIX C

GENERIC DATA

APPENDIX C
GENERIC DATA

C.1 INTRODUCTION

This appendix contains generic offsite dose calculation parameter factors, or values. Site specific factors are provided in the station annex Appendix F. The factors described in section C.2 are found in the prescribed references and are not repeated in this appendix.

C.2 10CFR50 DOSE COMMITMENT FACTORS

With the exception of H-3, the dose commitment factors for 10CFR50 related calculations are exactly those provided in Regulatory Guide 1.109 (Reference 6). The following table lists the parameters and the corresponding data tables in the RG 1.109:

PATHWAY	ADULT	TEENAGER	CHILD	INFANT
Inhalation	RG 1.109:Table E-7	RG 1.109:Table E-8	RG 1.109:Table E-9	RG 1.109:Table E-10
Ingestion	RG 1.109:Table E-11	RG 1.109:Table E-12	RG 1.109:Table E-13	RG 1.109:Table E-14

These tables are contained in Regulatory Guide 1.109 (Reference 6). Each table (E-7 through E-14) provides dose factors for seven organs for each of 73 radionuclides. For radionuclides not found in these tables, dose factors will be derived from ICRP 2 (Reference 50) or NUREG-0172 (Reference 51). The values for H-3 are taken from NUREG-4013 (Reference 107).

Table C-1
Miscellaneous Dose Assessment Factors -
Environmental Parameters

Parameter	Value	Comment	Equation	Basis[a]
f_g	0.76		A-10, A-11	A
f_L	1.0		A-10, A-11	A
f_p	1.0		A-12, A-14	A
f_s	1.0		A-12, A-14	A
t_b	262,800 hrs	30 years	A-8	C
t_f	48 hrs	Cow Milk Pathway	A-12	A
t_f	480 hrs	Cow Meat Pathway	A-14	A
t_h	1440 hrs	60 days for produce	A-10	A
t_h	2160 hrs	90 days for produce	A-12, A-14	A
t_L	24 hrs	1 day for leafy vegetables	A-10	A
Q_F	50 Kg/da		A-12, A-13, A-14, A-15	B
r	0.2	For Particulates	A-10, A-12, A-14	A
Y_p	0.7 Kg/m^2		A-12, A-14	A
Y_s	2.0 Kg/m^2		A-12, A-14	A
Y_v	2.0 Kg/m^2		A-10	A
λ_w	0.0021 hr^{-1}		A-10, A-12, A-14	A
H	8 gm/m^3	Absolute Atmospheric Humidity	A-11, A-13, A-15	D

[a]Basis key:

A: Reference 6, Table E-15.
B: Reference 6, Table E-3.
C: The parameter t_b is taken as the midpoint of plant operating life (based upon an assumed 60 year plant operating lifetime).
D: Reference 14, Section 5.3.1.3.

Table C-2
Miscellaneous Dose Assessment Factors -
Consumption Parameters

Type	Variable	Infant	Child	Teenager	Adult
Air	BR_a (m^3/yr)	1400	3700	8000	8000
Milk	U_{am} (L/yr)	330	330	400	310
Produce	U_a^S (Kg/yr)	0	520	630	520
Leafy Vegetables	U_a^L (Kg/yr)	0	26	42	64
Meat	U_{af} (Kg/yr)	0	41	65	110
Water	U_a^W (L/yr)	330	510	510	730
Fish	U_a^F (Kg/yr)	0	6.9	16	21

From Regulatory Guide 1.109, Table E-5.

Table C-3
Stable Element Transfer Data

Element	F_f Meat (d/kg)	F_M(Cow) Milk (d/L)	Reference
H	1.2E-02	1.0E-02	6
Be	1.5E-03	3.2E-03	Footnote 1
C	3.1E-02	1.2E-02	6
F	2.9E-03	1.4E-02	Footnote 2
Na	3.0E-02	4.0E-02	6
Mg	1.5E-03	3.2E-03	Footnote 1
Al	1.5E-02	1.3E-03	Footnote 3
P	4.6E-02	2.5E-02	6
Cl	2.9E-03	1.4E-02	Footnote 2
Ar	NA	NA	NA
K	1.8E-02	7.2E-03	16
Ca	1.6E-03	1.1E-02	16
Sc	2.4E-03	7.5E-06	Footnote 4
Ti	3.4E-02	5.0E-06	Footnote 5
V	2.8E-01	1.3E-03	Footnote 6
Cr	2.4E-03	2.2E-03	6
Mn	8.0E-04	2.5E-04	6
Fe	4.0E-02	1.2E-03	6
Co	1.3E-02	1.0E-03	6
Ni	5.3E-02	6.7E-03	6
Cu	8.0E-03	1.4E-02	6
Zn	3.0E-02	3.9E-02	6
Ga	1.5E-02	1.3E-03	Footnote 3
Ge	9.1E-04	9.9E-05	Footnote 7
As	1.7E-02	5.0E-04	Footnote 8
Se	7.7E-02	1.0E-03	Footnote 9
Br	2.9E-03	2.2E-02	F_f Footnote 2;F_M from Ref. 16
Kr	NA	NA	NA
Rb	3.1E-02	3.0E-02	6
Sr	6.0E-04	8.0E-04	6
Y	4.6E-03	1.0E-05	6
Zr	3.4E-02	5.0E-06	6
Nb	2.8E-01	2.5E-03	6
Mo	8.0E-03	7.5E-03	6
Tc	4.0E-01	2.5E-02	6
Ru	4.0E-01	1.0E-06	6
Rh	1.5E-03	1.0E-02	6
Pd	5.3E-02	6.7E-03	Footnote 10
Cd	3.0E-02	2.0E-02	Footnote 11
In	1.5E-02	1.3E-03	Footnote 3
Sn	9.1E-04	9.9E-05	Footnote 7
Sb	5.0E-03	2.0E-05	98
Ag	1.7E-02	5.0E-02	6
Te	7.7E-02	1.0E-03	6
I	2.9E-03	6.0E-03	6
Xe	NA	NA	NA
Cs	4.0E-03	1.2E-02	6
Ba	3.2E-03	4.0E-04	6
La	2.0E-04	5.0E-06	6
Ce	1.2E-03	1.0E-04	6
Pr	4.7E-03	5.0E-06	6
Nd	3.3E-03	5.0E-06	6

Table C-3 (Cont'd)
Stable Element Transfer Data

Element	F_f Meat (d/kg)	F_M (Cow) Milk (d/L)	Reference
Pm	2.9E-04	2.0E-05	16
Sm	2.9E-04	2.0E-05	16
Eu	2.9E-04	2.0E-05	16
Gd	2.9E-04	2.0E-05	16
Dy	2.9E-04	2.0E-05	16
Er	2.9E-04	2.0E-05	16
Tm	2.9E-04	2.0E-05	16
Yb	2.9E-04	2.0E-05	16
Lu	2.9E-04	2.0E-05	16
Hf	3.4E-02	5.0E-06	Footnote 5
Ta	2.8E-01	1.3E-03	F_M - Ref.16; F_f -Footnote 6
W	1.3E-03	5.0E-04	6
Re	1.0E-01	1.3E-03	F_M - Ref.16; F_f -Footnote 12
Os	2.2E-01	6.0E-04	Footnote 13
Ir	7.3E-03	5.5E-03	Footnote 14
Pt	5.3E-02	6.7E-03	Footnote 10
Au	1.3E-02	3.2E-02	Footnote 15
Hg	3.0E-02	9.7E-06	F_M - Ref.16; F_f -Footnote 11
Tl	1.5E-02	1.3E-03	F_M - Ref.16; F_f -Footnote 3
Pb	9.1E-04	9.9E-05	98
Bi	1.7E-02	5.0E-04	98
Ra	5.5E-04	5.9E-04	98
Th	1.6E-06	5.0E-06	98
U	1.6E-06	1.2E-04	98
Np	2.0E-04	5.0E-06	6
Am	1.6E-06	2.0E-05	98

Notes:

1. NA = It is assumed that noble gases are not deposited on the ground.
2. Elements listed are those considered for 10CFR20 assessment and compliance.

Footnotes:

There are numerous F_f and F_M values that were not found in published literature. In these cases, the periodic table was used in conjunction with published values. The periodic table was used based on a general assumption that elements have similar characteristics when in the same column of the periodic table. The values of elements in the same column of the periodic table, excluding atomic numbers 58-71 and 90-103, were averaged then assigned to elements missing values located in the same column of the periodic table. This method was used for all columns where there were missing values except column 3A, where there was no data, hence, the average of column 2B and 4A were used.

1. Values obtained by averaging Reference 6 values of Ca, Sr, Ba and Ra.
2. F_f value obtained by assigning the Reference 6 value for I. F_M value obtained by averaging I(Ref. 6) and Br (Ref.16).
3. F_f values obtained by averaging Zn (Ref.6) and Pb (Ref. 98); there were novalues for elements in the same column; an average is taken between values of columns 2B and 4A on the periodic table. F_M values obtained by using the value for Tl from Reference 16.
4. Values obtained by averaging Reference 6 values of Y and La.
5. Values obtained by assigning the Reference 6 value for Zr.
6. F_f values obtained from Ref. 6 value for Nb. F_M values obtained by averaging values for Nb (Ref.6) and Ta (Ref. 16).
7. Values obtained from the Reference 6 values for Pb.
8. Values obtained from the Reference 6 values for Bi.
9. Values obtained from the Reference 6 values for Te.
10. Values obtained from the Reference 6 values for Ni.
11. F_f values obtained from Ref. 6 values for Zn. F_M values obtained by averaging the Reference 6 values for Zn and Hg.
12. Values obtained by averaging Reference 6 values for Mn, Tc, Nd and Reference 98 value for U.
13. Values obtained by averaging Reference 6 values from Fe and Ru.
14. Values obtained by averaging Reference 6 values from Co and Rh.
15. Values obtained by averaging Reference 6 values from Cu and Ag.

Table C-4
Atmospheric Stability Classes

Description	Pasquill Stability Class	$^a\sigma_\theta$ (degrees)	Temperature Change with Height (°C/100 m)
Extremely Unstable	A	>22.5	<-1.9
Moderately Unstable	B	17.5 to 22.5	-1.9 to -1.7
Slightly Unstable	C	12.5 to 17.5	-1.7 to -1.5
Neutral	D	7.5 to 12.5	-1.5 to -0.5
Slightly Stable	E	3.8 to 7.5	-0.5 to 1.5
Moderately Stable	F	2.1 to 3.8	1.5 to 4.0
Extremely Stable	G	0 to 2.1	>4.0

$^a\sigma_\theta$ is the standard deviation of horizontal wind direction fluctuation over a period of 15 minutes to 1 hour.

From Regulatory Guide 1.21, Table 4B.

Table C-5
Vertical Dispersion Parameters

Section 1

Vertical Dispersion Parameters σ_z

σ_z (meters) = aR^b+c with σ_z limited to a maximum of 1000 meters
R = downwind range (meters)
a, b and c have the values listed below:

Stability Class	100 < R < 1000 a	b	c	R > 1000 a	b	c
A	*	*	*	0.00024	2.094	-9.6
B	*	*	*	*	*	*
C	0.113	0.911	0.0	*	*	*
D	0.222	0.725	-1.7	1.26	0.516	-13.0
E	0.211	0.678	-1.3	6.73	0.305	-34.0
F	0.086	0.74	-0.35	18.05	0.18	-48.6
G	0.052	0.74	-0.21	10.83	0.18	-29.2

Basis: Reference 53, except for cases denoted by an asterisk. In these cases, the value of σ_z is obtained by a polynomial approximation to the data from Reference 53 (see Section 2 of this table). The functions given in Reference 50 are not used because they are discontinuous at 1000 meters.

Section 2

Polynomial Approximation for σ_z:
σ_z (meters) = $\exp[a_0 + a_1P + a_2P^2 + a_3P^3]$ with σ_z limited to a maximum of 1000 meters
$P = \log_e[R(\text{meters})]$

a_0, a_1, a_2 and a_3 have the values listed below:

Stability Class	Range	Coefficients	
A	$100 \leq R \leq 1000$	a_0 =	-10.50
		a_1 =	6.879
		a_2 =	-1.309
		a_3 =	0.0957
B	$100 \leq R \leq 1000$	a_0 =	-0.449
		a_1 =	0.218
		a_2 =	0.112
		a_3 =	-0.00517
B	R > 1000	a_0 =	319.148
		a_1 =	-127.806
		a_2 =	17.093
		a_3 =	-0.750
C	R > 1000	a_0 =	5.300
		a_1 =	-1.866
		a_2 =	0.3509
		a_3 =	-0.01514

Table C-6
Allowable Concentration of Dissolved or Entrained Noble Gases
Released from the Site to Unrestricted Areas in Liquid Waste

	Allowable Concentration (μCi/mL)[a]
Nuclide	Zion
Kr 85m	2E-4
Kr 85	5E-4
Kr 87	4E-5
Kr 88	9E-5
Ar 41	7E-5
Xe 131m	7E-4
Xe 133m	5E-4
Xe 133	6E-4
Xe 135m	2E-4
Xe 135	2E-4

[a]Computed from Equation 17 of ICRP Publication 2 (Reference 50) adjusted for infinite cloud submersion in water, and R = 0.01 rem/week, ρ_w = 1.0 gm/cm^3, and P_w / P_t = 1.0.

Table C-7
Radiological Decay Constants (λ_i) in hr^{-1}

Isotope	Lambda		Isotope	Lambda		Isotope	Lambda
H-3	6.44E-06		As-73	3.6E-04		Tc-104	2.31E+00
Be-7	5.4E-04		As-74	1.62E-03		Ru-97	9.96E-03
C-14	1.38E-08		As-76	2.63E-02		Ru-103	7.34E-04
F-18	3.78E-01		As-77	1.79E-02		Ru-105	1.56E-01
Na-22	3.04E-05		Se-73	9.69E-02		Ru-106	7.84E-05
Na-24	4.62E-02		Se-75	2.41E-04		Rh-106	8.33E+01
Mg-27	4.39E+00		Br-77	1.21E-02		Pd-109	5.15E-02
Mg-28	3.31E-02		Br-80	2.38E+00		Cd-109	6.22E-05
Al-26	1.10E-10		Br-82	1.96E-02		In-111	1.02E-02
Al-28	1.85E+01		Br-83	2.90E-01		In-115M	1.59E-01
P-32	2.02E-03		Br-84	1.30E+00		In-116	7.66E-01
Cl-38	1.12E+00		Br-85	1.45E+01		Sn-113	2.51E-04
Ar-41	3.79E-01		Kr-79	1.98E-02		Sn-117M	2.12E-03
K-40	6.19E-14		Kr-81	3.77E-10		Sn-119M	9.85E-05
K-42	5.61E-02		Kr-83M	3.79E-01		Sb-117	2.48E-01
K-43	3.07E-02		Kr-85M	1.55E-01		Sb-122	1.07E-02
Ca-47	6.37E-03		Kr-85	7.38E-06		Sb-124	4.80E-04
Sc-44	1.76E-01		Kr-87	5.44E-01		Sb-125	2.86E-05
Sc-46M	1.33E+02		Kr-88	2.44E-01		Sb-126	2.33E-03
Sc-46	3.44E-04		Kr-90	7.71E+00		Ag-108M	6.23E-07
Sc-47	8.44E-03		Rb-84	8.78E-04		Ag-108	1.75E+01
Ti-44	1.67E-06		Rb-86	1.55E-03		Ag-110M	1.16E-04
V-48	1.81E-03		Rb-87	1.67E-15		Ag-111	3.87E-03
Cr-51	1.04E-03		Rb-88	2.33E+00		Te-121M	1.88E-04
Mn-52M	1.94E+00		Rb-89	2.69E+00		Te-121	1.72E-03
Mn-52	5.16E-03		Sr-85	4.45E-04		Te-123M	2.41E-04
Mn-54	9.23E-05		Sr-87M	2.47E-01		Te-125M	4.98E-04
Mn-56	2.69E-01		Sr-89	5.71E-04		Te-125	0.00E+00
Fe-52	8.37E-02		Sr-90	2.77E-06		Te-127M	2.65E-04
Fe-55	2.93E-05		Sr-91	7.29E-02		Te-127	7.41E-02
Fe-59	6.47E-04		Sr-92	2.56E-01		Te-129M	8.59E-04
Co-57	1.07E-04		Y-86	4.70E-02		Te-129	5.96E-01
Co-58	4.08E-04		Y-87	8.63E-03		Te-131M	2.31E-02
Co-60	1.50E-05		Y-88	2.71E-04		Te-131	1.66E+00
Ni-63	7.90E-07		Y-90	1.08E-02		Te-132	8.86E-03
Ni-65	2.75E-01		Y-91M	8.35E-01		Te-134	9.93E-01
Cu-64	5.46E-02		Y-91	4.94E-04		I-123	5.28E-02
Cu-67	4.67E-04		Y-92	1.96E-01		I-124	6.91E-03
Cu-68	8.31E+01		Y-93	6.86E-02		I-125	4.80E-04
Zn-65	1.18E-04		Zr-95	4.51E-04		I-130	5.61E-02
Zn-69M	5.04E-02		Zr-97	4.10E-02		I-131	3.59E-03
Zn-69	7.46E-01		Nb-94	3.90E-09		I-132	3.01E-01
Ga-66	7.37E-02		Nb-95	8.00E-03		I-133	3.33E-02
Ga-67	8.85E-03		Nb-97M	4.15E+01		I-134	7.89E-01
Ga-68	6.10E-01		Nb-97	5.76E-01		I-135	1.05E-01
Ga-72	4.91E-02		Mo-99	1.05E-02		Xe-127	7.93E-04
Ge-77	6.13E-02		Tc-99M	1.15E-01		Xe-129M	3.25E-03
As-72	2.67E-02		Tc-101	2.92E+00		Xe-131M	2.44E-03

Table C-7 (Cont'd)
Radiological Decay Constants (λ_i) in hr^{-1}

Isotope	Lambda		Isotope	Lambda
Xe-133M	1.32E-02		Yb-175	6.89E-03
Xe-133	5.51E-03		Lu-177	4.30E-03
Xe-135M	2.70E+00		Hf-181	6.81E-04
Xe-135	7.61E-02		Ta-182	2.52E-04
Xe-137	1.08E+01		Ta-183	5.78E-03
Xe-138	2.94E+00		W-187	2.91E-02
Cs-129	2.16E-02		Re-188	4.08E-02
Cs-132	4.46E-03		Os-191	1.88E-03
Cs-134	3.84E-05		Ir-194	3.62E-02
Cs-136	2.19E-03		Pt-195M	7.18E-03
Cs-137	2.62E-06		Pt-197	3.79E-02
Cs-138	1.29E+00		Au-195M	8.15E+01
Cs-139	4.41E+00		Au-195	1.58E-04
Ba-131	2.45E-03		Au-198	1.07E-02
Ba-133M	1.78E-02		Au-199	9.20E-03
Ba-133	7.53E-06		Hg-197	2.91E-02
Ba-135M	2.41E-02		Hg-203	6.20E-04
Ba-137M	1.63E+01		Tl-201	9.49E-03
Ba-137	0.00E+00		Tl-206	9.90E+00
Ba-139	4.99E-01		Tl-208	1.36E+01
Ba-140	2.26E-03		Pb-203	1.33E-02
Ba-141	2.27E+00		Pb-210	3.55E-06
Ba-142	3.88E+00		Pb-212	6.51E-02
La-140	1.72E-02		Pb-214	1.55E+00
La-142	4.35E-01		Bi-206	4.63E-03
Ce-139	2.10E-04		Bi-207	2.37E-06
Ce-141	8.88E-04		Bi-214	2.09E+00
Ce-143	2.10E-02		Ra-226	4.94E-08
Ce-144	1.02E-04		Th-232	5.63E-15
Pr-142	3.62E-02		U-238	1.77E-14
Pr-143	2.13E-03		Np-239	1.23E-02
Pr-144	2.40E+00		Am-241	1.83E-07
Nd-147	2.63E-03			
Nd-149	4.01E-01			
Pm-145	4.47E-06			
Pm-148M	6.99E-04			
Pm-148	5.38E-03			
Pm-149	1.31E-02			
Sm-153	1.48E-02			
Eu-152	5.82E-06			
Eu-154	8.99E-06			
Eu-155	1.59E-05			
Gd-153	1.20E-04			
Dy-157	8.60E-02			
Er-169	3.07E-03			
Er-171	9.22E-02			
Tm-170	2.25E-04			
Yb-169	9.03E-04			

(λ_i) =Radiological Decay Constant
= $0.693/T_i$

T_i = Radiological Half-Life in hours (from Reference 70).
Except for Cu-68, Tc-104, Ba-137, Ta-183, TL-206, Bi-206 which are from References 100.

Table C-8
Bioaccumulation Factors (BF_i) to be Used
in the Absence of Site-Specific Data

Element	BF_i for Freshwater Fish (pCi/kg per pCi/L)	Reference
H	9.0E-01	6
Be	2.8E+01	Footnote 2
C	4.6E+03	6
F	2.2E+02	Footnote 16
Na	1.0E+02	6
Mg	2.8E+01	Footnote 2
Al	2.2E+03	Footnote 13
P	1.0E+05	6
Cl	2.2E+02	Footnote 16
Ar	NA	NA
K	1.0E+03	Footnote 1
Ca	2.8E+01	Footnote 2
Sc	2.5E+01	Footnote 3
Ti	3.3E+00	Footnote 4
V	3.0E+04	Footnote 5
Cr	2.0E+02	6
Mn	4.0E+02	6
Fe	1.0E+02	6
Co	5.0E+01	6
Ni	1.0E+02	6
Cu	5.0E+01	6
Zn	2.0E+03	6
Ga	2.2E+03	Footnote 13
Ge	2.4E+03	Footnote 12
As	3.3E+04	Footnote 14
Se	4.0E+02	Footnote 15
Br	4.2E+02	6
Kr	NA	NA
Rb	2.0E+03	6
Sr	3.0E+01	6
Y	2.5E+01	6
Zr	3.3E+00	6
Nb	3.0E+04	6
Mo	1.0E+01	6
Tc	1.5E+01	6
Ru	1.0E+01	6
Rh	1.0E+01	6
Pd	1.0E+02	Footnote 9
Cd	2.0E+03	Footnote 11
In	2.2E+03	Footnote 13
Sn	2.4E+03	Footnote 12
Sb	1.0E+00	98
Ag	2.3E+00	56
Te	4.0E+02	6
I	1.5E+01	6
Xe	NA	NA
Cs	2.0E+03	6
Ba	4.0E+00	6
La	2.5E+01	6
Ce	1.0E+00	6
Pr	2.5E+01	6
Nd	2.5E+01	6
Pm	3.0E+01	98
Sm	3.0E+01	Footnote 3

Table C-8 (Cont'd)
Bioaccumulation Factors (BF_i) to be Used
in the Absence of Site-Specific Data

Element	BF_i for Freshwater Fish (pCi/kg per pCi/L)	Reference
Eu	1.0E+02	Footnote 3
Gd	2.6E+01	Footnote 3
Dy	2.2E+03	Footnote 3
Er	3.3E+04	Footnote 3
Tm	4.0E+02	Footnote 3
Yb	2.2E+02	Footnote 3
Lu	2.5E+01	Footnote 3
Hf	3.3E+00	Footnote 4
Ta	3.0E+04	Footnote 5
W	1.2E+03	6
Re	2.1E+02	Footnote 6
Os	5.5E+01	Footnote 7
Ir	3.0E+01	Footnote 8
Pt	1.0E+02	Footnote 9
Au	2.6E+01	Footnote 10
Hg	2.0E+03	Footnote 11
Tl	2.2E+03	Footnote 13
Pb	3.0E+02	98
Bi	2.0E+01	98
Ra	5.0E+01	98
Th	3.0E+01	98
U	1.0E+01	98
Np	1.0E+01	6
Am	3.0E+01	98

Footnotes:
NA = It is assumed that noble gases are not accumulated.

In Reference 6, see Table A-1.

A number of bioaccumulation factors could not be found in literature. In this case, the periodic table was used in conjunction with published element values. This method was used for periodic table columns except where there were no values for column 3A so the average of columns 2B and 4A was assigned.

1. Value is the average of Reference 6 values in literature for H, Na, Rb and Cs.
2. Value is the average of Ref. 6 values in literature for Sr, Ba and Ref. 98 values for Ra.
3. Value is the same as the Reference 6 value used for Y.
4. Value is the same as the Reference 6 value used for Zr.
5. Value is the same as the Reference 6 value used for Nb.
6. Value is the average of Reference 6 values in literature for Mn and Tc.
7. Value is the average of Reference 6 values in literature for Fe and Ru.
8. Value is the average of Reference 6 values in literature for Co and Rh.
9. Value is the same as the Reference 6 value used for Ni.
10. Value is the average of Reference 6 values in literature for Cu and Reference 56 value for Ag.
11. Value used is the same as the Reference 6 value used for Zn.
12. Value is the average of Reference 6 value in literature for C and Reference 98 value for Pb.
13. Value is the average of columns 2B and 4A, where column 2B is the "Reference 6 value for Zn" and column 4A is the average of "Reference 6 value for C and Reference 98 value for Pb".
14. Value is the average of Ref. 6 value found in literature for P and the Ref. 98 values for Bi and Sb.
15. Value is the same as the Reference 6 value used for Te.
16. Value is the average of Reference 6 values found in literature for Br and I.

Table C-9
Dose Factors for Noble Gases

	Beta Air Dose Factor	Beta Skin Dose Factor	Gamma Air Dose Factor	Gamma Total Body Dose Factor
	N_i	L_i	M_i	K_i
Nuclide	(mrad/yr per uCi/m^3)	(mrem/yr per uCi/m^3)	(mrad/yr per uCi/m^3)	(mrem/yr per uCi/m^3)
Kr-83m	2.88E+02	---	1.93E+01	7.56E-02
Kr-85m	1.97E+03	1.46E+03	1.23E+03	1.17E+03
Kr-85	1.95E+03	1.34E+03	1.72E+01	1.61E+01
Kr-87	1.03E+04	9.73E+03	6.17E+03	5.92E+03
Kr-88	2.93E+03	2.37E+03	1.52E+04	1.47E+04
Kr-89	1.06E+04	1.01E+04	1.73E+04	1.66E+04
Kr-90	7.83E+03	7.29E+03	1.63E+04	1.56E+04
Xe-131m	1.11E+03	4.76E+02	1.56E+02	9.15E+01
Xe-133m	1.48E+03	9.94E+02	3.27E+02	2.51E+02
Xe-133	1.05E+03	3.06E+02	3.53E+02	2.94E+02
Xe-135m	7.39E+02	7.11E+02	3.36E+03	3.12E+03
Xe-135	2.46E+03	1.86E+03	1.92E+03	1.81E+03
Xe-137	1.27E+04	1.22E+04	1.51E+03	1.42E+03
Xe-138	4.75E+03	4.13E+03	9.21E+03	8.83E+03
Ar-41	3.28E+03	2.69E+03	9.30E+03	8.84E+03

Source: Table B-1 of Reference 6.

Table C-10
External Dose Factors for Standing on Contaminated Ground
DFG_{ij} (mrem/hr per pCi/ m^2)

Element	Whole Body Dose Factor	Reference	Element	Dose Factor	Reference
H-3	0.00E+00	6	Be-7	5.95E-10	99
C-14	0.00E+00	6	F-18	1.19E-08	99
Na-22	2.42E-08	99	Na-24	2.50E-08	6
Mg-27	1.14E-08	99	Mg-28	1.48E-08	99
Al-26	2.95E-08	99	Al-28	2.00E-08	99
P-32	0.00E+00	6	Cl-38	1.70E-08	99
Ar-41	1.39E-08	99	K-40	2.22E-09	99
K-42	4.64E-09	99	K-43	1.19E-08	99
Ca-47	1.14E-08	99	Sc-44	2.50E-08	99
Sc-46m	1.21E-09	99	Sc-46	2.24E-08	99
Sc-47	1.46E-09	99	Ti-44	1.95E-09	99
V-48	3.21E-08	99	Cr-51	2.20E-10	6
Mn-52m	2.79E-08	99	Mn-52	3.80E-08	99
Mn-54	5.80E-09	6	Mn-56	1.10E-08	6
Fe-52	9.12E-09	99	Fe-55	0.00E+00	6
Fe-59	8.00E-09	6	Co-57	1.65E-09	99
Co-58	7.00E-09	6	Co-60	1.70E-08	6
Ni-63	0.00E+00	6	Ni-65	3.70E-09	6
Cu-64	1.50E-09	6	Cu-67	1.52E-09	99
Cu-68	8.60E-09[1]	--	Zn-65	4.00E-09	6
Zn-69m	5.06E-09	99	Zn-69	0.00E+00	6
Ga-66	2.70E-08	99	Ga-67	1.89E-09	99
Ga-68	1.24E-08	99	Ga-72	3.00E-08	99
Ge-77	1.34E-08	99	As-72	2.23E-08	99
As-73	1.16E-10	99	As-74	9.41E-09	99
As-76	6.46E-09	99	As-77	1.79E-10	99
Se-73	1.38E-08	99	Se-75	4.98E-09	99
Br-77	3.84E-09	99	Br-80	2.01E-09	99
Br-82	3.00E-08	99	Br-83	6.40E-11	6
Br-84	1.20E-08	6	Br-85	0.00E+00	6
Kr-79	3.07E-09	99	Kr-81	1.59E-10	99
Kr-83m	1.42E-11	99	Kr-85m	2.24E-09	99
Kr-85	1.35E-10	99	Kr-87	1.03E-08	99
Kr-88	2.07E-08	99	Kr-90	1.56E-08	99
Rb-84	1.07E-08	99	Rb-86	6.30E-10	6
Rb-87	0.00E+00	99	Rb-88	3.50E-09	6
Rb-89	1.50E-08	6	Sr-85	6.16E-09	99
Sr-87m	3.92E-09	99	Sr-89	5.60E-13	6
Sr-90	1.84E-11	99	Sr-91	7.10E-09	6
Sr-92	9.00E-09	6	Y-86	4.00E-08	99
Y-87	5.53E-09	99	Y-88	2.88E-08	99
Y-90	2.20E-12	6	Y-91m	3.80E-09	6
Y-91	2.40E-11	6	Y-92	1.60E-09	6
Y-93	5.70E-10	6	Zr-95	5.00E-09	6
Zr-97	5.50E-09	6	Nb-94	1.84E-08	99
Nb-95	5.10E-09	6	Nb-97m	8.57E-09	99
Nb-97	8.48E-09	99	Mo-99	1.90E-09	6
Tc-99m	9.60E-10	6	Tc-101	2.70E-09	6
Tc-104	1.83E-08[1]	--	Ru-97	2.99E-09	99
Ru-103	3.60E-09	6	Ru-105	4.50E-09	6
Ru/Rh-106	5.76E-09[3]	6, 99	Pc-109	3.80E-10	99
Cc-109	1.12E-10	99	In-111	5.11E-09	99
In-115m	2.01E-09	99	In-116	0.00E+00[2]	--
Sn-113	1.15E-09	99	Sn-117m	1.96E-08	99
Sn-119m	7.05E-11	99	Sb-117	0.00E+00[2]	--
Sb-122	2.71E-09[1]	--	Sb-124	1.16E-08[1]	--
Sb-125	4.56E-09	99	Sb-126	7.13E-10	99
Ag-108m	1.92E-08	99	Ag-108	1.14E-09	99
Ag-110m	1.80E-08	6	Ag-111	6.75E-10	99
Te-121m	2.65E-09	99	Te-121	6.75E-09	99
Te-123m	1.88E-09	99	Te-125m	3.50E-11	6
Te-125	0.00E+00[2]	--	Te-127m	1.10E-12	6
Te-127	1.00E-11	6	Te-129m	7.70E-10	6
Te-129	7.10E-10	6	Te-131m	8.40E-09	6

Table C-10 (cont.)
External Dose Factors for Standing on Contaminated Ground
DFG_{ij} (mrem/hr per pCi/ m^2)

Element	Whole Body Dose Factor	Reference	Element	Dose Factor	Reference
Te-131	2.20E-09	6	Te-I-132	3.40E-09[5]	6
Te-134	1.05E-08	99	I-123	2.12E-09	99
I-124	1.23E-08	99	I-125	2.89E-10	99
I-130	1.40E-08	6	I-131	2.80E-09	6
I-133	3.70E-09	6	I-134	1.60E-08	6
I-135	1.20E-08	6	Xe-127	3.44E-09	99
Xe-129m	5.57E-10	99	Xe-131m	2.13E-10	99
Xe-133m	4.81E-10	99	Xe-133	5.91E-10	99
Xe-135m	5.23E-09	99	Xe-135	3.36E-09	99
Xe-137	4.26E-09	99	Xe-138	1.30E-08	99
Cs-129	3.39E-09	99	Cs-132	8.40E-09	99
Cs-134	1.20E-08	6	Cs-136	1.50E-08	6
Cs-137/Ba-137m	1.14E-08[4]	6, 99	Cs-138	2.10E-08	6
Cs-139	5.15E-09	99	Ba-131	5.74E-09	99
Ba-133m	8.10E-10	99	Ba-133	4.85E-09	99
Ba-135m	7.26E-10	99	Ba-137m	7.17E-09	99
Ba-137	0.00E+00[2]	--	Ba-139	2.40E-09	6
Ba-La-140	1.71E-08[6]	6	Ba-141	4.30E-09	6
Ba-142	7.90E-09	6	La-142	1.50E-08	6
Ce-139	2.04E-09	99	Ce-141	5.50E-10	6
Ce-143	2.20E-09	6	Ce-Pr-144	5.20E-10[7]	6
Pr-142	1.84E-09	99	Pr-143	0.00E+00	6
Nc-147	1.00E-09	6	Nc-149	5.32E-09	99
Pm-145	3.38E-10	99	Pm-148m	2.35E-08	99
Pm-148	7.22E-09	99	Pm-149	5.32E-10	99
Sm-153	8.95E-10	99	Eu-152	1.30E-08	99
Eu-154	1.41E-08	99	Eu-155	8.27E-10	99
Gc-153	1.46E-09	99	Dy-157	4.39E-09	99
Er-169	6.12E-14	99	Er-171	5.11E-09	99
Tm-170	3.41E-10	99	Yb-169	4.12E-09	99
Yb-175	4.94E-10	99	Lu-177	4.60E-10	99
Hf-181	6.67E-09	99	Ta-182	1.42E-08	99
Ta-183	2.93E-09[1]	--	W-187	3.10E-09	6
Re-188	1.89E-09	99	Os-191	9.83E-10	99
Ir-194	2.31E-09	99	Pt-195m	9.79E-10	99
Pt-197	3.57E-10	99	Au-195m	2.54E-09	99
Au-195	1.14E-09	99	Au-198	5.19E-09	99
Au-199	1.18E-09	99	Hg-197	9.33E-10	99
Hg-203	2.89E-09	99	Tl-201	1.24E-09	99
Tl-206	0.00E+00[2]	--	Tl-208	3.58E-08	99
Pb-203	3.88E-09	99	Pb-210	3.57E-11	99
Pb-212	1.91E-09	99	Pb-214	3.18E-09	99
Bi-206	3.74E-08	99	Bi-207	1.77E-08	99
Bi-214	1.71E-08	99	Ra-226	8.78E-11	99
Th-232	8.14E-12	99	U-238	7.98E-12	99
Np-239	9.50E-10	6	Am-241	3.48E-10	99

1 Valued derived by comparing the percentage and MeV of the nuclide's gammas and then comparing to Cesium-137, as a value was not available in the literature.

2 0.0 due to low yield and short half life. A value was not available in the literature.

3 Value is the sum of Ru-106 (1.50E-9) and Rh-106 (4.26E-9). The Rh-106 value is from Reference 99 and the Ru-106 value is from Reference 6.

4 Value is the sum of Cs-137 (4.20E-9) and Ba-137m (7.17E-9). The values are from references 6 and 99, respectively.

5 Value is the sum of Te-132 (1.70E-9) and I-132 (1.70E-9).

6 Value is the sum of Ba-140 (2.10E-9) and La-140 (1.50E-8) from reference 6. In Reference 6, see Table E-6.

7 Value is the sum of Ce-144 (3.20E-10) and Pr-144 (2.00E-10) from reference 6.

Note: Dose assessments for 10CFR20 and 40CFR190 compliance are made for an adult only.

Dose assessments for 10CFR50 Appendix are made using dose factors of Regulatory Guide 1.109 (Reference 6) for all age groups.

Table C-11

Sector Code Definitions

Sector Code	Sector Direction	Angle from North (Degrees)
A	N	$348.75 < \theta \leq 11.25$
B	NNE	$11.25 < \theta \leq 33.75$
C	NE	$33.75 < \theta \leq 56.25$
D	ENE	$56.25 < \theta \leq 78.75$
E	E	$78.75 < \theta \leq 101.25$
F	ESE	$101.25 < \theta \leq 123.75$
G	SE	$123.75 < \theta \leq 146.25$
H	SSE	$146.25 < \theta \leq 168.75$
J	S	$168.75 < \theta \leq 191.25$
K	SSW	$191.25 < \theta \leq 213.75$
L	SW	$213.75 < \theta \leq 236.25$
M	WSW	$236.25 < \theta \leq 258.75$
N	W	$258.75 < \theta \leq 281.25$
P	WNW	$281.25 < \theta \leq 303.75$
Q	NW	$303.75 < \theta \leq 326.25$
R	NNW	$326.25 < \theta \leq 348.75$

APPENDIX D

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APPENDIX E

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APPENDIX F

STATION-SPECIFIC DATA FOR ZION UNITS 1 AND 2

APPENDIX F
STATION-SPECIFIC DATA FOR ZION UNITS 1 AND 2

F.1 INTRODUCTION

This appendix contains data relevant to the Zion site. Included is a figure showing the unrestricted area boundary, restricted area boundary and values of parameters used in offsite dose assessment.

Table F-1
Aquatic Environmental Dose Parameters

General Information[a]

The existence of irrigation is not mentioned in Zion Environmental Report.

Recreation includes one or more of the following: boating, water skiing, swimming, and sport fishing.

Water and Fish Ingestion Parameters

Parameter[b]	Value
D^w	6
Z	10

Limits on Radioactivity in Unprotected Outdoor Tanks[c,d,e]

Outside Temporary Tank Activity Concentration $\leq$10% of 10CFR20 Appendix B Table 2 Column 2 Limits

[a] This is based on information in Zion Environmental Report Section 2.3.2.2.

[b] The parameters are defined in Section A.2.1 of Appendix A. Based on Lake Michigan Model discussed in Section C.1.3.1.2 of Appendix C.

[c] See Section A.2.4 of Appendix A.

[d] Tritium and dissolved or entrained noble gases are excluded from this limit

[e] The sum of the fractions for each radionuclide cannot exceed unity

Table F-2

Station Characteristics

STATION: Zion Nuclear Power Station

LOCATION: Zion, Illinois

Characteristics of Elevated Release Point

1) Release Height = ____m 2) Diameter = _____m

3) Exit Speed = _____ms^{-1} 4) Heat Content = ____Kcal s^{-1}

Characteristics of Vent Stack Release Point

1) Release Height = 55.32 m[a] 2) Diameter = 2.32 m

3) Exit Speed = 11.2 ms^{-1}[a]

Characteristics of Ground Level Point

1) Release Height = 0 m

2) Building Factor (D) = 57.6 m[a]

Meterological Data

A 250 ft Tower is Located 700 m NNW of Vent Stack release point

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Tower Data Used in Calculations

Release Point	Wind Speed and Direction	Differential Temperature
Elevated	(NA)	(NA)
Vent	125	250-35
Ground	35	250-35

[a] Used in calculating the meteorological and dose factors in Tables F-5, F-6, and F-7. See Sections B.3 through B.6 of Appendix B.

Table F-3

Critical Ranges

Direction	Site Sector	Unrestricted Area Boundary[a] (m)	Restricted Area Boundary (m)	Nearest Resident[b] (m)	Nearest Dairy Farm Within 5 Miles[c] (m)
N	A	469	375	4000	None
NNE	B	475	400	d	None
NE	C	400	325	d	None
ENE	D	400	200	d	None
E	E	400	175	d	None
ESE	F	400	175	d	None
SE	G	400	175	d	None
SSE	H	400	200	d	None
S	J	433	350	d	None
SSW	K	439	375	3700	None
SW	L	518	475	2000	None
WSW	M	671	671	2000	None
W	N	658	658	1100	None
WNW	P	893	893	2000	None
NW	Q	847	847	2000	None
NNW	R	725	250	2400	None

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[a] Used in calculating the meteorological and dose factors in Tables F-5 and F-7. See sections B.3 through B.6 of Appendix B.

[b] 1992 annual survey by Teledyne Isotopes Midwest Laboratories. The distances are rounded to the nearest conservative 100 meters.

[c] 1992 annual milk animal census by Teledyne Isotopes Midwest Laboratories. Used in calculating the D/Q values in Table F-6. The distances are rounded to the nearest conservative 100 meters.

[d] Lake Michigan

Table F-4

Average Wind Speeds

Downwind Direction	Site Sector	Average Wind Speed (m/sec)[a]	
		Mixed Mode	Ground Level
N	A	5.0	3.2
NNE	B	5.3	3.3
NE	C	5.8	4.1
ENE	D	5.6	3.9
E	E	5.7	3.9
ESE	F	5.1	3.3
SE	G	4.9	3.0
SSE	H	5.1	3.4
S	J	5.9	4.6
SSW	K	5.8	4.4
SW	L	5.1	4.0
WSW	M	5.2	4.6
W	N	5.1	4.4
WNW	P	4.8	3.7
NW	Q	4.7	3.1
NNW	R	5.1	3.9

[a] Calculated in Reference 81 using formulas in Section B.1.3 of Appendix B. Based on Zion site meteorological data, January 1979 through December 1987.

Table F-5
X/Q and D/Q Maxima at or Beyond the Unrestricted Area Boundary

Downwind Direction	Site Sector	Radius (meters)	Mixed Mode (Vent) Release		Ground Level Release	
			χ/Q (sec/m^3)	D/Q (1/m^2)	χ/Q (sec/m^3)	D/Q (1/m^2)
N	A	469	2.032E-6	1.168E-8	9.548E-6	3.680E-8
NNE	B	475	1.792E-6	9.983E-9	1.004E-5	3.256E-8
NE	C	400	2.710E-6	1.997E-8	1.386E-5	5.708E-8
ENE	D	400	2.180E-6	1.734E-8	1.160E-5	4.855E-8
E	E	400	1.949E-6	1.889E-8	1.169E-5	5.211E-8
ESE	F	400	1.650E-9	1.319E-8	1.280E-5	4.730E-8
SE	G	400	1.646E-6	1.237E-8	1.312E-5	4.985E-8
SSE	H	400	1.001E-6	9.230E-9	7.852E-6	3.238E-8
S	J	433	1.272E-6	1.524E-8	7.058E-6	3.562E-8
SSW	K	439	9.650E-7	1.357E-8	5.768E-6	3.290E-8
SW	L	518	4.590E-7	6.081E-9	3.125E-6	1.625E-8
WSW	M	671	2.311E-7	3.509E-9	1.393E-6	8.964E-9
W	N	658	2.394E-7	3.381E-9	1.445E-6	8.440E-9
WNW	P	893	1.427E-7	1.869E-9	8.817E-7	4.789E-9
NW	Q	847	2.110E-7	2.671E-9	1.310E-6	6.607E-9
NNW	R	725	3.740E-7	4.535E-9	2.038E-6	1.148E-8

Zion Site Meteorological Data 01/79 - 12/87

NOTE: Based on the formulas in Sections B.3 and B.4 of Appendix B. χ/Q is used for beta skin and inhalation pathways. See Sections A.1.2, A.1.3 and A.1.4.2 of Appendix A. D/Q is used for produce and leafy vegetable pathways. Section A.1.4 of Appendix A. The mixed mode level release data are provided for reference purposes only. Routine dose calculations are performed using ground level data. Radius is the approximate distance from the midpoint between gaseous effluent release points to the location of the highest χ/Q Q or D/Q at or beyond the unrestricted area boundary (UAB).

Table F-5a
χ/Q and D/Q Maxima at or Beyond the Restricted Area Boundary

Downwind Direction	Site Sector	Radius (meters)	Mixed Mode (Vent) Release		Ground Level Release	
			χ/Q (sec/m^3)	D/Q (1/m^2)	χ/Q (sec/m^3)	D/Q (1/m^2)
N	A	375	3.015E-6	1.605E-8	1.420E-5	5.165E-8
NNE	B	400	2.426E-6	1.278E-8	1.363E-5	4.230E-8
NE	C	325	3.917E-6	2.653E-8	2.009E-5	7.781E-8
ENE	D	200	7.441E-6	4.345E-8	4.027E-5	1.330E-7
E	E	175	8.400E-6	5.512E-8	5.177E-5	1.719E-7
ESE	F	175	7.025E-6	3.590E-8	5.670E-5	1.559E-7
SE	G	175	7.002E-6	3.298E-8	5.811E-5	1.644E-7
SSE	H	200	3.362E-6	2.113E-8	2.730E-5	8.871E-8
S	J	350	1.851E-6	2.054E-8	1.031E-5	4.906E-8
SSW	K	375	1.270E-6	1.676E-8	7.631E-6	4.174E-8
SW	L	475	5.307E-7	6.818E-9	3.626E-6	1.858E-8
WSW	M	671	2.311E-7	3.509E-9	1.393E-6	8.964E-9
W	N	658	2.394E-7	3.381E-9	1.445E-6	8.440E-9
WNW	P	893	1.427E-7	1.869E-9	8.817E-7	4.789E-9
NW	Q	847	2.11E-7	2.871E-9	1.310E-6	6.607E-9
NNW	R	250	2.79E-6	1.778E-8	1.316E-5	5.779E-8

Zion Site Meteorological Data 01/79 - 12/87

NOTE: Based on the formulas in Sections B.3 and B.4 of Appendix B. The mixed mode level release data are provided for reference purposes only. Routine dose calculations are performed using ground level data. Radius is the approximate distance from the midpoint between gaseous effluent release points to the location of the highest χ/Q or D/Q at or beyond the restricted area boundary (RAB).

Table F-5b
Maximum Offsite Gamma-χ/Q

Downwind Direction	Site Sector	Radius (meters)	Ground Gamma-χ/Q (sec/m^3)	Vent Gamma-χ/Q (sec/m^3)
N	A	469	2.51E-06	8.16E-07
NNE	B	475	2.51E-06	7.26E-07
NE	C	400	3.33E-06	1.05E-06
ENE	D	400	2.90E-06	8.87E-07
E	E	400	2.97E-06	8.62E-07
ESE	F	400	3.17E-06	7.84E-07
SE	G	400	3.52E-06	8.35E-07
SSE	H	400	2.13E-06	5.70E-07
S	J	433	1.98E-06	6.29E-07
SSW	K	439	1.78E-06	5.65E-07
SW	L	518	1.05E-06	3.39E-07
WSW	M	671	5.32E-07	2.17E-07
W	N	658	5.42E-07	2.13E-07
WNW	P	893	3.58E-07	1.41E-07
NW	Q	847	5.15E-07	2.00E-07
NNW	R	725	7.59E-07	3.26E-07

Table F-6

χ/Q and D/Q at the Nearest Resident Locations within 5 miles

Location Description	Direction	Site Sector	Distance		Ground Level Release		Mixed Mode (Vent) Release	
			miles	meters	χ/Q sec/m^3	D/Q m^{-2}	χ/Q sec/m^3	D/Q m^{-2}
NEAREST RESIDENCE	N	A	2.49	4000	5.00E-07	7.30E-10	5.60E-08	5.80E-11
NEAREST RESIDENCE	NNE	B	4.97	8000	2.20E-07	2.20E-10	4.20E-08	2.50E-11
NEAREST RESIDENCE	NE	C	4.97	8000	2.40E-07	3.10E-10	5.20E-08	6.40E-11
NEAREST RESIDENCE	ENE	D	4.97	8000	2.00E-07	2.80E-10	4.80E-08	7.10E-11
NEAREST RESIDENCE	E	E	4.97	8000	2.40E-07	4.30E-10	6.80E-08	1.40E-10
NEAREST RESIDENCE	ESE	F	4.97	8000	1.80E-07	3.10E-10	5.50E-08	1.00E-10
NEAREST RESIDENCE	SE	G	4.97	8000	1.50E-07	2.70E-10	5.20E-08	8.80E-11
NEAREST RESIDENCE	SSE	H	4.97	8000	1.10E-07	1.70E-10	3.50E-08	5.30E-11
NEAREST RESIDENCE	S	J	4.97	8000	1.10E-07	2.40E-10	4.20E-08	7.70E-11
NEAREST RESIDENCE	SSW	K	2.30	3700	3.20E-07	1.20E-09	9.30E-08	4.70E-10
NEAREST RESIDENCE	SW	L	1.86	3000	3.70E-07	1.20E-09	7.80E-08	3.80E-10
NEAREST RESIDENCE	WSW	M	1.24	2000	4.70E-07	1.50E-09	5.00E-08	4.20E-10
NEAREST RESIDENCE	W	N	0.68	1100	1.50E-06	3.70E-09	3.40E-08	5.30E-10
NEAREST RESIDENCE	WNW	P	1.24	2000	5.20E-07	1.40E-09	4.10E-08	2.20E-10
NEAREST RESIDENCE	NW	Q	1.24	2000	5.60E-07	1.50E-09	4.20E-08	2.30E-10
NEAREST RESIDENCE	NNW	R	1.49	2400	6.30E-07	1.90E-09	6.80E-08	4.10E-10

Table F-6a

χ/Q and D/Q at the Nearest Cow Milk Locations within 5 miles

Location Description	Direction	Site Sector	Distance		Ground Level Release		Mixed Mode (Vent) Release	
			miles	meters	χ/Q sec/m^3	D/Q m^{-2}	χ/Q sec/m^3	D/Q m^{-2}
COW MILK	N	A	4.97	8000	1.90E-07	2.10E-10	4.10E-08	1.90E-11
COW MILK	NNE	B	4.97	8000	2.20E-07	2.20E-10	4.20E-08	2.50E-11
COW MILK	NE	C	4.97	8000	2.40E-07	3.10E-10	5.20E-08	6.40E-11
COW MILK	ENE	D	4.97	8000	2.00E-07	2.80E-10	4.80E-08	7.10E-11
COW MILK	E	E	4.97	8000	2.40E-07	4.30E-10	6.80E-08	1.40E-10
COW MILK	ESE	F	4.97	8000	1.80E-07	3.10E-10	5.50E-08	1.00E-10
COW MILK	SE	G	4.97	8000	1.50E-07	2.70E-10	5.20E-08	8.80E-11
COW MILK	SSE	H	4.97	8000	1.10E-07	1.70E-10	3.50E-08	5.30E-11
COW MILK	S	J	4.97	8000	1.10E-07	2.40E-10	4.20E-08	7.70E-11
COW MILK	SSW	K	4.97	8000	1.00E-07	3.10E-10	4.90E-08	1.40E-10
COW MILK	SW	L	4.97	8000	8.50E-08	2.20E-10	3.90E-08	8.20E-11
COW MILK	WSW	M	4.97	8000	5.80E-08	1.30E-10	2.40E-08	5.00E-11
COW MILK	W	N	4.97	8000	6.90E-08	1.20E-10	2.50E-08	3.40E-11
COW MILK	WNW	P	4.97	8000	6.60E-08	1.20E-10	2.60E-08	2.70E-11
COW MILK	NW	Q	4.97	8000	7.10E-08	1.30E-10	2.70E-08	2.90E-11
COW MILK	NNW	R	4.97	8000	1.10E-07	2.20E-10	3.40E-08	5.70E-11

Table F-6b

χ/Q and D/Q at the Nearest Cow Milk Locations within 5 miles

Location Description	Direction	Site Sector	Distance		Ground Level Release		Mixed Mode (Vent) Release	
			miles	meters	χ/Q sec/m^3	D/Q m^{-2}	χ/Q sec/m^3	D/Q m^{-2}
COW MEAT	N	A	4.97	8000	1.90E-07	2.10E-10	4.10E-08	1.90E-11
COW MEAT	NNE	B	4.97	8000	2.20E-07	2.20E-10	4.20E-08	2.50E-11
COW MEAT	NE	C	4.97	8000	2.40E-07	3.10E-10	5.20E-08	6.40E-11
COW MEAT	ENE	D	4.97	8000	2.00E-07	2.80E-10	4.80E-08	7.10E-11
COW MEAT	E	E	4.97	8000	2.40E-07	4.30E-10	6.80E-08	1.40E-10
COW MEAT	ESE	F	4.97	8000	1.80E-07	3.10E-10	5.50E-08	1.00E-10
COW MEAT	SE	G	4.97	8000	1.50E-07	2.70E-10	5.20E-08	8.80E-11
COW MEAT	SSE	H	4.97	8000	1.10E-07	1.70E-10	3.50E-08	5.30E-11
COW MEAT	S	J	4.97	8000	1.10E-07	2.40E-10	4.20E-08	7.70E-11
COW MEAT	SSW	K	4.97	8000	1.00E-07	3.10E-10	4.90E-08	1.40E-10
COW MEAT	SW	L	4.97	8000	8.50E-08	2.20E-10	3.90E-08	8.20E-11
COW MEAT	WSW	M	4.47	7200	6.70E-08	1.60E-10	2.70E-08	6.00E-11
COW MEAT	W	N	3.48	5600	1.10E-07	2.20E-10	3.30E-08	6.10E-11
COW MEAT	WNW	P	4.97	8000	6.60E-08	1.20E-10	2.60E-08	2.70E-11
COW MEAT	NW	Q	4.97	8000	7.10E-08	1.30E-10	2.70E-08	2.90E-11
COW MEAT	NNW	R	4.97	8000	1.10E-07	2.20E-10	3.40E-08	5.70E-11

Table F-7

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Kr-85

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	1.403E-05	1.356E-05	469.	4.313E-05	4.171E-05
NNE	475.	475.	1.249E-05	1.207E-05	475.	4.315E-05	4.173E-05
NE	400.	400.	1.803E-05	1.743E-05	400.	5.723E-05	5.534E-05
ENE	400.	400.	1.526E-05	1.476E-05	400.	4.984E-05	4.819E-05
E	400.	400.	1.482E-05	1.433E-05	400.	5.110E-05	4.941E-05
ESE	400.	400.	1.349E-05	1.304E-05	400.	5.450E-05	5.270E-05
SE	400.	400.	1.436E-05	1.388E-05	400.	6.049E-05	5.849E-05
SSE	400.	400.	9.798E-06	9.474E-06	400.	3.657E-05	3.536E-05
S	433.	433.	1.082E-05	1.046E-05	433.	3.398E-05	3.286E-05
SSW	439.	439.	9.715E-06	9.394E-06	439.	3.053E-05	2.952E-05
SW	518.	518.	5.829E-06	5.636E-06	518.	1.805E-05	1.746E-05
WSW	671.	671.	3.737E-06	3.614E-06	671.	9.147E-06	8.845E-06
W	658.	658.	3.664E-06	3.543E-06	658.	9.329E-06	9.021E-06
WNW	893.	893.	2.425E-06	2.345E-06	893.	6.158E-06	5.955E-06
NW	847.	847.	3.444E-06	3.330E-06	847.	8.861E-06	8.569E-06
NNW	725.	725.	5.601E-06	5.416E-06	725.	1.305E-05	1.262E-05

Zion Site Meteorological Data 1/79 - 12/87

Table F-8
Site Specific Potable Water Dose Factors for Adult Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	8.31E-01	8.31E-01	8.31E-01	8.31E-01	8.31E-01	8.31E-01
Na-24	2.36E+01	2.36E+01	2.36E+01	2.36E+01	2.36E+01	2.36E+01	2.36E+01
Cr-51	0.00E+00	0.00E+00	3.69E-02	2.21E-02	8.13E-03	4.90E-02	9.28E+00
Mn-54	0.00E+00	6.34E+01	1.21E+01	0.00E+00	1.89E+01	0.00E+00	1.94E+02
Mn-56	0.00E+00	1.60E+00	2.83E-01	0.00E+00	2.03E+00	0.00E+00	5.09E+01
Fe-55	3.81E+01	2.64E+01	6.14E+00	0.00E+00	0.00E+00	1.47E+01	1.51E+01
Fe-59	6.02E+01	1.41E+02	5.42E+01	0.00E+00	0.00E+00	3.95E+01	4.72E+02
Co-58	0.00E+00	1.03E+01	2.32E+01	0.00E+00	0.00E+00	0.00E+00	2.09E+02
Co-60	0.00E+00	2.97E+01	6.55E+01	0.00E+00	0.00E+00	0.00E+00	5.58E+02
Ni-63	1.80E+03	1.25E+02	6.05E+01	0.00E+00	0.00E+00	0.00E+00	2.61E+01
Ni-65	7.32E+00	9.51E-01	4.34E-01	0.00E+00	0.00E+00	0.00E+00	2.41E+01
Cu-64	0.00E+00	1.16E+00	5.42E-01	0.00E+00	2.91E+00	0.00E+00	9.85E+01
Zn-65	6.71E+01	2.14E+02	9.65E+01	0.00E+00	1.43E+02	0.00E+00	1.35E+02
Zn-69	1.43E-01	2.73E-01	1.90E-02	0.00E+00	1.78E-01	0.00E+00	4.11E-02
Br-83	0.00E+00	0.00E+00	5.58E-01	0.00E+00	0.00E+00	0.00E+00	8.03E-01
Br-84	0.00E+00	0.00E+00	7.23E-01	0.00E+00	0.00E+00	0.00E+00	5.67E-06
Br-85	0.00E+00	0.00E+00	2.97E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.93E+02	1.36E+02	0.00E+00	0.00E+00	0.00E+00	5.77E+01
Rb-88	0.00E+00	8.39E-01	4.45E-01	0.00E+00	0.00E+00	0.00E+00	1.16E-11
Rb-89	0.00E+00	5.56E-01	3.91E-01	0.00E+00	0.00E+00	0.00E+00	3.23E-14
Sr-89	4.27E+03	0.00E+00	1.23E+02	0.00E+00	0.00E+00	0.00E+00	6.85E+02
Sr-90	1.21E+05	0.00E+00	2.43E+03	0.00E+00	0.00E+00	0.00E+00	3.04E+03
Sr-91	7.86E+01	0.00E+00	3.18E+00	0.00E+00	0.00E+00	0.00E+00	3.74E+02
Sr-92	2.98E+01	0.00E+00	1.29E+00	0.00E+00	0.00E+00	0.00E+00	5.91E+02
Y-90	1.33E-01	0.00E+00	3.58E-03	0.00E+00	0.00E+00	0.00E+00	1.41E+03
Y-91M	1.26E-03	0.00E+00	4.88E-05	0.00E+00	0.00E+00	0.00E+00	3.70E-03
Y-91	1.96E+00	0.00E+00	5.23E-02	0.00E+00	0.00E+00	0.00E+00	1.08E+03
Y-92	1.17E-02	0.00E+00	3.43E-04	0.00E+00	0.00E+00	0.00E+00	2.05E+02
Y-93	3.72E-02	0.00E+00	1.03E-03	0.00E+00	0.00E+00	0.00E+00	1.18E+03
Zr-95	4.22E-01	1.35E-01	9.15E-02	0.00E+00	2.12E-01	0.00E+00	4.29E+02
Zr-97	2.33E-02	4.70E-03	2.15E-03	0.00E+00	7.10E-03	0.00E+00	1.46E+03
Nb-95	8.63E-02	4.80E-02	2.58E-02	0.00E+00	4.74E-02	0.00E+00	2.91E+02
Mo-99	0.00E+00	5.98E+01	1.14E+01	0.00E+00	1.35E+02	0.00E+00	1.39E+02
Tc- 99M	3.43E-03	9.68E-03	1.23E-01	0.00E+00	1.47E-01	4.74E-03	5.73E+00
Tc-101	3.52E-03	5.08E-03	4.98E-02	0.00E+00	9.14E-02	2.59E-03	1.53E-14
Ru-103	2.57E+00	0.00E+00	1.11E+00	0.00E+00	9.79E+00	0.00E+00	3.00E+02
Ru-105	2.14E-01	0.00E+00	8.43E-02	0.00E+00	2.76E+00	0.00E+00	1.31E+02
Ru-106	3.81E+01	0.00E+00	4.83E+00	0.00E+00	7.36E+01	0.00E+00	2.47E+03
Ag-110M	2.22E+00	2.05E+00	1.22E+00	0.00E+00	4.04E+00	0.00E+00	8.38E+02
Te-125M	3.72E+01	1.35E+01	4.98E+00	1.12E+01	1.51E+02	0.00E+00	1.48E+02

Table F-8 (continued)
Site Specific Potable Water Dose Factors for Adult Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	9.39E+01	3.36E+01	1.14E+01	2.40E+01	3.81E+02	0.00E+00	3.15E+02
Te-127	1.53E+00	5.48E-01	3.30E-01	1.13E+00	6.21E+00	0.00E+00	1.20E+02
Te-129M	1.60E+02	5.95E+01	2.52E+01	5.48E+01	6.66E+02	0.00E+00	8.03E+02
Te-129	4.36E-01	1.64E-01	1.06E-01	3.34E-01	1.83E+00	0.00E+00	3.29E-01
Te-131M	2.40E+01	1.17E+01	9.78E+00	1.86E+01	1.19E+02	0.00E+00	1.17E+03
Te-131	2.73E-01	1.14E-01	8.63E-02	2.25E-01	1.20E+00	0.00E+00	3.87E-02
Te-132	3.50E+01	2.26E+01	2.12E+01	2.50E+01	2.18E+02	0.00E+00	1.07E+03
I-130	1.05E+01	3.09E+01	1.22E+01	2.62E+03	4.83E+01	0.00E+00	2.66E+01
I-131	5.77E+01	8.25E+01	4.73E+01	2.70E+04	1.41E+02	0.00E+00	2.18E+01
I-132	2.82E+00	7.53E+00	2.64E+00	2.64E+02	1.20E+01	0.00E+00	1.41E+00
I-133	1.97E+01	3.43E+01	1.04E+01	5.03E+03	5.98E+01	0.00E+00	3.08E+01
I-134	1.47E+00	3.99E+00	1.43E+00	6.92E+01	6.35E+00	0.00E+00	3.48E-03
I-135	6.14E+00	1.61E+01	5.94E+00	1.06E+03	2.58E+01	0.00E+00	1.82E+01
Cs-134	8.63E+02	2.05E+03	1.68E+03	0.00E+00	6.64E+02	2.21E+02	3.59E+01
Cs-136	9.03E+01	3.56E+02	2.57E+02	0.00E+00	1.98E+02	2.72E+01	4.05E+01
Cs-137	1.11E+03	1.51E+03	9.90E+02	0.00E+00	5.13E+02	1.71E+02	2.93E+01
Cs-138	7.66E-01	1.51E+00	7.49E-01	0.00E+00	1.11E+00	1.10E-01	6.45E-06
Ba-139	1.35E+00	9.58E-04	3.94E-02	0.00E+00	8.96E-04	5.44E-04	2.39E+00
Ba-140	2.82E+02	3.54E-01	1.84E+01	0.00E+00	1.20E-01	2.03E-01	5.80E+02
Ba-141	6.53E-01	4.94E-04	2.21E-02	0.00E+00	4.59E-04	2.80E-04	3.08E-10
Ba-142	2.95E-01	3.04E-04	1.86E-02	0.00E+00	2.57E-04	1.72E-04	4.16E-19
La-140	3.47E-02	1.75E-02	4.62E-03	0.00E+00	0.00E+00	0.00E+00	1.28E+03
La-142	1.78E-03	8.07E-04	2.01E-04	0.00E+00	0.00E+00	0.00E+00	5.89E+00
Ce-141	1.30E-01	8.78E-02	9.96E-03	0.00E+00	4.08E-02	0.00E+00	3.36E+02
Ce-143	2.29E-02	1.69E+01	1.87E-03	0.00E+00	7.45E-03	0.00E+00	6.32E+02
Ce-144	6.77E+00	2.83E+00	3.63E-01	0.00E+00	1.68E+00	0.00E+00	2.29E+03
Pr-143	1.28E-01	5.12E-02	6.32E-03	0.00E+00	2.95E-02	0.00E+00	5.59E+02
Pr-144	4.17E-04	1.73E-04	2.12E-05	0.00E+00	9.78E-05	0.00E+00	6.01E-11
Nd-147	8.72E-02	1.01E-01	6.03E-03	0.00E+00	5.89E-02	0.00E+00	4.84E+02
W-187	1.43E+00	1.19E+00	4.17E-01	0.00E+00	0.00E+00	0.00E+00	3.91E+02
Np-239	1.65E-02	1.62E-03	8.95E-04	0.00E+00	5.06E-03	0.00E+00	3.33E+02

Notes:

1) Units are mrem/hr per µCi/ml.

Table F-8a
Site Specific Potable Water Dose Factors for Teen Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	5.85E-01	5.85E-01	5.85E-01	5.85E-01	5.85E-01	5.85E-01
Na-24	2.23E+01	2.23E+01	2.23E+01	2.23E+01	2.23E+01	2.23E+01	2.23E+01
Cr-51	0.00E+00	0.00E+00	3.49E-02	1.94E-02	7.65E-03	4.98E-02	5.86E+00
Mn-54	0.00E+00	5.72E+01	1.13E+01	0.00E+00	1.71E+01	0.00E+00	1.17E+02
Mn-56	0.00E+00	1.53E+00	2.72E-01	0.00E+00	1.94E+00	0.00E+00	1.01E+02
Fe-55	3.66E+01	2.60E+01	6.06E+00	0.00E+00	0.00E+00	1.65E+01	1.12E+01
Fe-59	5.69E+01	1.33E+02	5.13E+01	0.00E+00	0.00E+00	4.19E+01	3.14E+02
Co-58	0.00E+00	9.42E+00	2.17E+01	0.00E+00	0.00E+00	0.00E+00	1.30E+02
Co-60	0.00E+00	2.72E+01	6.13E+01	0.00E+00	0.00E+00	0.00E+00	3.55E+02
Ni-63	1.72E+03	1.21E+02	5.81E+01	0.00E+00	0.00E+00	0.00E+00	1.93E+01
Ni-65	7.26E+00	9.27E-01	4.22E-01	0.00E+00	0.00E+00	0.00E+00	5.03E+01
Cu-64	0.00E+00	1.11E+00	5.24E-01	0.00E+00	2.82E+00	0.00E+00	8.64E+01
Zn-65	5.58E+01	1.94E+02	9.04E+01	0.00E+00	1.24E+02	0.00E+00	8.21E+01
Zn-69	1.42E-01	2.71E-01	1.90E-02	0.00E+00	1.77E-01	0.00E+00	5.00E-01
Br-83	0.00E+00	0.00E+00	5.56E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	7.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	2.96E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.89E+02	1.36E+02	0.00E+00	0.00E+00	0.00E+00	4.27E+01
Rb-88	0.00E+00	8.26E-01	4.40E-01	0.00E+00	0.00E+00	0.00E+00	7.07E-08
Rb-89	0.00E+00	5.33E-01	3.77E-01	0.00E+00	0.00E+00	0.00E+00	8.17E-10
Sr-89	4.26E+03	0.00E+00	1.22E+02	0.00E+00	0.00E+00	0.00E+00	5.08E+02
Sr-90	9.88E+04	0.00E+00	1.98E+03	0.00E+00	0.00E+00	0.00E+00	2.26E+03
Sr-91	7.82E+01	0.00E+00	3.11E+00	0.00E+00	0.00E+00	0.00E+00	3.55E+02
Sr-92	2.96E+01	0.00E+00	1.26E+00	0.00E+00	0.00E+00	0.00E+00	7.53E+02
Y-90	1.33E-01	0.00E+00	3.58E-03	0.00E+00	0.00E+00	0.00E+00	1.09E+03
Y-91M	1.25E-03	0.00E+00	4.78E-05	0.00E+00	0.00E+00	0.00E+00	5.90E-02
Y-91	1.95E+00	0.00E+00	5.22E-02	0.00E+00	0.00E+00	0.00E+00	7.98E+02
Y-92	1.17E-02	0.00E+00	3.39E-04	0.00E+00	0.00E+00	0.00E+00	3.22E+02
Y-93	3.71E-02	0.00E+00	1.02E-03	0.00E+00	0.00E+00	0.00E+00	1.13E+03
Zr-95	3.99E-01	1.26E-01	8.66E-02	0.00E+00	1.85E-01	0.00E+00	2.91E+02
Zr-97	2.30E-02	4.54E-03	2.09E-03	0.00E+00	6.89E-03	0.00E+00	1.23E+03
Nb-95	7.97E-02	4.42E-02	2.43E-02	0.00E+00	4.28E-02	0.00E+00	1.89E+02
Mo-99	0.00E+00	5.84E+01	1.11E+01	0.00E+00	1.34E+02	0.00E+00	1.05E+02
Tc- 99M	3.22E-03	8.97E-03	1.16E-01	0.00E+00	1.34E-01	4.98E-03	5.89E+00
Tc-101	3.49E-03	4.96E-03	4.87E-02	0.00E+00	8.97E-02	3.02E-03	8.48E-10
Ru-103	2.47E+00	0.00E+00	1.06E+00	0.00E+00	8.71E+00	0.00E+00	2.06E+02
Ru-105	2.11E-01	0.00E+00	8.20E-02	0.00E+00	2.66E+00	0.00E+00	1.71E+02
Ru-106	3.80E+01	0.00E+00	4.79E+00	0.00E+00	7.33E+01	0.00E+00	1.82E+03
Ag-110M	1.99E+00	1.88E+00	1.14E+00	0.00E+00	3.59E+00	0.00E+00	5.28E+02
Te-125M	3.71E+01	1.34E+01	4.96E+00	1.04E+01	0.00E+00	0.00E+00	1.09E+02

Table F-8a (continued)
Site Specific Potable Water Dose Factors for Teen Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	9.37E+01	3.32E+01	1.11E+01	2.23E+01	3.80E+02	0.00E+00	2.34E+02
Te-127	1.53E+00	5.43E-01	3.29E-01	1.06E+00	6.20E+00	0.00E+00	1.18E+02
Te-129M	1.58E+02	5.86E+01	2.50E+01	5.10E+01	6.61E+02	0.00E+00	5.93E+02
Te-129	4.34E-01	1.62E-01	1.06E-01	3.10E-01	1.82E+00	0.00E+00	2.37E+00
Te-131M	2.36E+01	1.13E+01	9.46E+00	1.71E+01	1.18E+02	0.00E+00	9.10E+02
Te-131	2.70E-01	1.11E-01	8.45E-02	2.08E-01	1.18E+00	0.00E+00	2.22E-02
Te-132	3.38E+01	2.14E+01	2.02E+01	2.26E+01	2.05E+02	0.00E+00	6.78E+02
I-130	9.98E+00	2.89E+01	1.15E+01	2.35E+03	4.45E+01	0.00E+00	2.22E+01
I-131	5.67E+01	7.94E+01	4.26E+01	2.32E+04	1.37E+02	0.00E+00	1.57E+01
I-132	2.70E+00	7.07E+00	2.54E+00	2.38E+02	1.11E+01	0.00E+00	3.08E+00
I-133	1.95E+01	3.30E+01	1.01E+01	4.61E+03	5.79E+01	0.00E+00	2.50E+01
I-134	1.41E+00	3.75E+00	1.35E+00	6.25E+01	5.91E+00	0.00E+00	4.94E-02
I-135	5.91E+00	1.52E+01	5.64E+00	9.79E+02	2.40E+01	0.00E+00	1.69E+01
Cs-134	8.11E+02	1.91E+03	8.86E+02	0.00E+00	6.07E+02	2.32E+02	2.37E+01
Cs-136	8.32E+01	3.28E+02	2.20E+02	0.00E+00	1.78E+02	2.81E+01	2.64E+01
Cs-137	1.09E+03	1.44E+03	5.03E+02	0.00E+00	4.91E+02	1.91E+02	2.05E+01
Cs-138	7.52E-01	1.44E+00	7.22E-01	0.00E+00	1.07E+00	1.24E-01	6.55E-04
Ba-139	1.35E+00	9.48E-04	3.92E-02	0.00E+00	8.93E-04	6.53E-04	1.20E+01
Ba-140	2.75E+02	3.37E-01	1.77E+01	0.00E+00	1.14E-01	2.27E-01	4.24E+02
Ba-141	6.50E-01	4.85E-04	2.17E-02	0.00E+00	4.51E-04	3.32E-04	1.39E-06
Ba-142	2.90E-01	2.90E-04	1.78E-02	0.00E+00	2.45E-04	1.93E-04	8.90E-13
La-140	3.37E-02	1.66E-02	4.41E-03	0.00E+00	0.00E+00	0.00E+00	9.52E+02
La-142	1.73E-03	7.70E-04	1.92E-04	0.00E+00	0.00E+00	0.00E+00	2.34E+01
Ce-141	1.29E-01	8.60E-02	9.88E-03	0.00E+00	4.05E-02	0.00E+00	2.46E+02
Ce-143	2.28E-02	1.66E+01	1.85E-03	0.00E+00	7.43E-03	0.00E+00	4.98E+02
Ce-144	6.74E+00	2.79E+00	3.62E-01	0.00E+00	1.67E+00	0.00E+00	1.70E+03
Pr-143	1.27E-01	5.07E-02	6.32E-03	0.00E+00	2.95E-02	0.00E+00	4.18E+02
Pr-144	4.17E-04	1.71E-04	2.11E-05	0.00E+00	9.79E-05	0.00E+00	4.59E-07
Nd-147	9.09E-02	9.88E-02	5.92E-03	0.00E+00	5.80E-02	0.00E+00	3.57E+02
W-187	1.41E+00	1.15E+00	4.04E-01	0.00E+00	0.00E+00	0.00E+00	3.12E+02
Np-239	1.71E-02	1.61E-03	8.93E-04	0.00E+00	5.05E-03	0.00E+00	2.59E+02

Notes:

1) Units are mrem/hr per μCi/ml.

Table F-8b
Site Specific Potable Water Dose Factors for Child Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.12E+00	1.12E+00	1.12E+00	1.12E+00	1.12E+00	1.12E+00
Na-24	5.62E+01	5.62E+01	5.62E+01	5.62E+01	5.62E+01	5.62E+01	5.62E+01
Cr-51	0.00E+00	0.00E+00	8.62E-02	4.79E-02	1.31E-02	8.74E-02	4.57E+00
Mn-54	0.00E+00	1.04E+02	2.76E+01	0.00E+00	2.91E+01	0.00E+00	8.70E+01
Mn-56	0.00E+00	3.24E+00	7.31E-01	0.00E+00	3.91E+00	0.00E+00	4.69E+02
Fe-55	1.11E+02	5.91E+01	1.83E+01	0.00E+00	0.00E+00	3.34E+01	1.09E+01
Fe-59	1.60E+02	2.59E+02	1.29E+02	0.00E+00	0.00E+00	7.50E+01	2.69E+02
Co-58	0.00E+00	1.74E+01	5.34E+01	0.00E+00	0.00E+00	0.00E+00	1.02E+02
Co-60	0.00E+00	5.13E+01	1.51E+02	0.00E+00	0.00E+00	0.00E+00	2.84E+02
Ni-63	5.21E+03	2.79E+02	1.77E+02	0.00E+00	0.00E+00	0.00E+00	1.88E+01
Ni-65	2.15E+01	2.03E+00	1.18E+00	0.00E+00	0.00E+00	0.00E+00	2.48E+02
Cu-64	0.00E+00	2.37E+00	1.43E+00	0.00E+00	5.74E+00	0.00E+00	1.11E+02
Zn-65	1.33E+02	3.54E+02	2.20E+02	0.00E+00	2.23E+02	0.00E+00	6.21E+01
Zn-69	4.24E-01	6.13E-01	5.67E-02	0.00E+00	3.72E-01	0.00E+00	3.87E+01
Br-83	0.00E+00	0.00E+00	1.66E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	1.92E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	8.84E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	6.49E+02	3.99E+02	0.00E+00	0.00E+00	0.00E+00	4.18E+01
Rb-88	0.00E+00	1.84E+00	1.28E+00	0.00E+00	0.00E+00	0.00E+00	9.03E-02
Rb-89	0.00E+00	1.13E+00	1.01E+00	0.00E+00	0.00E+00	0.00E+00	9.88E-03
Sr-89	1.28E+04	0.00E+00	3.65E+02	0.00E+00	0.00E+00	0.00E+00	4.95E+02
Sr-90	2.48E+05	0.00E+00	4.99E+03	0.00E+00	0.00E+00	0.00E+00	2.22E+03
Sr-91	2.33E+02	0.00E+00	8.78E+00	0.00E+00	0.00E+00	0.00E+00	5.14E+02
Sr-92	8.75E+01	0.00E+00	3.51E+00	0.00E+00	0.00E+00	0.00E+00	1.66E+03
Y-90	3.98E-01	0.00E+00	1.07E-02	0.00E+00	0.00E+00	0.00E+00	1.13E+03
Y-91M	3.70E-03	0.00E+00	1.35E-04	0.00E+00	0.00E+00	0.00E+00	7.25E+00
Y-91	5.83E+00	0.00E+00	1.56E-01	0.00E+00	0.00E+00	0.00E+00	7.77E+02
Y-92	3.49E-02	0.00E+00	9.98E-04	0.00E+00	0.00E+00	0.00E+00	1.01E+03
Y-93	1.10E-01	0.00E+00	3.03E-03	0.00E+00	0.00E+00	0.00E+00	1.65E+03
Zr-95	1.12E+00	2.47E-01	2.20E-01	0.00E+00	3.54E-01	0.00E+00	2.58E+02
Zr-97	6.77E-02	9.79E-03	5.78E-03	0.00E+00	1.41E-02	0.00E+00	1.48E+03
Nb-95	2.18E-01	8.49E-02	6.07E-02	0.00E+00	7.97E-02	0.00E+00	1.57E+02
Mo-99	0.00E+00	1.29E+02	3.19E+01	0.00E+00	2.75E+02	0.00E+00	1.07E+02
Tc- 99M	8.94E-03	1.75E-02	2.91E-01	0.00E+00	2.55E-01	8.91E-03	9.98E+00
Tc-101	1.04E-02	1.09E-02	1.38E-01	0.00E+00	1.85E-01	5.74E-03	3.45E-02
Ru-103	7.08E+00	0.00E+00	2.72E+00	0.00E+00	1.78E+01	0.00E+00	1.83E+02
Ru-105	6.25E-01	0.00E+00	2.27E-01	0.00E+00	5.49E+00	0.00E+00	4.08E+02
Ru-106	1.13E+02	0.00E+00	1.41E+01	0.00E+00	1.53E+02	0.00E+00	1.76E+03
Ag-110M	5.22E+00	3.53E+00	2.82E+00	0.00E+00	6.57E+00	0.00E+00	4.20E+02
Te-125M	1.10E+02	2.99E+01	1.47E+01	3.10E+01	0.00E+00	0.00E+00	1.07E+02

Table F-8b (continued)
Site Specific Potable Water Dose Factors for Child Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	2.80E+02	7.54E+01	3.32E+01	6.70E+01	7.98E+02	0.00E+00	2.27E+02
Te-127	4.56E+00	1.23E+00	9.79E-01	3.16E+00	1.30E+01	0.00E+00	1.78E+02
Te-129M	4.72E+02	1.32E+02	7.33E+01	1.52E+02	1.39E+03	0.00E+00	5.76E+02
Te-129	1.30E+00	3.62E-01	3.08E-01	9.26E-01	3.80E+00	0.00E+00	8.08E+01
Te-131M	6.98E+01	2.41E+01	2.57E+01	4.96E+01	2.34E+02	0.00E+00	9.79E+02
Te-131	8.04E-01	2.45E-01	2.39E-01	6.15E-01	2.43E+00	0.00E+00	4.22E+00
Te-132	9.79E+01	4.33E+01	5.23E+01	6.31E+01	4.02E+02	0.00E+00	4.36E+02
I-130	2.83E+01	5.72E+01	2.95E+01	6.30E+03	8.55E+01	0.00E+00	2.67E+01
I-131	1.67E+02	1.68E+02	9.53E+01	5.54E+04	2.75E+02	0.00E+00	1.49E+01
I-132	7.75E+00	1.42E+01	6.55E+00	6.61E+02	2.18E+01	0.00E+00	1.68E+01
I-133	5.74E+01	7.09E+01	2.68E+01	1.32E+04	1.18E+02	0.00E+00	2.86E+01
I-134	4.06E+00	7.54E+00	3.47E+00	1.73E+02	1.15E+01	0.00E+00	5.00E+00
I-135	1.70E+01	3.05E+01	1.44E+01	2.70E+03	4.68E+01	0.00E+00	2.33E+01
Cs-134	2.27E+03	3.72E+03	7.85E+02	0.00E+00	1.15E+03	4.14E+02	2.01E+01
Cs-136	2.28E+02	6.26E+02	4.05E+02	0.00E+00	3.33E+02	4.97E+01	2.20E+01
Cs-137	3.17E+03	3.03E+03	4.48E+02	0.00E+00	9.88E+02	3.56E+02	1.90E+01
Cs-138	2.21E+00	3.07E+00	1.95E+00	0.00E+00	2.16E+00	2.33E-01	1.41E+00
Ba-139	4.01E+00	2.14E-03	1.16E-01	0.00E+00	1.87E-03	1.26E-03	2.32E+02
Ba-140	8.05E+02	7.05E-01	4.70E+01	0.00E+00	2.30E-01	4.21E-01	4.08E+02
Ba-141	1.94E+00	1.09E-03	6.31E-02	0.00E+00	9.39E-04	6.38E-03	1.10E+00
Ba-142	8.47E-01	6.10E-04	4.73E-02	0.00E+00	4.93E-04	3.59E-04	1.10E-02
La-140	9.79E-02	3.42E-02	1.15E-02	0.00E+00	0.00E+00	0.00E+00	9.53E+02
La-142	5.08E-03	1.62E-03	5.07E-04	0.00E+00	0.00E+00	0.00E+00	3.21E+02
Ce-141	3.85E-01	1.92E-01	2.85E-02	0.00E+00	8.41E-02	0.00E+00	2.39E+02
Ce-143	6.77E-02	3.67E+01	5.32E-03	0.00E+00	1.54E-02	0.00E+00	5.38E+02
Ce-144	2.02E+01	6.32E+00	1.08E+00	0.00E+00	3.50E+00	0.00E+00	1.65E+03
Pr-143	3.81E-01	1.14E-01	1.89E-02	0.00E+00	6.19E-02	0.00E+00	4.11E+02
Pr-144	1.25E-03	3.87E-04	6.29E-05	0.00E+00	2.04E-04	0.00E+00	8.32E-01
Nd-147	2.70E-01	2.19E-01	1.70E-02	0.00E+00	1.20E-01	0.00E+00	3.47E+02
W-187	4.16E+00	2.46E+00	1.10E+00	0.00E+00	0.00E+00	0.00E+00	3.46E+02
Np-239	5.09E-02	3.65E-03	2.57E-03	0.00E+00	1.06E-02	0.00E+00	2.70E+02

Notes:

1) Units are mrem/hr per μCi/ml.

Table F-8c
Site Specific Potable Water Dose Factors for Infant Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00
Na-24	6.33E+01	6.33E+01	6.33E+01	6.33E+01	6.33E+01	6.33E+01	6.33E+01
Cr-51	0.00E+00	0.00E+00	8.84E-02	5.77E-02	1.26E-02	1.12E-01	2.58E+00
Mn-54	0.00E+00	1.25E+02	2.83E+01	0.00E+00	2.77E+01	0.00E+00	4.58E+01
Mn-56	0.00E+00	5.13E+00	8.84E-01	0.00E+00	4.41E+00	0.00E+00	4.66E+02
Fe-55	8.72E+01	5.63E+01	1.50E+01	0.00E+00	0.00E+00	2.75E+01	7.15E+00
Fe-59	1.93E+02	3.37E+02	1.33E+02	0.00E+00	0.00E+00	9.97E+01	1.61E+02
Co-58	0.00E+00	2.26E+01	5.63E+01	0.00E+00	0.00E+00	0.00E+00	5.62E+01
Co-60	0.00E+00	6.77E+01	1.60E+02	0.00E+00	0.00E+00	0.00E+00	1.61E+02
Ni-63	3.98E+03	2.46E+02	1.38E+02	0.00E+00	0.00E+00	0.00E+00	1.22E+01
Ni-65	2.95E+01	3.34E+00	1.52E+00	0.00E+00	0.00E+00	0.00E+00	2.54E+02
Cu-64	0.00E+00	3.82E+00	1.77E+00	0.00E+00	6.46E+00	0.00E+00	7.84E+01
Zn-65	1.15E+02	3.96E+02	1.82E+02	0.00E+00	1.92E+02	0.00E+00	3.34E+02
Zn-69	5.85E-01	1.05E+00	7.84E-02	0.00E+00	4.38E-01	0.00E+00	8.59E+01
Br-83	0.00E+00	0.00E+00	2.28E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	2.40E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	1.22E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.07E+03	5.27E+02	0.00E+00	0.00E+00	0.00E+00	2.73E+01
Rb-88	0.00E+00	3.12E+00	1.71E+00	0.00E+00	0.00E+00	0.00E+00	3.04E+00
Rb-89	0.00E+00	1.79E+00	1.24E+00	0.00E+00	0.00E+00	0.00E+00	6.11E-01
Sr-89	1.57E+04	0.00E+00	4.51E+02	0.00E+00	0.00E+00	0.00E+00	3.24E+02
Sr-90	1.77E+05	0.00E+00	3.60E+03	0.00E+00	0.00E+00	0.00E+00	1.45E+03
Sr-91	3.14E+02	0.00E+00	1.13E+01	0.00E+00	0.00E+00	0.00E+00	3.71E+02
Sr-92	1.20E+02	0.00E+00	4.47E+00	0.00E+00	0.00E+00	0.00E+00	1.30E+03
Y-90	5.45E-01	0.00E+00	1.46E-02	0.00E+00	0.00E+00	0.00E+00	7.52E+02
Y-91M	5.08E-03	0.00E+00	1.73E-04	0.00E+00	0.00E+00	0.00E+00	1.69E+01
Y-91	7.09E+00	0.00E+00	1.89E-01	0.00E+00	0.00E+00	0.00E+00	5.08E+02
Y-92	4.80E-02	0.00E+00	1.35E-03	0.00E+00	0.00E+00	0.00E+00	9.15E+02
Y-93	1.52E-01	0.00E+00	4.15E-03	0.00E+00	0.00E+00	0.00E+00	1.20E+03
Zr-95	1.29E+00	3.15E-01	2.23E-01	0.00E+00	3.39E-01	0.00E+00	1.57E+02
Zr-97	9.28E-02	1.59E-02	7.27E-03	0.00E+00	1.61E-02	0.00E+00	1.02E+03
Nb-95	2.63E-01	1.08E-01	6.27E-02	0.00E+00	7.77E-02	0.00E+00	9.15E+01
Mo-99	0.00E+00	2.13E+02	4.16E+01	0.00E+00	3.19E+02	0.00E+00	7.02E+01
Tc- 99M	1.20E-02	2.48E-02	3.20E-01	0.00E+00	2.67E-01	1.30E-02	7.21E+00
Tc-101	1.42E-02	1.79E-02	1.77E-01	0.00E+00	2.13E-01	9.78E-03	3.05E+00
Ru-103	9.28E+00	0.00E+00	3.10E+00	0.00E+00	1.93E+01	0.00E+00	1.13E+02
Ru-105	8.53E-01	0.00E+00	2.87E-01	0.00E+00	6.27E+00	0.00E+00	3.39E+02
Ru-106	1.51E+02	0.00E+00	1.89E+01	0.00E+00	1.79E+02	0.00E+00	1.15E+03
Ag-110M	6.24E+00	4.56E+00	3.02E+00	0.00E+00	6.52E+00	0.00E+00	2.36E+02
Te-125M	1.46E+02	4.88E+01	1.98E+01	4.92E+01	0.00E+00	0.00E+00	6.96E+01

Table F-8c (continued)
Site Specific Potable Water Dose Factors for Infant Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	3.67E+02	1.22E+02	4.44E+01	1.06E+02	9.03E+02	0.00E+00	1.48E+02
Te-127	6.27E+00	2.10E+00	1.35E+00	5.10E+00	1.53E+01	0.00E+00	1.32E+02
Te-129M	6.27E+02	2.15E+02	9.66E+01	2.41E+02	1.57E+03	0.00E+00	3.74E+02
Te-129	1.78E+00	6.14E-01	4.16E-01	1.49E+00	4.43E+00	0.00E+00	1.42E+02
Te-131M	9.53E+01	3.84E+01	3.17E+01	7.77E+01	2.64E+02	0.00E+00	6.46E+02
Te-131	1.10E+00	4.08E-01	3.10E-01	9.84E-01	2.82E+00	0.00E+00	4.46E+01
Te-132	1.30E+02	6.46E+01	6.03E+01	9.53E+01	4.04E+02	0.00E+00	2.39E+02
I-130	3.76E+01	8.28E+01	3.32E+01	9.28E+03	9.09E+01	0.00E+00	1.77E+01
I-131	2.25E+02	2.65E+02	1.17E+02	8.72E+04	3.10E+02	0.00E+00	9.47E+00
I-132	1.04E+01	2.11E+01	7.52E+00	9.91E+02	2.36E+01	0.00E+00	1.71E+01
I-133	7.84E+01	1.14E+02	3.34E+01	2.08E+04	1.34E+02	0.00E+00	1.93E+01
I-134	5.45E+00	1.12E+01	3.97E+00	2.60E+02	1.25E+01	0.00E+00	1.15E+01
I-135	2.28E+01	4.54E+01	1.66E+01	4.07E+03	5.06E+01	0.00E+00	1.64E+01
Cs-134	2.36E+03	4.41E+03	4.45E+02	0.00E+00	1.13E+03	4.65E+02	1.20E+01
Cs-136	2.88E+02	8.46E+02	3.16E+02	0.00E+00	3.37E+02	6.90E+01	1.29E+01
Cs-137	3.27E+03	3.83E+03	2.71E+02	0.00E+00	1.03E+03	4.16E+02	1.20E+01
Cs-138	3.02E+00	4.90E+00	2.38E+00	0.00E+00	2.45E+00	3.82E-01	7.84E+00
Ba-139	5.52E+00	3.66E-03	1.60E-01	0.00E+00	2.20E-03	2.22E-03	3.50E+02
Ba-140	1.07E+03	1.07E+00	5.52E+01	0.00E+00	2.55E-01	6.58E-01	2.63E+02
Ba-141	2.66E+00	1.82E-03	8.40E-02	0.00E+00	1.10E-03	1.11E-03	3.25E+01
Ba-142	1.15E+00	9.59E-04	5.68E-02	0.00E+00	5.52E-04	5.81E-04	4.76E+00
La-140	1.32E-01	5.22E-02	1.34E-02	0.00E+00	0.00E+00	0.00E+00	6.13E+02
La-142	6.90E-03	2.53E-03	6.06E-04	0.00E+00	0.00E+00	0.00E+00	4.30E+02
Ce-141	4.93E-01	3.01E-01	3.54E-02	0.00E+00	9.28E-02	0.00E+00	1.55E+02
Ce-143	9.28E-02	6.16E+01	7.02E-03	0.00E+00	1.79E-02	0.00E+00	3.59E+02
Ce-144	1.87E+01	7.65E+00	1.05E+00	0.00E+00	3.09E+00	0.00E+00	1.07E+03
Pr-143	5.10E-01	1.91E-01	2.53E-02	0.00E+00	7.09E-02	0.00E+00	2.69E+02
Pr-144	1.72E-03	6.65E-04	8.65E-05	0.00E+00	2.41E-04	0.00E+00	3.09E+01
Nd-147	3.47E-01	3.56E-01	2.18E-02	0.00E+00	1.37E-01	0.00E+00	2.26E+02
W-187	5.66E+00	3.94E+00	1.36E+00	0.00E+00	0.00E+00	0.00E+00	2.31E+02
Np-239	6.96E-02	6.23E-03	3.52E-03	0.00E+00	1.24E-02	0.00E+00	1.80E+02

Notes:

1) Units are mrem/hr per µCi/ml.

Table F-9
Site Specific Fish Ingestion Dose Factors for Adult Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.29E-01	1.29E-01	1.29E-01	1.29E-01	1.29E-01	1.29E-01
Na-24	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02
Cr-51	0.00E+00	0.00E+00	1.27E+00	7.61E-01	2.81E-01	1.69E+00	3.20E+02
Mn-54	0.00E+00	4.38E+03	8.35E+02	0.00E+00	1.30E+03	0.00E+00	1.34E+04
Mn-56	0.00E+00	1.10E+02	1.95E+01	0.00E+00	1.40E+02	0.00E+00	3.51E+03
Fe-55	6.58E+02	4.55E+02	1.06E+02	0.00E+00	0.00E+00	2.54E+02	2.61E+02
Fe-59	1.04E+03	2.44E+03	9.36E+02	0.00E+00	0.00E+00	6.82E+02	8.14E+03
Co-58	0.00E+00	8.92E+01	2.00E+02	0.00E+00	0.00E+00	0.00E+00	1.81E+03
Co-60	0.00E+00	2.56E+02	5.65E+02	0.00E+00	0.00E+00	0.00E+00	4.81E+03
Ni-63	3.11E+04	2.16E+03	1.04E+03	0.00E+00	0.00E+00	0.00E+00	4.50E+02
Ni-65	1.26E+02	1.64E+01	7.49E+00	0.00E+00	0.00E+00	0.00E+00	4.17E+02
Cu-64	0.00E+00	9.97E+00	4.68E+00	0.00E+00	2.51E+01	0.00E+00	8.50E+02
Zn-65	2.32E+04	7.37E+04	3.33E+04	0.00E+00	4.93E+04	0.00E+00	4.64E+04
Zn-69	4.93E+01	9.43E+01	6.56E+00	0.00E+00	6.13E+01	0.00E+00	1.42E+01
Br-83	0.00E+00	0.00E+00	4.04E+01	0.00E+00	0.00E+00	0.00E+00	5.82E+01
Br-84	0.00E+00	0.00E+00	5.24E+01	0.00E+00	0.00E+00	0.00E+00	4.11E-04
Br-85	0.00E+00	0.00E+00	2.15E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.01E+05	4.71E+04	0.00E+00	0.00E+00	0.00E+00	1.99E+04
Rb-88	0.00E+00	2.90E+02	1.54E+02	0.00E+00	0.00E+00	0.00E+00	4.00E-09
Rb-89	0.00E+00	1.92E+02	1.35E+02	0.00E+00	0.00E+00	0.00E+00	1.12E-11
Sr-89	2.21E+04	0.00E+00	6.35E+02	0.00E+00	0.00E+00	0.00E+00	3.55E+03
Sr-90	6.26E+05	0.00E+00	1.26E+04	0.00E+00	0.00E+00	0.00E+00	1.57E+04
Sr-91	4.07E+02	0.00E+00	1.64E+01	0.00E+00	0.00E+00	0.00E+00	1.94E+03
Sr-92	1.54E+02	0.00E+00	6.68E+00	0.00E+00	0.00E+00	0.00E+00	3.06E+03
Y-90	5.76E-01	0.00E+00	1.54E-02	0.00E+00	0.00E+00	0.00E+00	6.10E+03
Y-91M	5.44E-03	0.00E+00	2.11E-04	0.00E+00	0.00E+00	0.00E+00	1.60E-02
Y-91	8.44E+00	0.00E+00	2.26E-01	0.00E+00	0.00E+00	0.00E+00	4.64E+03
Y-92	5.06E-02	0.00E+00	1.48E-03	0.00E+00	0.00E+00	0.00E+00	8.86E+02
Y-93	1.60E-01	0.00E+00	4.43E-03	0.00E+00	0.00E+00	0.00E+00	5.09E+03
Zr-95	2.40E-01	7.70E-02	5.21E-02	0.00E+00	1.21E-01	0.00E+00	2.44E+02
Zr-97	1.33E-02	2.68E-03	1.22E-03	0.00E+00	4.04E-03	0.00E+00	8.30E+02
Nb-95	4.47E+02	2.48E+02	1.34E+02	0.00E+00	2.46E+02	0.00E+00	1.51E+06
Mo-99	0.00E+00	1.03E+02	1.96E+01	0.00E+00	2.34E+02	0.00E+00	2.39E+02
Tc- 99M	8.87E-03	2.51E-02	3.19E-01	0.00E+00	3.81E-01	1.23E-02	1.48E+01
Tc-101	9.12E-03	1.31E-02	1.29E-01	0.00E+00	2.37E-01	6.72E-03	3.95E-14
Ru-103	4.43E+00	0.00E+00	1.91E+00	0.00E+00	1.69E+01	0.00E+00	5.17E+02
Ru-105	3.69E-01	0.00E+00	1.46E-01	0.00E+00	4.76E+00	0.00E+00	2.26E+02
Ru-106	6.58E+01	0.00E+00	8.33E+00	0.00E+00	1.27E+02	0.00E+00	4.26E+03
Ag-110M	8.81E-01	8.15E-01	4.84E-01	0.00E+00	1.60E+00	0.00E+00	3.33E+02
Te-125M	2.57E+03	9.30E+02	3.44E+02	7.72E+02	1.04E+04	0.00E+00	1.02E+04

Table F-9 (continued)
Site Specific Fish Ingestion Dose Factors for Adult Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	6.48E+03	2.32E+03	7.90E+02	1.66E+03	2.63E+04	0.00E+00	2.17E+04
Te-127	1.05E+02	3.78E+01	2.28E+01	7.80E+01	4.29E+02	0.00E+00	8.31E+03
Te-129M	1.10E+04	4.11E+03	1.74E+03	3.78E+03	4.60E+04	0.00E+00	5.54E+04
Te-129	3.01E+01	1.13E+01	7.33E+00	2.31E+01	1.26E+02	0.00E+00	2.27E+01
Te-131M	1.66E+03	8.10E+02	6.75E+02	1.28E+03	8.21E+03	0.00E+00	8.04E+04
Te-131	1.89E+01	7.88E+00	5.96E+00	1.55E+01	8.26E+01	0.00E+00	2.67E+00
Te-132	2.41E+03	1.56E+03	1.47E+03	1.72E+03	1.50E+04	0.00E+00	7.38E+04
I-130	2.71E+01	8.01E+01	3.16E+01	6.79E+03	1.25E+02	0.00E+00	6.89E+01
I-131	1.49E+02	2.14E+02	1.22E+02	7.00E+04	3.66E+02	0.00E+00	5.64E+01
I-132	7.29E+00	1.95E+01	6.82E+00	6.82E+02	3.11E+01	0.00E+00	3.66E+00
I-133	5.10E+01	8.87E+01	2.70E+01	1.30E+04	1.55E+02	0.00E+00	7.97E+01
I-134	3.81E+00	1.03E+01	3.70E+00	1.79E+02	1.64E+01	0.00E+00	9.01E-03
I-135	1.59E+01	4.17E+01	1.54E+01	2.75E+03	6.68E+01	0.00E+00	4.70E+01
Cs-134	2.98E+05	7.09E+05	5.79E+05	0.00E+00	2.29E+05	7.61E+04	1.24E+04
Cs-136	3.12E+04	1.23E+05	8.86E+04	0.00E+00	6.85E+04	9.38E+03	1.40E+04
Cs-137	3.82E+05	5.22E+05	3.42E+05	0.00E+00	1.77E+05	5.89E+04	1.01E+04
Cs-138	2.64E+02	5.22E+02	2.59E+02	0.00E+00	3.84E+02	3.79E+01	2.23E-03
Ba-139	9.29E-01	6.62E-04	2.72E-02	0.00E+00	6.19E-04	3.75E-04	1.65E+00
Ba-140	1.94E+02	2.44E-01	1.27E+01	0.00E+00	8.30E-02	1.40E-01	4.00E+02
Ba-141	4.51E-01	3.41E-04	1.52E-02	0.00E+00	3.17E-04	1.93E-04	2.13E-10
Ba-142	2.04E-01	2.10E-04	1.28E-02	0.00E+00	1.77E-04	1.19E-04	2.87E-19
La-140	1.50E-01	7.54E-02	1.99E-02	0.00E+00	0.00E+00	0.00E+00	5.54E+03
La-142	7.66E-03	3.48E-03	8.68E-04	0.00E+00	0.00E+00	0.00E+00	2.54E+01
Ce-141	2.24E-02	1.52E-02	1.72E-03	0.00E+00	7.04E-03	0.00E+00	5.79E+01
Ce-143	3.95E-03	2.92E+00	3.23E-04	0.00E+00	1.29E-03	0.00E+00	1.09E+02
Ce-144	1.17E+00	4.88E-01	6.27E-02	0.00E+00	2.90E-01	0.00E+00	3.95E+02
Pr-143	5.51E-01	2.21E-01	2.73E-02	0.00E+00	1.27E-01	0.00E+00	2.41E+03
Pr-144	1.80E-03	7.48E-04	9.16E-05	0.00E+00	4.22E-04	0.00E+00	2.59E-10
Nd-147	3.76E-01	4.35E-01	2.60E-02	0.00E+00	2.54E-01	0.00E+00	2.09E+03
W-187	2.96E+02	2.47E+02	8.65E+01	0.00E+00	0.00E+00	0.00E+00	8.10E+04
Np-239	2.85E-02	2.80E-03	1.54E-03	0.00E+00	8.74E-03	0.00E+00	5.75E+02

Table F-9a
Site Specific Fish Ingestion Dose Factors for Teen Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	9.92E-02	9.92E-02	9.92E-02	9.92E-02	9.92E-02	9.92E-02
Na-24	4.20E+02	4.20E+02	4.20E+02	4.20E+02	4.20E+02	4.20E+02	4.20E+02
Cr-51	0.00E+00	0.00E+00	1.31E+00	7.30E-01	2.88E-01	1.88E+00	2.21E+02
Mn-54	0.00E+00	4.30E+03	8.54E+02	0.00E+00	1.28E+03	0.00E+00	8.83E+03
Mn-56	0.00E+00	1.15E+02	2.05E+01	0.00E+00	1.46E+02	0.00E+00	7.59E+03
Fe-55	6.89E+02	4.89E+02	1.14E+02	0.00E+00	0.00E+00	3.10E+02	2.12E+02
Fe-59	1.07E+03	2.50E+03	9.65E+02	0.00E+00	0.00E+00	7.88E+02	5.91E+03
Co-58	0.00E+00	8.86E+01	2.04E+02	0.00E+00	0.00E+00	0.00E+00	1.22E+03
Co-60	0.00E+00	2.56E+02	5.77E+02	0.00E+00	0.00E+00	0.00E+00	3.34E+03
Ni-63	3.23E+04	2.28E+03	1.09E+03	0.00E+00	0.00E+00	0.00E+00	3.63E+02
Ni-65	1.37E+02	1.75E+01	7.95E+00	0.00E+00	0.00E+00	0.00E+00	9.47E+02
Cu-64	0.00E+00	1.05E+01	4.93E+00	0.00E+00	2.65E+01	0.00E+00	8.14E+02
Zn-65	2.10E+04	7.30E+04	3.40E+04	0.00E+00	4.67E+04	0.00E+00	3.09E+04
Zn-69	5.36E+01	1.02E+02	7.15E+00	0.00E+00	6.68E+01	0.00E+00	1.88E+02
Br-83	0.00E+00	0.00E+00	4.40E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	5.53E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	2.34E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.09E+05	5.11E+04	0.00E+00	0.00E+00	0.00E+00	1.61E+04
Rb-88	0.00E+00	3.11E+02	1.66E+02	0.00E+00	0.00E+00	0.00E+00	2.66E-05
Rb-89	0.00E+00	2.01E+02	1.42E+02	0.00E+00	0.00E+00	0.00E+00	3.08E-07
Sr-89	2.41E+04	0.00E+00	6.89E+02	0.00E+00	0.00E+00	0.00E+00	2.87E+03
Sr-90	5.58E+05	0.00E+00	1.12E+04	0.00E+00	0.00E+00	0.00E+00	1.27E+04
Sr-91	4.42E+02	0.00E+00	1.76E+01	0.00E+00	0.00E+00	0.00E+00	2.00E+03
Sr-92	1.67E+02	0.00E+00	7.11E+00	0.00E+00	0.00E+00	0.00E+00	4.25E+03
Y-90	6.25E-01	0.00E+00	1.68E-02	0.00E+00	0.00E+00	0.00E+00	5.15E+03
Y-91M	5.88E-03	0.00E+00	2.25E-04	0.00E+00	0.00E+00	0.00E+00	2.78E-01
Y-91	9.17E+00	0.00E+00	2.46E-01	0.00E+00	0.00E+00	0.00E+00	3.76E+03
Y-92	5.52E-02	0.00E+00	1.60E-03	0.00E+00	0.00E+00	0.00E+00	1.51E+03
Y-93	1.75E-01	0.00E+00	4.79E-03	0.00E+00	0.00E+00	0.00E+00	5.34E+03
Zr-95	2.48E-01	7.82E-02	5.38E-02	0.00E+00	1.15E-01	0.00E+00	1.81E+02
Zr-97	1.43E-02	2.82E-03	1.30E-03	0.00E+00	4.28E-03	0.00E+00	7.64E+02
Nb-95	4.50E+02	2.50E+02	1.37E+02	0.00E+00	2.42E+02	0.00E+00	1.07E+06
Mo-99	0.00E+00	1.10E+02	2.10E+01	0.00E+00	2.52E+02	0.00E+00	1.97E+02
Tc- 99M	9.08E-03	2.53E-02	3.28E-01	0.00E+00	3.78E-01	1.41E-02	1.66E+01
Tc-101	9.85E-03	1.40E-02	1.38E-01	0.00E+00	2.53E-01	8.54E-03	2.39E-09
Ru-103	4.65E+00	0.00E+00	1.99E+00	0.00E+00	1.64E+01	0.00E+00	3.89E+02
Ru-105	3.98E-01	0.00E+00	1.54E-01	0.00E+00	5.02E+00	0.00E+00	3.21E+02
Ru-106	7.15E+01	0.00E+00	9.01E+00	0.00E+00	1.38E+02	0.00E+00	3.43E+03
Ag-110M	8.60E-01	8.14E-01	4.95E-01	0.00E+00	1.55E+00	0.00E+00	2.29E+02
Te-125M	2.79E+03	1.01E+03	3.74E+02	7.81E+02	0.00E+00	0.00E+00	8.24E+03

Table F-9a (continued)
Site Specific Fish Ingestion Dose Factors for Teen Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	7.06E+03	2.50E+03	8.39E+02	1.68E+03	2.86E+04	0.00E+00	1.76E+04
Te-127	1.15E+02	4.09E+01	2.48E+01	7.95E+01	4.67E+02	0.00E+00	8.90E+03
Te-129M	1.19E+04	4.41E+03	1.88E+03	3.84E+03	4.98E+04	0.00E+00	4.47E+04
Te-129	3.27E+01	1.22E+01	7.95E+00	2.33E+01	1.37E+02	0.00E+00	1.79E+02
Te-131M	1.78E+03	8.54E+02	7.12E+02	1.28E+03	8.90E+03	0.00E+00	6.85E+04
Te-131	2.04E+01	8.39E+00	6.36E+00	1.57E+01	8.90E+01	0.00E+00	1.67E+00
Te-132	2.55E+03	1.61E+03	1.52E+03	1.70E+03	1.55E+04	0.00E+00	5.11E+04
I-130	2.82E+01	8.15E+01	3.26E+01	6.65E+03	1.26E+02	0.00E+00	6.27E+01
I-131	1.60E+02	2.24E+02	1.20E+02	6.54E+04	3.86E+02	0.00E+00	4.43E+01
I-132	7.63E+00	2.00E+01	7.17E+00	6.73E+02	3.15E+01	0.00E+00	8.70E+00
I-133	5.50E+01	9.33E+01	2.85E+01	1.30E+04	1.64E+02	0.00E+00	7.06E+01
I-134	3.99E+00	1.06E+01	3.80E+00	1.76E+02	1.67E+01	0.00E+00	1.40E-01
I-135	1.67E+01	4.30E+01	1.59E+01	2.76E+03	6.79E+01	0.00E+00	4.76E+01
Cs-134	3.05E+05	7.19E+05	3.33E+05	0.00E+00	2.28E+05	8.72E+04	8.94E+03
Cs-136	3.13E+04	1.23E+05	8.28E+04	0.00E+00	6.71E+04	1.06E+04	9.92E+03
Cs-137	4.09E+05	5.44E+05	1.89E+05	0.00E+00	1.85E+05	7.19E+04	7.73E+03
Cs-138	2.83E+02	5.44E+02	2.72E+02	0.00E+00	4.01E+02	4.67E+01	2.47E-01
Ba-139	1.01E+00	7.14E-04	2.95E-02	0.00E+00	6.73E-04	4.92E-04	9.05E+00
Ba-140	2.07E+02	2.54E-01	1.34E+01	0.00E+00	8.61E-02	1.71E-01	3.20E+02
Ba-141	4.90E-01	3.66E-04	1.63E-02	0.00E+00	3.39E-04	2.50E-04	1.04E-06
Ba-142	2.18E-01	2.18E-04	1.34E-02	0.00E+00	1.85E-04	1.45E-04	6.70E-13
La-140	1.59E-01	7.80E-02	2.07E-02	0.00E+00	0.00E+00	0.00E+00	4.48E+03
La-142	8.16E-03	3.63E-03	9.03E-04	0.00E+00	0.00E+00	0.00E+00	1.10E+02
Ce-141	2.43E-02	1.62E-02	1.86E-03	0.00E+00	7.62E-03	0.00E+00	4.63E+01
Ce-143	4.29E-03	3.12E+00	3.48E-04	0.00E+00	1.40E-03	0.00E+00	9.38E+01
Ce-144	1.27E+00	5.25E-01	6.82E-02	0.00E+00	3.14E-01	0.00E+00	3.19E+02
Pr-143	5.97E-01	2.38E-01	2.97E-02	0.00E+00	1.39E-01	0.00E+00	1.97E+03
Pr-144	1.96E-03	8.03E-04	9.94E-05	0.00E+00	4.61E-04	0.00E+00	2.16E-06
Nd-147	4.28E-01	4.65E-01	2.79E-02	0.00E+00	2.73E-01	0.00E+00	1.68E+03
W-187	3.20E+02	2.60E+02	9.13E+01	0.00E+00	0.00E+00	0.00E+00	7.05E+04
Np-239	3.21E-02	3.03E-03	1.68E-03	0.00E+00	9.50E-03	0.00E+00	4.87E+02

Notes:

1) Units are mrem/hr per µCi/ml.

Table F-9b
Site Specific Fish Ingestion Dose Factors for Child Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	8.21E-02	8.21E-02	8.21E-02	8.21E-02	8.21E-02	8.21E-02
Na-24	4.56E+02	4.56E+02	4.56E+02	4.56E+02	4.56E+02	4.56E+02	4.56E+02
Cr-51	0.00E+00	0.00E+00	1.40E+00	7.77E-01	2.12E-01	1.42E+00	7.43E+01
Mn-54	0.00E+00	3.37E+03	8.97E+02	0.00E+00	9.44E+02	0.00E+00	2.83E+03
Mn-56	0.00E+00	1.05E+02	2.37E+01	0.00E+00	1.27E+02	0.00E+00	1.52E+04
Fe-55	9.05E+02	4.80E+02	1.49E+02	0.00E+00	0.00E+00	2.71E+02	8.89E+01
Fe-59	1.30E+03	2.10E+03	1.05E+03	0.00E+00	0.00E+00	6.09E+02	2.19E+03
Co-58	0.00E+00	7.08E+01	2.17E+02	0.00E+00	0.00E+00	0.00E+00	4.13E+02
Co-60	0.00E+00	2.08E+02	6.14E+02	0.00E+00	0.00E+00	0.00E+00	1.15E+03
Ni-63	4.23E+04	2.27E+03	1.44E+03	0.00E+00	0.00E+00	0.00E+00	1.53E+02
Ni-65	1.75E+02	1.64E+01	9.60E+00	0.00E+00	0.00E+00	0.00E+00	2.01E+03
Cu-64	0.00E+00	9.64E+00	5.82E+00	0.00E+00	2.33E+01	0.00E+00	4.52E+02
Zn-65	2.16E+04	5.74E+04	3.57E+04	0.00E+00	3.62E+04	0.00E+00	1.01E+04
Zn-69	6.89E+01	9.96E+01	9.20E+00	0.00E+00	6.04E+01	0.00E+00	6.28E+03
Br-83	0.00E+00	0.00E+00	5.65E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	6.54E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	3.01E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.05E+05	6.48E+04	0.00E+00	0.00E+00	0.00E+00	6.78E+03
Rb-88	0.00E+00	2.99E+02	2.08E+02	0.00E+00	0.00E+00	0.00E+00	1.47E+01
Rb-89	0.00E+00	1.84E+02	1.64E+02	0.00E+00	0.00E+00	0.00E+00	1.60E+00
Sr-89	3.11E+04	0.00E+00	8.90E+02	0.00E+00	0.00E+00	0.00E+00	1.21E+03
Sr-90	6.04E+05	0.00E+00	1.22E+04	0.00E+00	0.00E+00	0.00E+00	5.40E+03
Sr-91	5.66E+02	0.00E+00	2.14E+01	0.00E+00	0.00E+00	0.00E+00	1.25E+03
Sr-92	2.13E+02	0.00E+00	8.54E+00	0.00E+00	0.00E+00	0.00E+00	4.04E+03
Y-90	8.08E-01	0.00E+00	2.16E-02	0.00E+00	0.00E+00	0.00E+00	2.30E+03
Y-91M	7.51E-03	0.00E+00	2.73E-04	0.00E+00	0.00E+00	0.00E+00	1.47E+01
Y-91	1.18E+01	0.00E+00	3.17E-01	0.00E+00	0.00E+00	0.00E+00	1.58E+03
Y-92	7.08E-02	0.00E+00	2.03E-03	0.00E+00	0.00E+00	0.00E+00	2.05E+03
Y-93	2.24E-01	0.00E+00	6.16E-03	0.00E+00	0.00E+00	0.00E+00	3.34E+03
Zr-95	3.01E-01	6.62E-02	5.89E-02	0.00E+00	9.47E-02	0.00E+00	6.90E+01
Zr-97	1.81E-02	2.62E-03	1.55E-03	0.00E+00	3.76E-03	0.00E+00	3.97E+02
Nb-95	5.31E+02	2.07E+02	1.48E+02	0.00E+00	1.94E+02	0.00E+00	3.82E+05
Mo-99	0.00E+00	1.05E+02	2.59E+01	0.00E+00	2.23E+02	0.00E+00	8.65E+01
Tc- 99M	1.09E-02	2.14E-02	3.54E-01	0.00E+00	3.10E-01	1.08E-02	1.22E+01
Tc-101	1.26E-02	1.32E-02	1.68E-01	0.00E+00	2.25E-01	6.99E-03	4.20E-02
Ru-103	5.75E+00	0.00E+00	2.21E+00	0.00E+00	1.45E+01	0.00E+00	1.49E+02
Ru-105	5.07E-01	0.00E+00	1.84E-01	0.00E+00	4.46E+00	0.00E+00	3.31E+02
Ru-106	9.20E+01	0.00E+00	1.15E+01	0.00E+00	1.24E+02	0.00E+00	1.43E+03
Ag-110M	9.75E-01	6.59E-01	5.26E-01	0.00E+00	1.23E+00	0.00E+00	7.83E+01
Te-125M	3.59E+03	9.72E+02	4.78E+02	1.01E+03	0.00E+00	0.00E+00	3.46E+03

Table F-9b (continued)
Site Specific Fish Ingestion Dose Factors for Child Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	9.09E+03	2.45E+03	1.08E+03	2.17E+03	2.59E+04	0.00E+00	7.36E+03
Te-127	1.48E+02	4.00E+01	3.18E+01	1.03E+02	4.22E+02	0.00E+00	5.79E+03
Te-129M	1.53E+04	4.28E+03	2.38E+03	4.94E+03	4.50E+04	0.00E+00	1.87E+04
Te-129	4.22E+01	1.18E+01	1.00E+01	3.01E+01	1.23E+02	0.00E+00	2.62E+03
Te-131M	2.27E+03	7.83E+02	8.34E+02	1.61E+03	7.58E+03	0.00E+00	3.18E+04
Te-131	2.61E+01	7.96E+00	7.77E+00	2.00E+01	7.90E+01	0.00E+00	1.37E+02
Te-132	3.18E+03	1.41E+03	1.70E+03	2.05E+03	1.31E+04	0.00E+00	1.42E+04
I-130	3.45E+01	6.96E+01	3.59E+01	7.67E+03	1.04E+02	0.00E+00	3.26E+01
I-131	2.03E+02	2.04E+02	1.16E+02	6.75E+04	3.35E+02	0.00E+00	1.82E+01
I-132	9.44E+00	1.73E+01	7.98E+00	8.05E+02	2.65E+01	0.00E+00	2.04E+01
I-133	6.99E+01	8.64E+01	3.27E+01	1.60E+04	1.44E+02	0.00E+00	3.48E+01
I-134	4.94E+00	9.18E+00	4.22E+00	2.11E+02	1.40E+01	0.00E+00	6.09E+00
I-135	2.06E+01	3.72E+01	1.76E+01	3.29E+03	5.70E+01	0.00E+00	2.83E+01
Cs-134	3.68E+05	6.04E+05	1.27E+05	0.00E+00	1.87E+05	6.72E+04	3.26E+03
Cs-136	3.70E+04	1.02E+05	6.58E+04	0.00E+00	5.41E+04	8.07E+03	3.57E+03
Cs-137	5.14E+05	4.92E+05	7.27E+04	0.00E+00	1.60E+05	5.77E+04	3.08E+03
Cs-138	3.59E+02	4.99E+02	3.16E+02	0.00E+00	3.51E+02	3.78E+01	2.30E+02
Ba-139	1.30E+00	6.95E-04	3.78E-02	0.00E+00	6.07E-04	4.09E-04	7.52E+01
Ba-140	2.61E+02	2.29E-01	1.53E+01	0.00E+00	7.46E-02	1.37E-01	1.32E+02
Ba-141	6.29E-01	3.52E-04	2.05E-02	0.00E+00	3.05E-04	2.07E-03	3.59E-01
Ba-142	2.75E-01	1.98E-04	1.54E-02	0.00E+00	1.60E-04	1.16E-04	3.59E-03
La-140	1.99E-01	6.94E-02	2.34E-02	0.00E+00	0.00E+00	0.00E+00	1.94E+03
La-142	1.03E-02	3.28E-03	1.03E-03	0.00E+00	0.00E+00	0.00E+00	6.51E+02
Ce-141	3.12E-02	1.56E-02	2.31E-03	0.00E+00	6.83E-03	0.00E+00	1.94E+01
Ce-143	5.50E-03	2.98E+00	4.32E-04	0.00E+00	1.25E-03	0.00E+00	4.37E+01
Ce-144	1.64E+00	5.13E-01	8.73E-02	0.00E+00	2.84E-01	0.00E+00	1.34E+02
Pr-143	7.73E-01	2.32E-01	3.83E-02	0.00E+00	1.26E-01	0.00E+00	8.34E+02
Pr-144	2.54E-03	7.85E-04	1.28E-04	0.00E+00	4.15E-04	0.00E+00	1.69E+00
Nd-147	5.49E-01	4.44E-01	3.44E-02	0.00E+00	2.44E-01	0.00E+00	7.04E+02
W-187	4.05E+02	2.40E+02	1.08E+02	0.00E+00	0.00E+00	0.00E+00	3.37E+04
Np-239	4.13E-02	2.97E-03	2.08E-03	0.00E+00	8.57E-03	0.00E+00	2.19E+02

Notes:

1) Units are mrem/hr per μCi/ml.

2) The infant age group is assumed to receive no dose through the fish ingestion pathway, therefore no dose factors are supplied.

Table F-10
Ground Plane Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na-24	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07
Cr-51	4.65E+06	4.65E+06	4.65E+06	4.65E+06	4.65E+06	4.65E+06	4.65E+06
Mn-54	1.38E+09	1.38E+09	1.38E+09	1.38E+09	1.38E+09	1.38E+09	1.38E+09
Mn-56	9.03E+05	9.03E+05	9.03E+05	9.03E+05	9.03E+05	9.03E+05	9.03E+05
Fe-55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-59	2.73E+08	2.73E+08	2.73E+08	2.73E+08	2.73E+08	2.73E+08	2.73E+08
Co-58	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08
Co-60	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10
Ni-63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni-65	2.97E+05	2.97E+05	2.97E+05	2.97E+05	2.97E+05	2.97E+05	2.97E+05
Cu-64	6.05E+05	6.05E+05	6.05E+05	6.05E+05	6.05E+05	6.05E+05	6.05E+05
Zn-65	7.46E+08	7.46E+08	7.46E+08	7.46E+08	7.46E+08	7.46E+08	7.46E+08
Zn-69	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-83	4.87E+03	4.87E+03	4.87E+03	4.87E+03	4.87E+03	4.87E+03	4.87E+03
Br-84	2.03E+05	2.03E+05	2.03E+05	2.03E+05	2.03E+05	2.03E+05	2.03E+05
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	9.01E+06	9.01E+06	9.01E+06	9.01E+06	9.01E+06	9.01E+06	9.01E+06
Rb-88	3.31E+04	3.31E+04	3.31E+04	3.31E+04	3.31E+04	3.31E+04	3.31E+04
Rb-89	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05
Sr-89	2.16E+04	2.16E+04	2.16E+04	2.16E+04	2.16E+04	2.16E+04	2.16E+04
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-91	2.14E+06	2.14E+06	2.14E+06	2.14E+06	2.14E+06	2.14E+06	2.14E+06
Sr-92	7.76E+05	7.76E+05	7.76E+05	7.76E+05	7.76E+05	7.76E+05	7.76E+05
Y-90	4.50E+03	4.50E+03	4.50E+03	4.50E+03	4.50E+03	4.50E+03	4.50E+03
Y-91M	1.00E+05	1.00E+05	1.00E+05	1.00E+05	1.00E+05	1.00E+05	1.00E+05
Y-91	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06
Y-92	1.80E+05	1.80E+05	1.80E+05	1.80E+05	1.80E+05	1.80E+05	1.80E+05
Y-93	1.83E+05	1.83E+05	1.83E+05	1.83E+05	1.83E+05	1.83E+05	1.83E+05
Zr-95	2.45E+08	2.45E+08	2.45E+08	2.45E+08	2.45E+08	2.45E+08	2.45E+08
Zr-97	2.96E+06	2.96E+06	2.96E+06	2.96E+06	2.96E+06	2.96E+06	2.96E+06
Nb-95	1.37E+08	1.37E+08	1.37E+08	1.37E+08	1.37E+08	1.37E+08	1.37E+08
Mo-99	3.99E+06	3.99E+06	3.99E+06	3.99E+06	3.99E+06	3.99E+06	3.99E+06
Tc- 99M	1.84E+05	1.84E+05	1.84E+05	1.84E+05	1.84E+05	1.84E+05	1.84E+05
Tc-101	2.03E+04	2.03E+04	2.03E+04	2.03E+04	2.03E+04	2.03E+04	2.03E+04
Ru-103	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08
Ru-105	6.36E+05	6.36E+05	6.36E+05	6.36E+05	6.36E+05	6.36E+05	6.36E+05
Ru-106	4.22E+08	4.22E+08	4.22E+08	4.22E+08	4.22E+08	4.22E+08	4.22E+08
Ag-110M	3.45E+09	3.45E+09	3.45E+09	3.45E+09	3.45E+09	3.45E+09	3.45E+09

Table F-10 (Continued)
Ground Plane Dose Factors (same for all age groups)

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.56E+06	1.56E+06	1.56E+06	1.56E+06	1.56E+06	1.56E+06	1.56E+06
Te-127M	9.16E+04	9.16E+04	9.16E+04	9.16E+04	9.16E+04	9.16E+04	9.16E+04
Te-127	2.99E+03	2.99E+03	2.99E+03	2.99E+03	2.99E+03	2.99E+03	2.99E+03
Te-129M	1.98E+07	1.98E+07	1.98E+07	1.98E+07	1.98E+07	1.98E+07	1.98E+07
Te-129	2.62E+04	2.62E+04	2.62E+04	2.62E+04	2.62E+04	2.62E+04	2.62E+04
Te-131M	8.02E+06	8.02E+06	8.02E+06	8.02E+06	8.02E+06	8.02E+06	8.02E+06
Te-131	2.92E+04	2.92E+04	2.92E+04	2.92E+04	2.92E+04	2.92E+04	2.92E+04
Te-132	4.22E+06	4.22E+06	4.22E+06	4.22E+06	4.22E+06	4.22E+06	4.22E+06
I-130	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06
I-131	1.72E+07	1.72E+07	1.72E+07	1.72E+07	1.72E+07	1.72E+07	1.72E+07
I-132	1.25E+06	1.25E+06	1.25E+06	1.25E+06	1.25E+06	1.25E+06	1.25E+06
I-133	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06
I-134	4.46E+05	4.46E+05	4.46E+05	4.46E+05	4.46E+05	4.46E+05	4.46E+05
I-135	2.53E+06	2.53E+06	2.53E+06	2.53E+06	2.53E+06	2.53E+06	2.53E+06
Cs-134	6.94E+09	6.94E+09	6.94E+09	6.94E+09	6.94E+09	6.94E+09	6.94E+09
Cs-136	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08
Cs-137	1.76E+10	1.76E+10	1.76E+10	1.76E+10	1.76E+10	1.76E+10	1.76E+10
Cs-138	3.59E+05	3.59E+05	3.59E+05	3.59E+05	3.59E+05	3.59E+05	3.59E+05
Ba-139	1.06E+05	1.06E+05	1.06E+05	1.06E+05	1.06E+05	1.06E+05	1.06E+05
Ba-140	2.05E+07	2.05E+07	2.05E+07	2.05E+07	2.05E+07	2.05E+07	2.05E+07
Ba-141	4.17E+04	4.17E+04	4.17E+04	4.17E+04	4.17E+04	4.17E+04	4.17E+04
Ba-142	4.44E+04	4.44E+04	4.44E+04	4.44E+04	4.44E+04	4.44E+04	4.44E+04
La-140	1.92E+07	1.92E+07	1.92E+07	1.92E+07	1.92E+07	1.92E+07	1.92E+07
La-142	7.60E+05	7.60E+05	7.60E+05	7.60E+05	7.60E+05	7.60E+05	7.60E+05
Ce-141	1.37E+07	1.37E+07	1.37E+07	1.37E+07	1.37E+07	1.37E+07	1.37E+07
Ce-143	2.31E+06	2.31E+06	2.31E+06	2.31E+06	2.31E+06	2.31E+06	2.31E+06
Ce-144	6.96E+07	6.96E+07	6.96E+07	6.96E+07	6.96E+07	6.96E+07	6.96E+07
Pr-143	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-144	1.84E+03	1.84E+03	1.84E+03	1.84E+03	1.84E+03	1.84E+03	1.84E+03
Nd-147	8.48E+06	8.48E+06	8.48E+06	8.48E+06	8.48E+06	8.48E+06	8.48E+06
W-187	2.35E+06	2.35E+06	2.35E+06	2.35E+06	2.35E+06	2.35E+06	2.35E+06
Np-239	1.71E+06	1.71E+06	1.71E+06	1.71E+06	1.71E+06	1.71E+06	1.71E+06

Notes:

1) Units are m^2 mrem/yr per µCi/sec.

2) All age groups are assumed to receive the same dose.

Table F-11
Adult Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	7.18E+02	7.18E+02	7.18E+02	7.18E+02	7.18E+02	7.18E+02
Na-24	1.02E+04	1.02E+04	1.02E+04	1.02E+04	1.02E+04	1.02E+04	1.02E+04
Cr-51	0.00E+00	0.00E+00	1.00E+02	5.95E+01	2.28E+01	1.44E+04	3.32E+03
Mn-54	0.00E+00	3.96E+04	6.30E+03	0.00E+00	9.84E+03	1.40E+06	7.74E+04
Mn-56	0.00E+00	1.24E+00	1.83E-01	0.00E+00	1.30E+00	9.44E+03	2.02E+04
Fe-55	2.46E+04	1.70E+04	3.94E+03	0.00E+00	0.00E+00	7.21E+04	6.03E+03
Fe-59	1.18E+04	2.78E+04	1.06E+04	0.00E+00	0.00E+00	1.02E+06	1.88E+05
Co-58	0.00E+00	1.58E+03	2.07E+03	0.00E+00	0.00E+00	9.28E+05	1.06E+05
Co-60	0.00E+00	1.15E+04	1.48E+04	0.00E+00	0.00E+00	5.97E+06	2.85E+05
Ni-63	4.32E+05	3.14E+04	1.45E+04	0.00E+00	0.00E+00	1.78E+05	1.34E+04
Ni-65	1.54E+00	2.10E-01	9.12E-02	0.00E+00	0.00E+00	5.60E+03	1.23E+04
Cu-64	0.00E+00	1.46E+00	6.15E-01	0.00E+00	4.62E+00	6.78E+03	4.90E+04
Zn-65	3.24E+04	1.03E+05	4.66E+04	0.00E+00	6.90E+04	8.64E+05	5.34E+04
Zn-69	3.38E-02	6.51E-02	4.52E-03	0.00E+00	4.22E-02	9.20E+02	1.63E+01
Br-83	0.00E+00	0.00E+00	2.41E+02	0.00E+00	0.00E+00	0.00E+00	2.32E+02
Br-84	0.00E+00	0.00E+00	3.13E+02	0.00E+00	0.00E+00	0.00E+00	1.64E-03
Br-85	0.00E+00	0.00E+00	1.28E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.35E+05	5.90E+04	0.00E+00	0.00E+00	0.00E+00	1.66E+04
Rb-88	0.00E+00	3.87E+02	1.93E+02	0.00E+00	0.00E+00	0.00E+00	3.34E-09
Rb-89	0.00E+00	2.56E+02	1.70E+02	0.00E+00	0.00E+00	0.00E+00	9.28E-12
Sr-89	3.04E+05	0.00E+00	8.72E+03	0.00E+00	0.00E+00	1.40E+06	3.50E+05
Sr-90	2.87E+07	0.00E+00	5.77E+05	0.00E+00	0.00E+00	9.60E+06	7.22E+05
Sr-91	6.19E+01	0.00E+00	2.50E+00	0.00E+00	0.00E+00	3.65E+04	1.91E+05
Sr-92	6.74E+00	0.00E+00	2.91E-01	0.00E+00	0.00E+00	1.65E+04	4.30E+04
Y-90	2.09E+03	0.00E+00	5.61E+01	0.00E+00	0.00E+00	1.70E+05	5.06E+05
Y-91M	2.61E-01	0.00E+00	1.02E-02	0.00E+00	0.00E+00	1.92E+03	1.33E+00
Y-91	4.62E+05	0.00E+00	1.24E+04	0.00E+00	0.00E+00	1.70E+06	3.85E+05
Y-92	1.03E+01	0.00E+00	3.02E-01	0.00E+00	0.00E+00	1.57E+04	7.35E+04
Y-93	9.44E+01	0.00E+00	2.61E+00	0.00E+00	0.00E+00	4.85E+04	4.22E+05
Zr-95	1.07E+05	3.44E+04	2.33E+04	0.00E+00	5.42E+04	1.77E+06	1.50E+05
Zr-97	9.68E+01	1.96E+01	9.04E+00	0.00E+00	2.97E+01	7.87E+04	5.23E+05
Nb-95	1.41E+04	7.82E+03	4.21E+03	0.00E+00	7.74E+03	5.05E+05	1.04E+05
Mo-99	0.00E+00	1.21E+02	2.30E+01	0.00E+00	2.91E+02	9.12E+04	2.48E+05
Tc- 99M	1.03E-03	2.91E-03	3.70E-02	0.00E+00	4.42E-02	7.64E+02	4.16E+03
Tc-101	4.18E-05	6.02E-05	5.90E-04	0.00E+00	1.08E-03	3.99E+02	1.09E-11
Ru-103	1.53E+03	0.00E+00	6.58E+02	0.00E+00	5.83E+03	5.05E+05	1.10E+05
Ru-105	7.90E-01	0.00E+00	3.11E-01	0.00E+00	1.02E+00	1.10E+04	4.82E+04
Ru-106	6.91E+04	0.00E+00	8.72E+03	0.00E+00	1.34E+05	9.36E+06	9.12E+05
Ag-110M	1.08E+04	1.00E+04	5.94E+03	0.00E+00	1.97E+04	4.63E+06	3.02E+05

Table F-11 (Continued)
Adult Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.42E+03	1.58E+03	4.67E+02	1.05E+03	1.24E+04	3.14E+05	7.06E+04
Te-127M	1.26E+04	5.77E+03	1.57E+03	3.29E+03	4.58E+04	9.60E+05	1.50E+05
Te-127	1.40E+00	6.42E-01	3.10E-01	1.06E+00	5.10E+00	6.51E+03	5.74E+04
Te-129M	9.76E+03	4.67E+03	1.58E+03	3.44E+03	3.66E+04	1.16E+06	3.83E+05
Te-129	4.98E-02	2.39E-02	1.24E-02	3.90E-02	1.87E-01	1.94E+03	1.57E+02
Te-131M	6.99E+01	4.36E+01	2.90E+01	5.50E+01	3.09E+02	1.46E+05	5.56E+05
Te-131	1.11E-02	5.95E-03	3.59E-03	9.36E-03	4.37E-02	1.39E+03	1.84E+01
Te-132	2.60E+02	2.15E+02	1.62E+02	1.90E+02	1.46E+03	2.88E+05	5.10E+05
I-130	4.58E+03	1.34E+04	5.28E+03	1.14E+06	2.09E+04	0.00E+00	7.69E+03
I-131	2.52E+04	3.58E+04	2.05E+04	1.19E+07	6.13E+04	0.00E+00	6.28E+03
I-132	1.16E+03	3.26E+03	1.16E+03	1.14E+05	5.18E+03	0.00E+00	4.06E+02
I-133	8.64E+03	1.48E+04	4.52E+03	2.15E+06	2.58E+04	0.00E+00	8.88E+03
I-134	6.44E+02	1.73E+03	6.15E+02	2.98E+04	2.75E+03	0.00E+00	1.01E+00
I-135	2.68E+03	6.98E+03	2.57E+03	4.48E+05	1.11E+04	0.00E+00	5.25E+03
Cs-134	3.73E+05	8.48E+05	7.28E+05	0.00E+00	2.87E+05	9.76E+04	1.04E+04
Cs-136	3.90E+04	1.46E+05	1.10E+05	0.00E+00	8.56E+04	1.20E+04	1.17E+04
Cs-137	4.78E+05	6.21E+05	4.28E+05	0.00E+00	2.22E+05	7.52E+04	8.40E+03
Cs-138	3.31E+02	6.21E+02	3.24E+02	0.00E+00	4.80E+02	4.86E+01	1.86E-03
Ba-139	9.36E-01	6.66E-04	2.74E-02	0.00E+00	6.22E-04	3.76E+03	8.96E+02
Ba-140	3.90E+04	4.90E+01	2.57E+03	0.00E+00	1.67E+01	1.27E+06	2.18E+05
Ba-141	1.00E-01	7.53E-05	3.36E-03	0.00E+00	7.00E-05	1.94E+03	1.16E-07
Ba-142	2.63E-02	2.70E-05	1.66E-03	0.00E+00	2.29E-05	1.19E+03	1.57E-16
La-140	3.44E+02	1.74E+02	4.58E+01	0.00E+00	0.00E+00	1.36E+05	4.58E+05
La-142	6.83E-01	3.10E-01	7.72E-02	0.00E+00	0.00E+00	6.33E+03	2.11E+03
Ce-141	1.99E+04	1.35E+04	1.53E+03	0.00E+00	6.26E+03	3.62E+05	1.20E+05
Ce-143	1.86E+02	1.38E+02	1.53E+01	0.00E+00	6.08E+01	7.98E+04	2.26E+05
Ce-144	3.43E+06	1.43E+06	1.84E+05	0.00E+00	8.48E+05	7.78E+06	8.16E+05
Pr-143	9.36E+03	3.75E+03	4.64E+02	0.00E+00	2.16E+03	2.81E+05	2.00E+05
Pr-144	3.01E-02	1.25E-02	1.53E-03	0.00E+00	7.05E-03	1.02E+03	2.15E-08
Nd-147	5.27E+03	6.10E+03	3.65E+02	0.00E+00	3.56E+03	2.21E+05	1.73E+05
W-187	8.48E+00	7.08E+00	2.48E+00	0.00E+00	0.00E+00	2.90E+04	1.55E+05
Np-239	2.30E+02	2.03E+02	1.24E+01	0.00E+00	7.00E+01	3.76E+04	1.19E+05

Notes:

1) Units are mrem/yr per $\mu Ci/m^3$.

Table F-11a
Teen Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	7.25E+02	7.25E+02	7.25E+02	7.25E+02	7.25E+02	7.25E+02
Na-24	1.38E+04	1.38E+04	1.38E+04	1.38E+04	1.38E+04	1.38E+04	1.38E+04
Cr-51	0.00E+00	0.00E+00	1.35E+02	7.50E+01	3.07E+01	2.10E+04	3.00E+03
Mn-54	0.00E+00	5.11E+04	8.40E+03	0.00E+00	1.27E+04	1.98E+06	6.68E+04
Mn-56	0.00E+00	1.70E+00	2.52E-01	0.00E+00	1.79E+00	1.52E+04	5.74E+04
Fe-55	3.34E+04	2.38E+04	5.54E+03	0.00E+00	0.00E+00	1.24E+05	6.39E+03
Fe-59	1.59E+04	3.70E+04	1.43E+04	0.00E+00	0.00E+00	1.53E+06	1.78E+05
Co-58	0.00E+00	2.07E+03	2.78E+03	0.00E+00	0.00E+00	1.34E+06	9.52E+04
Co-60	0.00E+00	1.51E+04	1.98E+04	0.00E+00	0.00E+00	8.72E+06	2.59E+05
Ni-63	5.80E+05	4.34E+04	1.98E+04	0.00E+00	0.00E+00	3.07E+05	1.42E+04
Ni-65	2.18E+00	2.93E-01	1.27E-01	0.00E+00	0.00E+00	9.36E+03	3.67E+04
Cu-64	0.00E+00	2.03E+00	8.48E-01	0.00E+00	6.41E+00	1.11E+04	6.14E+04
Zn-65	3.86E+04	1.34E+05	6.24E+04	0.00E+00	8.64E+04	1.24E+06	4.66E+04
Zn-69	4.83E-02	9.20E-02	6.46E-03	0.00E+00	6.02E-02	1.58E+03	2.85E+02
Br-83	0.00E+00	0.00E+00	3.44E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	4.33E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	1.83E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.90E+05	8.40E+04	0.00E+00	0.00E+00	0.00E+00	1.77E+04
Rb-88	0.00E+00	5.46E+02	2.72E+02	0.00E+00	0.00E+00	0.00E+00	2.92E-05
Rb-89	0.00E+00	3.52E+02	2.33E+02	0.00E+00	0.00E+00	0.00E+00	3.38E-07
Sr-89	4.34E+05	0.00E+00	1.25E+04	0.00E+00	0.00E+00	2.42E+06	3.71E+05
Sr-90	3.31E+07	0.00E+00	6.66E+05	0.00E+00	0.00E+00	1.65E+07	7.65E+05
Sr-91	8.80E+01	0.00E+00	3.51E+00	0.00E+00	0.00E+00	6.07E+04	2.59E+05
Sr-92	9.52E+00	0.00E+00	4.06E-01	0.00E+00	0.00E+00	2.74E+04	1.19E+05
Y-90	2.98E+03	0.00E+00	8.00E+01	0.00E+00	0.00E+00	2.93E+05	5.59E+05
Y-91M	3.70E-01	0.00E+00	1.42E-02	0.00E+00	0.00E+00	3.20E+03	3.02E+01
Y-91	6.61E+05	0.00E+00	1.77E+04	0.00E+00	0.00E+00	2.94E+06	4.09E+05
Y-92	1.47E+01	0.00E+00	4.29E-01	0.00E+00	0.00E+00	2.68E+04	1.65E+05
Y-93	1.35E+02	0.00E+00	3.72E+00	0.00E+00	0.00E+00	8.32E+04	5.79E+05
Zr-95	1.46E+05	4.58E+04	3.15E+04	0.00E+00	6.74E+04	2.69E+06	1.49E+05
Zr-97	1.38E+02	2.72E+01	1.26E+01	0.00E+00	4.12E+01	1.30E+05	6.30E+05
Nb-95	1.86E+04	1.03E+04	5.66E+03	0.00E+00	1.00E+04	7.51E+05	9.68E+04
Mo-99	0.00E+00	1.69E+02	3.22E+01	0.00E+00	4.11E+02	1.54E+05	2.69E+05
Tc- 99M	1.38E-03	3.86E-03	4.99E-02	0.00E+00	5.76E-02	1.15E+03	6.13E+03
Tc-101	5.92E-05	8.40E-05	8.24E-04	0.00E+00	1.52E-03	6.67E+02	8.72E-07
Ru-103	2.10E+03	0.00E+00	8.96E+02	0.00E+00	7.43E+03	7.83E+05	1.09E+05
Ru-105	1.12E+00	0.00E+00	4.34E-01	0.00E+00	1.41E+00	1.82E+04	9.04E+04
Ru-106	9.84E+04	0.00E+00	1.24E+04	0.00E+00	1.90E+05	1.61E+07	9.60E+05
Ag-110M	1.38E+04	1.31E+04	7.99E+03	0.00E+00	2.50E+04	6.75E+06	2.73E+05

Table F-11a (Continued)
Teen Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	4.88E+03	2.24E+03	6.67E+02	1.40E+03	0.00E+00	5.36E+05	7.50E+04
Te-127M	1.80E+04	8.16E+03	2.18E+03	4.38E+03	6.54E+04	1.66E+06	1.59E+05
Te-127	2.01E+00	9.12E-01	4.42E-01	1.42E+00	7.28E+00	1.12E+04	8.08E+04
Te-129M	1.39E+04	6.58E+03	2.25E+03	4.58E+03	5.19E+04	1.98E+06	4.05E+05
Te-129	7.10E-02	3.38E-02	1.76E-02	5.18E-02	2.66E-01	3.30E+03	1.62E+03
Te-131M	9.84E+01	6.01E+01	4.02E+01	7.25E+01	4.39E+02	2.38E+05	6.21E+05
Te-131	1.58E-02	8.32E-03	5.04E-03	1.24E-02	6.18E-02	2.34E+03	1.51E+01
Te-132	3.60E+02	2.90E+02	2.19E+02	2.46E+02	1.95E+03	4.49E+05	4.63E+05
I-130	6.24E+03	1.79E+04	7.17E+03	1.49E+06	2.75E+04	0.00E+00	9.12E+03
I-131	3.54E+04	4.91E+04	2.64E+04	1.46E+07	8.40E+04	0.00E+00	6.49E+03
I-132	1.59E+03	4.38E+03	1.58E+03	1.51E+05	6.92E+03	0.00E+00	1.27E+03
I-133	1.22E+04	2.05E+04	6.22E+03	2.92E+06	3.59E+04	0.00E+00	1.03E+04
I-134	8.88E+02	2.32E+03	8.40E+02	3.95E+04	3.66E+03	0.00E+00	2.04E+01
I-135	3.70E+03	9.44E+03	3.49E+03	6.21E+05	1.49E+04	0.00E+00	6.95E+03
Cs-134	5.02E+05	1.13E+06	5.49E+05	0.00E+00	3.75E+05	1.46E+05	9.76E+03
Cs-136	5.15E+04	1.94E+05	1.37E+05	0.00E+00	1.10E+05	1.78E+04	1.09E+04
Cs-137	6.70E+05	8.48E+05	3.11E+05	0.00E+00	3.04E+05	1.21E+05	8.48E+03
Cs-138	4.66E+02	8.56E+02	4.46E+02	0.00E+00	6.62E+02	7.87E+01	2.70E-01
Ba-139	1.34E+00	9.44E-04	3.90E-02	0.00E+00	8.88E-04	6.46E+03	6.45E+03
Ba-140	5.47E+04	6.70E+01	3.52E+03	0.00E+00	2.28E+01	2.03E+06	2.29E+05
Ba-141	1.42E-01	1.06E-04	4.74E-03	0.00E+00	9.84E-05	3.29E+03	7.46E-04
Ba-142	3.70E-02	3.70E-05	2.27E-03	0.00E+00	3.14E-05	1.91E+03	4.79E-10
La-140	4.79E+02	2.36E+02	6.26E+01	0.00E+00	0.00E+00	2.14E+05	4.87E+05
La-142	9.60E-01	4.25E-01	1.06E-01	0.00E+00	0.00E+00	1.02E+04	1.20E+04
Ce-141	2.84E+04	1.90E+04	2.17E+03	0.00E+00	8.88E+03	6.14E+05	1.26E+05
Ce-143	2.66E+02	1.94E+02	2.16E+01	0.00E+00	8.64E+01	1.30E+05	2.55E+05
Ce-144	4.89E+06	2.02E+06	2.62E+05	0.00E+00	1.21E+06	1.34E+07	8.64E+05
Pr-143	1.34E+04	5.31E+03	6.62E+02	0.00E+00	3.09E+03	4.83E+05	2.14E+05
Pr-144	4.30E-02	1.76E-02	2.18E-03	0.00E+00	1.01E-02	1.75E+03	2.35E-04
Nd-147	7.86E+03	8.56E+03	5.13E+02	0.00E+00	5.02E+03	3.72E+05	1.82E+05
W-187	1.20E+01	9.76E+00	3.43E+00	0.00E+00	0.00E+00	4.74E+04	1.77E+05
Np-239	3.38E+02	2.88E+02	1.77E+01	0.00E+00	1.00E+02	6.49E+04	1.32E+05

Notes:

1) Units are mrem/yr per $\mu Ci/m^3$.

Table F-11b
Child Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	6.40E+02	6.40E+02	6.40E+02	6.40E+02	6.40E+02	6.40E+02
Na-24	1.61E+04	1.61E+04	1.61E+04	1.61E+04	1.61E+04	1.61E+04	1.61E+04
Cr-51	0.00E+00	0.00E+00	1.54E+02	8.55E+01	2.43E+01	1.70E+04	1.08E+03
Mn-54	0.00E+00	4.29E+04	9.51E+03	0.00E+00	1.00E+04	1.58E+06	2.29E+04
Mn-56	0.00E+00	1.66E+00	3.12E-01	0.00E+00	1.67E+00	1.31E+04	1.23E+05
Fe-55	4.74E+04	2.52E+04	7.77E+03	0.00E+00	0.00E+00	1.11E+05	2.87E+03
Fe-59	2.07E+04	3.34E+04	1.67E+04	0.00E+00	0.00E+00	1.27E+06	7.07E+04
Co-58	0.00E+00	1.77E+03	3.16E+03	0.00E+00	0.00E+00	1.11E+06	3.44E+04
Co-60	0.00E+00	1.31E+04	2.26E+04	0.00E+00	0.00E+00	7.07E+06	9.62E+04
Ni-63	8.21E+05	4.63E+04	2.80E+04	0.00E+00	0.00E+00	2.75E+05	6.33E+03
Ni-65	2.99E+00	2.96E-01	1.64E-01	0.00E+00	0.00E+00	8.18E+03	8.40E+04
Cu-64	0.00E+00	1.99E+00	1.07E+00	0.00E+00	6.03E+00	9.58E+03	3.67E+04
Zn-65	4.26E+04	1.13E+05	7.03E+04	0.00E+00	7.14E+04	9.95E+05	1.63E+04
Zn-69	6.70E-02	9.66E-02	8.92E-03	0.00E+00	5.85E-02	1.42E+03	1.02E+04
Br-83	0.00E+00	0.00E+00	4.74E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	5.48E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	2.53E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.98E+05	1.14E+05	0.00E+00	0.00E+00	0.00E+00	7.99E+03
Rb-88	0.00E+00	5.62E+02	3.66E+02	0.00E+00	0.00E+00	0.00E+00	1.72E+01
Rb-89	0.00E+00	3.45E+02	2.90E+02	0.00E+00	0.00E+00	0.00E+00	1.89E+00
Sr-89	5.99E+05	0.00E+00	1.72E+04	0.00E+00	0.00E+00	2.16E+06	1.67E+05
Sr-90	3.85E+07	0.00E+00	7.66E+05	0.00E+00	0.00E+00	1.48E+07	3.43E+05
Sr-91	1.21E+02	0.00E+00	4.59E+00	0.00E+00	0.00E+00	5.33E+04	1.74E+05
Sr-92	1.31E+01	0.00E+00	5.25E-01	0.00E+00	0.00E+00	2.40E+04	2.42E+05
Y-90	4.11E+03	0.00E+00	1.11E+02	0.00E+00	0.00E+00	2.62E+05	2.68E+05
Y-91M	5.07E-01	0.00E+00	1.84E-02	0.00E+00	0.00E+00	2.81E+03	1.72E+03
Y-91	9.14E+05	0.00E+00	2.44E+04	0.00E+00	0.00E+00	2.63E+06	1.84E+05
Y-92	2.04E+01	0.00E+00	5.81E-01	0.00E+00	0.00E+00	2.39E+04	2.39E+05
Y-93	1.86E+02	0.00E+00	5.11E+00	0.00E+00	0.00E+00	7.44E+04	3.89E+05
Zr-95	1.90E+05	4.18E+04	3.70E+04	0.00E+00	5.96E+04	2.23E+06	6.11E+04
Zr-97	1.88E+02	2.72E+01	1.60E+01	0.00E+00	3.89E+01	1.13E+05	3.51E+05
Nb-95	2.35E+04	9.18E+03	6.55E+03	0.00E+00	8.62E+03	6.14E+05	3.70E+04
Mo-99	0.00E+00	1.72E+02	4.26E+01	0.00E+00	3.92E+02	1.35E+05	1.27E+05
Tc- 99M	1.78E-03	3.48E-03	5.77E-02	0.00E+00	5.07E-02	9.51E+02	4.81E+03
Tc-101	8.10E-05	8.51E-05	1.08E-03	0.00E+00	1.45E-03	5.85E+02	1.63E+01
Ru-103	2.79E+03	0.00E+00	1.07E+03	0.00E+00	7.03E+03	6.62E+05	4.48E+04
Ru-105	1.53E+00	0.00E+00	5.55E-01	0.00E+00	1.34E+00	1.59E+04	9.95E+04
Ru-106	1.36E+05	0.00E+00	1.69E+04	0.00E+00	1.84E+05	1.43E+07	4.29E+05
Ag-110M	1.69E+04	1.14E+04	9.14E+03	0.00E+00	2.12E+04	5.48E+06	1.00E+05

Table F-11b (Continued)
Child Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	6.73E+03	2.33E+03	9.14E+02	1.92E+03	0.00E+00	4.77E+05	3.38E+04
Te-127M	2.49E+04	8.55E+03	3.02E+03	6.07E+03	6.36E+04	1.48E+06	7.14E+04
Te-127	2.77E+00	9.51E-01	6.11E-01	1.96E+00	7.07E+00	1.00E+04	5.62E+04
Te-129M	1.92E+04	6.85E+03	3.04E+03	6.33E+03	5.03E+04	1.76E+06	1.82E+05
Te-129	9.77E-02	3.50E-02	2.38E-02	7.14E-02	2.57E-01	2.93E+03	2.55E+04
Te-131M	1.34E+02	5.92E+01	5.07E+01	9.77E+01	4.00E+02	2.06E+05	3.08E+05
Te-131	2.17E-02	8.44E-03	6.59E-03	1.70E-02	5.88E-02	2.05E+03	1.33E+03
Te-132	4.81E+02	2.72E+02	2.63E+02	3.17E+02	1.77E+03	3.77E+05	1.38E+05
I-130	8.18E+03	1.64E+04	8.44E+03	1.85E+06	2.45E+04	0.00E+00	5.11E+03
I-131	4.81E+04	4.81E+04	2.73E+04	1.62E+07	7.88E+04	0.00E+00	2.84E+03
I-132	2.12E+03	4.07E+03	1.88E+03	1.94E+05	6.25E+03	0.00E+00	3.20E+03
I-133	1.66E+04	2.03E+04	7.70E+03	3.85E+06	3.38E+04	0.00E+00	5.48E+03
I-134	1.17E+03	2.16E+03	9.95E+02	5.07E+04	3.30E+03	0.00E+00	9.55E+02
I-135	4.92E+03	8.73E+03	4.14E+03	7.92E+05	1.34E+04	0.00E+00	4.44E+03
Cs-134	6.51E+05	1.01E+06	2.25E+05	0.00E+00	3.30E+05	1.21E+05	3.85E+03
Cs-136	6.51E+04	1.71E+05	1.16E+05	0.00E+00	9.55E+04	1.45E+04	4.18E+03
Cs-137	9.07E+05	8.25E+05	1.28E+05	0.00E+00	2.82E+05	1.04E+05	3.62E+03
Cs-138	6.33E+02	8.40E+02	5.55E+02	0.00E+00	6.22E+02	6.81E+01	2.70E+02
Ba-139	1.84E+00	9.84E-04	5.37E-02	0.00E+00	8.62E-04	5.77E+03	5.77E+04
Ba-140	7.40E+04	6.48E+01	4.33E+03	0.00E+00	2.11E+01	1.74E+06	1.02E+05
Ba-141	1.96E-01	1.09E-04	6.36E-03	0.00E+00	9.47E-05	2.92E+03	2.75E+02
Ba-142	5.00E-02	3.60E-05	2.79E-03	0.00E+00	2.91E-05	1.64E+03	2.74E+00
La-140	6.44E+02	2.25E+02	7.55E+01	0.00E+00	0.00E+00	1.83E+05	2.26E+05
La-142	1.30E+00	4.11E-01	1.29E-01	0.00E+00	0.00E+00	8.70E+03	7.59E+04
Ce-141	3.92E+04	1.95E+04	2.90E+03	0.00E+00	8.55E+03	5.44E+05	5.66E+04
Ce-143	3.66E+02	1.99E+02	2.87E+01	0.00E+00	8.36E+01	1.15E+05	1.27E+05
Ce-144	6.77E+06	2.12E+06	3.61E+05	0.00E+00	1.17E+06	1.20E+07	3.89E+05
Pr-143	1.85E+04	5.55E+03	9.14E+02	0.00E+00	3.00E+03	4.33E+05	9.73E+04
Pr-144	5.96E-02	1.85E-02	3.00E-03	0.00E+00	9.77E-03	1.57E+03	1.97E+02
Nd-147	1.08E+04	8.73E+03	6.81E+02	0.00E+00	4.81E+03	3.28E+05	8.21E+04
W-187	1.63E+01	9.66E+00	4.33E+00	0.00E+00	0.00E+00	4.11E+04	9.10E+04
Np-239	4.66E+02	3.01E+02	2.35E+01	0.00E+00	9.73E+01	5.81E+04	6.40E+04

Notes:

1) Units are mrem/yr per $\mu Ci/m^3$.

Table F-11c
Infant Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	3.68E+02	3.68E+02	3.68E+02	3.68E+02	3.68E+02	3.68E+02
Na-24	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04
Cr-51	0.00E+00	0.00E+00	8.95E+01	5.75E+01	1.32E+01	1.28E+04	3.57E+02
Mn-54	0.00E+00	2.53E+04	4.98E+03	0.00E+00	4.98E+03	1.00E+06	7.06E+03
Mn-56	0.00E+00	1.54E+00	2.21E-01	0.00E+00	1.10E+00	1.25E+04	7.17E+04
Fe-55	1.97E+04	1.17E+04	3.33E+03	0.00E+00	0.00E+00	8.69E+04	1.09E+03
Fe-59	1.36E+04	2.35E+04	9.48E+03	0.00E+00	0.00E+00	1.02E+06	2.48E+04
Co-58	0.00E+00	1.22E+03	1.82E+03	0.00E+00	0.00E+00	7.77E+05	1.11E+04
Co-60	0.00E+00	8.02E+03	1.18E+04	0.00E+00	0.00E+00	4.51E+06	3.19E+04
Ni-63	3.39E+05	2.04E+04	1.16E+04	0.00E+00	0.00E+00	2.09E+05	2.42E+03
Ni-65	2.39E+00	2.84E-01	1.23E-01	0.00E+00	0.00E+00	8.12E+03	5.01E+04
Cu-64	0.00E+00	1.88E+00	7.74E-01	0.00E+00	3.98E+00	9.30E+03	1.50E+04
Zn-65	1.93E+04	6.26E+04	3.11E+04	0.00E+00	3.25E+04	6.47E+05	5.14E+04
Zn-69	5.39E-02	9.67E-02	7.18E-03	0.00E+00	4.02E-02	1.47E+03	1.32E+04
Br-83	0.00E+00	0.00E+00	3.81E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	4.00E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	2.04E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.90E+05	8.82E+04	0.00E+00	0.00E+00	0.00E+00	3.04E+03
Rb-88	0.00E+00	5.57E+02	2.87E+02	0.00E+00	0.00E+00	0.00E+00	3.39E+02
Rb-89	0.00E+00	3.21E+02	2.06E+02	0.00E+00	0.00E+00	0.00E+00	6.82E+01
Sr-89	3.98E+05	0.00E+00	1.14E+04	0.00E+00	0.00E+00	2.03E+06	6.40E+04
Sr-90	1.55E+07	0.00E+00	3.12E+05	0.00E+00	0.00E+00	1.12E+07	1.31E+05
Sr-91	9.56E+01	0.00E+00	3.46E+00	0.00E+00	0.00E+00	5.26E+04	7.34E+04
Sr-92	1.05E+01	0.00E+00	3.91E-01	0.00E+00	0.00E+00	2.38E+04	1.40E+05
Y-90	3.29E+03	0.00E+00	8.82E+01	0.00E+00	0.00E+00	2.69E+05	1.04E+05
Y-91M	4.07E-01	0.00E+00	1.39E-02	0.00E+00	0.00E+00	2.79E+03	2.35E+03
Y-91	5.88E+05	0.00E+00	1.57E+04	0.00E+00	0.00E+00	2.45E+06	7.03E+04
Y-92	1.64E+01	0.00E+00	4.61E-01	0.00E+00	0.00E+00	2.45E+04	1.27E+05
Y-93	1.50E+02	0.00E+00	4.07E+00	0.00E+00	0.00E+00	7.64E+04	1.67E+05
Zr-95	1.15E+05	2.79E+04	2.03E+04	0.00E+00	3.11E+04	1.75E+06	2.17E+04
Zr-97	1.50E+02	2.56E+01	1.17E+01	0.00E+00	2.59E+01	1.10E+05	1.40E+05
Nb-95	1.57E+04	6.43E+03	3.78E+03	0.00E+00	4.72E+03	4.79E+05	1.27E+04
Mo-99	0.00E+00	1.65E+02	3.23E+01	0.00E+00	2.65E+02	1.35E+05	4.87E+04
Tc- 99M	1.40E-03	2.88E-03	3.72E-02	0.00E+00	3.11E-02	8.11E+02	2.03E+03
Tc-101	6.51E-05	8.23E-05	8.12E-04	0.00E+00	9.79E-04	5.84E+02	8.44E+02
Ru-103	2.02E+03	0.00E+00	6.79E+02	0.00E+00	4.24E+03	5.52E+05	1.61E+04
Ru-105	1.22E+00	0.00E+00	4.10E-01	0.00E+00	8.99E-01	1.57E+04	4.84E+04
Ru-106	8.68E+04	0.00E+00	1.09E+04	0.00E+00	1.07E+05	1.16E+07	1.64E+05
Ag-110M	9.98E+03	7.22E+03	5.00E+03	0.00E+00	1.09E+04	3.67E+06	3.30E+04

Table F-11c (Continued)
Infant Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	4.76E+03	1.99E+03	6.58E+02	1.62E+03	0.00E+00	4.47E+05	1.29E+04
Te-127M	1.67E+04	6.90E+03	2.07E+03	4.87E+03	3.75E+04	1.31E+06	2.73E+04
Te-127	2.23E+00	9.53E-01	4.89E-01	1.85E+00	4.86E+00	1.03E+04	2.44E+04
Te-129M	1.41E+04	6.09E+03	2.23E+03	5.47E+03	3.18E+04	1.68E+06	6.90E+04
Te-129	7.88E-02	3.47E-02	1.88E-02	6.75E-02	1.75E-01	3.00E+03	2.63E+04
Te-131M	1.07E+02	5.50E+01	3.63E+01	8.93E+01	2.65E+02	1.99E+05	1.19E+05
Te-131	1.74E-02	8.22E-03	5.00E-03	1.58E-02	3.99E-02	2.06E+03	8.22E+03
Te-132	3.72E+02	2.37E+02	1.76E+02	2.79E+02	1.03E+03	3.40E+05	4.41E+04
I-130	6.36E+03	1.39E+04	5.57E+03	1.60E+06	1.53E+04	0.00E+00	1.99E+03
I-131	3.79E+04	4.44E+04	1.96E+04	1.48E+07	5.18E+04	0.00E+00	1.06E+03
I-132	1.69E+03	3.54E+03	1.26E+03	1.69E+05	3.95E+03	0.00E+00	1.90E+03
I-133	1.32E+04	1.92E+04	5.60E+03	3.56E+06	2.24E+04	0.00E+00	2.16E+03
I-134	9.21E+02	1.88E+03	6.65E+02	4.45E+04	2.09E+03	0.00E+00	1.29E+03
I-135	3.86E+03	7.60E+03	2.77E+03	6.96E+05	8.47E+03	0.00E+00	1.83E+03
Cs-134	3.96E+05	7.03E+05	7.45E+04	0.00E+00	1.90E+05	7.97E+04	1.33E+03
Cs-136	4.83E+04	1.35E+05	5.29E+04	0.00E+00	5.64E+04	1.18E+04	1.43E+03
Cs-137	5.49E+05	6.12E+05	4.55E+04	0.00E+00	1.72E+05	7.13E+04	1.33E+03
Cs-138	5.05E+02	7.81E+02	3.98E+02	0.00E+00	4.10E+02	6.54E+01	8.76E+02
Ba-139	1.48E+00	9.84E-04	4.30E-02	0.00E+00	5.92E-04	5.95E+03	5.10E+04
Ba-140	5.60E+04	5.60E+01	2.90E+03	0.00E+00	1.34E+01	1.60E+06	3.84E+04
Ba-141	1.57E-01	1.08E-04	4.97E-03	0.00E+00	6.50E-05	2.97E+03	4.75E+03
Ba-142	3.98E-02	3.30E-05	1.96E-03	0.00E+00	1.90E-05	1.55E+03	6.93E+02
La-140	5.05E+02	2.00E+02	5.15E+01	0.00E+00	0.00E+00	1.68E+05	8.48E+04
La-142	1.03E+00	3.77E-01	9.04E-02	0.00E+00	0.00E+00	8.22E+03	5.95E+04
Ce-141	2.77E+04	1.67E+04	1.99E+03	0.00E+00	5.25E+03	5.17E+05	2.16E+04
Ce-143	2.93E+02	1.93E+02	2.21E+01	0.00E+00	5.64E+01	1.16E+05	4.97E+04
Ce-144	3.19E+06	1.21E+06	1.76E+05	0.00E+00	5.38E+05	9.84E+06	1.48E+05
Pr-143	1.40E+04	5.24E+03	6.99E+02	0.00E+00	1.97E+03	4.33E+05	3.72E+04
Pr-144	4.79E-02	1.85E-02	2.41E-03	0.00E+00	6.72E-03	1.61E+03	4.28E+03
Nd-147	7.94E+03	8.13E+03	5.00E+02	0.00E+00	3.15E+03	3.22E+05	3.12E+04
W-187	1.30E+01	9.02E+00	3.12E+00	0.00E+00	0.00E+00	3.96E+04	3.56E+04
Np-239	3.71E+02	2.98E+02	1.88E+01	0.00E+00	6.62E+01	5.95E+04	2.49E+04

Notes:

1) Units are mrem/yr per $\mu Ci/m^3$.

Table F-12
Adult Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03
Na-24	2.69E+05	2.69E+05	2.69E+05	2.69E+05	2.69E+05	2.69E+05	2.69E+05
Cr-51	0.00E+00	0.00E+00	4.64E+04	2.77E+04	1.02E+04	6.15E+04	1.17E+07
Mn-54	0.00E+00	3.13E+08	5.97E+07	0.00E+00	9.31E+07	0.00E+00	9.58E+08
Mn-56	0.00E+00	1.54E+01	2.73E+00	0.00E+00	1.95E+01	0.00E+00	4.91E+02
Fe-55	2.10E+08	1.45E+08	3.38E+07	0.00E+00	0.00E+00	8.08E+07	8.31E+07
Fe-59	1.26E+08	2.96E+08	1.13E+08	0.00E+00	0.00E+00	8.27E+07	9.87E+08
Co-58	0.00E+00	3.08E+07	6.90E+07	0.00E+00	0.00E+00	0.00E+00	6.24E+08
Co-60	0.00E+00	1.67E+08	3.69E+08	0.00E+00	0.00E+00	0.00E+00	3.14E+09
Ni-63	1.04E+10	7.21E+08	3.49E+08	0.00E+00	0.00E+00	0.00E+00	1.50E+08
Ni-65	5.97E+01	7.75E+00	3.54E+00	0.00E+00	0.00E+00	0.00E+00	1.97E+02
Cu-64	0.00E+00	9.09E+03	4.27E+03	0.00E+00	2.29E+04	0.00E+00	7.75E+05
Zn-65	3.17E+08	1.01E+09	4.56E+08	0.00E+00	6.75E+08	0.00E+00	6.36E+08
Zn-69	4.95E-06	9.48E-06	6.59E-07	0.00E+00	6.16E-06	0.00E+00	1.42E-06
Br-83	0.00E+00	0.00E+00	3.00E+00	0.00E+00	0.00E+00	0.00E+00	4.32E+00
Br-84	0.00E+00	0.00E+00	2.20E-11	0.00E+00	0.00E+00	0.00E+00	1.72E-16
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.20E+08	1.03E+08	0.00E+00	0.00E+00	0.00E+00	4.34E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	9.95E+09	0.00E+00	2.86E+08	0.00E+00	0.00E+00	0.00E+00	1.60E+09
Sr-90	6.95E+11	0.00E+00	1.40E+10	0.00E+00	0.00E+00	0.00E+00	1.75E+10
Sr-91	3.01E+05	0.00E+00	1.22E+04	0.00E+00	0.00E+00	0.00E+00	1.43E+06
Sr-92	4.12E+02	0.00E+00	1.78E+01	0.00E+00	0.00E+00	0.00E+00	8.17E+03
Y-90	1.33E+04	0.00E+00	3.57E+02	0.00E+00	0.00E+00	0.00E+00	1.41E+08
Y-91M	4.93E-09	0.00E+00	1.91E-10	0.00E+00	0.00E+00	0.00E+00	1.45E-08
Y-91	5.12E+06	0.00E+00	1.37E+05	0.00E+00	0.00E+00	0.00E+00	2.82E+09
Y-92	8.95E-01	0.00E+00	2.62E-02	0.00E+00	0.00E+00	0.00E+00	1.57E+04
Y-93	1.67E+02	0.00E+00	4.62E+00	0.00E+00	0.00E+00	0.00E+00	5.31E+06
Zr-95	1.18E+06	3.77E+05	2.55E+05	0.00E+00	5.92E+05	0.00E+00	1.20E+09
Zr-97	3.35E+02	6.77E+01	3.09E+01	0.00E+00	1.02E+02	0.00E+00	2.10E+07
Nb-95	1.43E+05	7.95E+04	4.27E+04	0.00E+00	7.86E+04	0.00E+00	4.83E+08
Mo-99	0.00E+00	6.14E+06	1.17E+06	0.00E+00	1.39E+07	0.00E+00	1.42E+07
Tc- 99M	3.06E+00	8.64E+00	1.10E+02	0.00E+00	1.31E+02	4.23E+00	5.11E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	4.77E+06	0.00E+00	2.05E+06	0.00E+00	1.82E+07	0.00E+00	5.57E+08
Ru-105	5.27E+01	0.00E+00	2.08E+01	0.00E+00	6.81E+02	0.00E+00	3.23E+04
Ru-106	1.93E+08	0.00E+00	2.44E+07	0.00E+00	3.72E+08	0.00E+00	1.25E+10
Ag-110M	1.05E+07	9.75E+06	5.79E+06	0.00E+00	1.92E+07	0.00E+00	3.98E+09

Table F-12 (Continued)
Adult Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	9.67E+07	3.50E+07	1.30E+07	2.91E+07	3.93E+08	0.00E+00	3.86E+08
Te-127M	3.49E+08	1.25E+08	4.26E+07	8.92E+07	1.42E+09	0.00E+00	1.17E+09
Te-127	5.68E+03	2.04E+03	1.23E+03	4.21E+03	2.31E+04	0.00E+00	4.48E+05
Te-129M	2.51E+08	9.37E+07	3.97E+07	8.62E+07	1.05E+09	0.00E+00	1.26E+09
Te-129	7.14E-04	2.68E-04	1.74E-04	5.48E-04	3.00E-03	0.00E+00	5.39E-04
Te-131M	9.09E+05	4.45E+05	3.71E+05	7.04E+05	4.50E+06	0.00E+00	4.41E+07
Te-131	1.26E-15	5.26E-16	3.97E-16	1.03E-15	5.51E-15	0.00E+00	1.78E-16
Te-132	4.28E+06	2.77E+06	2.60E+06	3.06E+06	2.67E+07	0.00E+00	1.31E+08
I-130	3.89E+05	1.15E+06	4.52E+05	9.72E+07	1.79E+06	0.00E+00	9.87E+05
I-131	8.07E+07	1.15E+08	6.62E+07	3.78E+10	1.98E+08	0.00E+00	3.05E+07
I-132	5.58E+01	1.49E+02	5.22E+01	5.22E+03	2.38E+02	0.00E+00	2.80E+01
I-133	2.08E+06	3.62E+06	1.10E+06	5.32E+08	6.31E+06	0.00E+00	3.25E+06
I-134	8.55E-05	2.32E-04	8.31E-05	4.02E-03	3.69E-04	0.00E+00	2.02E-07
I-135	3.87E+04	1.01E+05	3.74E+04	6.68E+06	1.62E+05	0.00E+00	1.14E+05
Cs-134	4.67E+09	1.11E+10	9.08E+09	0.00E+00	3.59E+09	1.19E+09	1.94E+08
Cs-136	4.25E+07	1.68E+08	1.21E+08	0.00E+00	9.33E+07	1.28E+07	1.90E+07
Cs-137	6.36E+09	8.70E+09	5.70E+09	0.00E+00	2.95E+09	9.81E+08	1.68E+08
Cs-138	3.32E-11	6.56E-11	3.25E-11	0.00E+00	4.82E-11	4.76E-12	2.80E-16
Ba-139	2.71E-02	1.93E-05	7.92E-04	0.00E+00	1.80E-05	1.09E-05	4.80E-02
Ba-140	1.29E+08	1.61E+05	8.42E+06	0.00E+00	5.49E+04	9.24E+04	2.65E+08
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	1.98E+03	9.97E+02	2.63E+02	0.00E+00	0.00E+00	0.00E+00	7.32E+07
La-142	1.94E-04	8.83E-05	2.20E-05	0.00E+00	0.00E+00	0.00E+00	6.45E-01
Ce-141	1.97E+05	1.33E+05	1.51E+04	0.00E+00	6.19E+04	0.00E+00	5.09E+08
Ce-143	9.94E+02	7.35E+05	8.13E+01	0.00E+00	3.24E+02	0.00E+00	2.75E+07
Ce-144	3.29E+07	1.38E+07	1.77E+06	0.00E+00	8.16E+06	0.00E+00	1.11E+10
Pr-143	6.27E+04	2.51E+04	3.11E+03	0.00E+00	1.45E+04	0.00E+00	2.75E+08
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	3.37E+04	3.90E+04	2.33E+03	0.00E+00	2.28E+04	0.00E+00	1.87E+08
W-187	3.79E+04	3.17E+04	1.11E+04	0.00E+00	0.00E+00	0.00E+00	1.04E+07
Np-239	1.42E+03	1.40E+02	7.72E+01	0.00E+00	4.37E+02	0.00E+00	2.87E+07

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table F-12a
Teen Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.47E+03	1.47E+03	1.47E+03	1.47E+03	1.47E+03	1.47E+03
Na-24	2.39E+05	2.39E+05	2.39E+05	2.39E+05	2.39E+05	2.39E+05	2.39E+05
Cr-51	0.00E+00	0.00E+00	6.16E+04	3.42E+04	1.35E+04	8.79E+04	1.03E+07
Mn-54	0.00E+00	4.54E+08	9.01E+07	0.00E+00	1.36E+08	0.00E+00	9.32E+08
Mn-56	0.00E+00	1.39E+01	2.47E+00	0.00E+00	1.76E+01	0.00E+00	9.13E+02
Fe-55	3.26E+08	2.31E+08	5.39E+07	0.00E+00	0.00E+00	1.47E+08	1.00E+08
Fe-59	1.79E+08	4.18E+08	1.61E+08	0.00E+00	0.00E+00	1.32E+08	9.89E+08
Co-58	0.00E+00	4.37E+07	1.01E+08	0.00E+00	0.00E+00	0.00E+00	6.02E+08
Co-60	0.00E+00	2.49E+08	5.60E+08	0.00E+00	0.00E+00	0.00E+00	3.24E+09
Ni-63	1.61E+10	1.13E+09	5.45E+08	0.00E+00	0.00E+00	0.00E+00	1.81E+08
Ni-65	5.55E+01	7.10E+00	3.23E+00	0.00E+00	0.00E+00	0.00E+00	3.85E+02
Cu-64	0.00E+00	8.24E+03	3.87E+03	0.00E+00	2.08E+04	0.00E+00	6.39E+05
Zn-65	4.24E+08	1.47E+09	6.86E+08	0.00E+00	9.41E+08	0.00E+00	6.23E+08
Zn-69	4.64E-06	8.84E-06	6.19E-07	0.00E+00	5.78E-06	0.00E+00	1.63E-05
Br-83	0.00E+00	0.00E+00	2.81E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	2.00E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.75E+08	1.29E+08	0.00E+00	0.00E+00	0.00E+00	4.06E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	1.51E+10	0.00E+00	4.33E+08	0.00E+00	0.00E+00	0.00E+00	1.80E+09
Sr-90	9.22E+11	0.00E+00	1.84E+10	0.00E+00	0.00E+00	0.00E+00	2.11E+10
Sr-91	2.81E+05	0.00E+00	1.12E+04	0.00E+00	0.00E+00	0.00E+00	1.27E+06
Sr-92	3.84E+02	0.00E+00	1.64E+01	0.00E+00	0.00E+00	0.00E+00	9.78E+03
Y-90	1.24E+04	0.00E+00	3.35E+02	0.00E+00	0.00E+00	0.00E+00	1.02E+08
Y-91M	4.59E-09	0.00E+00	1.75E-10	0.00E+00	0.00E+00	0.00E+00	2.17E-07
Y-91	7.84E+06	0.00E+00	2.10E+05	0.00E+00	0.00E+00	0.00E+00	3.21E+09
Y-92	8.41E-01	0.00E+00	2.43E-02	0.00E+00	0.00E+00	0.00E+00	2.31E+04
Y-93	1.57E+02	0.00E+00	4.30E+00	0.00E+00	0.00E+00	0.00E+00	4.80E+06
Zr-95	1.72E+06	5.44E+05	3.74E+05	0.00E+00	7.99E+05	0.00E+00	1.26E+09
Zr-97	3.10E+02	6.14E+01	2.83E+01	0.00E+00	9.31E+01	0.00E+00	1.66E+07
Nb-95	1.93E+05	1.07E+05	5.90E+04	0.00E+00	1.04E+05	0.00E+00	4.58E+08
Mo-99	0.00E+00	5.63E+06	1.07E+06	0.00E+00	1.29E+07	0.00E+00	1.01E+07
Tc- 99M	2.70E+00	7.52E+00	9.75E+01	0.00E+00	1.12E+02	4.17E+00	4.94E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	6.82E+06	0.00E+00	2.91E+06	0.00E+00	2.40E+07	0.00E+00	5.69E+08
Ru-105	4.90E+01	0.00E+00	1.90E+01	0.00E+00	6.18E+02	0.00E+00	3.95E+04
Ru-106	3.09E+08	0.00E+00	3.90E+07	0.00E+00	5.97E+08	0.00E+00	1.48E+10
Ag-110M	1.52E+07	1.44E+07	8.73E+06	0.00E+00	2.74E+07	0.00E+00	4.03E+09

Table F-12a (Continued)
Teen Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.49E+08	5.35E+07	1.99E+07	4.15E+07	0.00E+00	0.00E+00	4.38E+08
Te-127M	5.51E+08	1.96E+08	6.56E+07	1.31E+08	2.24E+09	0.00E+00	1.37E+09
Te-127	5.36E+03	1.90E+03	1.15E+03	3.70E+03	2.17E+04	0.00E+00	4.14E+05
Te-129M	3.61E+08	1.34E+08	5.72E+07	1.17E+08	1.51E+09	0.00E+00	1.36E+09
Te-129	6.68E-04	2.49E-04	1.63E-04	4.77E-04	2.80E-03	0.00E+00	3.65E-03
Te-131M	8.42E+05	4.04E+05	3.37E+05	6.07E+05	4.21E+06	0.00E+00	3.24E+07
Te-131	1.17E-15	4.82E-16	3.66E-16	9.01E-16	5.11E-15	0.00E+00	9.60E-17
Te-132	3.89E+06	2.46E+06	2.32E+06	2.60E+06	2.36E+07	0.00E+00	7.81E+07
I-130	3.47E+05	1.01E+06	4.01E+05	8.20E+07	1.55E+06	0.00E+00	7.73E+05
I-131	7.68E+07	1.08E+08	5.78E+07	3.14E+10	1.85E+08	0.00E+00	2.13E+07
I-132	5.03E+01	1.32E+02	4.72E+01	4.43E+03	2.07E+02	0.00E+00	5.73E+01
I-133	1.93E+06	3.28E+06	1.00E+06	4.58E+08	5.75E+06	0.00E+00	2.48E+06
I-134	7.73E-05	2.05E-04	7.36E-05	3.41E-03	3.23E-04	0.00E+00	2.70E-06
I-135	3.49E+04	8.99E+04	3.33E+04	5.78E+06	1.42E+05	0.00E+00	9.97E+04
Cs-134	7.10E+09	1.67E+10	7.75E+09	0.00E+00	5.31E+09	2.03E+09	2.08E+08
Cs-136	4.35E+07	1.71E+08	1.15E+08	0.00E+00	9.31E+07	1.47E+07	1.38E+07
Cs-137	1.01E+10	1.35E+10	4.69E+09	0.00E+00	4.59E+09	1.78E+09	1.92E+08
Cs-138	3.07E-11	5.89E-11	2.94E-11	0.00E+00	4.35E-11	5.06E-12	2.67E-14
Ba-139	2.55E-02	1.79E-05	7.42E-04	0.00E+00	1.69E-05	1.23E-05	2.27E-01
Ba-140	1.38E+08	1.69E+05	8.90E+06	0.00E+00	5.74E+04	1.14E+05	2.13E+08
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	1.81E+03	8.88E+02	2.36E+02	0.00E+00	0.00E+00	0.00E+00	5.10E+07
La-142	1.78E-04	7.92E-05	1.97E-05	0.00E+00	0.00E+00	0.00E+00	2.41E+00
Ce-141	2.83E+05	1.89E+05	2.17E+04	0.00E+00	8.89E+04	0.00E+00	5.40E+08
Ce-143	9.29E+02	6.76E+05	7.55E+01	0.00E+00	3.03E+02	0.00E+00	2.03E+07
Ce-144	5.27E+07	2.18E+07	2.83E+06	0.00E+00	1.30E+07	0.00E+00	1.33E+10
Pr-143	7.01E+04	2.80E+04	3.49E+03	0.00E+00	1.63E+04	0.00E+00	2.31E+08
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	3.67E+04	4.00E+04	2.39E+03	0.00E+00	2.35E+04	0.00E+00	1.44E+08
W-187	3.53E+04	2.87E+04	1.01E+04	0.00E+00	0.00E+00	0.00E+00	7.78E+06
Np-239	1.38E+03	1.30E+02	7.24E+01	0.00E+00	4.09E+02	0.00E+00	2.10E+07

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per μCi/m^3.

Table F-12b
Child Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	2.29E+03	2.29E+03	2.29E+03	2.29E+03	2.29E+03	2.29E+03
Na-24	3.73E+05	3.73E+05	3.73E+05	3.73E+05	3.73E+05	3.73E+05	3.73E+05
Cr-51	0.00E+00	0.00E+00	1.17E+05	6.49E+04	1.77E+04	1.18E+05	6.20E+06
Mn-54	0.00E+00	6.65E+08	1.77E+08	0.00E+00	1.86E+08	0.00E+00	5.58E+08
Mn-56	0.00E+00	1.82E+01	4.10E+00	0.00E+00	2.20E+01	0.00E+00	2.63E+03
Fe-55	8.01E+08	4.25E+08	1.32E+08	0.00E+00	0.00E+00	2.40E+08	7.87E+07
Fe-59	3.97E+08	6.42E+08	3.20E+08	0.00E+00	0.00E+00	1.86E+08	6.69E+08
Co-58	0.00E+00	6.45E+07	1.97E+08	0.00E+00	0.00E+00	0.00E+00	3.76E+08
Co-60	0.00E+00	3.78E+08	1.12E+09	0.00E+00	0.00E+00	0.00E+00	2.10E+09
Ni-63	3.95E+10	2.11E+09	1.34E+09	0.00E+00	0.00E+00	0.00E+00	1.42E+08
Ni-65	1.02E+02	9.59E+00	5.60E+00	0.00E+00	0.00E+00	0.00E+00	1.18E+03
Cu-64	0.00E+00	1.09E+04	6.56E+03	0.00E+00	2.62E+04	0.00E+00	5.10E+05
Zn-65	8.12E+08	2.16E+09	1.35E+09	0.00E+00	1.36E+09	0.00E+00	3.80E+08
Zn-69	8.56E-06	1.24E-05	1.14E-06	0.00E+00	7.50E-06	0.00E+00	7.80E-04
Br-83	0.00E+00	0.00E+00	5.18E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	3.39E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	4.54E+08	2.79E+08	0.00E+00	0.00E+00	0.00E+00	2.92E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	3.59E+10	0.00E+00	1.03E+09	0.00E+00	0.00E+00	0.00E+00	1.39E+09
Sr-90	1.87E+12	0.00E+00	3.77E+10	0.00E+00	0.00E+00	0.00E+00	1.67E+10
Sr-91	5.17E+05	0.00E+00	1.95E+04	0.00E+00	0.00E+00	0.00E+00	1.14E+06
Sr-92	7.04E+02	0.00E+00	2.82E+01	0.00E+00	0.00E+00	0.00E+00	1.33E+04
Y-90	2.31E+04	0.00E+00	6.18E+02	0.00E+00	0.00E+00	0.00E+00	6.57E+07
Y-91M	8.42E-09	0.00E+00	3.06E-10	0.00E+00	0.00E+00	0.00E+00	1.65E-05
Y-91	1.87E+07	0.00E+00	4.99E+05	0.00E+00	0.00E+00	0.00E+00	2.49E+09
Y-92	1.55E+00	0.00E+00	4.43E-02	0.00E+00	0.00E+00	0.00E+00	4.47E+04
Y-93	2.89E+02	0.00E+00	7.94E+00	0.00E+00	0.00E+00	0.00E+00	4.31E+06
Zr-95	3.86E+06	8.50E+05	7.56E+05	0.00E+00	1.22E+06	0.00E+00	8.86E+08
Zr-97	5.67E+02	8.19E+01	4.83E+01	0.00E+00	1.18E+02	0.00E+00	1.24E+07
Nb-95	4.12E+05	1.61E+05	1.15E+05	0.00E+00	1.51E+05	0.00E+00	2.97E+08
Mo-99	0.00E+00	7.69E+06	1.90E+06	0.00E+00	1.64E+07	0.00E+00	6.36E+06
Tc- 99M	4.64E+00	9.10E+00	1.51E+02	0.00E+00	1.32E+02	4.62E+00	5.18E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.53E+07	0.00E+00	5.89E+06	0.00E+00	3.86E+07	0.00E+00	3.96E+08
Ru-105	8.97E+01	0.00E+00	3.25E+01	0.00E+00	7.89E+02	0.00E+00	5.86E+04
Ru-106	7.45E+08	0.00E+00	9.30E+07	0.00E+00	1.01E+09	0.00E+00	1.16E+10
Ag-110M	3.21E+07	2.17E+07	1.74E+07	0.00E+00	4.04E+07	0.00E+00	2.58E+09

**Table F-12b (Continued)
Child Vegetation Dose Factors**

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.51E+08	9.52E+07	4.68E+07	9.86E+07	0.00E+00	0.00E+00	3.39E+08
Te-127M	1.32E+09	3.56E+08	1.57E+08	3.16E+08	3.77E+09	0.00E+00	1.07E+09
Te-127	9.89E+03	2.67E+03	2.12E+03	6.84E+03	2.81E+04	0.00E+00	3.86E+05
Te-129M	8.40E+08	2.35E+08	1.30E+08	2.71E+08	2.47E+09	0.00E+00	1.02E+09
Te-129	1.24E-03	3.45E-04	2.94E-04	8.83E-04	3.62E-03	0.00E+00	7.70E-02
Te-131M	1.54E+06	5.32E+05	5.66E+05	1.09E+06	5.15E+06	0.00E+00	2.16E+07
Te-131	2.15E-15	6.57E-16	6.41E-16	1.65E-15	6.51E-15	0.00E+00	1.13E-14
Te-132	6.97E+06	3.09E+06	3.73E+06	4.49E+06	2.86E+07	0.00E+00	3.11E+07
I-130	6.10E+05	1.23E+06	6.35E+05	1.36E+08	1.84E+06	0.00E+00	5.76E+05
I-131	1.43E+08	1.44E+08	8.17E+07	4.75E+10	2.36E+08	0.00E+00	1.28E+07
I-132	8.93E+01	1.64E+02	7.54E+01	7.61E+03	2.51E+02	0.00E+00	1.93E+02
I-133	3.52E+06	4.36E+06	1.65E+06	8.09E+08	7.26E+06	0.00E+00	1.76E+06
I-134	1.37E-04	2.55E-04	1.17E-04	5.86E-03	3.90E-04	0.00E+00	1.69E-04
I-135	6.20E+04	1.12E+05	5.28E+04	9.89E+06	1.71E+05	0.00E+00	8.51E+04
Cs-134	1.60E+10	2.63E+10	5.55E+09	0.00E+00	8.16E+09	2.93E+09	1.42E+08
Cs-136	8.18E+07	2.25E+08	1.46E+08	0.00E+00	1.20E+08	1.79E+07	7.90E+06
Cs-137	2.39E+10	2.29E+10	3.38E+09	0.00E+00	7.46E+09	2.68E+09	1.43E+08
Cs-138	5.58E-11	7.75E-11	4.92E-11	0.00E+00	5.45E-11	5.87E-12	3.57E-11
Ba-139	4.69E-02	2.51E-05	1.36E-03	0.00E+00	2.19E-05	1.47E-05	2.71E+00
Ba-140	2.77E+08	2.43E+05	1.62E+07	0.00E+00	7.90E+04	1.45E+05	1.40E+08
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	3.25E+03	1.13E+03	3.82E+02	0.00E+00	0.00E+00	0.00E+00	3.16E+07
La-142	3.23E-04	1.03E-04	3.22E-05	0.00E+00	0.00E+00	0.00E+00	2.04E+01
Ce-141	6.55E+05	3.27E+05	4.85E+04	0.00E+00	1.43E+05	0.00E+00	4.08E+08
Ce-143	1.71E+03	9.28E+05	1.34E+02	0.00E+00	3.89E+02	0.00E+00	1.36E+07
Ce-144	1.27E+08	3.98E+07	6.78E+06	0.00E+00	2.21E+07	0.00E+00	1.04E+10
Pr-143	1.46E+05	4.38E+04	7.24E+03	0.00E+00	2.37E+04	0.00E+00	1.57E+08
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	7.27E+04	5.89E+04	4.56E+03	0.00E+00	3.23E+04	0.00E+00	9.33E+07
W-187	6.41E+04	3.80E+04	1.70E+04	0.00E+00	0.00E+00	0.00E+00	5.34E+06
Np-239	2.55E+03	1.83E+02	1.29E+02	0.00E+00	5.30E+02	0.00E+00	1.36E+07

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per μCi/m^3.

3) The infant age group is assumed to receive no due through the vegetation ingestion pathway therefore no dose factors are supplied.

Table F-13
Adult Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	4.35E+02	4.35E+02	4.35E+02	4.35E+02	4.35E+02	4.35E+02
Na-24	2.46E+06	2.46E+06	2.46E+06	2.46E+06	2.46E+06	2.46E+06	2.46E+06
Cr-51	0.00E+00	0.00E+00	2.86E+04	1.71E+04	6.29E+03	3.79E+04	7.18E+06
Mn-54	0.00E+00	8.41E+06	1.61E+06	0.00E+00	2.50E+06	0.00E+00	2.58E+07
Mn-56	0.00E+00	4.13E-03	7.32E-04	0.00E+00	5.24E-03	0.00E+00	1.32E-01
Fe-55	2.51E+07	1.74E+07	4.05E+06	0.00E+00	0.00E+00	9.68E+06	9.95E+06
Fe-59	2.97E+07	6.98E+07	2.67E+07	0.00E+00	0.00E+00	1.95E+07	2.33E+08
Co-58	0.00E+00	4.72E+06	1.06E+07	0.00E+00	0.00E+00	0.00E+00	9.56E+07
Co-60	0.00E+00	1.64E+07	3.62E+07	0.00E+00	0.00E+00	0.00E+00	3.08E+08
Ni-63	6.73E+09	4.66E+08	2.26E+08	0.00E+00	0.00E+00	0.00E+00	9.73E+07
Ni-65	3.70E-01	4.81E-02	2.19E-02	0.00E+00	0.00E+00	0.00E+00	1.22E+00
Cu-64	0.00E+00	2.36E+04	1.11E+04	0.00E+00	5.95E+04	0.00E+00	2.01E+06
Zn-65	1.37E+09	4.36E+09	1.97E+09	0.00E+00	2.92E+09	0.00E+00	2.75E+09
Zn-69	2.01E-12	3.84E-12	2.67E-13	0.00E+00	2.50E-12	0.00E+00	5.78E-13
Br-83	0.00E+00	0.00E+00	9.65E-02	0.00E+00	0.00E+00	0.00E+00	1.39E-01
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.60E+09	1.21E+09	0.00E+00	0.00E+00	0.00E+00	5.12E+08
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	1.45E+09	0.00E+00	4.16E+07	0.00E+00	0.00E+00	0.00E+00	2.33E+08
Sr-90	5.38E+10	0.00E+00	1.08E+09	0.00E+00	0.00E+00	0.00E+00	1.35E+09
Sr-91	2.87E+04	0.00E+00	1.16E+03	0.00E+00	0.00E+00	0.00E+00	1.37E+05
Sr-92	4.84E-01	0.00E+00	2.09E-02	0.00E+00	0.00E+00	0.00E+00	9.58E+00
Y-90	7.10E+01	0.00E+00	1.90E+00	0.00E+00	0.00E+00	0.00E+00	7.52E+05
Y-91M	6.42E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.89E-19
Y-91	8.59E+03	0.00E+00	2.30E+02	0.00E+00	0.00E+00	0.00E+00	4.73E+06
Y-92	5.57E-05	0.00E+00	1.63E-06	0.00E+00	0.00E+00	0.00E+00	9.75E-01
Y-93	2.22E-01	0.00E+00	6.12E-03	0.00E+00	0.00E+00	0.00E+00	7.03E+03
Zr-95	9.44E+02	3.03E+02	2.05E+02	0.00E+00	4.75E+02	0.00E+00	9.59E+05
Zr-97	4.32E-01	8.72E-02	3.99E-02	0.00E+00	1.32E-01	0.00E+00	2.70E+04
Nb-95	8.26E+04	4.60E+04	2.47E+04	0.00E+00	4.54E+04	0.00E+00	2.79E+08
Mo-99	0.00E+00	2.47E+07	4.70E+06	0.00E+00	5.60E+07	0.00E+00	5.73E+07
Tc- 99M	3.31E+00	9.35E+00	1.19E+02	0.00E+00	1.42E+02	4.58E+00	5.53E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.02E+03	0.00E+00	4.39E+02	0.00E+00	3.88E+03	0.00E+00	1.19E+05
Ru-105	8.51E-04	0.00E+00	3.36E-04	0.00E+00	1.10E-02	0.00E+00	5.20E-01
Ru-106	2.04E+04	0.00E+00	2.58E+03	0.00E+00	3.94E+04	0.00E+00	1.32E+06
Ag-110M	5.82E+07	5.39E+07	3.20E+07	0.00E+00	1.06E+08	0.00E+00	2.20E+10

Table F-13 (Continued)
Adult Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.63E+07	5.91E+06	2.18E+06	4.90E+06	6.63E+07	0.00E+00	6.51E+07
Te-127M	4.58E+07	1.64E+07	5.58E+06	1.17E+07	1.86E+08	0.00E+00	1.54E+08
Te-127	6.66E+02	2.39E+02	1.44E+02	4.94E+02	2.71E+03	0.00E+00	5.26E+04
Te-129M	6.02E+07	2.24E+07	9.52E+06	2.07E+07	2.51E+08	0.00E+00	3.03E+08
Te-129	2.83E-10	1.06E-10	6.88E-11	2.17E-10	1.19E-09	0.00E+00	2.13E-10
Te-131M	3.61E+05	1.76E+05	1.47E+05	2.79E+05	1.79E+06	0.00E+00	1.75E+07
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	2.39E+06	1.55E+06	1.45E+06	1.71E+06	1.49E+07	0.00E+00	7.32E+07
I-130	4.18E+05	1.23E+06	4.86E+05	1.04E+08	1.92E+06	0.00E+00	1.06E+06
I-131	2.96E+08	4.23E+08	2.43E+08	1.39E+11	7.26E+08	0.00E+00	1.12E+08
I-132	1.65E-01	4.40E-01	1.54E-01	1.54E+01	7.02E-01	0.00E+00	8.27E-02
I-133	3.88E+06	6.74E+06	2.06E+06	9.91E+08	1.18E+07	0.00E+00	6.06E+06
I-134	1.89E-12	5.13E-12	1.83E-12	8.89E-11	8.16E-12	0.00E+00	4.47E-15
I-135	1.29E+04	3.38E+04	1.25E+04	2.23E+06	5.42E+04	0.00E+00	3.82E+04
Cs-134	5.65E+09	1.35E+10	1.10E+10	0.00E+00	4.35E+09	1.45E+09	2.35E+08
Cs-136	2.63E+08	1.04E+09	7.46E+08	0.00E+00	5.77E+08	7.91E+07	1.18E+08
Cs-137	7.38E+09	1.01E+10	6.61E+09	0.00E+00	3.43E+09	1.14E+09	1.95E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	4.43E-08	3.16E-11	1.30E-09	0.00E+00	2.95E-11	1.79E-11	7.86E-08
Ba-140	2.69E+07	3.38E+04	1.76E+06	0.00E+00	1.15E+04	1.93E+04	5.54E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	4.52E+00	2.28E+00	6.02E-01	0.00E+00	0.00E+00	0.00E+00	1.67E+05
La-142	1.89E-11	8.59E-12	2.14E-12	0.00E+00	0.00E+00	0.00E+00	6.28E-08
Ce-141	4.84E+03	3.28E+03	3.72E+02	0.00E+00	1.52E+03	0.00E+00	1.25E+07
Ce-143	4.15E+01	3.07E+04	3.39E+00	0.00E+00	1.35E+01	0.00E+00	1.15E+06
Ce-144	3.58E+05	1.50E+05	1.92E+04	0.00E+00	8.87E+04	0.00E+00	1.21E+08
Pr-143	1.58E+02	6.34E+01	7.83E+00	0.00E+00	3.66E+01	0.00E+00	6.92E+05
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	9.48E+01	1.10E+02	6.56E+00	0.00E+00	6.41E+01	0.00E+00	5.26E+05
W-187	6.51E+03	5.44E+03	1.90E+03	0.00E+00	0.00E+00	0.00E+00	1.78E+06
Np-239	3.67E+00	3.61E-01	1.99E-01	0.00E+00	1.12E+00	0.00E+00	7.40E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table F-13a
Teen Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	5.66E+02	5.66E+02	5.66E+02	5.66E+02	5.66E+02	5.66E+02
Na-24	4.29E+06	4.29E+06	4.29E+06	4.29E+06	4.29E+06	4.29E+06	4.29E+06
Cr-51	0.00E+00	0.00E+00	4.99E+04	2.77E+04	1.09E+04	7.12E+04	8.38E+06
Mn-54	0.00E+00	1.40E+07	2.78E+06	0.00E+00	4.18E+06	0.00E+00	2.87E+07
Mn-56	0.00E+00	7.32E-03	1.30E-03	0.00E+00	9.27E-03	0.00E+00	4.82E-01
Fe-55	4.45E+07	3.16E+07	7.36E+06	0.00E+00	0.00E+00	2.00E+07	1.37E+07
Fe-59	5.18E+07	1.21E+08	4.67E+07	0.00E+00	0.00E+00	3.81E+07	2.86E+08
Co-58	0.00E+00	7.94E+06	1.83E+07	0.00E+00	0.00E+00	0.00E+00	1.09E+08
Co-60	0.00E+00	2.78E+07	6.26E+07	0.00E+00	0.00E+00	0.00E+00	3.62E+08
Ni-63	1.18E+10	8.35E+08	4.01E+08	0.00E+00	0.00E+00	0.00E+00	1.33E+08
Ni-65	6.78E-01	8.66E-02	3.94E-02	0.00E+00	0.00E+00	0.00E+00	4.70E+00
Cu-64	0.00E+00	4.21E+04	1.98E+04	0.00E+00	1.06E+05	0.00E+00	3.26E+06
Zn-65	2.11E+09	7.31E+09	3.41E+09	0.00E+00	4.68E+09	0.00E+00	3.10E+09
Zn-69	3.70E-12	7.05E-12	4.94E-13	0.00E+00	4.61E-12	0.00E+00	1.30E-11
Br-83	0.00E+00	0.00E+00	1.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	4.73E+09	2.22E+09	0.00E+00	0.00E+00	0.00E+00	7.01E+08
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	2.67E+09	0.00E+00	7.66E+07	0.00E+00	0.00E+00	0.00E+00	3.18E+08
Sr-90	8.13E+10	0.00E+00	1.63E+09	0.00E+00	0.00E+00	0.00E+00	1.86E+09
Sr-91	5.27E+04	0.00E+00	2.10E+03	0.00E+00	0.00E+00	0.00E+00	2.39E+05
Sr-92	8.85E-01	0.00E+00	3.77E-02	0.00E+00	0.00E+00	0.00E+00	2.26E+01
Y-90	1.30E+02	0.00E+00	3.51E+00	0.00E+00	0.00E+00	0.00E+00	1.08E+06
Y-91M	1.18E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.55E-18
Y-91	1.58E+04	0.00E+00	4.24E+02	0.00E+00	0.00E+00	0.00E+00	6.48E+06
Y-92	1.03E-04	0.00E+00	2.98E-06	0.00E+00	0.00E+00	0.00E+00	2.82E+00
Y-93	4.09E-01	0.00E+00	1.12E-02	0.00E+00	0.00E+00	0.00E+00	1.25E+04
Zr-95	1.65E+03	5.21E+02	3.58E+02	0.00E+00	7.65E+02	0.00E+00	1.20E+06
Zr-97	7.87E-01	1.56E-01	7.17E-02	0.00E+00	2.36E-01	0.00E+00	4.22E+04
Nb-95	1.41E+05	7.82E+04	4.30E+04	0.00E+00	7.58E+04	0.00E+00	3.34E+08
Mo-99	0.00E+00	4.46E+07	8.51E+06	0.00E+00	1.02E+08	0.00E+00	8.00E+07
Tc- 99M	5.74E+00	1.60E+01	2.07E+02	0.00E+00	2.39E+02	8.89E+00	1.05E+04
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.81E+03	0.00E+00	7.74E+02	0.00E+00	6.38E+03	0.00E+00	1.51E+05
Ru-105	1.55E-03	0.00E+00	6.03E-04	0.00E+00	1.96E-02	0.00E+00	1.25E+00
Ru-106	3.75E+04	0.00E+00	4.73E+03	0.00E+00	7.24E+04	0.00E+00	1.80E+06
Ag-110M	9.63E+07	9.11E+07	5.54E+07	0.00E+00	1.74E+08	0.00E+00	2.56E+10

Table F-13a (Continued)
Teen Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.01E+07	1.08E+07	4.02E+06	8.40E+06	0.00E+00	0.00E+00	8.87E+07
Te-127M	8.44E+07	2.99E+07	1.00E+07	2.01E+07	3.42E+08	0.00E+00	2.10E+08
Te-127	1.24E+03	4.38E+02	2.66E+02	8.52E+02	5.00E+03	0.00E+00	9.54E+04
Te-129M	1.10E+08	4.09E+07	1.74E+07	3.55E+07	4.61E+08	0.00E+00	4.13E+08
Te-129	5.20E-10	1.94E-10	1.27E-10	3.72E-10	2.18E-09	0.00E+00	2.84E-09
Te-131M	6.57E+05	3.15E+05	2.63E+05	4.74E+05	3.28E+06	0.00E+00	2.53E+07
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	4.27E+06	2.71E+06	2.55E+06	2.85E+06	2.60E+07	0.00E+00	8.57E+07
I-130	7.35E+05	2.13E+06	8.49E+05	1.73E+08	3.27E+06	0.00E+00	1.63E+06
I-131	5.37E+08	7.52E+08	4.04E+08	2.19E+11	1.29E+09	0.00E+00	1.49E+08
I-132	2.92E-01	7.64E-01	2.74E-01	2.57E+01	1.20E+00	0.00E+00	3.33E-01
I-133	7.08E+06	1.20E+07	3.66E+06	1.68E+09	2.11E+07	0.00E+00	9.09E+06
I-134	3.35E-12	8.89E-12	3.19E-12	1.48E-10	1.40E-11	0.00E+00	1.17E-13
I-135	2.29E+04	5.91E+04	2.19E+04	3.80E+06	9.33E+04	0.00E+00	6.54E+04
Cs-134	9.82E+09	2.31E+10	1.07E+10	0.00E+00	7.34E+09	2.80E+09	2.87E+08
Cs-136	4.47E+08	1.76E+09	1.18E+09	0.00E+00	9.58E+08	1.51E+08	1.42E+08
Cs-137	1.34E+10	1.78E+10	6.20E+09	0.00E+00	6.06E+09	2.35E+09	2.53E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	8.20E-08	5.77E-11	2.39E-09	0.00E+00	5.44E-11	3.98E-11	7.31E-07
Ba-140	4.85E+07	5.95E+04	3.13E+06	0.00E+00	2.02E+04	4.00E+04	7.49E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	8.12E+00	3.99E+00	1.06E+00	0.00E+00	0.00E+00	0.00E+00	2.29E+05
La-142	3.41E-11	1.51E-11	3.77E-12	0.00E+00	0.00E+00	0.00E+00	4.61E-07
Ce-141	8.88E+03	5.93E+03	6.81E+02	0.00E+00	2.79E+03	0.00E+00	1.70E+07
Ce-143	7.62E+01	5.55E+04	6.20E+00	0.00E+00	2.49E+01	0.00E+00	1.67E+06
Ce-144	6.58E+05	2.72E+05	3.54E+04	0.00E+00	1.63E+05	0.00E+00	1.66E+08
Pr-143	2.90E+02	1.16E+02	1.44E+01	0.00E+00	6.74E+01	0.00E+00	9.55E+05
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	1.82E+02	1.98E+02	1.19E+01	0.00E+00	1.17E+02	0.00E+00	7.16E+05
W-187	1.19E+04	9.71E+03	3.40E+03	0.00E+00	0.00E+00	0.00E+00	2.63E+06
Np-239	7.00E+00	6.60E-01	3.67E-01	0.00E+00	2.07E+00	0.00E+00	1.06E+05

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table F-13b
Child Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	8.97E+02	8.97E+02	8.97E+02	8.97E+02	8.97E+02	8.97E+02
Na-24	8.93E+06	8.93E+06	8.93E+06	8.93E+06	8.93E+06	8.93E+06	8.93E+06
Cr-51	0.00E+00	0.00E+00	1.02E+05	5.65E+04	1.54E+04	1.03E+05	5.39E+06
Mn-54	0.00E+00	2.10E+07	5.59E+06	0.00E+00	5.88E+06	0.00E+00	1.76E+07
Mn-56	0.00E+00	1.28E-02	2.88E-03	0.00E+00	1.54E-02	0.00E+00	1.85E+00
Fe-55	1.12E+08	5.93E+07	1.84E+07	0.00E+00	0.00E+00	3.35E+07	1.10E+07
Fe-59	1.20E+08	1.94E+08	9.69E+07	0.00E+00	0.00E+00	5.64E+07	2.02E+08
Co-58	0.00E+00	1.21E+07	3.71E+07	0.00E+00	0.00E+00	0.00E+00	7.08E+07
Co-60	0.00E+00	4.32E+07	1.27E+08	0.00E+00	0.00E+00	0.00E+00	2.39E+08
Ni-63	2.96E+10	1.59E+09	1.01E+09	0.00E+00	0.00E+00	0.00E+00	1.07E+08
Ni-65	1.66E+00	1.56E-01	9.11E-02	0.00E+00	0.00E+00	0.00E+00	1.91E+01
Cu-64	0.00E+00	7.39E+04	4.47E+04	0.00E+00	1.79E+05	0.00E+00	3.47E+06
Zn-65	4.13E+09	1.10E+10	6.85E+09	0.00E+00	6.94E+09	0.00E+00	1.93E+09
Zn-69	9.10E-12	1.32E-11	1.22E-12	0.00E+00	7.98E-12	0.00E+00	8.29E-10
Br-83	0.00E+00	0.00E+00	4.37E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	8.78E+09	5.40E+09	0.00E+00	0.00E+00	0.00E+00	5.65E+08
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	6.62E+09	0.00E+00	1.89E+08	0.00E+00	0.00E+00	0.00E+00	2.56E+08
Sr-90	1.68E+11	0.00E+00	3.38E+09	0.00E+00	0.00E+00	0.00E+00	1.51E+09
Sr-91	1.29E+05	0.00E+00	4.88E+03	0.00E+00	0.00E+00	0.00E+00	2.86E+05
Sr-92	2.16E+00	0.00E+00	8.67E-02	0.00E+00	0.00E+00	0.00E+00	4.09E+01
Y-90	3.23E+02	0.00E+00	8.64E+00	0.00E+00	0.00E+00	0.00E+00	9.19E+05
Y-91M	2.87E-19	0.00E+00	1.04E-20	0.00E+00	0.00E+00	0.00E+00	5.62E-16
Y-91	3.90E+04	0.00E+00	1.04E+03	0.00E+00	0.00E+00	0.00E+00	5.20E+06
Y-92	2.53E-04	0.00E+00	7.23E-06	0.00E+00	0.00E+00	0.00E+00	7.30E+00
Y-93	1.00E+00	0.00E+00	2.75E-02	0.00E+00	0.00E+00	0.00E+00	1.50E+04
Zr-95	3.83E+03	8.43E+02	7.50E+02	0.00E+00	1.21E+03	0.00E+00	8.79E+05
Zr-97	1.91E+00	2.77E-01	1.63E-01	0.00E+00	3.97E-01	0.00E+00	4.19E+04
Nb-95	3.18E+05	1.24E+05	8.85E+04	0.00E+00	1.16E+05	0.00E+00	2.29E+08
Mo-99	0.00E+00	8.12E+07	2.01E+07	0.00E+00	1.73E+08	0.00E+00	6.72E+07
Tc- 99M	1.32E+01	2.58E+01	4.28E+02	0.00E+00	3.75E+02	1.31E+01	1.47E+04
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	4.28E+03	0.00E+00	1.65E+03	0.00E+00	1.08E+04	0.00E+00	1.11E+05
Ru-105	3.79E-03	0.00E+00	1.38E-03	0.00E+00	3.33E-02	0.00E+00	2.48E+00
Ru-106	9.24E+04	0.00E+00	1.15E+04	0.00E+00	1.25E+05	0.00E+00	1.44E+06
Ag-110M	2.09E+08	1.41E+08	1.13E+08	0.00E+00	2.63E+08	0.00E+00	1.68E+10

Table F-13b (Continued)
Child Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	7.38E+07	2.00E+07	9.84E+06	2.07E+07	0.00E+00	0.00E+00	7.12E+07
Te-127M	2.08E+08	5.60E+07	2.47E+07	4.97E+07	5.93E+08	0.00E+00	1.68E+08
Te-127	3.04E+03	8.19E+02	6.51E+02	2.10E+03	8.64E+03	0.00E+00	1.19E+05
Te-129M	2.71E+08	7.58E+07	4.21E+07	8.75E+07	7.97E+08	0.00E+00	3.31E+08
Te-129	1.28E-09	3.58E-10	3.05E-10	9.16E-10	3.75E-09	0.00E+00	7.99E-08
Te-131M	1.60E+06	5.53E+05	5.88E+05	1.14E+06	5.35E+06	0.00E+00	2.24E+07
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	1.02E+07	4.52E+06	5.46E+06	6.58E+06	4.19E+07	0.00E+00	4.55E+07
I-130	1.72E+06	3.47E+06	1.79E+06	3.82E+08	5.19E+06	0.00E+00	1.62E+06
I-131	1.30E+09	1.31E+09	7.45E+08	4.33E+11	2.15E+09	0.00E+00	1.17E+08
I-132	6.91E-01	1.27E+00	5.84E-01	5.89E+01	1.94E+00	0.00E+00	1.49E+00
I-133	1.72E+07	2.13E+07	8.05E+06	3.95E+09	3.55E+07	0.00E+00	8.57E+06
I-134	7.94E-12	1.47E-11	6.79E-12	3.39E-10	2.26E-11	0.00E+00	9.78E-12
I-135	5.43E+04	9.78E+04	4.62E+04	8.66E+06	1.50E+05	0.00E+00	7.45E+04
Cs-134	2.26E+10	3.72E+10	7.84E+09	0.00E+00	1.15E+10	4.13E+09	2.00E+08
Cs-136	1.01E+09	2.77E+09	1.80E+09	0.00E+00	1.48E+09	2.20E+08	9.75E+07
Cs-137	3.22E+10	3.09E+10	4.55E+09	0.00E+00	1.01E+10	3.62E+09	1.93E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	2.01E-07	1.08E-10	5.84E-09	0.00E+00	9.39E-11	6.33E-11	1.16E-05
Ba-140	1.17E+08	1.03E+05	6.84E+06	0.00E+00	3.34E+04	6.12E+04	5.94E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	1.95E+01	6.80E+00	2.29E+00	0.00E+00	0.00E+00	0.00E+00	1.90E+05
La-142	8.24E-11	2.63E-11	8.22E-12	0.00E+00	0.00E+00	0.00E+00	5.20E-06
Ce-141	2.19E+04	1.09E+04	1.62E+03	0.00E+00	4.78E+03	0.00E+00	1.36E+07
Ce-143	1.87E+02	1.01E+05	1.47E+01	0.00E+00	4.26E+01	0.00E+00	1.49E+06
Ce-144	1.62E+06	5.09E+05	8.66E+04	0.00E+00	2.82E+05	0.00E+00	1.33E+08
Pr-143	7.18E+02	2.16E+02	3.57E+01	0.00E+00	1.17E+02	0.00E+00	7.75E+05
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	4.48E+02	3.63E+02	2.81E+01	0.00E+00	1.99E+02	0.00E+00	5.75E+05
W-187	2.89E+04	1.71E+04	7.67E+03	0.00E+00	0.00E+00	0.00E+00	2.40E+06
Np-239	1.72E+01	1.24E+00	8.69E-01	0.00E+00	3.58E+00	0.00E+00	9.15E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per μCi/m^3.

Table F-13c
Infant Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03
Na-24	1.56E+07	1.56E+07	1.56E+07	1.56E+07	1.56E+07	1.56E+07	1.56E+07
Cr-51	0.00E+00	0.00E+00	1.61E+05	1.05E+05	2.30E+04	2.05E+05	4.70E+06
Mn-54	0.00E+00	3.90E+07	8.84E+06	0.00E+00	8.64E+06	0.00E+00	1.43E+07
Mn-56	0.00E+00	3.13E-02	5.39E-03	0.00E+00	2.69E-02	0.00E+00	2.84E+00
Fe-55	1.35E+08	8.73E+07	2.33E+07	0.00E+00	0.00E+00	4.27E+07	1.11E+07
Fe-59	2.24E+08	3.92E+08	1.54E+08	0.00E+00	0.00E+00	1.16E+08	1.87E+08
Co-58	0.00E+00	2.43E+07	6.05E+07	0.00E+00	0.00E+00	0.00E+00	6.04E+07
Co-60	0.00E+00	8.82E+07	2.08E+08	0.00E+00	0.00E+00	0.00E+00	2.10E+08
Ni-63	3.49E+10	2.16E+09	1.21E+09	0.00E+00	0.00E+00	0.00E+00	1.07E+08
Ni-65	3.51E+00	3.97E-01	1.81E-01	0.00E+00	0.00E+00	0.00E+00	3.02E+01
Cu-64	0.00E+00	1.84E+05	8.51E+04	0.00E+00	3.11E+05	0.00E+00	3.77E+06
Zn-65	5.55E+09	1.90E+10	8.78E+09	0.00E+00	9.23E+09	0.00E+00	1.61E+10
Zn-69	1.94E-11	3.49E-11	2.60E-12	0.00E+00	1.45E-11	0.00E+00	2.85E-09
Br-83	0.00E+00	0.00E+00	9.27E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.23E+10	1.10E+10	0.00E+00	0.00E+00	0.00E+00	5.70E+08
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	1.26E+10	0.00E+00	3.61E+08	0.00E+00	0.00E+00	0.00E+00	2.59E+08
Sr-90	1.86E+11	0.00E+00	3.77E+09	0.00E+00	0.00E+00	0.00E+00	1.52E+09
Sr-91	2.70E+05	0.00E+00	9.76E+03	0.00E+00	0.00E+00	0.00E+00	3.19E+05
Sr-92	4.60E+00	0.00E+00	1.71E-01	0.00E+00	0.00E+00	0.00E+00	4.96E+01
Y-90	6.82E+02	0.00E+00	1.83E+01	0.00E+00	0.00E+00	0.00E+00	9.42E+05
Y-91M	6.09E-19	0.00E+00	2.07E-20	0.00E+00	0.00E+00	0.00E+00	2.03E-15
Y-91	7.33E+04	0.00E+00	1.95E+03	0.00E+00	0.00E+00	0.00E+00	5.25E+06
Y-92	5.37E-04	0.00E+00	1.51E-05	0.00E+00	0.00E+00	0.00E+00	1.02E+01
Y-93	2.14E+00	0.00E+00	5.83E-02	0.00E+00	0.00E+00	0.00E+00	1.69E+04
Zr-95	6.81E+03	1.66E+03	1.18E+03	0.00E+00	1.79E+03	0.00E+00	8.26E+05
Zr-97	4.05E+00	6.96E-01	3.18E-01	0.00E+00	7.01E-01	0.00E+00	4.44E+04
Nb-95	5.94E+05	2.45E+05	1.41E+05	0.00E+00	1.75E+05	0.00E+00	2.07E+08
Mo-99	0.00E+00	2.08E+08	4.05E+07	0.00E+00	3.10E+08	0.00E+00	6.84E+07
Tc- 99M	2.74E+01	5.65E+01	7.27E+02	0.00E+00	6.08E+02	2.95E+01	1.64E+04
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	8.67E+03	0.00E+00	2.90E+03	0.00E+00	1.80E+04	0.00E+00	1.05E+05
Ru-105	8.00E-03	0.00E+00	2.69E-03	0.00E+00	5.88E-02	0.00E+00	3.18E+00
Ru-106	1.90E+05	0.00E+00	2.38E+04	0.00E+00	2.25E+05	0.00E+00	1.44E+06
Ag-110M	3.86E+08	2.82E+08	1.86E+08	0.00E+00	4.03E+08	0.00E+00	1.46E+10

Table F-13c (Continued)
Infant Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.51E+08	5.04E+07	2.04E+07	5.08E+07	0.00E+00	0.00E+00	7.19E+07
Te-127M	4.21E+08	1.40E+08	5.10E+07	1.22E+08	1.04E+09	0.00E+00	1.70E+08
Te-127	6.45E+03	2.16E+03	1.39E+03	5.25E+03	1.57E+04	0.00E+00	1.35E+05
Te-129M	5.57E+08	1.91E+08	8.58E+07	2.14E+08	1.39E+09	0.00E+00	3.33E+08
Te-129	2.72E-09	9.38E-10	6.35E-10	2.28E-09	6.77E-09	0.00E+00	2.17E-07
Te-131M	3.37E+06	1.36E+06	1.12E+06	2.75E+06	9.35E+06	0.00E+00	2.29E+07
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	2.10E+07	1.04E+07	9.71E+06	1.54E+07	6.51E+07	0.00E+00	3.85E+07
I-130	3.53E+06	7.77E+06	3.12E+06	8.71E+08	8.53E+06	0.00E+00	1.67E+06
I-131	2.72E+09	3.20E+09	1.41E+09	1.05E+12	3.74E+09	0.00E+00	1.14E+08
I-132	1.43E+00	2.91E+00	1.04E+00	1.36E+02	3.25E+00	0.00E+00	2.36E+00
I-133	3.63E+07	5.29E+07	1.55E+07	9.62E+09	6.22E+07	0.00E+00	8.95E+06
I-134	1.65E-11	3.37E-11	1.20E-11	7.87E-10	3.77E-11	0.00E+00	3.49E-11
I-135	1.13E+05	2.25E+05	8.19E+04	2.01E+07	2.50E+05	0.00E+00	8.13E+04
Cs-134	3.65E+10	6.80E+10	6.87E+09	0.00E+00	1.75E+10	7.18E+09	1.85E+08
Cs-136	1.97E+09	5.80E+09	2.16E+09	0.00E+00	2.31E+09	4.72E+08	8.80E+07
Cs-137	5.15E+10	6.02E+10	4.27E+09	0.00E+00	1.62E+10	6.55E+09	1.88E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	4.29E-07	2.84E-10	1.24E-08	0.00E+00	1.71E-10	1.72E-10	2.72E-05
Ba-140	2.41E+08	2.41E+05	1.24E+07	0.00E+00	5.72E+04	1.48E+05	5.92E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	4.06E+01	1.60E+01	4.12E+00	0.00E+00	0.00E+00	0.00E+00	1.88E+05
La-142	1.73E-10	6.35E-11	1.52E-11	0.00E+00	0.00E+00	0.00E+00	1.08E-05
Ce-141	4.34E+04	2.64E+04	3.11E+03	0.00E+00	8.15E+03	0.00E+00	1.37E+07
Ce-143	3.96E+02	2.63E+05	3.00E+01	0.00E+00	7.65E+01	0.00E+00	1.53E+06
Ce-144	2.33E+06	9.52E+05	1.30E+05	0.00E+00	3.85E+05	0.00E+00	1.33E+08
Pr-143	1.49E+03	5.56E+02	7.37E+01	0.00E+00	2.07E+02	0.00E+00	7.84E+05
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	8.88E+02	9.12E+02	5.59E+01	0.00E+00	3.51E+02	0.00E+00	5.78E+05
W-187	6.08E+04	4.23E+04	1.46E+04	0.00E+00	0.00E+00	0.00E+00	2.48E+06
Np-239	3.64E+01	3.26E+00	1.84E+00	0.00E+00	6.50E+00	0.00E+00	9.42E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table F-14
Adult Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	8.88E+02	8.88E+02	8.88E+02	8.88E+02	8.88E+02	8.88E+02
Na-24	2.95E+05	2.95E+05	2.95E+05	2.95E+05	2.95E+05	2.95E+05	2.95E+05
Cr-51	0.00E+00	0.00E+00	3.43E+03	2.05E+03	7.55E+02	4.55E+03	8.62E+05
Mn-54	0.00E+00	1.01E+06	1.93E+05	0.00E+00	3.00E+05	0.00E+00	3.09E+06
Mn-56	0.00E+00	4.95E-04	8.79E-05	0.00E+00	6.29E-04	0.00E+00	1.58E-02
Fe-55	3.26E+05	2.26E+05	5.26E+04	0.00E+00	0.00E+00	1.26E+05	1.29E+05
Fe-59	3.86E+05	9.07E+05	3.48E+05	0.00E+00	0.00E+00	2.53E+05	3.02E+06
Co-58	0.00E+00	5.66E+05	1.27E+06	0.00E+00	0.00E+00	0.00E+00	1.15E+07
Co-60	0.00E+00	1.97E+06	4.34E+06	0.00E+00	0.00E+00	0.00E+00	3.70E+07
Ni-63	8.07E+08	5.60E+07	2.71E+07	0.00E+00	0.00E+00	0.00E+00	1.17E+07
Ni-65	4.44E-02	5.77E-03	2.63E-03	0.00E+00	0.00E+00	0.00E+00	1.46E-01
Cu-64	0.00E+00	2.63E+03	1.23E+03	0.00E+00	6.63E+03	0.00E+00	2.24E+05
Zn-65	1.65E+08	5.24E+08	2.37E+08	0.00E+00	3.50E+08	0.00E+00	3.30E+08
Zn-69	2.41E-13	4.61E-13	3.21E-14	0.00E+00	3.00E-13	0.00E+00	6.93E-14
Br-83	0.00E+00	0.00E+00	1.16E-02	0.00E+00	0.00E+00	0.00E+00	1.67E-02
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	3.12E+08	1.45E+08	0.00E+00	0.00E+00	0.00E+00	6.15E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	3.05E+09	0.00E+00	8.74E+07	0.00E+00	0.00E+00	0.00E+00	4.88E+08
Sr-90	1.13E+11	0.00E+00	2.27E+09	0.00E+00	0.00E+00	0.00E+00	2.84E+09
Sr-91	6.03E+04	0.00E+00	2.44E+03	0.00E+00	0.00E+00	0.00E+00	2.87E+05
Sr-92	1.02E+00	0.00E+00	4.39E-02	0.00E+00	0.00E+00	0.00E+00	2.01E+01
Y-90	8.52E+00	0.00E+00	2.28E-01	0.00E+00	0.00E+00	0.00E+00	9.03E+04
Y-91M	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E-20
Y-91	1.03E+03	0.00E+00	2.76E+01	0.00E+00	0.00E+00	0.00E+00	5.67E+05
Y-92	6.68E-06	0.00E+00	1.95E-07	0.00E+00	0.00E+00	0.00E+00	1.17E-01
Y-93	2.66E-02	0.00E+00	7.34E-04	0.00E+00	0.00E+00	0.00E+00	8.43E+02
Zr-95	1.13E+02	3.63E+01	2.46E+01	0.00E+00	5.70E+01	0.00E+00	1.15E+05
Zr-97	5.19E-02	1.05E-02	4.79E-03	0.00E+00	1.58E-02	0.00E+00	3.24E+03
Nb-95	9.92E+03	5.52E+03	2.97E+03	0.00E+00	5.45E+03	0.00E+00	3.35E+07
Mo-99	0.00E+00	2.97E+06	5.65E+05	0.00E+00	6.72E+06	0.00E+00	6.88E+06
Tc- 99M	3.97E-01	1.12E+00	1.43E+01	0.00E+00	1.70E+01	5.50E-01	6.64E+02
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.22E+02	0.00E+00	5.26E+01	0.00E+00	4.66E+02	0.00E+00	1.43E+04
Ru-105	1.02E-04	0.00E+00	4.03E-05	0.00E+00	1.32E-03	0.00E+00	6.25E-02
Ru-106	2.45E+03	0.00E+00	3.10E+02	0.00E+00	4.73E+03	0.00E+00	1.58E+05
Ag-110M	6.99E+06	6.46E+06	3.84E+06	0.00E+00	1.27E+07	0.00E+00	2.64E+09

Table F-14 (Continued)
Adult Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.96E+06	7.09E+05	2.62E+05	5.88E+05	7.95E+06	0.00E+00	7.81E+06
Te-127M	5.49E+06	1.96E+06	6.69E+05	1.40E+06	2.23E+07	0.00E+00	1.84E+07
Te-127	8.00E+01	2.87E+01	1.73E+01	5.92E+01	3.26E+02	0.00E+00	6.31E+03
Te-129M	7.22E+06	2.69E+06	1.14E+06	2.48E+06	3.01E+07	0.00E+00	3.64E+07
Te-129	3.39E-11	1.27E-11	8.26E-12	2.60E-11	1.43E-10	0.00E+00	2.56E-11
Te-131M	4.33E+04	2.12E+04	1.76E+04	3.35E+04	2.14E+05	0.00E+00	2.10E+06
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	2.87E+05	1.86E+05	1.74E+05	2.05E+05	1.79E+06	0.00E+00	8.78E+06
I-130	5.01E+05	1.48E+06	5.84E+05	1.25E+08	2.31E+06	0.00E+00	1.27E+06
I-131	3.55E+08	5.08E+08	2.91E+08	1.67E+11	8.71E+08	0.00E+00	1.34E+08
I-132	1.98E-01	5.29E-01	1.85E-01	1.85E+01	8.42E-01	0.00E+00	9.93E-02
I-133	4.65E+06	8.09E+06	2.47E+06	1.19E+09	1.41E+07	0.00E+00	7.27E+06
I-134	2.27E-12	6.15E-12	2.20E-12	1.07E-10	9.79E-12	0.00E+00	5.36E-15
I-135	1.55E+04	4.06E+04	1.50E+04	2.68E+06	6.51E+04	0.00E+00	4.58E+04
Cs-134	1.70E+10	4.04E+10	3.30E+10	0.00E+00	1.31E+10	4.34E+09	7.06E+08
Cs-136	7.88E+08	3.11E+09	2.24E+09	0.00E+00	1.73E+09	2.37E+08	3.53E+08
Cs-137	2.21E+10	3.03E+10	1.98E+10	0.00E+00	1.03E+10	3.42E+09	5.86E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	5.32E-09	3.79E-12	1.56E-10	0.00E+00	3.54E-12	2.15E-12	9.44E-09
Ba-140	3.23E+06	4.05E+03	2.11E+05	0.00E+00	1.38E+03	2.32E+03	6.64E+06
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	5.43E-01	2.74E-01	7.23E-02	0.00E+00	0.00E+00	0.00E+00	2.01E+04
La-142	2.27E-12	1.03E-12	2.57E-13	0.00E+00	0.00E+00	0.00E+00	7.53E-09
Ce-141	5.81E+02	3.93E+02	4.46E+01	0.00E+00	1.83E+02	0.00E+00	1.50E+06
Ce-143	4.98E+00	3.68E+03	4.07E-01	0.00E+00	1.62E+00	0.00E+00	1.38E+05
Ce-144	4.29E+04	1.79E+04	2.30E+03	0.00E+00	1.06E+04	0.00E+00	1.45E+07
Pr-143	1.90E+01	7.60E+00	9.40E-01	0.00E+00	4.39E+00	0.00E+00	8.31E+04
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	1.14E+01	1.32E+01	7.87E-01	0.00E+00	7.69E+00	0.00E+00	6.31E+04
W-187	7.82E+02	6.53E+02	2.28E+02	0.00E+00	0.00E+00	0.00E+00	2.14E+05
Np-239	4.40E-01	4.33E-02	2.39E-02	0.00E+00	1.35E-01	0.00E+00	8.88E+03

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per μCi/m^3.

Table F-14a
Teen Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03
Na-24	5.15E+05	5.15E+05	5.15E+05	5.15E+05	5.15E+05	5.15E+05	5.15E+05
Cr-51	0.00E+00	0.00E+00	5.99E+03	3.33E+03	1.31E+03	8.55E+03	1.01E+06
Mn-54	0.00E+00	1.68E+06	3.34E+05	0.00E+00	5.02E+05	0.00E+00	3.45E+06
Mn-56	0.00E+00	8.78E-04	1.56E-04	0.00E+00	1.11E-03	0.00E+00	5.78E-02
Fe-55	5.79E+05	4.11E+05	9.57E+04	0.00E+00	0.00E+00	2.60E+05	1.78E+05
Fe-59	6.74E+05	1.57E+06	6.07E+05	0.00E+00	0.00E+00	4.96E+05	3.72E+06
Co-58	0.00E+00	9.53E+05	2.20E+06	0.00E+00	0.00E+00	0.00E+00	1.31E+07
Co-60	0.00E+00	3.34E+06	7.52E+06	0.00E+00	0.00E+00	0.00E+00	4.35E+07
Ni-63	1.42E+09	1.00E+08	4.81E+07	0.00E+00	0.00E+00	0.00E+00	1.59E+07
Ni-65	8.13E-02	1.04E-02	4.73E-03	0.00E+00	0.00E+00	0.00E+00	5.63E-01
Cu-64	0.00E+00	4.69E+03	2.20E+03	0.00E+00	1.19E+04	0.00E+00	3.64E+05
Zn-65	2.53E+08	8.78E+08	4.09E+08	0.00E+00	5.62E+08	0.00E+00	3.72E+08
Zn-69	4.44E-13	8.46E-13	5.92E-14	0.00E+00	5.53E-13	0.00E+00	1.56E-12
Br-83	0.00E+00	0.00E+00	2.13E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	5.68E+08	2.67E+08	0.00E+00	0.00E+00	0.00E+00	8.41E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	5.61E+09	0.00E+00	1.61E+08	0.00E+00	0.00E+00	0.00E+00	6.69E+08
Sr-90	1.71E+11	0.00E+00	3.41E+09	0.00E+00	0.00E+00	0.00E+00	3.90E+09
Sr-91	1.11E+05	0.00E+00	4.41E+03	0.00E+00	0.00E+00	0.00E+00	5.02E+05
Sr-92	1.86E+00	0.00E+00	7.92E-02	0.00E+00	0.00E+00	0.00E+00	4.74E+01
Y-90	1.56E+01	0.00E+00	4.21E-01	0.00E+00	0.00E+00	0.00E+00	1.29E+05
Y-91M	1.41E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.66E-19
Y-91	1.90E+03	0.00E+00	5.08E+01	0.00E+00	0.00E+00	0.00E+00	7.77E+05
Y-92	1.23E-05	0.00E+00	3.57E-07	0.00E+00	0.00E+00	0.00E+00	3.39E-01
Y-93	4.90E-02	0.00E+00	1.34E-03	0.00E+00	0.00E+00	0.00E+00	1.50E+03
Zr-95	1.98E+02	6.25E+01	4.30E+01	0.00E+00	9.18E+01	0.00E+00	1.44E+05
Zr-97	9.44E-02	1.87E-02	8.61E-03	0.00E+00	2.83E-02	0.00E+00	5.06E+03
Nb-95	1.69E+04	9.38E+03	5.16E+03	0.00E+00	9.09E+03	0.00E+00	4.01E+07
Mo-99	0.00E+00	5.36E+06	1.02E+06	0.00E+00	1.23E+07	0.00E+00	9.59E+06
Tc- 99M	6.89E-01	1.92E+00	2.49E+01	0.00E+00	2.86E+01	1.07E+00	1.26E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	2.17E+02	0.00E+00	9.29E+01	0.00E+00	7.66E+02	0.00E+00	1.81E+04
Ru-105	1.86E-04	0.00E+00	7.24E-05	0.00E+00	2.35E-03	0.00E+00	1.51E-01
Ru-106	4.50E+03	0.00E+00	5.67E+02	0.00E+00	8.68E+03	0.00E+00	2.16E+05
Ag-110M	1.16E+07	1.09E+07	6.65E+06	0.00E+00	2.09E+07	0.00E+00	3.07E+09

Table F-14a (Continued)
Teen Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.61E+06	1.30E+06	4.82E+05	1.01E+06	0.00E+00	0.00E+00	1.06E+07
Te-127M	1.01E+07	3.59E+06	1.20E+06	2.41E+06	4.10E+07	0.00E+00	2.52E+07
Te-127	1.48E+02	5.25E+01	3.19E+01	1.02E+02	6.00E+02	0.00E+00	1.14E+04
Te-129M	1.32E+07	4.90E+06	2.09E+06	4.26E+06	5.53E+07	0.00E+00	4.96E+07
Te-129	6.24E-11	2.33E-11	1.52E-11	4.46E-11	2.62E-10	0.00E+00	3.41E-10
Te-131M	7.88E+04	3.78E+04	3.15E+04	5.68E+04	3.94E+05	0.00E+00	3.03E+06
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	5.13E+05	3.25E+05	3.06E+05	3.42E+05	3.12E+06	0.00E+00	1.03E+07
I-130	8.82E+05	2.55E+06	1.02E+06	2.08E+08	3.93E+06	0.00E+00	1.96E+06
I-131	6.45E+08	9.02E+08	4.85E+08	2.63E+11	1.55E+09	0.00E+00	1.78E+08
I-132	3.50E-01	9.17E-01	3.29E-01	3.09E+01	1.44E+00	0.00E+00	3.99E-01
I-133	8.50E+06	1.44E+07	4.40E+06	2.01E+09	2.53E+07	0.00E+00	1.09E+07
I-134	4.03E-12	1.07E-11	3.83E-12	1.78E-10	1.68E-11	0.00E+00	1.41E-13
I-135	2.75E+04	7.09E+04	2.63E+04	4.56E+06	1.12E+05	0.00E+00	7.85E+04
Cs-134	2.94E+10	6.93E+10	3.22E+10	0.00E+00	2.20E+10	8.41E+09	8.62E+08
Cs-136	1.34E+09	5.28E+09	3.54E+09	0.00E+00	2.87E+09	4.53E+08	4.25E+08
Cs-137	4.02E+10	5.34E+10	1.86E+10	0.00E+00	1.82E+10	7.06E+09	7.60E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	9.84E-09	6.92E-12	2.87E-10	0.00E+00	6.53E-12	4.77E-12	8.78E-08
Ba-140	5.82E+06	7.14E+03	3.75E+05	0.00E+00	2.42E+03	4.80E+03	8.98E+06
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	9.75E-01	4.79E-01	1.27E-01	0.00E+00	0.00E+00	0.00E+00	2.75E+04
La-142	4.09E-12	1.82E-12	4.53E-13	0.00E+00	0.00E+00	0.00E+00	5.53E-08
Ce-141	1.07E+03	7.12E+02	8.17E+01	0.00E+00	3.35E+02	0.00E+00	2.04E+06
Ce-143	9.15E+00	6.66E+03	7.44E-01	0.00E+00	2.99E+00	0.00E+00	2.00E+05
Ce-144	7.90E+04	3.27E+04	4.24E+03	0.00E+00	1.95E+04	0.00E+00	1.99E+07
Pr-143	3.48E+01	1.39E+01	1.73E+00	0.00E+00	8.08E+00	0.00E+00	1.15E+05
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	2.19E+01	2.38E+01	1.43E+00	0.00E+00	1.40E+01	0.00E+00	8.59E+04
W-187	1.43E+03	1.17E+03	4.08E+02	0.00E+00	0.00E+00	0.00E+00	3.15E+05
Np-239	8.40E-01	7.92E-02	4.40E-02	0.00E+00	2.49E-01	0.00E+00	1.27E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table F-14b
Child Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03
Na-24	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06
Cr-51	0.00E+00	0.00E+00	1.22E+04	6.78E+03	1.85E+03	1.24E+04	6.47E+05
Mn-54	0.00E+00	2.52E+06	6.70E+05	0.00E+00	7.06E+05	0.00E+00	2.11E+06
Mn-56	0.00E+00	1.53E-03	3.46E-04	0.00E+00	1.85E-03	0.00E+00	2.22E-01
Fe-55	1.45E+06	7.71E+05	2.39E+05	0.00E+00	0.00E+00	4.36E+05	1.43E+05
Fe-59	1.56E+06	2.53E+06	1.26E+06	0.00E+00	0.00E+00	7.33E+05	2.63E+06
Co-58	0.00E+00	1.46E+06	4.46E+06	0.00E+00	0.00E+00	0.00E+00	8.49E+06
Co-60	0.00E+00	5.18E+06	1.53E+07	0.00E+00	0.00E+00	0.00E+00	2.87E+07
Ni-63	3.56E+09	1.90E+08	1.21E+08	0.00E+00	0.00E+00	0.00E+00	1.28E+07
Ni-65	1.99E-01	1.87E-02	1.09E-02	0.00E+00	0.00E+00	0.00E+00	2.29E+00
Cu-64	0.00E+00	8.24E+03	4.98E+03	0.00E+00	1.99E+04	0.00E+00	3.87E+05
Zn-65	4.96E+08	1.32E+09	8.22E+08	0.00E+00	8.33E+08	0.00E+00	2.32E+08
Zn-69	1.09E-12	1.58E-12	1.46E-13	0.00E+00	9.57E-13	0.00E+00	9.95E-11
Br-83	0.00E+00	0.00E+00	5.24E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.05E+09	6.48E+08	0.00E+00	0.00E+00	0.00E+00	6.78E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	1.39E+10	0.00E+00	3.97E+08	0.00E+00	0.00E+00	0.00E+00	5.38E+08
Sr-90	3.53E+11	0.00E+00	7.11E+09	0.00E+00	0.00E+00	0.00E+00	3.16E+09
Sr-91	2.72E+05	0.00E+00	1.03E+04	0.00E+00	0.00E+00	0.00E+00	6.00E+05
Sr-92	4.54E+00	0.00E+00	1.82E-01	0.00E+00	0.00E+00	0.00E+00	8.60E+01
Y-90	3.87E+01	0.00E+00	1.04E+00	0.00E+00	0.00E+00	0.00E+00	1.10E+05
Y-91M	3.45E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.75E-17
Y-91	4.68E+03	0.00E+00	1.25E+02	0.00E+00	0.00E+00	0.00E+00	6.24E+05
Y-92	3.03E-05	0.00E+00	8.67E-07	0.00E+00	0.00E+00	0.00E+00	8.75E-01
Y-93	1.20E-01	0.00E+00	3.31E-03	0.00E+00	0.00E+00	0.00E+00	1.80E+03
Zr-95	4.60E+02	1.01E+02	9.00E+01	0.00E+00	1.45E+02	0.00E+00	1.05E+05
Zr-97	2.30E-01	3.32E-02	1.96E-02	0.00E+00	4.77E-02	0.00E+00	5.03E+03
Nb-95	3.82E+04	1.49E+04	1.06E+04	0.00E+00	1.40E+04	0.00E+00	2.75E+07
Mo-99	0.00E+00	9.75E+06	2.41E+06	0.00E+00	2.08E+07	0.00E+00	8.06E+06
Tc- 99M	1.58E+00	3.10E+00	5.14E+01	0.00E+00	4.50E+01	1.57E+00	1.76E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	5.14E+02	0.00E+00	1.97E+02	0.00E+00	1.29E+03	0.00E+00	1.33E+04
Ru-105	4.55E-04	0.00E+00	1.65E-04	0.00E+00	4.00E-03	0.00E+00	2.97E-01
Ru-106	1.11E+04	0.00E+00	1.38E+03	0.00E+00	1.50E+04	0.00E+00	1.72E+05
Ag-110M	2.51E+07	1.69E+07	1.35E+07	0.00E+00	3.15E+07	0.00E+00	2.01E+09

**Table F-14b (Continued)
Child Grass-Goat-Milk Dose Factors**

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	8.86E+06	2.40E+06	1.18E+06	2.49E+06	0.00E+00	0.00E+00	8.55E+06
Te-127M	2.50E+07	6.72E+06	2.96E+06	5.97E+06	7.12E+07	0.00E+00	2.02E+07
Te-127	3.64E+02	9.83E+01	7.82E+01	2.52E+02	1.04E+03	0.00E+00	1.42E+04
Te-129M	3.26E+07	9.09E+06	5.05E+06	1.05E+07	9.56E+07	0.00E+00	3.97E+07
Te-129	1.54E-10	4.30E-11	3.66E-11	1.10E-10	4.51E-10	0.00E+00	9.59E-09
Te-131M	1.92E+05	6.63E+04	7.06E+04	1.36E+05	6.42E+05	0.00E+00	2.69E+06
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	1.22E+06	5.42E+05	6.55E+05	7.89E+05	5.03E+06	0.00E+00	5.46E+06
I-130	2.06E+06	4.17E+06	2.15E+06	4.59E+08	6.23E+06	0.00E+00	1.95E+06
I-131	1.56E+09	1.57E+09	8.94E+08	5.20E+11	2.58E+09	0.00E+00	1.40E+08
I-132	8.29E-01	1.52E+00	7.00E-01	7.07E+01	2.33E+00	0.00E+00	1.79E+00
I-133	2.06E+07	2.55E+07	9.66E+06	4.74E+09	4.25E+07	0.00E+00	1.03E+07
I-134	9.53E-12	1.77E-11	8.14E-12	4.07E-10	2.71E-11	0.00E+00	1.17E-11
I-135	6.52E+04	1.17E+05	5.55E+04	1.04E+07	1.80E+05	0.00E+00	8.94E+04
Cs-134	6.79E+10	1.11E+11	2.35E+10	0.00E+00	3.45E+10	1.24E+10	6.01E+08
Cs-136	3.03E+09	8.32E+09	5.39E+09	0.00E+00	4.43E+09	6.61E+08	2.92E+08
Cs-137	9.67E+10	9.26E+10	1.37E+10	0.00E+00	3.02E+10	1.09E+10	5.80E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	2.42E-08	1.29E-11	7.01E-10	0.00E+00	1.13E-11	7.59E-12	1.40E-06
Ba-140	1.41E+07	1.23E+04	8.21E+05	0.00E+00	4.01E+03	7.34E+03	7.12E+06
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	2.33E+00	8.16E-01	2.75E-01	0.00E+00	0.00E+00	0.00E+00	2.27E+04
La-142	9.88E-12	3.15E-12	9.87E-13	0.00E+00	0.00E+00	0.00E+00	6.24E-07
Ce-141	2.62E+03	1.31E+03	1.94E+02	0.00E+00	5.74E+02	0.00E+00	1.63E+06
Ce-143	2.25E+01	1.22E+04	1.76E+00	0.00E+00	5.11E+00	0.00E+00	1.78E+05
Ce-144	1.95E+05	6.11E+04	1.04E+04	0.00E+00	3.38E+04	0.00E+00	1.59E+07
Pr-143	8.62E+01	2.59E+01	4.28E+00	0.00E+00	1.40E+01	0.00E+00	9.30E+04
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	5.37E+01	4.35E+01	3.37E+00	0.00E+00	2.39E+01	0.00E+00	6.89E+04
W-187	3.47E+03	2.05E+03	9.21E+02	0.00E+00	0.00E+00	0.00E+00	2.88E+05
Np-239	2.07E+00	1.48E-01	1.04E-01	0.00E+00	4.29E-01	0.00E+00	1.10E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table F-14c
Infant Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	2.78E+03	2.78E+03	2.78E+03	2.78E+03	2.78E+03	2.78E+03
Na-24	1.87E+06	1.87E+06	1.87E+06	1.87E+06	1.87E+06	1.87E+06	1.87E+06
Cr-51	0.00E+00	0.00E+00	1.93E+04	1.26E+04	2.76E+03	2.46E+04	5.64E+05
Mn-54	0.00E+00	4.68E+06	1.06E+06	0.00E+00	1.04E+06	0.00E+00	1.72E+06
Mn-56	0.00E+00	3.75E-03	6.47E-04	0.00E+00	3.22E-03	0.00E+00	3.41E-01
Fe-55	1.76E+06	1.13E+06	3.03E+05	0.00E+00	0.00E+00	5.55E+05	1.44E+05
Fe-59	2.92E+06	5.09E+06	2.01E+06	0.00E+00	0.00E+00	1.51E+06	2.43E+06
Co-58	0.00E+00	2.91E+06	7.26E+06	0.00E+00	0.00E+00	0.00E+00	7.25E+06
Co-60	0.00E+00	1.06E+07	2.50E+07	0.00E+00	0.00E+00	0.00E+00	2.52E+07
Ni-63	4.19E+09	2.59E+08	1.45E+08	0.00E+00	0.00E+00	0.00E+00	1.29E+07
Ni-65	4.21E-01	4.77E-02	2.17E-02	0.00E+00	0.00E+00	0.00E+00	3.63E+00
Cu-64	0.00E+00	2.05E+04	9.48E+03	0.00E+00	3.46E+04	0.00E+00	4.20E+05
Zn-65	6.66E+08	2.28E+09	1.05E+09	0.00E+00	1.11E+09	0.00E+00	1.93E+09
Zn-69	2.33E-12	4.19E-12	3.12E-13	0.00E+00	1.74E-12	0.00E+00	3.42E-10
Br-83	0.00E+00	0.00E+00	1.11E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.67E+09	1.32E+09	0.00E+00	0.00E+00	0.00E+00	6.84E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	2.64E+10	0.00E+00	7.58E+08	0.00E+00	0.00E+00	0.00E+00	5.43E+08
Sr-90	3.91E+11	0.00E+00	7.92E+09	0.00E+00	0.00E+00	0.00E+00	3.19E+09
Sr-91	5.66E+05	0.00E+00	2.05E+04	0.00E+00	0.00E+00	0.00E+00	6.70E+05
Sr-92	9.65E+00	0.00E+00	3.59E-01	0.00E+00	0.00E+00	0.00E+00	1.04E+02
Y-90	8.19E+01	0.00E+00	2.20E+00	0.00E+00	0.00E+00	0.00E+00	1.13E+05
Y-91M	7.31E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.44E-16
Y-91	8.79E+03	0.00E+00	2.34E+02	0.00E+00	0.00E+00	0.00E+00	6.30E+05
Y-92	6.44E-05	0.00E+00	1.81E-06	0.00E+00	0.00E+00	0.00E+00	1.23E+00
Y-93	2.57E-01	0.00E+00	6.99E-03	0.00E+00	0.00E+00	0.00E+00	2.03E+03
Zr-95	8.17E+02	1.99E+02	1.41E+02	0.00E+00	2.15E+02	0.00E+00	9.91E+04
Zr-97	4.87E-01	8.35E-02	3.81E-02	0.00E+00	8.42E-02	0.00E+00	5.33E+03
Nb-95	7.13E+04	2.94E+04	1.70E+04	0.00E+00	2.10E+04	0.00E+00	2.48E+07
Mo-99	0.00E+00	2.49E+07	4.86E+06	0.00E+00	3.72E+07	0.00E+00	8.21E+06
Tc- 99M	3.29E+00	6.78E+00	8.73E+01	0.00E+00	7.29E+01	3.54E+00	1.97E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.04E+03	0.00E+00	3.48E+02	0.00E+00	2.16E+03	0.00E+00	1.27E+04
Ru-105	9.60E-04	0.00E+00	3.23E-04	0.00E+00	7.06E-03	0.00E+00	3.82E-01
Ru-106	2.28E+04	0.00E+00	2.85E+03	0.00E+00	2.70E+04	0.00E+00	1.73E+05
Ag-110M	4.63E+07	3.38E+07	2.24E+07	0.00E+00	4.84E+07	0.00E+00	1.75E+09

Table F-14c (Continued)
Infant Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.81E+07	6.05E+06	2.45E+06	6.09E+06	0.00E+00	0.00E+00	8.62E+06
Te-127M	5.05E+07	1.68E+07	6.12E+06	1.46E+07	1.24E+08	0.00E+00	2.04E+07
Te-127	7.74E+02	2.59E+02	1.66E+02	6.30E+02	1.89E+03	0.00E+00	1.63E+04
Te-129M	6.68E+07	2.29E+07	1.03E+07	2.57E+07	1.67E+08	0.00E+00	3.99E+07
Te-129	3.26E-10	1.13E-10	7.62E-11	2.74E-10	8.13E-10	0.00E+00	2.61E-08
Te-131M	4.05E+05	1.63E+05	1.35E+05	3.30E+05	1.12E+06	0.00E+00	2.74E+06
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	2.52E+06	1.25E+06	1.17E+06	1.84E+06	7.81E+06	0.00E+00	4.62E+06
I-130	4.24E+06	9.32E+06	3.74E+06	1.04E+09	1.02E+07	0.00E+00	2.00E+06
I-131	3.26E+09	3.85E+09	1.69E+09	1.26E+12	4.49E+09	0.00E+00	1.37E+08
I-132	1.72E+00	3.49E+00	1.24E+00	1.64E+02	3.90E+00	0.00E+00	2.83E+00
I-133	4.36E+07	6.35E+07	1.86E+07	1.15E+10	7.46E+07	0.00E+00	1.07E+07
I-134	1.98E-11	4.05E-11	1.44E-11	9.44E-10	4.53E-11	0.00E+00	4.19E-11
I-135	1.36E+05	2.70E+05	9.83E+04	2.42E+07	3.01E+05	0.00E+00	9.76E+04
Cs-134	1.09E+11	2.04E+11	2.06E+10	0.00E+00	5.25E+10	2.15E+10	5.54E+08
Cs-136	5.91E+09	1.74E+10	6.49E+09	0.00E+00	6.93E+09	1.42E+09	2.64E+08
Cs-137	1.54E+11	1.81E+11	1.28E+10	0.00E+00	4.85E+10	1.96E+10	5.65E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	5.14E-08	3.41E-11	1.49E-09	0.00E+00	2.05E-11	2.07E-11	3.26E-06
Ba-140	2.89E+07	2.89E+04	1.49E+06	0.00E+00	6.87E+03	1.78E+04	7.11E+06
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	4.88E+00	1.92E+00	4.95E-01	0.00E+00	0.00E+00	0.00E+00	2.26E+04
La-142	2.08E-11	7.62E-12	1.82E-12	0.00E+00	0.00E+00	0.00E+00	1.29E-06
Ce-141	5.20E+03	3.17E+03	3.73E+02	0.00E+00	9.78E+02	0.00E+00	1.64E+06
Ce-143	4.75E+01	3.15E+04	3.60E+00	0.00E+00	9.19E+00	0.00E+00	1.84E+05
Ce-144	2.79E+05	1.14E+05	1.56E+04	0.00E+00	4.62E+04	0.00E+00	1.60E+07
Pr-143	1.78E+02	6.67E+01	8.84E+00	0.00E+00	2.48E+01	0.00E+00	9.41E+04
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	1.07E+02	1.09E+02	6.70E+00	0.00E+00	4.22E+01	0.00E+00	6.93E+04
W-187	7.29E+03	5.07E+03	1.75E+03	0.00E+00	0.00E+00	0.00E+00	2.98E+05
Np-239	4.37E+00	3.91E-01	2.21E-01	0.00E+00	7.80E-01	0.00E+00	1.13E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table F-15
Adult Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.85E+02	1.85E+02	1.85E+02	1.85E+02	1.85E+02	1.85E+02
Na-24	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03
Cr-51	0.00E+00	0.00E+00	7.04E+03	4.21E+03	1.55E+03	9.34E+03	1.77E+06
Mn-54	0.00E+00	9.18E+06	1.75E+06	0.00E+00	2.73E+06	0.00E+00	2.81E+07
Mn-56	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-55	2.93E+08	2.03E+08	4.72E+07	0.00E+00	0.00E+00	1.13E+08	1.16E+08
Fe-59	2.65E+08	6.24E+08	2.39E+08	0.00E+00	0.00E+00	1.74E+08	2.08E+09
Co-58	0.00E+00	1.82E+07	4.09E+07	0.00E+00	0.00E+00	0.00E+00	3.70E+08
Co-60	0.00E+00	7.52E+07	1.66E+08	0.00E+00	0.00E+00	0.00E+00	1.41E+09
Ni-63	1.89E+10	1.31E+09	6.33E+08	0.00E+00	0.00E+00	0.00E+00	2.73E+08
Ni-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu-64	0.00E+00	2.52E-07	1.18E-07	0.00E+00	6.36E-07	0.00E+00	2.15E-05
Zn-65	3.56E+08	1.13E+09	5.12E+08	0.00E+00	7.57E+08	0.00E+00	7.13E+08
Zn-69	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-83	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	4.88E+08	2.28E+08	0.00E+00	0.00E+00	0.00E+00	9.63E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	3.01E+08	0.00E+00	8.65E+06	0.00E+00	0.00E+00	0.00E+00	4.83E+07
Sr-90	1.43E+10	0.00E+00	2.87E+08	0.00E+00	0.00E+00	0.00E+00	3.59E+08
Sr-91	1.43E-10	0.00E+00	5.79E-12	0.00E+00	0.00E+00	0.00E+00	6.83E-10
Sr-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-90	1.08E+02	0.00E+00	2.91E+00	0.00E+00	0.00E+00	0.00E+00	1.15E+06
Y-91M	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-91	1.13E+06	0.00E+00	3.03E+04	0.00E+00	0.00E+00	0.00E+00	6.23E+08
Y-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93	4.39E-12	0.00E+00	1.21E-13	0.00E+00	0.00E+00	0.00E+00	1.39E-07
Zr-95	1.87E+06	6.01E+05	4.07E+05	0.00E+00	9.43E+05	0.00E+00	1.91E+09
Zr-97	2.04E-05	4.12E-06	1.88E-06	0.00E+00	6.22E-06	0.00E+00	1.28E+00
Nb-95	2.30E+06	1.28E+06	6.89E+05	0.00E+00	1.27E+06	0.00E+00	7.78E+09
Mo-99	0.00E+00	9.93E+04	1.89E+04	0.00E+00	2.25E+05	0.00E+00	2.30E+05
Tc- 99M	0.00E+00	1.22E-20	1.56E-19	0.00E+00	1.85E-19	0.00E+00	7.23E-18
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.05E+08	0.00E+00	4.53E+07	0.00E+00	4.01E+08	0.00E+00	1.23E+10
Ru-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	2.80E+09	0.00E+00	3.54E+08	0.00E+00	5.40E+09	0.00E+00	1.81E+11
Ag-110M	6.68E+06	6.18E+06	3.67E+06	0.00E+00	1.22E+07	0.00E+00	2.52E+09

Table F-15 (Continued)
Adult Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.59E+08	1.30E+08	4.81E+07	1.08E+08	1.46E+09	0.00E+00	1.43E+09
Te-127M	1.12E+09	3.99E+08	1.36E+08	2.85E+08	4.53E+09	0.00E+00	3.74E+09
Te-127	2.50E-10	8.98E-11	5.41E-11	1.85E-10	1.02E-09	0.00E+00	1.97E-08
Te-129M	1.13E+09	4.23E+08	1.79E+08	3.89E+08	4.73E+09	0.00E+00	5.71E+09
Te-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-131M	4.49E+02	2.20E+02	1.83E+02	3.48E+02	2.23E+03	0.00E+00	2.18E+04
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	1.40E+06	9.03E+05	8.48E+05	9.98E+05	8.70E+06	0.00E+00	4.27E+07
I-130	2.03E-06	5.98E-06	2.36E-06	5.07E-04	9.33E-06	0.00E+00	5.15E-06
I-131	1.07E+07	1.54E+07	8.80E+06	5.03E+09	2.63E+07	0.00E+00	4.05E+06
I-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-133	3.70E-01	6.43E-01	1.96E-01	9.45E+01	1.12E+00	0.00E+00	5.78E-01
I-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135	4.66E-17	1.22E-16	4.50E-17	8.04E-15	1.95E-16	0.00E+00	1.38E-16
Cs-134	6.58E+08	1.57E+09	1.28E+09	0.00E+00	5.07E+08	1.68E+08	2.74E+07
Cs-136	1.20E+07	4.73E+07	3.40E+07	0.00E+00	2.63E+07	3.61E+06	5.37E+06
Cs-137	8.72E+08	1.19E+09	7.81E+08	0.00E+00	4.05E+08	1.35E+08	2.31E+07
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	2.88E+07	3.61E+04	1.88E+06	0.00E+00	1.23E+04	2.07E+04	5.92E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	3.76E-02	1.90E-02	5.01E-03	0.00E+00	0.00E+00	0.00E+00	1.39E+03
La-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-141	1.40E+04	9.49E+03	1.08E+03	0.00E+00	4.41E+03	0.00E+00	3.63E+07
Ce-143	1.99E-02	1.47E+01	1.63E-03	0.00E+00	6.47E-03	0.00E+00	5.49E+02
Ce-144	1.46E+06	6.09E+05	7.83E+04	0.00E+00	3.61E+05	0.00E+00	4.93E+08
Pr-143	2.10E+04	8.42E+03	1.04E+03	0.00E+00	4.86E+03	0.00E+00	9.20E+07
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	7.21E+03	8.33E+03	4.98E+02	0.00E+00	4.87E+03	0.00E+00	4.00E+07
W-187	2.07E-02	1.73E-02	6.04E-03	0.00E+00	0.00E+00	0.00E+00	5.66E+00
Np-239	2.57E-01	2.53E-02	1.40E-02	0.00E+00	7.90E-02	0.00E+00	5.19E+03

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per μCi/m^3.

Table F-15a
Teen Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.10E+02	1.10E+02	1.10E+02	1.10E+02	1.10E+02	1.10E+02
Na-24	1.16E-03	1.16E-03	1.16E-03	1.16E-03	1.16E-03	1.16E-03	1.16E-03
Cr-51	0.00E+00	0.00E+00	5.63E+03	3.13E+03	1.23E+03	8.04E+03	9.46E+05
Mn-54	0.00E+00	7.00E+06	1.39E+06	0.00E+00	2.09E+06	0.00E+00	1.44E+07
Mn-56	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-55	2.38E+08	1.69E+08	3.94E+07	0.00E+00	0.00E+00	1.07E+08	7.31E+07
Fe-59	2.12E+08	4.95E+08	1.91E+08	0.00E+00	0.00E+00	1.56E+08	1.17E+09
Co-58	0.00E+00	1.41E+07	3.24E+07	0.00E+00	0.00E+00	0.00E+00	1.94E+08
Co-60	0.00E+00	5.83E+07	1.31E+08	0.00E+00	0.00E+00	0.00E+00	7.60E+08
Ni-63	1.52E+10	1.07E+09	5.15E+08	0.00E+00	0.00E+00	0.00E+00	1.71E+08
Ni-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu-64	0.00E+00	2.06E-07	9.68E-08	0.00E+00	5.21E-07	0.00E+00	1.60E-05
Zn-65	2.50E+08	8.69E+08	4.05E+08	0.00E+00	5.56E+08	0.00E+00	3.68E+08
Zn-69	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-83	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	4.08E+08	1.91E+08	0.00E+00	0.00E+00	0.00E+00	6.03E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	2.54E+08	0.00E+00	7.28E+06	0.00E+00	0.00E+00	0.00E+00	3.03E+07
Sr-90	9.89E+09	0.00E+00	1.98E+08	0.00E+00	0.00E+00	0.00E+00	2.26E+08
Sr-91	1.21E-10	0.00E+00	4.80E-12	0.00E+00	0.00E+00	0.00E+00	5.47E-10
Sr-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-90	9.13E+01	0.00E+00	2.46E+00	0.00E+00	0.00E+00	0.00E+00	7.53E+05
Y-91M	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-91	9.54E+05	0.00E+00	2.56E+04	0.00E+00	0.00E+00	0.00E+00	3.91E+08
Y-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93	3.71E-12	0.00E+00	1.02E-13	0.00E+00	0.00E+00	0.00E+00	1.13E-07
Zr-95	1.50E+06	4.74E+05	3.26E+05	0.00E+00	6.96E+05	0.00E+00	1.09E+09
Zr-97	1.70E-05	3.37E-06	1.55E-06	0.00E+00	5.10E-06	0.00E+00	9.11E-01
Nb-95	1.80E+06	9.98E+05	5.49E+05	0.00E+00	9.67E+05	0.00E+00	4.27E+09
Mo-99	0.00E+00	8.21E+04	1.57E+04	0.00E+00	1.88E+05	0.00E+00	1.47E+05
Tc- 99M	0.00E+00	0.00E+00	1.24E-19	0.00E+00	1.43E-19	0.00E+00	6.29E-18
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	8.56E+07	0.00E+00	3.66E+07	0.00E+00	3.02E+08	0.00E+00	7.15E+09
Ru-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	2.36E+09	0.00E+00	2.97E+08	0.00E+00	4.55E+09	0.00E+00	1.13E+11
Ag-110M	5.06E+06	4.79E+06	2.91E+06	0.00E+00	9.13E+06	0.00E+00	1.35E+09

Table F-15a (Continued)
Teen Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.03E+08	1.09E+08	4.06E+07	8.47E+07	0.00E+00	0.00E+00	8.95E+08
Te-127M	9.41E+08	3.34E+08	1.12E+08	2.24E+08	3.82E+09	0.00E+00	2.35E+09
Te-127	2.12E-10	7.53E-11	4.57E-11	1.46E-10	8.60E-10	0.00E+00	1.64E-08
Te-129M	9.49E+08	3.52E+08	1.50E+08	3.06E+08	3.97E+09	0.00E+00	3.56E+09
Te-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-131M	3.75E+02	1.80E+02	1.50E+02	2.70E+02	1.87E+03	0.00E+00	1.44E+04
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	1.14E+06	7.24E+05	6.81E+05	7.63E+05	6.94E+06	0.00E+00	2.29E+07
I-130	1.63E-06	4.72E-06	1.88E-06	3.85E-04	7.27E-06	0.00E+00	3.63E-06
I-131	8.92E+06	1.25E+07	6.71E+06	3.64E+09	2.15E+07	0.00E+00	2.47E+06
I-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-133	3.09E-01	5.25E-01	1.60E-01	7.32E+01	9.20E-01	0.00E+00	3.97E-01
I-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135	3.79E-17	9.75E-17	3.61E-17	6.27E-15	1.54E-16	0.00E+00	1.08E-16
Cs-134	5.23E+08	1.23E+09	5.71E+08	0.00E+00	3.91E+08	1.49E+08	1.53E+07
Cs-136	9.34E+06	3.68E+07	2.47E+07	0.00E+00	2.00E+07	3.15E+06	2.96E+06
Cs-137	7.24E+08	9.63E+08	3.36E+08	0.00E+00	3.28E+08	1.27E+08	1.37E+07
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	2.38E+07	2.91E+04	1.53E+06	0.00E+00	9.88E+03	1.96E+04	3.67E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	3.09E-02	1.52E-02	4.04E-03	0.00E+00	0.00E+00	0.00E+00	8.73E+02
La-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-141	1.18E+04	7.87E+03	9.04E+02	0.00E+00	3.70E+03	0.00E+00	2.25E+07
Ce-143	1.67E-02	1.22E+01	1.36E-03	0.00E+00	5.46E-03	0.00E+00	3.66E+02
Ce-144	1.23E+06	5.08E+05	6.60E+04	0.00E+00	3.04E+05	0.00E+00	3.09E+08
Pr-143	1.77E+04	7.05E+03	8.79E+02	0.00E+00	4.10E+03	0.00E+00	5.81E+07
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	6.35E+03	6.90E+03	4.14E+02	0.00E+00	4.05E+03	0.00E+00	2.49E+07
W-187	1.73E-02	1.41E-02	4.94E-03	0.00E+00	0.00E+00	0.00E+00	3.82E+00
Np-239	2.25E-01	2.12E-02	1.18E-02	0.00E+00	6.66E-02	0.00E+00	3.41E+03

Notes:

1) Units are m^2 mrem/yr per µCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per µCi/m^3.

Table F-15b
Child Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.34E+02	1.34E+02	1.34E+02	1.34E+02	1.34E+02	1.34E+02
Na-24	1.84E-03	1.84E-03	1.84E-03	1.84E-03	1.84E-03	1.84E-03	1.84E-03
Cr-51	0.00E+00	0.00E+00	8.78E+03	4.87E+03	1.33E+03	8.90E+03	4.66E+05
Mn-54	0.00E+00	8.01E+06	2.13E+06	0.00E+00	2.25E+06	0.00E+00	6.72E+06
Mn-56	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-55	4.57E+08	2.42E+08	7.51E+07	0.00E+00	0.00E+00	1.37E+08	4.49E+07
Fe-59	3.76E+08	6.08E+08	3.03E+08	0.00E+00	0.00E+00	1.76E+08	6.34E+08
Co-58	0.00E+00	1.64E+07	5.03E+07	0.00E+00	0.00E+00	0.00E+00	9.59E+07
Co-60	0.00E+00	6.93E+07	2.04E+08	0.00E+00	0.00E+00	0.00E+00	3.84E+08
Ni-63	2.91E+10	1.56E+09	9.91E+08	0.00E+00	0.00E+00	0.00E+00	1.05E+08
Ni-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu-64	0.00E+00	2.77E-07	1.67E-07	0.00E+00	6.68E-07	0.00E+00	1.30E-05
Zn-65	3.75E+08	1.00E+09	6.22E+08	0.00E+00	6.30E+08	0.00E+00	1.76E+08
Zn-69	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-83	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	5.78E+08	3.55E+08	0.00E+00	0.00E+00	0.00E+00	3.72E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	4.81E+08	0.00E+00	1.37E+07	0.00E+00	0.00E+00	0.00E+00	1.86E+07
Sr-90	1.57E+10	0.00E+00	3.15E+08	0.00E+00	0.00E+00	0.00E+00	1.40E+08
Sr-91	2.26E-10	0.00E+00	8.54E-12	0.00E+00	0.00E+00	0.00E+00	5.00E-10
Sr-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-90	1.73E+02	0.00E+00	4.62E+00	0.00E+00	0.00E+00	0.00E+00	4.92E+05
Y-91M	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-91	1.80E+06	0.00E+00	4.82E+04	0.00E+00	0.00E+00	0.00E+00	2.40E+08
Y-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93	6.97E-12	0.00E+00	1.91E-13	0.00E+00	0.00E+00	0.00E+00	1.04E-07
Zr-95	2.67E+06	5.86E+05	5.22E+05	0.00E+00	8.39E+05	0.00E+00	6.11E+08
Zr-97	3.16E-05	4.57E-06	2.70E-06	0.00E+00	6.56E-06	0.00E+00	6.93E-01
Nb-95	3.11E+06	1.21E+06	8.64E+05	0.00E+00	1.14E+06	0.00E+00	2.24E+09
Mo-99	0.00E+00	1.14E+05	2.82E+04	0.00E+00	2.44E+05	0.00E+00	9.44E+04
Tc- 99M	0.00E+00	1.18E-20	1.96E-19	0.00E+00	1.72E-19	0.00E+00	6.72E-18
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.55E+08	0.00E+00	5.95E+07	0.00E+00	3.90E+08	0.00E+00	4.00E+09
Ru-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	4.44E+09	0.00E+00	5.54E+08	0.00E+00	5.99E+09	0.00E+00	6.90E+10
Ag-110M	8.39E+06	5.67E+06	4.53E+06	0.00E+00	1.06E+07	0.00E+00	6.74E+08

Table F-15b (Continued)
Child Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	5.70E+08	1.54E+08	7.59E+07	1.60E+08	0.00E+00	0.00E+00	5.50E+08
Te-127M	1.77E+09	4.78E+08	2.11E+08	4.24E+08	5.06E+09	0.00E+00	1.44E+09
Te-127	3.99E-10	1.08E-10	8.56E-11	2.76E-10	1.14E-09	0.00E+00	1.56E-08
Te-129M	1.79E+09	5.00E+08	2.78E+08	5.77E+08	5.25E+09	0.00E+00	2.18E+09
Te-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-131M	6.97E+02	2.41E+02	2.57E+02	4.96E+02	2.33E+03	0.00E+00	9.78E+03
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	2.09E+06	9.23E+05	1.12E+06	1.34E+06	8.57E+06	0.00E+00	9.30E+06
I-130	2.92E-06	5.89E-06	3.04E-06	6.49E-04	8.81E-06	0.00E+00	2.76E-06
I-131	1.65E+07	1.66E+07	9.45E+06	5.50E+09	2.73E+07	0.00E+00	1.48E+06
I-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-133	5.75E-01	7.10E-01	2.69E-01	1.32E+02	1.18E+00	0.00E+00	2.86E-01
I-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135	6.86E-17	1.23E-16	5.84E-17	1.09E-14	1.89E-16	0.00E+00	9.40E-17
Cs-134	9.22E+08	1.51E+09	3.19E+08	0.00E+00	4.69E+08	1.68E+08	8.16E+06
Cs-136	1.61E+07	4.43E+07	2.87E+07	0.00E+00	2.36E+07	3.52E+06	1.56E+06
Cs-137	1.33E+09	1.28E+09	1.88E+08	0.00E+00	4.16E+08	1.50E+08	7.99E+06
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	4.39E+07	3.84E+04	2.56E+06	0.00E+00	1.25E+04	2.29E+04	2.22E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	5.66E-02	1.98E-02	6.67E-03	0.00E+00	0.00E+00	0.00E+00	5.52E+02
La-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-141	2.22E+04	1.11E+04	1.64E+03	0.00E+00	4.85E+03	0.00E+00	1.38E+07
Ce-143	3.14E-02	1.70E+01	2.46E-03	0.00E+00	7.14E-03	0.00E+00	2.49E+02
Ce-144	2.32E+06	7.26E+05	1.24E+05	0.00E+00	4.02E+05	0.00E+00	1.89E+08
Pr-143	3.34E+04	1.00E+04	1.66E+03	0.00E+00	5.44E+03	0.00E+00	3.61E+07
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	1.19E+04	9.65E+03	7.47E+02	0.00E+00	5.29E+03	0.00E+00	1.53E+07
W-187	3.21E-02	1.90E-02	8.52E-03	0.00E+00	0.00E+00	0.00E+00	2.67E+00
Np-239	4.23E-01	3.04E-02	2.14E-02	0.00E+00	8.79E-02	0.00E+00	2.25E+03

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per μCi/m^3.

3) The infant age group is assumed to receive no dose through the meat ingestion pathway therefore no dose factors are supplied.

Supplemental Table F-A
Mixed Mode Joint Frequency Distribution Table Summaries

250 Foot Elevation Data

Summary Table of Percent by Direction and Class

Class	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
A	.267	.504	.349	.248	.243	.315	.542	.409	.247	.214	.335	.440	.648	.737	.705	.400	6.604
B	.068	.110	.085	.055	.079	.069	.118	.117	.067	.050	.090	.105	.143	.138	.143	.152	1.590
C	.104	.162	.121	.059	.098	.087	.142	.139	.071	.065	.104	.132	.139	.141	.183	.146	1.892
D	.745	.992	.685	.498	.544	.536	.741	.887	.552	.603	.978	.933	1.115	1.136	1.361	1.003	13.309
E	1.512	1.507	1.234	1.161	1.021	.924	1.376	1.887	1.597	1.672	2.358	2.073	2.051	2.097	2.238	1.620	26.327
F	.729	.603	.521	.386	.409	.410	.568	.923	1.196	1.133	1.354	.977	.897	.875	.858	.644	12.483
G	.499	.412	.352	.283	.246	.247	.362	.700	1.366	1.480	1.008	.612	.421	.428	.463	.388	9.265
Total	3.924	4.292	3.346	2.689	2.640	2.588	3.848	5.062	5.097	5.217	6.227	5.272	5.414	5.552	5.950	4.353	71.471

Summary Table of Percent by Direction and Speed

Speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
.45	.003	.000	.005	.013	.009	.006	.000	.010	.014	.002	.000	.003	.000	.001	.001	.005	.074
1.05	.023	.022	.026	.043	.027	.036	.030	.035	.026	.023	.027	.027	.027	.030	.026	.031	.459
2.05	.194	.172	.200	.239	.270	.267	.262	.260	.224	.187	.189	.158	.159	.217	.213	.180	3.391
3.05	.320	.372	.529	.560	.576	.515	.586	.601	.414	.362	.393	.318	.343	.433	.572	.344	7.238
4.05	.478	.599	.629	.522	.514	.473	.722	.842	.562	.590	.595	.548	.546	.716	.831	.595	9.764
5.05	.649	.720	.650	.456	.374	.392	.753	.898	.886	.895	.937	.813	.809	1.029	1.145	.851	12.256
6.05	.656	.713	.484	.296	.247	.262	.528	.807	.976	.968	1.115	.993	.872	1.215	1.362	.971	12.467
8.05	1.106	1.257	.615	.372	.422	.478	.722	1.237	1.609	1.749	2.243	1.856	1.990	1.651	1.628	1.180	20.116
10.05	.458	.407	.191	.171	.182	.146	.229	.348	.365	.412	.677	.522	.630	.249	.164	.187	5.338
13.05	.037	.029	.016	.017	.020	.012	.017	.023	.022	.029	.048	.034	.037	.011	.007	.010	.369
18.00	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
99.00	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Total	3.924	4.292	3.346	2.689	2.640	2.588	3.848	5.062	5.097	5.217	6.227	5.272	5.414	5.552	5.950	4.353	71.471

NOTE: Wind directions in tables are presented in "wind from" and not "wind to" direction.

In order to determine the final mixed mode values, 71.471% of the elevated value (presented in the 250 FT Mixed Mode table) and 28.529% of the ground level value (presented in the 30 FT Mixed Mode table) are used to calculate the final values.

Supplemental Table F-A - Continued
Mixed Mode Joint Frequency Distribution Table Summaries

250 Foot Elevation Data

Summary Table of Percent by Speed and Class

Class Speed	A	B	C	D	E	F	G
.45	.001	.000	.003	.006	.025	.016	.023
1.05	.006	.004	.005	.034	.147	.070	.193
2.05	.119	.048	.074	.456	1.047	.616	1.031
3.05	.564	.166	.196	1.332	2.330	1.167	1.485
4.05	.940	.221	.275	1.932	3.494	1.459	1.443
5.05	1.250	.267	.320	2.204	4.388	2.178	1.647
6.05	1.204	.321	.306	2.176	4.544	2.456	1.460
8.05	1.923	.401	.539	3.884	7.909	3.699	1.760
10.05	.560	.151	.161	1.188	2.279	.784	.215
13.05	.037	.011	.013	.096	.165	.039	.007
18.00	.000	.000	.000	.000	.000	.000	.000
99.00	.000	.000	.000	.000	.000	.000	.000

Supplemental Table F-A - Continued
Mixed Mode Joint Frequency Distribution Table Summaries

35 Foot Elevation Data

Summary Table of Percent by Direction and Class

Class	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
A	.325	.401	.141	.095	.077	.100	.120	.122	.108	.127	.198	.209	.332	.278	.210	.186	3.029
B	.093	.099	.037	.028	.020	.014	.021	.048	.041	.020	.056	.061	.080	.049	.050	.058	.775
C	.103	.122	.047	.027	.030	.028	.028	.047	.029	.031	.065	.077	.090	.056	.054	.052	.885
D	.708	.607	.317	.291	.266	.182	.186	.283	.281	.283	.607	.505	.664	.413	.442	.396	6.431
E	1.140	.850	.531	.507	.431	.288	.289	.656	.894	.818	1.403	1.177	1.133	.621	.600	.384	11.722
F	.273	.144	.099	.098	.090	.066	.109	.165	.557	.449	.569	.436	.349	.232	.175	.109	3.919
G	.059	.029	.027	.018	.031	.038	.039	.063	.412	.289	.247	.159	.119	.114	.081	.042	1.768
Total	2.700	2.252	1.199	1.065	.946	.717	.792	1.384	2.322	2.017	3.144	2.623	2.766	1.764	1.611	1.227	28.529

Summary Table of Percent by Direction and Speed

Speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
.45	.001	.002	.001	.000	.001	.001	.001	.003	.002	.003	.002	.002	.000	.002	.003	.001	.025
1.05	.007	.006	.007	.008	.005	.008	.008	.009	.019	.020	.021	.012	.011	.011	.015	.011	.178
2.05	.082	.053	.034	.027	.033	.042	.058	.047	.162	.250	.218	.167	.120	.167	.218	.098	1.775
3.05	.170	.146	.103	.076	.075	.093	.180	.148	.483	.360	.315	.312	.327	.349	.356	.205	3.699
4.05	.214	.250	.157	.090	.086	.095	.183	.255	.614	.250	.350	.379	.389	.291	.350	.230	4.182
5.05	.273	.311	.149	.084	.090	.066	.127	.245	.469	.225	.369	.382	.391	.255	.251	.192	3.878
6.05	.438	.386	.181	.091	.107	.080	.083	.214	.278	.292	.470	.403	.450	.224	.211	.173	4.080
8.05	.892	.607	.268	.225	.208	.161	.118	.323	.219	.473	1.001	.677	.762	.388	.190	.262	6.775
10.05	.413	.313	.208	.333	.213	.118	.032	.114	.061	.128	.317	.209	.219	.061	.019	.046	2.804
13.05	.178	.155	.088	.117	.102	.050	.003	.025	.015	.014	.075	.079	.085	.014	.000	.009	1.009
18.00	.032	.023	.004	.013	.025	.003	.000	.000	.000	.001	.005	.003	.012	.003	.000	.000	.123
99.00	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Total	2.700	2.252	1.199	1.065	.946	.717	.792	1.384	2.322	2.017	3.144	2.623	2.766	1.764	1.611	1.227	28.529

NOTE: Wind directions in tables are presented in "wind from" and not "wind to" direction.

Supplemental Table F-A - Continued
Mixed Mode Joint Frequency Distribution Table Summaries

35 Foot Elevation Data

Summary Table of Percent by Speed and Class

Class Speed	A	B	C	D	E	F	G
.45	.000	.000	.000	.001	.003	.007	.015
1.05	.001	.000	.002	.004	.032	.048	.091
2.05	.028	.010	.010	.104	.421	.544	.658
3.05	.198	.055	.062	.486	1.333	1.014	.551
4.05	.445	.098	.104	.786	1.701	.818	.230
5.05	.424	.093	.118	.830	1.701	.582	.129
6.05	.429	.120	.146	.999	1.918	.404	.063
8.05	.937	.259	.275	1.985	2.893	.403	.023
10.05	.405	.098	.103	.845	1.270	.078	.007
13.05	.147	.039	.054	.348	.401	.019	.001
18.00	.014	.004	.012	.043	.049	.001	.000
99.00	.000	.000	.000	.000	.000	.000	.000

Supplemental Table F-B
Ground Level Joint Frequency Distribution Table Summaries

Summary Table of Percent by Direction and Class

Class	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
A	.573	.881	.500	.366	.343	.440	.582	.503	.397	.324	.509	.640	.941	.989	.950	.666	9.605
B	.175	.211	.131	.089	.087	.086	.113	.157	.131	.058	.139	.176	.219	.171	.215	.206	2.363
C	.213	.281	.165	.113	.103	.120	.152	.171	.115	.089	.168	.207	.235	.182	.250	.209	2.771
D	1.488	1.629	1.012	.801	.756	.681	.797	.971	1.036	.783	1.610	1.454	1.820	1.478	1.967	1.433	19.716
E	2.801	2.521	1.683	1.537	1.317	1.065	1.255	2.107	2.835	2.531	3.911	3.300	3.293	2.756	3.239	1.907	38.058
F	1.155	.710	.463	.384	.389	.313	.509	.692	1.908	1.815	1.987	1.547	1.385	1.331	1.143	.707	16.439
G	.472	.253	.176	.132	.127	.192	.258	.353	1.603	1.642	1.448	.987	1.028	1.192	.770	.416	11.049
Total	6.877	6.486	4.130	3.421	3.122	2.898	3.667	4.954	8.025	7.241	9.772	8.311	8.921	8.097	8.534	5.543	100.000

Summary Table of Percent by Direction and Speed

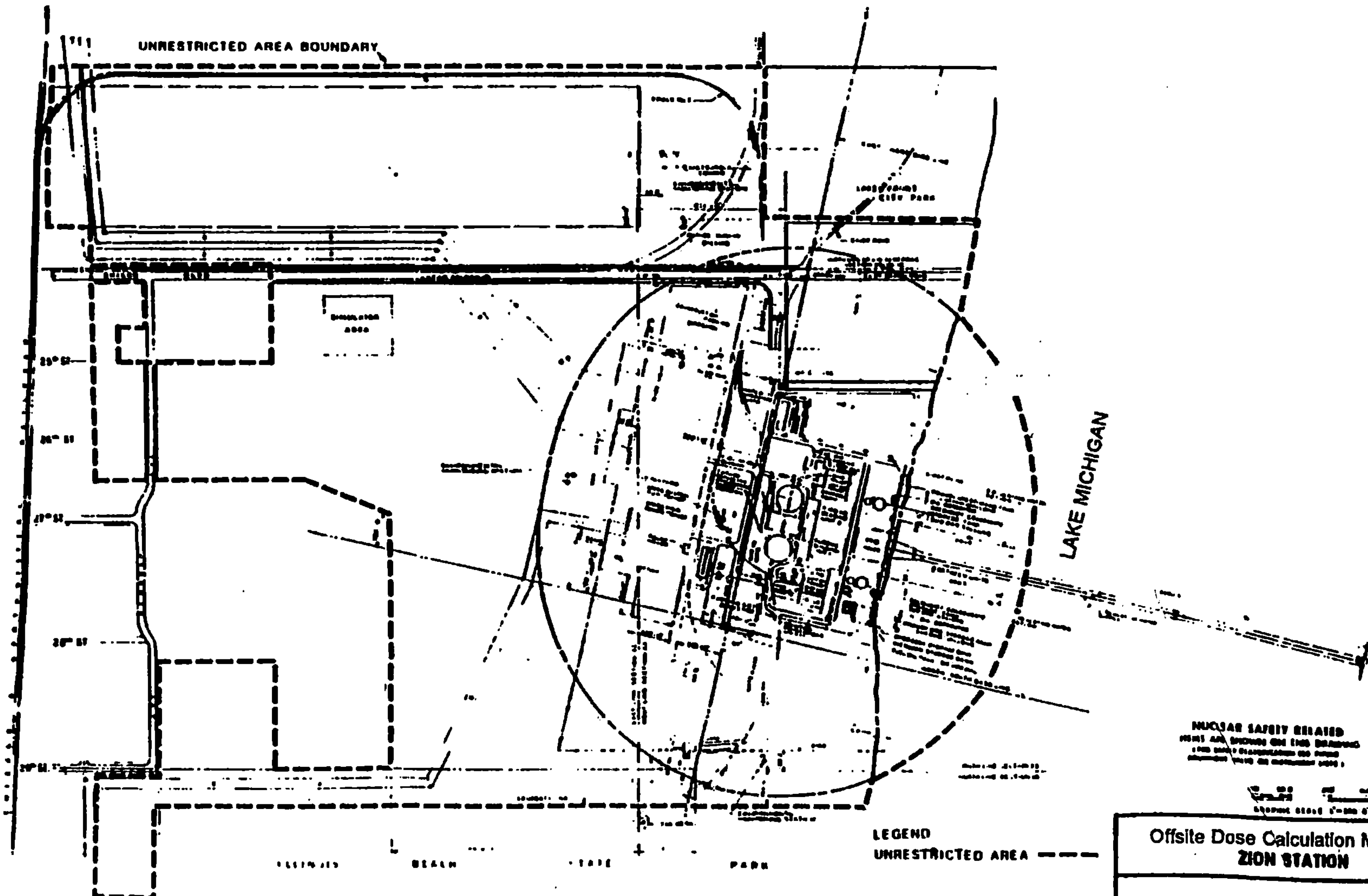
Speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
.45	.048	.065	.058	.009	.022	.012	.018	.037	.027	.042	.027	.052	.042	.043	.075	.054	.631
1.05	.206	.168	.156	.118	.121	.118	.135	.134	.216	.238	.271	.197	.233	.264	.350	.234	3.158
2.05	.903	.674	.518	.467	.458	.558	.636	.534	1.254	1.834	1.675	1.396	1.326	1.837	2.043	.990	17.102
3.05	1.089	1.031	.861	.743	.683	.806	1.309	1.075	2.628	1.993	1.781	1.670	1.944	2.220	2.304	1.333	23.474
4.05	1.054	1.309	.883	.554	.456	.478	.846	1.269	2.134	1.088	1.655	1.639	1.715	1.534	1.873	1.234	19.724
5.05	.931	1.129	.586	.345	.338	.230	.369	.797	1.005	.755	1.450	1.328	1.404	1.079	1.079	.836	13.661
6.05	.906	.841	.409	.273	.279	.231	.161	.477	.418	.573	1.176	.894	1.007	.550	.537	.468	9.201
8.05	1.119	.779	.354	.415	.393	.283	.158	.482	.265	.575	1.338	.845	.936	.489	.253	.338	9.022
10.05	.411	.312	.213	.366	.246	.127	.032	.123	.063	.129	.318	.208	.219	.062	.019	.046	2.896
13.05	.177	.154	.087	.118	.102	.050	.003	.026	.015	.014	.075	.078	.085	.014	.000	.009	1.008
18.00	.032	.023	.004	.013	.024	.003	.000	.000	.000	.001	.005	.003	.012	.003	.000	.000	.122
99.00	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Total	6.877	6.486	4.130	3.421	3.122	2.898	3.667	4.954	8.025	7.241	9.772	8.311	8.921	8.097	8.534	5.543	100.000

NOTE: Wind directions in tables are presented in "wind from" and not "wind to" direction.

Supplemental Table F-B - Continued
Ground Level Joint Frequency Distribution Table Summaries

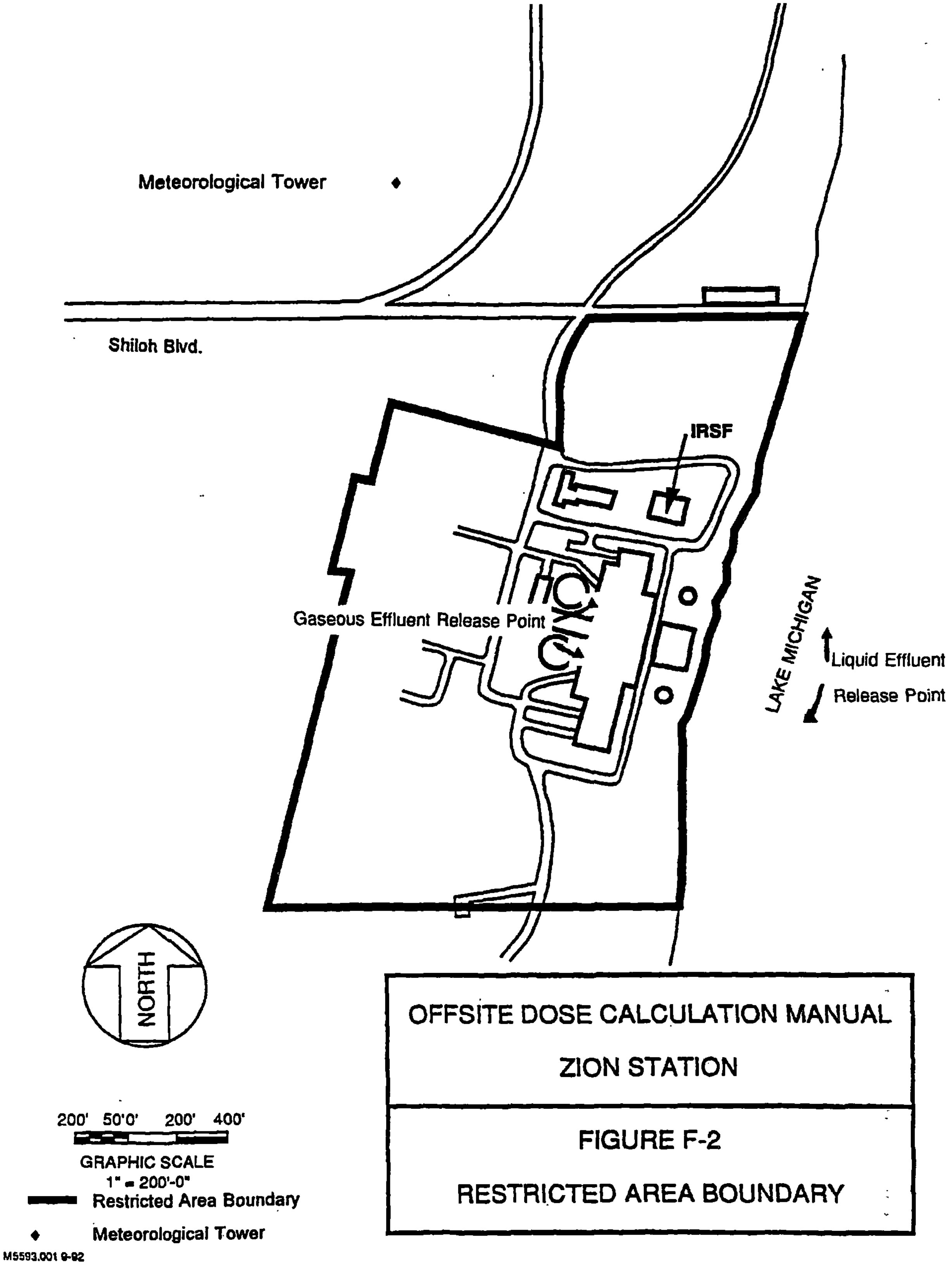
Summary Table of Percent by Speed and Class

Class Speed	A	B	C	D	E	F	G
.45	.006	.004	.005	.040	.172	.154	.249
1.05	.036	.013	.024	.121	.797	.823	1.344
2.05	.464	.141	.194	1.591	4.805	4.405	5.502
3.05	1.606	.433	.507	3.810	8.847	5.409	2.862
4.05	2.520	.563	.613	4.211	8.107	2.995	.715
5.05	1.909	.419	.509	3.384	5.795	1.394	.251
6.05	1.211	.306	.368	2.527	4.023	.681	.085
8.05	1.281	.342	.381	2.766	3.745	.478	.030
10.05	.410	.099	.104	.877	1.317	.078	.010
13.05	.147	.039	.054	.348	.400	.019	.001
18.00	.014	.004	.012	.042	.049	.001	.000
99.00	.000	.000	.000	.000	.000	.000	.000



Offsite Dose Calculation Manual
ZION STATION

FIGURE F-1
UNRESTRICTED AREA BOUNDARY



OFFSITE DOSE CALCULATION MANUAL

ZION STATION

FIGURE F-2

RESTRICTED AREA BOUNDARY

Appendix O

ODCM BASES and REFERENCE DOCUMENT

Appendix O

ODCM BASES and REFERENCE DOCUMENT

This document provides supplementary information on the bases of material in Chapters 1 through 6 and Appendices A through C.

O.1 BASES OF CHAPTER 1, INTRODUCTION

O.1.1 Offsite Radiation Doses Due to Nuclear Power Plants

It is estimated that the average radiation dose received by an individual in the United States is about 625 mrem/yr and that nuclear power stations account for less than two parts in a thousand of this radiation. These figures are based on data in Table 8.3 of NCRP 160, (Reference 80). The table includes the following data:

Source	Average Individual Dose (mrem/yr)
Ubiquitous Background	311
Medical	300
Consumer	13
Industrial, security, medical, educational and research	0.3
Occupational	0.5
Total	624.8

The radiological effects of nuclear power station operation on the environment are characterized as "usually so small that they are masked by normal fluctuations in natural background sources and by the normal uncertainties of the measurement process."

The text of Chapter 1 also states that "assessing compliance with regulatory limits requires calculations because some of the limits involve quantities that cannot be directly measured. . ." Limits that cannot be feasibly monitored by direct measurement include doses to internal organs and doses attributable to particular pathways (see Appendix A).

O.1.2 Historical and Concurrent Meteorology

The use of historical average atmospheric conditions for assessment of radiation doses due to airborne effluents is stipulated in the Bases Section 12.4 and 12.6 of the RETS.

O.2 BASES OF CHAPTER 2, REGULATIONS AND GUIDELINES

See the documents cited in the text.

O.3 BASES OF CHAPTER 3, PATHWAYS

General information on offsite exposure pathways may be found in several texts and monographs (see References 16, 18, 20, 22, 25, 28, 29 and 31).

O.3.1 Airborne Releases (Section 3.1)

Zion addresses radiation dose for the airborne pathways considered in NUREG 0133 (Reference 14). The airborne pathways found in NUREG 0133 are:

- Exposure to a cloud of noble gas.
- Exposure to standing on a contaminated ground plane.
- Inhalation of tritium and/or particulates.
- Ingestion of contaminated vegetation.
- Ingestion of contaminated cow and/or goat milk.
- Ingestion of contaminated cow meat.

The noble gas exposures are assessed at the site boundary. The ground plane, inhalation and ingestion exposures are determined at the location in the unrestricted area where the combination of pathways, age group and airborne deposition produce the highest potential dose to a member of the public. The ground plane and inhalation pathways are considered present at every location in the unrestricted area. Ingestion pathways are considered present at the locations determined by the land use census.

Soil uptake is not considered by the NUREG 0133 methodology but is addressed by Regulatory Guide 1.109 (Reference 6). Ingestion exposure through the mechanism of soil uptake has been shown to be minor as compared to direct deposition onto foliage. This assumption is based upon an analysis of three nuclides: I-131, Cs-134 and Cs-137. In a study of nuclear power station radiation exposures in the upper Mississippi River basin, these nuclides were found to contribute the major portion of the dose due to exposure to airborne radioactivity deposited on soil (see page IX-12 of Reference 20).

The relative importance of uptake from soil was assessed by use of Equation C-5 of Regulatory Guide 1.109. This equation calculates radioactivity concentration in vegetation. The first term inside the curly brackets of the equation represents the contribution from radioactivity directly deposited on plant foliage. The second term represents the contribution from radioactivity initially deposited on the ground and then taken up through the root system of the vegetation. For each of the three nuclides, the ratio of the uptake term to the direct deposition term was evaluated for two pathways; the grass-cow-milk pathway and the pathway of direct ingestion by man of produce and leafy vegetables. The parameter values used and the results are in Table O-1 of this document. For the six cases, the soil uptake term ranged from about 0.01% to about 10% of the direct deposition term (see the column labeled "Uptake ÷ Direct Dep" in Table O-1).

O.3.2 Liquid Releases (Section 3.2)

Zion addresses radiation dose for the waterborne pathways considered in NUREG 0133. The waterborne pathways found in NUREG 0133 are:

- Ingestion of contaminated potable water.
- Ingestion of fish taken from contaminated water.
- Ingestion of invertebrates taken from contaminated water.

These dose pathways are considered unless demonstrated not be present. Exposure can also occur through recreation (shoreline activities, swimming and boating) and irrigation pathways (irrigation of directly ingested vegetation and food crops for animal consumption), but these are considered to be minor when compared to direct ingestion.

The liquid pathways were evaluated based on surveys of surface water use and on liquid pathway dose calculations. Table O-2 of this document summarizes principal results of the surface water use surveys. On the basis of these surveys, it was decided to ignore the following pathways:

- Ingestion of vegetation contaminated because of irrigation with water containing radioactivity from plant liquid discharges.
- Ingestion of radioactivity that entered an animal food product (milk or meat) because the animal drank water contaminated by radioactive liquid effluents from the plant or because the animal consumed feed contaminated by irrigation with such water.

Calculations were performed to estimate annual doses from the following liquid pathways:

- Consumption of drinking water.
- Consumption of fish.
- Shoreline activities (with exposure to shoreline sediments).
- Swimming and boating.

O.3.3 Radiation from Contained Sources (Section 3.3)

Annual radiation doses due to contained sources of radioactivity at Zion are addressed in EH&S TSDs: 13-007, "Evaluation of Waste Classification A, B and C Storage and Staging Dose Rates"; 13-008, "Evaluation of ISFSI and Associated Processes Dose Rates" and 13-009, "Member of the Public Dose from All Onsite Sources."

O.4 BASES OF CHAPTER 4, INTRODUCTION TO METHODOLOGY

Most of the material in this chapter is based on Appendix A. Additional information on bases is provided below.

O.4.1 Introduction of Time Factors

The release rate of radioactive materials is the discharge of radioactive materials in liquid or gaseous effluents per unit time. The second is used as the practical reporting time unit for establishing release rates to show compliance with instantaneous limitations for noble gases. The hour is used as the practical reporting time unit is established average release rates to show conformance with the requirements of 10CFR50 for particulates released in gaseous effluents and for liquids effluents.

O.4.2 Release Point Classifications (Section 4.1.4)

For additional information, see Meteorology and Atomic Energy 1968 (Reference 18), Section 3-3.5.2, and Regulatory Guide 1.111 (Reference 7), Section B.2.

O.4.3 Airborne Releases (Section 4.2)

The energies and intensities of radiations emitted from them are listed in standard compendia (e.g., see Reference 70).

Gamma Radiation Mean Free Path

The mean free path **X** of gamma radiation is calculated using the following equations:

$$\mathbf{X = 1/\mu} \qquad \textbf{(O-1)}$$

$$\mu = (\mu/\rho)\rho \qquad \textbf{(O-2)}$$

X Mean Free Path [cm]

The average distance traveled by a photon before interacting with matter.

μ Attenuation Coefficient of Air $[cm^{-1}]$

Probability of photon absorption or
scattering per unit distance traveled in air.

ρ Density of Air [g/cc]

The results for photon mean free path (Section 4.2.1) are based on data in Reference 71. For a 4-MeV photon, the calculation is as follows:

μ/ρ = 0.0308 cm^2/g (per Table 5.2 of Reference 71)

ρ = 0.001293 g/cc (per Table 1.3 of Reference 71)

μ = (0.0308 cm^2/g) (0.001293 g/cc) = 3.982E-5 cm^{-1}

X = (1/3.982E-5 cm^{-1})(1 ft/30.48 cm) = 823.9 ft

Range of Beta Radiation in Air

The results for beta radiation range (Section 4.2.2) are based on equations in Reference 38. The range of beta radiation with a maximum energy greater than 2.5 MeV is given by the following equation (Reference 38, Page 100):

$$\mathbf{R = (530)\,(E_{max}) - 106} \quad \textbf{(O-3)}$$

R Range $[mg/cm^2]$

$\mathbf{E_{max}}$ Maximum Beta Energy [MeV]

For E_{max} = 4 MeV,

$$\mathbf{R = (530)(4) - 106 = 2.01E3\ mg/cm^2}$$

For an air density of 1.293 mg/cc, the range is

$$\mathbf{[(2.01E3\ mg/cm^2)/(1.293\ mg/cc)]\ (1\ ft/30.48\ cm) = 51.0\ ft}$$

For 0.01 $\le E_{max} \le$ 2.5 MeV, the range of beta radiation is given by the following equation (Reference 38, Page 99):

$$\mathbf{R = (412)(E_{max})^{1.265 - (0.0954)(1n\ E_{max})}} \qquad \textbf{(O-4)}$$

where R and E_{max} have the same definitions as for Equation O-3.

For example, for E_{max} = 0.1 MeV,
$$\mathbf{R = (412)\ (0.1)^{1.265 - (0.0954)1n(0.1)} = 13.5\ mg/cm^2}$$

For an air density of 1.293 mg/cc, the range is

$$\mathbf{[(13.5\ mg/cm^2)/(1.293\ mg/cc)]\ (1\ ft/30.48\ cm) = 0.34\ ft}$$

O.4.4 Radionuclide Types Considered For Airborne Effluent Exposure Pathways (Table 4-1)

The radionuclide types considered are the same as those recommended for concern in Regulatory Guide 1.109 except that carbon-14 is omitted. The reasons for this are discussed in the next section.

O.4.5 Reasons for Not Calculating Doses Due to Carbon-14

Carbon-14 is not considered because the RETS does not require it. Zion Station is required to consider only the following non-noble gas radionuclides: tritium and all radionuclides in particulate form with half-lives greater than 8 days. Although carbon-14 has a half-life of 5730 years, it does not fall in the last category (in particulate form with half-life greater than 8 days) because it is emitted as a gas, mainly CO_2 (see Reference 29, Page 167). Moreover, carbon-14 was not found to be a significant contributor to offsite radiation dose in a study of the potential radiological implications of nuclear facilities in the upper Mississippi River basin (see Reference 20, Page IX-8, Table IX-2).

O.5 BASES OF CHAPTER 5, MEASUREMENT

See the documents cited in the text.

O.6 BASES OF CHAPTER 6, IMPLEMENTATION OF THE OFFSITE DOSE ASSESSMENT PROGRAM

Chapter 6 is based on Zion*Solutions*' organizational structure and departmental responsibilities.

O.7 BASES OF AIRBORNE EFFLUENT CALCULATIONS (SECTION A.1 AND APPENDIX B)

The methodology used to calculate doses and dose rates due to releases of radioactivity in airborne effluents is discussed below. The calculations use equations presented in Section A.1 of Appendix A. The equations involve meteorological transport and dose factors that are either obtained from the literature or calculated as described in Appendix B.

For the most part, the methodology of this manual for airborne effluent dose calculations is identical to that of Regulatory Guides 1.109 (Reference 6) and 1.111 (Reference 7). In the discussion below, special attention will be given to the few differences.

O.7.1 Release Point Classifications (Section A.1.1 of Appendix A)

Regulatory Guide 1.109 uses two classifications for airborne releases (see Reference 6, Regulatory Position C.2):

- Releases from free standing stacks more than 80 meters high.
- All other releases.

This manual uses three classifications for airborne releases: stack, ground and vent level. The classifications used here are based on Regulatory Positions C.2.a and C.2.b of Regulatory Guide 1.111.

O.7.2 Meteorological Data (Section B.1.1 of Appendix B)

The information in Section B.1.1 of Appendix B is based on Sargent & Lundy reviews and analyses of meteorological data from Zion. The procedure for treating calms is based on guidance in Regulatory Guide 1.111, Regulatory Position C.4.

O.7.3 Joint Frequency Distribution (Section B.1.2 of Appendix B)

The information in Section B.1.2 of Appendix B is based on discussions with Sargent & Lundy. The procedure for determining the JFD for a vent release is based on Regulatory Position C.2.b of Regulatory Guide 1.111. An historical average JFD was calculated at Sargent & Lundy by a computer program that later evolved into the computer program METWRSUM (Reference 75). For further information on these calculations, see Reference 76.

Wind speed and direction may change with height. In accordance with Regulatory Position C.2.b of Regulatory Guide 1.111, JFD calculations for elevated releases were made using wind parameters representative of conditions at the actual release height, and calculations for ground level releases were made using wind parameters corresponding to a height of approximately 10 meters. As noted in Reference 76, in some cases interpolation of wind speed data measured at different heights was used to obtain data characteristic of the height of interest.

O.7.4 Average Wind Speed (Section B.1.3 of Appendix B)

The equations for obtaining average wind speed are based on the standard method of determining the average value of a quantity for which the frequency distribution is known. Average wind speeds Zionb were computed using Sargent & Lundy computer program AZAP (Reference 77).

Regulatory Position C.2.a of Regulatory Guide 1.109 and C.1.c of Regulatory Guide 1.111 specify that a wind speed class be represented by the wind speed of its midpoint (i.e., average of its upper and lower limits). In the calculations this is done for each wind speed class except the highest. The highest class contains all wind speeds greater than a specified value and so has an undefined upper limit. This class is represented by the lower limit of its wind speed range in all calculations for this manual (calculations of average wind speed, χ/Q, gamma dose factors, and total body dose factors).

O.7.5 Gaussian Plume Models (Section B.2 of Appendix B)

For discussion of the Gaussian plume diffusion model and its applications to dose assessment, see References 18 (Sections 2-7.2, 3-3, 4-6.2, 7-4, and 7-5), 24, 31 (Section 2.1), and 22 (Chapter 3).

Equation B-9 of Appendix B is identical to Equation 3.115 on Page 99 of Reference 18.

Equation B-10 of Appendix B is derived from Equation B-9 of Appendix B as follows:

- A location at ground level (z = 0) is assumed. Equation B-9 of Appendix B becomes:

$$\chi(x,y,0) = [Q/(\pi\, \sigma_y\, \sigma_z\, u)]\ \exp[-(y^2/2\sigma^2_y) - (h_e^2/2\sigma^2_z)] \qquad \textbf{(O-5)}$$

- This expression for $\chi(x,y,0)$ is integrated in the crosswind direction from $y = -\infty$ to $+\infty$. This yields the following result (see Equation 3.143 of Reference 18):

$$[2^{1/2}Q/(\pi^{1/2}\sigma_z u)]\exp(-h^2e^2/2\sigma^2_z)$$

- The above expression is divided by the width of a sector at downwind distance x, $2\pi x/16$. The result is:

$$[16/(2^{1/2}\pi^{3/2})][Q/(\sigma_z\ u\ x)]\exp(-h^2_e/2\sigma^2_z)$$

that is equal to

$$[2.032Q/(\sigma_z\ u\ x)]\exp(-h^2_e/2\sigma^2_z)$$

- The result above is multiplied by a fraction f representing the fraction of time that the wind blows into the sector of interest. This yields

$$[2.032\ f\ Q/(\sigma_z\ u\ x)]\exp(-h^2_e/2\sigma^2_z)$$

that is identical to the expression in Equation B-10 of Appendix B and also to Equation 3.144 of Reference 18.

O.7.6 Relative Concentration Factor χ/Q (Section B.3 of Appendix B)

O.7.6.1 Stack Release

Equation B-13 of Appendix B is the formula for calculating the relative concentration factor $(\chi/Q)_s$ due to a stack release. Equation B-13 of Appendix B is obtained from the formula for sector-averaged concentration, Equation B-10 of Appendix B, and is of the same form as Equation 3 of Regulatory Guide 1.111. In applying Equation B-13 of Appendix B, the vertical plume spread is calculated in the way specified in the regulatory guide.

The effective release height is calculated with Equation B-14 of Appendix B. The formulas used are in accordance with those in Regulatory Guide 1.111. However, the following should be noted:

- Plume heights are limited to a maximum of 100 meters. This is done to allow use of the plume depletion and relative deposition data in Regulatory Guide 1.111. These data are not provided for release heights above 100 meters. The limitation to 100 meters represents a conservative approximation for cases in which the release height and the plume rise formulas would lead to higher plumes.

- Due to the general flatness of the terrain in the vicinity of Zion, all terrain correction parameters were taken as zero.

- Plume rise due to buoyancy was ignored because typical nuclear power plant plumes are not significantly warmer than room temperature. This neglect of buoyancy (which can be significant for plumes from fossil plants) is in accord with the guidelines of Regulatory Guide 1.111. The regulatory guide states that plume rise is calculated in accordance with Reference 78, which neglects rise due to buoyancy (see last sentence on Page 5 of Reference 78).

O.7.6.2 Ground Level Release

Equation B-25 of Appendix B is the formula for calculating the relative concentration factor $(\chi/Q)_g$ due to a ground level release. Equation B-25 of Appendix B is obtained from the formula for sector-averaged concentration, Equation B-10 of Appendix B, and is of the same form as Equation 3 of Regulatory Guide 1.111. In applying Equation B-25 of Appendix B, the vertical dispersion coefficient is calculated using Equations B-26, B-27 and B-28 of Appendix B, which are based on the prescription in Regulatory Position C.2.c.

O.7.6.3 Vent Release

Equation B-29 of Appendix B may be used for calculating the relative concentration factor $(\chi/Q)_v$ due to a vent release. The relative concentration factor is obtained as a mixture of stack and ground level factors in accordance with the guidelines in Regulatory Position C.2.b of Regulatory Guide 1.111.

O.7.6.4 Removal Mechanisms

Regulatory Position C.3 of Regulatory Guide 1.111 discusses three removal mechanisms that reduce airborne radioactivity concentration: radioactive decay, dry deposition and wet deposition. In the dose calculations involving χ/Q (see Appendix A), radioactive decay is taken into account by adjusting the measured release rate of each radionuclide for radiodecay in transit from the release point to the dose point. However, wet and dry deposition are not considered. This is a conservative approximation made to simplify the calculations. If these deposition mechanisms were considered, the X/Q values for noble gases would be different from those for particulate.

O.7.6.5 Gamma-χ/Q (Section B.3.5)

The noble gas dose factors used in Equations A-1, A-3, A-4, A-5 of Appendix A are taken from Regulatory Guide 1.109, Table B-1. These values are based upon assumption of immersion in a semi-infinite cloud. For ground level and mixed mode releases this tends to overestimate the gamma air dose arising from a plume that is actually finite in nature.

For elevated releases, the Regulatory Guide 1.109 noble gas dose factors will underestimate exposure as they consider only immersion and not that portion of exposure arising from sky shine. At distances close in to the point of elevated release, the ground level concentration as predicted by χ/Q will be essentially zero. In such a case, the sky shine component of the exposure becomes significant and must be considered.

The gamma-χ/Q provides a simplified method of calculating gamma air dose and dose rates for a finite and/or elevated plume. Regulatory Guide 1.109, Section C.2 and Appendix B provide the methodology for calculating finite cloud gamma air dose factors from which the gamma-χ/Q values can be derived.

The gamma-χ/Q is defined such that for a given finite cloud the semi-infinite cloud methodology will yield the same gamma air dose as the finite cloud methodology.

Three gamma-χ/Q values are defined: for stack, vent and ground level releases, respectively. The gamma-χ/Q values are calculated by Equations B-30, B-31 and B-32 of Appendix B and makes use of the finite cloud gamma air dose factors described in Section B-5 of Appendix B.
These equations also utilize a noble gas nuclide fraction. These fractions can be based upon historical data or a calculated noble gas source term.

O.7.7 Relative Deposition Factor D/Q (Section B.4 of Appendix B)

Equations B-34, B-35, and B-36 of Appendix B are used to calculate values of the relative deposition factor D/Q [$1/m^2$]. These equations use data on deposition rate D_r [1/m] provided in Figures 6 through 9 of Regulatory Guide 1.111. Values of D/Q are obtained from D_r in accordance with the prescription in paragraph 5 of Regulatory Position C.3.b. Equation B-37 of Appendix B applies to a vent release and provides a value that is a mixture of stack and ground level factors in accordance with the guidelines in Regulatory Position C.2.b of Regulatory Guide 1.111.

O.7.8 Gamma Air Dose (Section A.1.2.1 of Appendix A and Section B.5 of Appendix B)

O.7.8.1 Dose (Equation A-1 of Appendix A)

Gamma air dose is calculated by Equation A-1 of Appendix A. This equation makes use of a term referred to as gamma-χ/Q (gamma-chi-over-q) which is explained in Section 4.2.1.1. It is derived from the methodology of NUREG 0133, Section 5.3.1..
NUREG 0133 deals only with two classes of noble gas releases; those from free-standing stacks more than 80 meters high and all other noble gas releases. Equation A-1 of Appendix A contains terms representing the appropriate release point classifications discussed in Section 4.1.4. The use of three release point classifications is based on Regulatory Guide 1.111, Regulatory Position C.2. The dose factors $\mathbf{M}_i$ used in Equation A-1 of Appendix A are identical to the gamma air dose factors $\mathbf{DFB}_i$ specified in Table B-1 of Regulatory Guide 1.109.

O.7.8.2 Dose Factors (Section B.5 of Appendix B)

Calculation of gamma-χ/Q involves the use of finite plume gamma air dose factors, each of which represents dose rate at a specified point per unit of radioactivity release rate. The dose factors are calculated by Equations B-40 through B-42 of Appendix B.

Equation B-40 of Appendix B is used to calculate the finite plume gamma air dose factors for a stack release. The formula is based on Equations 6 and B-1 of Regulatory Guide 1.109. Except for notation, Equation B-40 of Appendix B and the regulatory prescription are identical.

The finite plume gamma air dose factors for a ground level release are obtained by Equation B-40 of Appendix B using the ground level joint frequency distribution data and assuming an effective release height of zero. The use of a finite plume model differs from NUREG 0133 in that ground level releases are based on a semi-infinite cloud model (see Equation 7 of Regulatory Position C.2.b). The approach used here is more realistic than that in the regulatory guide.

Equation B-42 of Appendix B is used to calculate the gamma air dose factors for a vent release. The dose factors are obtained as a mixture of stack and ground level dose factors in accordance with the guidelines in Regulatory Position C.2.b of Regulatory Guide 1.111.

O.7.8.3 Use of Unrestricted Area Boundary Values for Gamma Air Dose Factors

To assess compliance with RETS limits on gamma air dose, maximum offsite values of gamma air dose should be determined. Therefore, the gamma-χ/Q values should be determined for the offsite locations where they are maximum. However, the values provided in Table F-5b of Appendix F are for the unrestricted area boundary. They are judged to be very good approximations to the maximum offsite values.

This judgment is based on published values for finite cloud gamma air dose factors used to calculate gamma-χ/Q (see Reference 79).

Reference 79 provides values of the gamma air factor as follows:

- For 13 of the 15 noble gas radionuclides included in the ODCM.
- For each of the seven atmospheric stability classes considered in this manual (A through G).
- For two release heights (0 and 100 meters).
- As a function of distance from the release point. (Data is provided for six downwind distances over the range from 400 to 16,090 meters.)

Examination of the dose factor in Reference 79 for the sector-averaged meandering plume model reveals the following:

- For a ground level release, the dose factor always decreases as distance from the release point increases. (The plume broadens as it moves away from the release point.)

- For an elevated release, the dose factor decreases as distance from the release point increases with only a few exceptions (five exceptions among the 546 dose factors that are provided). The exceptions involve only weak gamma emitters (Xe-131m, Xe-133m, and Xe-133) in combination with certain stability classes. (The exceptions are due to portions of an elevated plume moving closer to the ground as the plume moves away from the release point. This increases dose rate at ground level.)

The gamma air dose factors used to calculate gamma-χ/Q in Appendix F are based on historical average atmospheric conditions (see Section 4.1.5). Therefore, each gamma air dose factor involves an average over all of the meteorological stability classes, nearly all of which have dose factors that decrease as distance from the release point increases. Furthermore, the gamma air dose factors in the ODCM for ground level releases or for mixed mode releases include a large ground level component. The ground level dose factors will always decrease as distance increases, and the mixed mode factors are likely to decrease with distance because of the effect of their ground level component. Thus, it is judged that a gamma-χ/Q value calculated at the unrestricted area boundary in each sector is a very good approximation to the highest offsite value for that sector.

O.7.9 Beta Air Dose (Section A.1.2.2 of Appendix A and Section B.7 of Appendix B)

Beta air dose is calculated by Equation A-2 of Appendix A. This equation is explained in Section 4.2.2. It is based on Section 5.3.1 of NUREG 0133. Like Equation A-1 of Appendix A for gamma air dose, Equation A-2 of Appendix A contains a term representing each of the three release point classifications discussed in Section 4.1.4. The use of three release point classifications is based on Regulatory Guide 1.111, Regulatory Position C.2. The dose factors $\mathbf{N_i}$ used in Equation A-2 of Appendix A are identical to the beta air dose factors $\mathbf{DFB_i}$ specified in Table B-1 of Regulatory Guide 1.109.

O.7.10 Total Body Dose (Section A.1.2.3 of Appendix A and Section B.6 of Appendix B)

Total body dose is calculated by Equation A-3 of Appendix A. This equation is explained in Section 4.2.3. It is based on Section 5.3.1 of NUREG 0133. Like Equation A-1 of Appendix A for gamma air dose, Equation A-3 of Appendix A contains a term representing each of the three release point classifications discussed in Section 4.1.4. The use of three release point classifications is based on Regulatory Guide 1.111, Regulatory Position C.2. The dose factors $\mathbf{K_i}$ used in Equation A-3 of Appendix A are identical to the beta air dose factors $\mathbf{DFB_i}$ specified in Table B-1 of Regulatory Guide 1.109.

O.7.11 Skin Dose (Section A.1.2.4 of Appendix A and Section B.7 of Appendix B)

Skin dose is calculated by Equation A-4 of Appendix A. This equation is explained in Section 4.2.4. It is based on Section 5.2.1 of NUREG 0133. Like Equation A-1 of Appendix A for gamma air dose, Equation A-4 of Appendix A contains a term representing each of the three release point classifications discussed in Section 4.1.4. The use of three release point classifications is based on Regulatory Guide 1.111, Regulatory Position C.2. The dose factors L_i and M_i used in Equation A-4 of Appendix A are identical to the gamma and beta skin dose factors DFS_i specified in Table B-1 of Regulatory Guide 1.109.

The gamma contribution to skin dose is calculated with gamma-χ/Q in the same manner as that of Equation A-1 of Appendix A to calculate gamma air dose. This approach differs from that of the regulatory guide in that a finite cloud model is used in accounting for the portion of the dose contribution to the skin due to gamma emissions. This is more realistic than the semi-infinite cloud model used in the regulatory guide.

O.7.12 Total Body Dose Rate (Section A.1.3.1 of Appendix A)

Total body dose rate is calculated by Equation A-5 of Appendix A. This equation is explained in Section 4.2.3.

O.7.13 Skin Dose Rate (Section A.1.3.2 of Appendix A)

Skin dose rate is calculated by Equation A-6 of Appendix A. This equation is explained in Section 4.2.4.

O.7.14 Dose Due to Non-Noble Gas Radionuclides (Section A.1.4 of Appendix A)

The term dose in the title of Section A.1.4 of Appendix A includes both dose and dose commitment (see Section 4.1.1). This is based on its usage in the standard Technical Specifications (see Specification 3.11.2.3 of References 2 and 3).

The dose due to non-noble gas radionuclides is calculated by Equation A-7 of Appendix A. It is based on Section 5.3.1 of NUREG 0133.

O.7.15 Ground Deposition Dose (Section A.1.4.1 of Appendix A and Section B.8 of Appendix B)

The dose due to deposited radionuclides is calculated by Equations A-7and A-8 of Appendix A. These equations are explained in Section 4.2.5. The methodology is based upon Sections 5.3.1 and 5.3.1.2 of NUREG 0133. The ground plane dose conversion factors DFG_i used in Equation A-8 of Appendix A are identical to the dose factors provided in Table E-6 of R.G. 1.109.

Equation A-8 of Appendix A uses a value of 0.7 for the shielding factor which accounts for shielding due to occupancy of structures. This value is specified in Section 1 of Appendix B, Section II; of Regulatory Guide 1.109 and Section 5.3.1.2 of NUREG 0133.

O.7.16 Inhalation Dose (Section A.1.4.2 of Appendix A and Section B.9 of Appendix B)

The dose commitment due to inhalation is calculated by Equations A-7 and A-9 of Appendix A. This equation is explained in Section 4.2.6. It is based on Sections 5.3.1 and 5.3.1.1 of NUREG 0133. The dose factors, DFA_{ija}, used in Equation A-9 of Appendix A for 10CFR50 Appendix I compliance are identical to the inhalation dose factors provided in Tables E-7 through E-10 of Regulatory Guide 1.109.

O.7.17 Food Pathways Doses (Section A.1.4.3 of Appendix A and Section B.10 of Appendix B)

The dose commitment due to food pathways is calculated by Equations A-7 and A-10 through A-15 of Appendix A. These equations are discussed in Section 4.2.7. They are based the methodology found in Sections 5.3.1.3 through 5.3.1.5 of NUREG 0133. The dose calculations for particulate account for doses resulting from dry deposition of radioactive materials onto the ground and foliage. Wet deposition is not considered in evaluating long-term-average environmental doses at Zion for the reason put forth in Regulatory Guide 1.111 (see Page 1.111-12):

O.7.18 Inhalation Dose Rate (Section A.1.5 of Appendix A)

Inhalation dose commitment rate is calculated by Equation A-16 of Appendix A. This equation is explained in Section 4.2.6.

O.8 BASES OF LIQUID EFFLUENT CALCULATIONS (SECTION A.2 and Appendix B; SECTION II)

This section presents bases of the methodology used to calculate doses and radioactivity concentrations due to releases of radioactivity in liquid effluents. The calculations use equations presented in Section A.2 of Appendix A. The equations involve transport and dose factors that are determined as described in Appendix B; Section II.

O.8.1 Dose (Section A.2.1 of Appendix A and Section B.15 of Appendix B)

The dose due to radioactive materials in liquid effluents is calculated by Equations A-17 through A-20 of Appendix A. The dose is based upon the sum of contributions from drinking water (calculated by Equations A-17, A-18 and A-19 of Appendix A) and fish (calculated by Equations A-17, A-18 and A-20 of Appendix A). The equations are explained in Section 4.3 and Section B.15 of Appendix B. They are based on Sections 4.3 and 4.3.1 of NUREG 0133.

For Zion the flow and dilution parameters in Equations A-18 and A-19 of Appendix A are determined using the Lake Michigan model. The assumptions of this model are stated in Section B.15.3.1.2 of Appendix B. The assumptions used to obtain the additional dilution parameter for water consumption ($Z = 10$) are based on judgment, and the assumptions used to obtain the dilution flow for fish consumption ($D^w = 6$) are based on the cited observational data.

O.8.2 Concentration Due to Tank Discharges (Section A.2.3 of Appendix A)

The concentration of radioactivity in tank discharges is calculated by Equation A-22 of Appendix A. The basis of this equation is explained in Section B.16 of Appendix B.

O.9 BASES OF CALCULATIONS OF DOSE DUE TO CONTAINED SOURCES (SECTION A.3)

Annual radiation doses due to contained sources of radioactivity at Zion are addressed in EH&S TSDs: 13-007, "Evaluation of Waste Classification A, B and C Storage and Staging Dose Rates"; 13-008, "Evaluation of ISFSI and Associated Processes Dose Rates" and 13-009, "Member of the Public Dose from All Onsite Sources."

O.10 BASES OF APPENDIX C, GENERIC DATA

The bases of the data in Appendix C are presented in Appendix C.

Table O-1
Comparison of Contributions of Direct Deposition and Soil Uptake Terms To Radioactivity Concentration in Vegetation

For the Grass-Cow-Milk Pathway:

	r	λ_i (hrs^{-1})	λ_w (hrs^{-1})	λ_{EI} (hrs^{-1})	t_e (hrs)
I-131	1.0	3.59E-03	2.1E-03	5.69E-03	720
Cs-134	0.2	3.83E-05	2.1E-03	2.14E-03	720
Cs-137	0.2	2.62E-06	2.1E-03	2.10E-03	720

	Y_v (kg/m^2)	B_{iv}	t_b (hrs)	P (kg/m^2)	Uptake ÷ Direct Dep
I-131	0.7	2.0E-02	1.31E+05	240	9.40E-05
Cs-134	0.7	1.0E-02	1.31E+05	240	1.03E-02
Cs-137	0.7	1.0E-02	1.31E+05	240	4.36E-02

For Produce or Leafy Vegetables Ingested by Man:

	r	λ_i (hrs^{-1})	λ_w (hrs^{-1})	λ_{EI} (hrs^{-1})	t_e (hrs)
I-131	1.0	3.59E-03	2.1E-03	5.69E-03	1440
Cs-134	0.2	3.83E-05	2.1E-03	2.14E-03	1440
Cs-137	0.2	2.62E-06	2.1E-03	2.10E-03	1440

	Y_v (kg/m^2)	B_{iv}	t_b (hrs)	P (kg/m^2)	Uptake ÷ Direct Dep
I-131	2	2.0E-02	1.31E+05	240	2.64E-04
Cs-134	2	1.0E-02	1.31E+05	240	2.42E-02
Cs-137	2	1.0E-02	1.31E+05	240	1.02E-01

Note: The parameter definitions are the same as in Regulatory Guide 1.109.

Table O-2
Principal Surface Water Uses

Station	Body of Water	Recreation[a]	Irrigation	Nearest Public Potable Receiving Water Intake
Zion[a]	Lake Michigan	Yes	Not	Lake County Cited[b] Public Water District (1.4 mile north of site and 3000 ft out in Lake)

Note: This table summarizes selected information from the reports referenced in the footnotes below. For more complete information, see the referenced reports.

[a] Per Zion ER, Section 2.3.2.2.

[b] Existence of irrigation not mentioned in Zion ER.

Table O-3
Predicted PWR Annual Doses for Selected
Liquid Effluent Pathways

Pathway/Limit	Annual Whole Body Dose (mrem/yr per reactor) Zion[a]
Eating Fish	4.5E-2
Drinking Water	1.7E-3
Shoreline Activities	1.4E-4
Swimming and Boating	1.1E-5
10 CFR 50 Objective	3

Pathway/Limit	Annual Thyroid Dose (mrem/yr per reactor) Zion[a]
Eating Fish	3.6E-2
Drinking Water	1.7E-2
Shoreline Activities	1.4E-4
Swimming and Boating	1.1E-5
10CFR50 Objective	10

Note: This table summarizes selected information from the reports referenced in the footnotes below. For more complete information, see the referenced reports.

[a] Per Zion Appendix I Report (Reference 72), Table 1.1-7. Except for drinking water, these values are based on water in the discharge canal; drinking water is assumed to be from the Lake County Illinois intake (see Appendix I Report, Table 1.1-6).