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ZION NUCLEAR POWER STATION

Annual Radiological Groundwater Protection Program Report

1 January through 31 December 2017

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I. Summary and Conclusions

In 2006, Exelon instituted a comprehensive program to evaluate the impact of station operations on groundwater and surface water in the vicinity of Zion Nuclear Power Station. This report covers both groundwater and surface water samples, collected from the environment, on station property in 2017. During that time period, 460 analyses were performed on 46 samples from 12 locations. Phase 1 of the monitoring was part of a comprehensive study initiated by Exelon to determine whether groundwater or surface water at and in the vicinity of Zion Nuclear Power Station had been adversely impacted by any releases of radionuclides. Phase 1 was conducted by Conestoga Rovers and Associates (CRA) and the conclusions were made available to state and federal regulators as well as the public in station specific reports.

Phase 2 of the RGPP was conducted by Zion*Solutions* (Exelon was responsible for the program up to 8/31/2010; Zion*Solutions* became the licensee on 9/1/2010, thus assuming responsibility for the RGPP) personnel to initiate follow up of Phase 1 and begin long-term monitoring at groundwater and surface water locations selected during Phase 1. All analytical results from Phase 2 monitoring are reported herein.

In assessing all the data gathered for this report, it was concluded that the operation of Zion Nuclear Power Station had no adverse radiological impact on the environment, and there are no known active releases into the groundwater at Zion Nuclear Power Station.

Naturally-occurring Potassium-40 (K-40) was detected in 2 groundwater samples. No other gamma-emitting radionuclides were detected at concentrations greater than their respective Lower Limits of Detection (LLDs) as specified in the Offsite Dose Calculation Manual (ODCM) in any of the groundwater or surface water samples. Strontium-90 was not detected in any of the samples analyzed in 2017.

Tritium was not detected in any groundwater or surface water samples analyzed in 2017. In the case of tritium, Zion*Solutions* specified that its laboratories achieve a lower limit of detection 10 times lower than that required by federal regulation.

Gross Alpha and Gross Beta analyses in the dissolved and suspended fractions were performed on groundwater samples during all four quarters of sampling in 2017. Gross Alpha (dissolved) and Gross Alpha (suspended) was not detected at any of the locations. Gross Beta (dissolved) was detected in all 42 samples. The concentrations ranged from 2.2 to 17.4 pCi/L. Gross Beta (suspended) was not detected in any of the groundwater locations.

Iron-55 (Fe-55), Nickel-59 (Ni-59), and Nickel-63 (Ni-63) analyses were performed in 2017 on 46 samples from 11 groundwater and 1 surface water location. All results were less than their respective LLDs.

II. Introduction

The Zion Nuclear Power Station (ZNPS), consisting of two 1,100 MWt pressurized water reactor was owned and operated by Exelon Corporation, is located in Zion, Illinois adjacent to Lake Michigan. Unit No. 1 went critical in December 1973. Unit No. 2 went critical in September 1974. The plant permanently ceased operation in January of 1998 and has been permanently defueled. The site is located in northeast Illinois on the western shore of Lake Michigan, approximately 50 miles north of Chicago, Illinois, and is currently in the final stages of decommissioning, where the outer shells of the two containment buildings, waste water treatment facility (WWTF), fore bay and the ISFSI facility are the only structures remaining.

This report covers those analyses performed by Teledyne Brown Engineering (TBE) and Environmental Inc. (Midwest Labs) on samples collected in 2017.

A. Objective of the RGPP

The long-term objectives of the RGPP are as follows:

1. Identify suitable locations to monitor and evaluate potential impacts from station operations before significant radiological impact to the environment and potential drinking water sources.

2. Understand the local hydrogeologic regime in the vicinity of the station and maintain up-to-date knowledge of flow patterns on the surface and shallow subsurface.

3. Perform routine water sampling and radiological analysis of water from selected locations.

4. Report new leaks, spills, or other events with potential radiological significance to stakeholders in a timely manner.

5. Regularly assess analytical results to identify adverse trends.

6. Take necessary corrective actions to protect groundwater resources.

7. The RGPP supports implementation of License Termination Plan (LTP) requirements for groundwater characterization and ultimately groundwater compliance under the LTP for site release.

B. Implementation of the Objectives

The objectives identified have been implemented at Zion Nuclear Power Station as discussed below:

1. Exelon and its consultant-identified locations as described in the Phase 1 study. Phase 1 studies were conducted by Conestoga Rovers and Associates (CRA) and the results and conclusions were made available to state and federal regulators as well as the public in station specific reports.

2. The Zion Nuclear Power Station reports describe the local hydrogeologic regime. Periodically, the flow patterns on the surface and shallow subsurface are updated based on ongoing measurements. The 5-year hydrogeological report was conducted in 2016.

3. Zion Nuclear Power Station will continue to perform routine sampling and radiological analysis of water from selected locations.

4. Zion Nuclear Power Station has continued using established procedures to identify and report new leaks, spills, or other detections with potential radiological significance in a timely manner.

5. Zion Nuclear Power Station staff and consulting hydrogeologist assess analytical results on an ongoing basis to identify adverse trends.

C. Program Description

1. Sample Collection

Sample locations can be found in Table A–1 and Figure A–1, Appendix A.

Groundwater and Surface Water

Samples of water are collected, managed, transported and analyzed in accordance with approved procedures following EPA methods. Groundwater samples were collected. Sample locations, sample collection frequencies and analytical frequencies are controlled in accordance with approved station procedures. Contractor and/or station personnel are trained in the collection, preservation management, and shipment of samples, as well as in documentation of sampling events. Analytical laboratories are subject to internal quality assurance programs, industry cross-check programs, as well as nuclear industry audits. Station personnel review and evaluate all analytical data

deliverables as data are received.

Analytical data results are reviewed by both station personnel and an independent hydrogeologist for adverse trends or changes to hydrogeologic conditions.

D. Characteristics of Tritium (H-3)

Tritium (chemical symbol H-3) is a radioactive isotope of hydrogen. The most common form of tritium is tritium oxide, which is also called "tritiated water". The chemical properties of tritium are essentially those of ordinary hydrogen.

Tritiated water behaves the same as ordinary water in both the environment and the body. Tritium can be taken into the body by drinking water, breathing air, eating food, or absorption through skin. Once tritium enters the body, it disperses quickly and is uniformly distributed throughout the body. Tritium is excreted primarily through urine with a clearance rate characterized by an effective biological half-life of about 14 days. Within one month or so after ingestion, essentially all tritium is cleared. Organically bound tritium (tritium that is incorporated in organic compounds) can remain in the body for a longer period.

Tritium is produced naturally in the upper atmosphere when cosmic rays strike air molecules. Tritium is also produced during nuclear weapons explosions, as a by-product in reactors producing electricity, and in special production reactors, where the isotopes lithium-7 and/or boron-10 are activated to produce tritium. Like normal water, tritiated water is colorless and odorless. Tritiated water behaves chemically and physically like non-tritiated water in the subsurface, and therefore tritiated water will travel at the same velocity as the average groundwater velocity.

Tritium has a half-life of approximately 12.3 years. It decays spontaneously to Helium-3 (He-3). This radioactive decay releases a beta particle (low-energy electron). The radioactive decay of tritium is the source of the health risk from exposure to tritium. Tritium is one of the least dangerous radionuclides because it emits very weak radiation and leaves the body relatively quickly. Since tritium is almost always found as water, it goes directly into soft tissues and organs. The associated dose to these tissues is generally uniform and is dependent on the water content of the specific tissue.

III. Program Description

A. Sample Analysis

This section describes the general analytical methodologies used by TBE to analyze the environmental samples for radioactivity for the Zion Nuclear Power Station RGPP in 2017.
In order to achieve the stated objectives, the current program includes the following analyses:

1. Concentrations of gamma emitters in groundwater and surface water

2. Concentrations of strontium in groundwater and surface water

3. Concentrations of tritium in groundwater and surface water

4. Concentration of gross alpha and gross beta in groundwater and surface water

5. Concentrations of Iron-55 in groundwater and surface water

6. Concentrations of Nickel-59 and Nickel-63 in groundwater and surface water

B. Data Interpretation

The radiological data collected prior to Zion Nuclear Power Station becoming operational were used as a baseline with which these operational data were compared. For the purpose of this report, Zion Nuclear Power Station was considered operational at initial criticality. Several factors were important in the interpretation of the data:

1. <u>Lower Limit of Detection and Minimum Detectable Concentration</u>

   The lower limit of detection (LLD) is specified by federal regulation as a minimum sensitivity value that must be achieved routinely by the analytical parameter.

2. <u>Laboratory Measurements Uncertainty</u>

   The estimated uncertainty in measurement of tritium in environmental samples is frequently on the order of 50% of the measurement value.

   Statistically, the exact value of a measurement is expressed as a

range with a stated level of confidence. The convention is to report results with a 95% level of confidence. The uncertainty comes from calibration standard stated accuracy, sample volume or weight measurements, sampling uncertainty and other factors. Zion*Solutions* reports the uncertainty of a measurement created by statistical process (counting error) as well as all sources of error (Total Propagated Uncertainty or TPU). Each result has two values calculated. Zion*Solutions* reports the TPU by following the result with plus or minus ± the estimated sample standard deviation, as TPU, that is obtained by propagating all sources of analytical uncertainty in measurements.
Analytical uncertainties are reported at the 95% confidence level in this report for reporting consistency with the AREOR.

C. Background Analysis

A pre-operational Radiological Environmental Monitoring Program (pre-operational REMP) was conducted to establish background radioactivity levels prior to operation of the Station. The environmental media sampled and analyzed during the pre-operational REMP were atmospheric radiation, fall-out, domestic water, surface water, marine life, and foodstuffs. The results of the monitoring were detailed in the report entitled, Environmental Radiological Monitoring for Zion Nuclear Power Station, Commonwealth Edison Company, Annual Report 1973, issued May 1974.

The pre-operational REMP contained analytical results from samples collected from the surface water and groundwater.

Tritium levels in Lake Michigan water were studied in the vicinity of Zion Station throughout 1970. The concentration of tritium in the surface water samples from the Lake at Zion ranged from approximately 311 ± 20 pCi/L to 374 ± 34 pCi/L and averaged 340 pCi/L. There was no statistical difference in average tritium concentrations among the stations (eight stations from Kenosha to Waukegan).

Prior to 1998, surface water samples were collected at the following six locations along Lake Michigan:

- Kenosha, Wisconsin (intake located 10 miles north of the station)
- Lake County Public Water District (intake located 1.1 miles north of the Station)
- Waukegan, Illinois (intake located 6 miles south of the Station)
- North Chicago, Illinois (intake located 10 miles south of the Station)
- Great Lakes NTS (intake located 13 miles south of the Station)

- Lake Forest, Illinois (intake located 16.5 miles south of the Station)

After 1998, surface water samples were collected at the following four locations along Lake Michigan:

- Kenosha, Wisconsin (intake located 10 miles north of the station)
- Lake County Public Water District (intake located 1.1 miles north of the Station)
- Waukegan, Illinois (intake located 6 miles south of the Station)
- Lake Forest, Illinois (intake located 16.5 miles south of the Station)

Lake Michigan surface water data are collected as part of the REMP. Tritium concentrations in surface water samples from Lake Michigan taken between 1973 and 2017 have ranged from non-detect to 660 pCi/L.

Groundwater was collected from one off-site well on a quarterly basis. Gamma isotopic, Iron-55, Nickel-59, Nickel-63, Strontium-90 and tritium analyses were performed on all samples. Fe-55, Ni-59, Ni-63, Sr-90, tritium and gamma emitters were below their respective LLDs.

1. Background Concentrations of Tritium

   The purpose of the following discussion is to summarize background measurements of tritium in various media performed by others. Additional detail may be found by consulting references (CRA 2006).

   a. Tritium Production

      Tritium is created in the environment from naturally-occurring processes both cosmic and subterranean, as well as from anthropogenic (i.e., man-made) sources. In the upper atmosphere, "Cosmogenic" tritium is produced from the bombardment of stable nuclides and combines with oxygen to form tritiated water, which will then enter the hydrologic cycle. Below ground, "lithogenic" tritium is produced by the bombardment of natural lithium present in crystalline rocks by neutrons produced by the radioactive decay of naturally abundant uranium and thorium. Lithogenic production of tritium is usually negligible compared to other sources due to the limited abundance of lithium in rock. The lithogenic tritium is introduced directly to groundwater.

A major anthropogenic source of tritium and Sr-90 comes from the former atmospheric testing of thermonuclear weapons. Levels of tritium in precipitation increased significantly during the 1950s and early 1960s, and later with additional testing, resulting in the release of significant amounts of tritium to the atmosphere. The Canadian heavy water nuclear power reactors, other commercial power reactors, nuclear research and weapons production continue to influence tritium concentrations in the environment.

b. Precipitation Data

Precipitation samples are routinely collected at stations around the world for the analysis of tritium and other radionuclides. Two publicly available databases that provide tritium concentrations in precipitation are Global Network of Isotopes in Precipitation (GNIP) and USEPA's RadNet database. GNIP provides tritium precipitation concentration data for samples collected worldwide from 1960 to 2018. RadNet provides tritium precipitation concentration data for samples collected at stations throughout the U.S. from 1960 up to and including 2018. Based on GNIP data for sample stations located in the U.S. Midwest, tritium concentrations peaked around 1963. This peak, which approached 10,000 pCi/L for some stations, coincided with the atmospheric testing of thermonuclear weapons. Tritium concentrations in surface water showed a sharp decline up until 1975 followed by a gradual decline since that time. Tritium concentrations in Midwest precipitation have typically been below 100 pCi/L since around 1980. Tritium concentrations in wells may still be above the 200 pCi/L detection limit from the external causes described above. Water from previous years and decades is naturally captured in groundwater, so some well water sources today are affected by the surface water from the 1960s that were elevated in tritium.

c. Surface Water Data

Tritium concentrations are routinely measured in large surface water bodies, including Lake Michigan and the Mississippi River. Illinois surface water data were typically less than 100 pCi/L.

The USEPA RadNet surface water data typically has a

reported 'Combined Standard Uncertainty' of 35 to 50 pCi/L. According to USEPA, this corresponds to a ± 70 to 100 pCi/L 95% confidence bound on each given measurement. Therefore, the typical background data provided may be subject to measurement uncertainty of approximately ± 70 to 100 pCi/L.

The radio-analytical laboratory is counting tritium results to an Exelon specified LLD of 200 pCi/L. Typically, the lowest positive measurement will be reported within a range of 40 – 240 pCi/L or 140 ± 100 pCi/L. Clearly, these sample results cannot be distinguished as different from background at this concentration.

IV. Results and Discussion

A. Missed Samples

Sometime after the first half of May, Well Number 9 was damaged during demolition of the Spent Fuel Building and samples for the 3rd and 4th quarter could not be collected. After the containment structures are demolished, Well Number 9 will be permanently abandoned.

B. Groundwater and Surface Water Results

Groundwater and Surface Water

Samples were collected from on-site wells throughout the year in accordance with the station radiological groundwater protection program. Analytical results and anomalies are discussed below:

Tritium

Samples from all locations were analyzed for tritium activity (Table B–I.1, Appendix B) (Table B–II.1, Appendix B). Tritium was not detected in any groundwater or surface water samples analyzed. Zion Nuclear Power Station does not have any off-site wells.

Strontium

Sr-90 was not detected in any of the samples analyzed in 2017.

Iron

Iron-55 was not detected in any of the samples analyzed in 2017.

Nickel

Nickel-59 and Nickel-63 were not detected in any of the samples analyzed in 2017.

Gross Alpha and Gross Beta (Dissolved and Suspended)

Gross Alpha and Gross Beta analyses in the dissolved and suspended fractions were performed on groundwater water samples during all four quarters of sampling in 2017. Gross Alpha (dissolved) and Gross Alpha (suspended) were not detected at any of the locations. Gross Beta (dissolved) was detected in all 42 samples. The concentrations ranged from 2.2 to 17.4 pCi/L. Gross Beta (suspended) was not detected in any of the groundwater locations.

Gamma Emitters

Naturally-occurring K-40 was detected in 2 of 46 samples analyzed. The concentrations ranged from 61 to 72 pCi/L. All other gamma-emitting radionuclides were not detected in either groundwater or surface water samples analyzed (Table B–I.2, Appendix B) (Table B–II.1, Appendix B).

Other Naturally-occurring and Non-plant-Related Isotopes

Gross beta activity, present in the environment, may be detected from the following sources: Beryllium-7 (Be-7), Potasium-40 (K-40) and the decay products of naturally-occurring uranium and thorium (radon daughters), for example. There are also non-Zion plant-related, manmade sources such as Cesium-137 (Cs-137) and Stronium-90 (Sr-90) (sources: above ground testing of nuclear weapons, commercial plant accidents such as Chernobyl and Fukashima). Tritium, which is man-made in fission reactors, but also occurs naturally, is created in the upper atmosphere when cosmic radiations interact with nitrogen atoms, and reaches the ground by precipitation. Although a beta (electron) emitter, tritium is not detected by gross beta analysis due to the weak energy of the beta particle emitted, and the nature of gross beta analysis. It is, however, measured accurately at very low levels using liquid scintillation analysis.

Normally, gross beta is used as a screening tool and when elevated levels are identified, further investigative analysis follows. The Zion GWPP program requires completing these additional analysis for Cs-137, Sr-90, H-3, and other beta, gamma and alpha emitters specifically, in addition to analyzing for gross beta and regardless of gross beta levels, as it is not unusual to see spikes in natural gross beta due to a sudden release of radon or other natural radionuclides from soil or

well/surface water, or washout from a heavy rain event.

C. Drinking Water Well Survey

A drinking water well survey was conducted during the summer 2006 by CRA (CRA 2006) around the Zion Nuclear Power Station.

D. Summary of Results – Inter-Laboratory Comparison Program

Inter-Laboratory Comparison Program results for TBE are presented in the AREOR.

E. Leaks, Spills, and Releases

There were no leaks, spills or non-permitted releases in 2017.

F. Trends

There are no previously identified plumes; therefore, there are no trends.

G. Investigations

There are currently no investigations at this time.

H. Actions Taken

1. Compensatory Actions

   There have been no station events requiring compensatory actions at the Zion Nuclear Power Station.

2. Installation of Monitoring Wells

   No new wells were required to be installed.

3. Actions to Recover/Reverse Plumes

   There have been no station events requiring actions to recover/reverse any plumes.

APPENDIX A

ZION WELL LOCATIONS

TABLE A-1: Sampling Locations and Distance for the Radiological Groundwater Protection Program, Zion Station, 2017

Site	Site Type	Temporary/Permanent	Distance
MW-ZN-01S	Monitoring Well	Permanent	On-Site
MW-ZN-02S	Monitoring Well	Permanent	On-Site
MW-ZN-03S	Monitoring Well	Permanent	On-Site
MW-ZN-04S	Monitoring Well	Permanent	On-Site
MW-ZN-05S	Monitoring Well	Permanent	On-Site
MW-ZN-06S	Monitoring Well	Permanent	On-Site
MW-ZN-07S	Monitoring Well	Permanent	On-Site
MW-ZN-08S	Monitoring Well	Permanent	On-Site
MW-ZN-09S	Monitoring Well	Permanent	On-Site
MW-ZN-10S	Monitoring Well	Permanent	On-Site
MW-ZN-11S	Monitoring Well	Permanent	On-Site
SW-ZN-01	Surface Water	Lake Michigan	On-Site

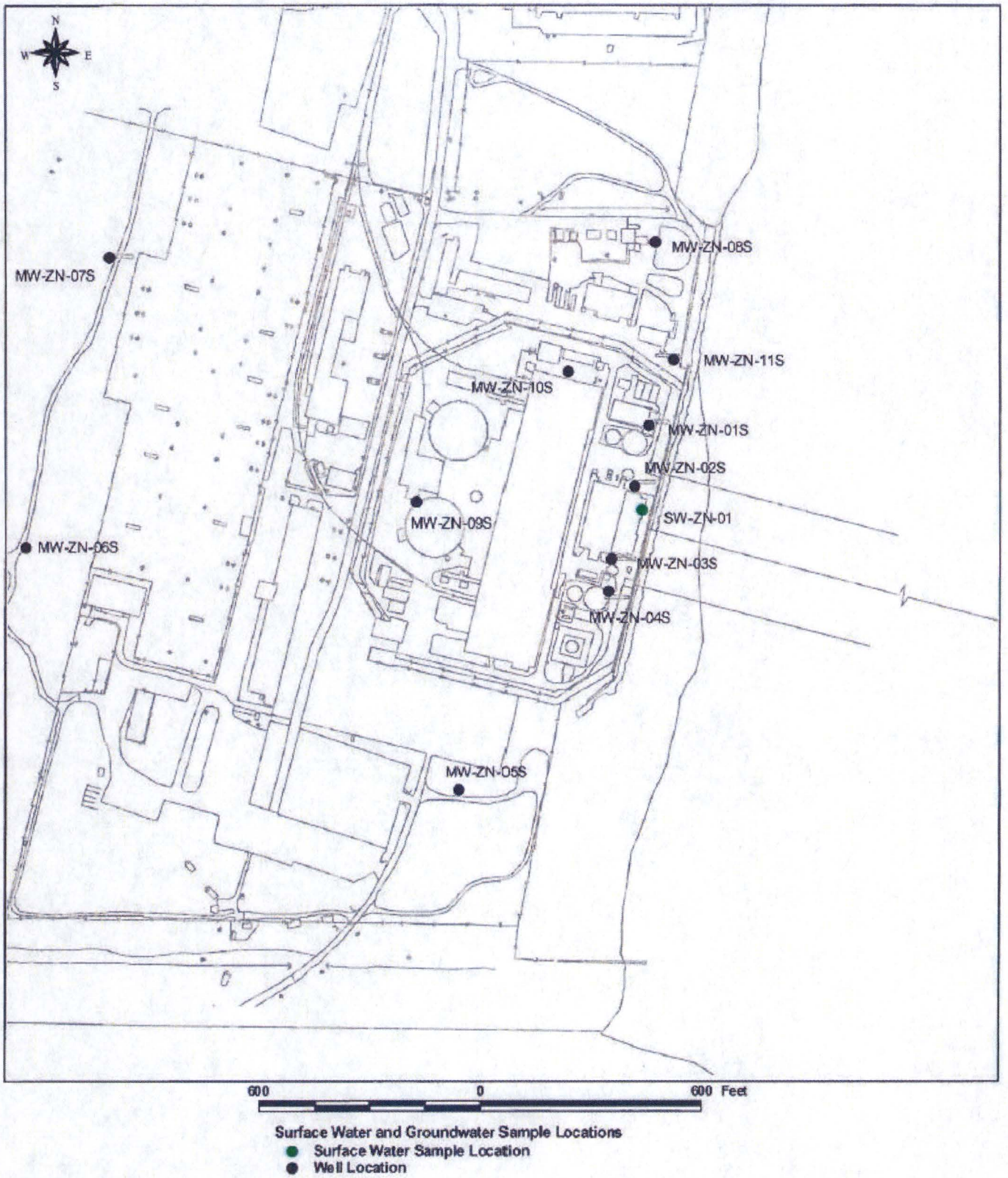

Figure A-1

Radiological Ground Water Protection Program
Groundwater and Surface Water Locations of the Zion Station, 2017

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APPENDIX B

DATA TABLES

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TABLE B-I.1

Concentrations of Tritium, Strontium, Gross Alpha and Gross Beta in Groundwater Samples Collected in the Vicinity of Zion Nuclear Power Station, 2017

Results in Units of pCi/liter ± 2 Sigma

SITE	COLLECTION DATE	H-3	Sr-90	Gr-A (Dis)	Gr-A (Sus)	Gr-B (Dis)	Gr-B (Sus)
MW-ZN-01S	03/18/17	< 188	< 0.5	< 1.7	< 0.7	7.5 ± 1.4	< 1.6
MW-ZN-01S	05/06/17	< 197	< 0.6	< 0.9	< 0.6	6.5 ± 1.1	< 1.5
MW-ZN-01S	08/18/17	< 177	< 0.8	< 1.7	< 0.6	9.6 ± 1.3	< 1.5
MW-ZN-01S	11/05/17	< 170	< 0.8	< 1.3	< 0.7	7.5 ± 1.1	< 1.6
MW-ZN-02S	03/24/17	< 186	< 0.5	< 1.4	< 0.7	7.1 ± 1.2	< 1.6
MW-ZN-02S	05/06/17	< 195	< 0.7	< 1.9	< 0.6	6.2 ± 1.0	< 1.5
MW-ZN-02S	08/18/17	< 170	< 0.7	< 1.2	< 0.6	2.7 ± 0.7	< 1.5
MW-ZN-02S	11/05/17	< 183	< 0.6	< 1.4	< 0.7	17.4 ± 1.5	< 1.6
MW-ZN-03S	03/24/17	< 192	< 0.4	< **4.2**	< 0.7	12.4 ± 1.9	< 1.6
MW-ZN-03S	05/06/17	< 193	< 0.7	< 1.2	< 0.6	7.0 ± 1.3	< 1.5
MW-ZN-03S	08/19/17	< 175	< 0.7	< 1.2	< 0.6	3.7 ± 0.8	< 1.5
MW-ZN-03S	11/05/17	< 184	< 0.6	< 2.1	< 0.7	12.2 ± 1.6	< 1.6
MW-ZN-04S	03/24/17	< 194	< 0.5	< 2.4	< 0.7	11.4 ± 1.7	< 1.6
MW-ZN-04S	05/06/17	< 194	< 0.7	< 0.8	< 0.6	8.1 ± 1.2	< 1.5
MW-ZN-04S	08/19/17	< 180	< 0.9	< 2.2	< 0.6	10.6 ± 1.5	< 1.5
MW-ZN-04S	11/12/17	< 186	< 0.6	< 1.5	< 0.7	13.9 ± 1.5	< 1.6
MW-ZN-05S	03/18/17	< 195	< 0.4	< 1.6	< 0.7	2.2 ± 1.1	< 1.6
MW-ZN-05S	05/06/17	< 194	< 0.7	< 0.7	< 0.6	5.3 ± 1.1	< 1.6
MW-ZN-05S	08/19/17	< 174	< 0.7	< 1.5	< 0.6	5.3 ± 1.2	< 1.5
MW-ZN-05S	11/04/17	< 182	< 0.6	< 1.3	< 0.7	4.9 ± 1.1	< 1.6
MW-ZN-06S	03/24/17	< 194	< 0.6	< 1.6	< 1.1	3.5 ± 1.2	< 1.9
MW-ZN-06S	05/14/17	< 194	< 0.9	< 2.9	< 0.5	5.3 ± 1.3	< 1.4
MW-ZN-06S	08/19/17	< 174	< 0.6	< 1.7	< 0.7	6.8 ± 1.4	< 1.5
MW-ZN-06S	11/12/17	< 187	< 0.5	< 1.4	< 0.7	5.0 ± 1.2	< 1.6
MW-ZN-07S	03/19/17	< 192	< 0.9	< 1.2	< 1.4	6.6 ± 1.2	< 2.2
MW-ZN-07S	05/07/17	< 192	< 0.6	< 3.0	< 0.5	3.3 ± 1.3	< 1.4
MW-ZN-07S	08/20/17	< 175	< 0.7	< 2.0	< 0.7	5.8 ± 1.4	< 1.5
MW-ZN-07S	11/12/17	< 182	< 0.4	< 2.1	< 0.5	5.4 ± 1.3	< 1.6
MW-ZN-08S	03/18/17	< 194	< 0.5	< 1.1	< 1.6	5.8 ± 1.1	< 2.4
MW-ZN-08S	05/14/17	< 195	< 1.0	< 2.6	< 0.5	4.3 ± 1.3	< 1.4
MW-ZN-08S	08/18/17	< 180	< 0.7	< 1.5	< 0.6	4.0 ± 1.1	< 1.5
MW-ZN-08S	11/04/17	< 183	< 0.5	< 1.6	< 0.5	6.3 ± 1.1	< 1.6
MW-ZN-09S	03/19/17	< 192	< 0.5	< 0.5	< 1.5	3.9 ± 0.7	< 2.2
MW-ZN-09S	05/07/17	< 199	< 0.6	< 1.8	< 0.5	6.8 ± 1.2	< 1.4
MW-ZN-10S	03/19/17	< 195	< 0.4	< 0.9	< 1.1	8.1 ± 1.0	< 1.9
MW-ZN-10S	05/07/17	< 190	< 0.9	< 1.6	< 0.5	8.9 ± 1.5	< 1.4
MW-ZN-10S	08/18/17	< 174	< 0.7	< 2.0	< 0.6	10.6 ± 1.4	< 1.5
MW-ZN-10S	11/05/17	< 183	< 0.6	< 1.6	< 0.5	6.8 ± 1.1	< 1.6
MW-ZN-11S	03/18/17	< 193	< 0.5	< 1.1	< 0.7	7.8 ± 1.2	< 1.6
MW-ZN-11S	05/14/17	< 189	< 0.7	< 1.8	< 0.5	5.3 ± 1.4	< 1.4
MW-ZN-11S	08/18/17	< 177	< 0.7	< 2.2	< 0.6	8.0 ± 1.4	< 1.5
MW-ZN-11S	11/04/17	< 188	< 0.5	< 0.9	< 0.5	7.0 ± 1.3	< 1.6

BOLD Vales = Unable to meet detection limits due to high solids content

TABLE B-I.2 **Concentrations of Gamma-Emitters in Groundwater Samples Collected in the Vicinity of Zion Nuclear Station, 2017**

Results in Units of pCi/liter ± 2 Sigma

SITE	COLLECTION DATE	K-40	Co-60	Nb-94	Sb-125	Cs-134	Cs-137
MW-ZN-01S	03/18/17	< 12	< 1	< 2	< 4	< 2	< 1
MW-ZN-01S	05/06/17	< 54	< 5	< 5	< 14	< 6	< 5
MW-ZN-01S	08/18/17	< 42	< 4	< 4	< 14	< 5	< 4
MW-ZN-01S	11/05/17	< 40	< 3	< 2	< 7	< 3	< 3
MW-ZN-02S	03/24/17	< 34	< 2	< 2	< 5	< 2	< 2
MW-ZN-02S	05/06/17	< 46	< 5	< 5	< 13	< 6	< 5
MW-ZN-02S	08/18/17	< 41	< 5	< 5	< 15	< 5	< 5
MW-ZN-02S	11/05/17	< 56	< 3	< 3	< 7	< 3	< 3
MW-ZN-03S	03/24/17	< 35	< 2	< 2	< 5	< 2	< 2
MW-ZN-03S	05/06/17	< 80	< 4	< 5	< 15	< 5	< 6
MW-ZN-03S	08/19/17	< 51	< 4	< 5	< 14	< 5	< 5
MW-ZN-03S	11/05/17	< 33	< 3	< 3	< 8	< 4	< 3
MW-ZN-04S	03/24/17	< 48	< 3	< 2	< 6	< 3	< 2
MW-ZN-04S	05/06/17	< 58	< 6	< 6	< 15	< 6	< 6
MW-ZN-04S	08/19/17	< 47	< 5	< 5	< 14	< 5	< 5
MW-ZN-04S	11/12/17	< 45	< 3	< 3	< 7	< 3	< 3
MW-ZN-05S	03/18/17	< 33	< 2	< 2	< 5	< 2	< 2
MW-ZN-05S	05/06/17	< 49	< 4	< 5	< 13	< 5	< 5
MW-ZN-05S	08/19/17	< 49	< 5	< 4	< 14	< 4	< 5
MW-ZN-05S	11/04/17	< 64	< 3	< 3	< 8	< 3	< 3
MW-ZN-06S	03/24/17	< 52	< 2	< 2	< 6	< 2	< 2
MW-ZN-06S	05/14/17	< 105	< 5	< 5	< 14	< 5	< 6
MW-ZN-06S	08/19/17	< 73	< 4	< 4	< 14	< 5	< 5
MW-ZN-06S	11/12/17	< 25	< 3	< 3	< 7	< 3	< 3
MW-ZN-07S	03/19/17	< 19	< 2	< 2	< 6	< 2	< 2
MW-ZN-07S	05/07/17	< 89	< 6	< 5	< 14	< 6	< 5
MW-ZN-07S	08/20/17	< 86	< 5	< 5	< 14	< 6	< 6
MW-ZN-07S	11/12/17	< 21	< 2	< 3	< 8	< 3	< 3
MW-ZN-08S	03/18/17	< 40	< 2	< 2	< 4	< 2	< 2
MW-ZN-08S	05/14/17	< 53	< 5	< 5	< 13	< 5	< 6
MW-ZN-08S	08/18/17	< 53	< 4	< 5	< 14	< 7	< 5
MW-ZN-08S	11/04/17	< 41	< 6	< 6	< 15	< 7	< 5
MW-ZN-09S	03/19/17	< 18	< 2	< 2	< 6	< 2	< 2
MW-ZN-09S	05/07/17	< 63	< 5	< 5	< 14	< 5	< 6
MW-ZN-10S	03/19/17	72 ± 30	< 3	< 2	< 8	< 3	< 3
MW-ZN-10S	05/07/17	< 44	< 4	< 5	< 13	< 5	< 5
MW-ZN-10S	08/18/17	< 46	< 4	< 4	< 15	< 5	< 5
MW-ZN-10S	11/05/17	< 49	< 5	< 4	< 14	< 4	< 5
MW-ZN-11S	03/18/17	< 20	< 2	< 2	< 5	< 2	< 2
MW-ZN-11S	05/14/17	< 43	< 3	< 3	< 15	< 5	< 5
MW-ZN-11S	08/18/17	< 38	< 6	< 4	< 15	< 6	< 5
MW-ZN-11S	11/04/17	61 ± 40	< 4	< 4	< 12	< 5	< 4

TABLE B-I.3 **Concentrations of Iron-55, Nickel-59, and Nickel-63 in Groundwater Samples Collected in the Vicinity of Zion Nuclear Station, 2017**

Results in Units of pCi/liter ± 2 Sigma

SITE	COLLECTION DATE	Fe-55	Ni-59	Ni-63
MW-ZN-01S	03/18/17	< 178	< 38	< 4.7
	05/06/17	< 180	< 67	< 3.3
	08/18/17	< 184	< 38	< 3.8
	11/05/17	< 188	< 66	< 4.4
MW-ZN-02S	03/24/17	< 180	< 88	< 4.6
	05/06/17	< 190	< 64	< 3.3
	08/18/17	< 195	< 41	< 3.7
	11/05/17	< 193	< 90	< 4.5
MW-ZN-03S	03/24/17	< 190	< 80	< 3.8
	05/06/17	< 171	< 54	< 3.0
	08/19/17	< 196	< 40	< 3.0
	11/05/17	< 199	< 80	< 3.9
MW-ZN-04S	03/24/17	< 179	< 71	< 4.7
	05/06/17	< 158	< 107	< 3.3
	08/19/17	< 198	< 39	< 3.6
	11/12/17	< 197	< 87	< 4.4
MW-ZN-05S	03/18/17	< 173	< 67	< 4.0
	05/06/17	< 186	< 76	< 3.4
	08/19/17	< 192	< 28	< 3.8
	11/04/17	< 192	< 58	< 4.6
MW-ZN-06S	03/24/17	< 198	< 53	< 4.8
	05/14/17	< 154	< 120	< 3.5
	08/19/17	< 164	< 68	< 3.9
	11/12/17	< 118	< 84	< 4.6
MW-ZN-07S	03/19/17	< 199	< 27	< 4.7
	05/07/17	< 144	< 58	< 3.4
	08/20/17	< 150	< 61	< 3.9
	11/12/17	< 128	< 57	< 4.5
MW-ZN-08S	03/18/17	< 193	< 90	< 4.9
	05/14/17	< 164	< 124	< 3.3
	08/18/17	< 198	< 19	< 3.7
	11/04/17	< 141	< 94	< 4.3
MW-ZN-09S	03/19/17	< 194	< 72	< 3.9
	05/07/17	< 196	< 55	< 3.3
MW-ZN-10S	03/19/17	< 195	< 65	< 4.9
	05/07/17	< 180	< 108	< 3.4
	08/18/17	< 178	< 60	< 3.8
	11/05/17	< 150	< 71	< 4.4
MW-ZN-11S	03/18/17	< 197	< 60	< 4.0
	05/14/17	< 113	< 58	< 3.3
	08/18/17	< 194	< 85	< 3.8
	11/04/17	< 144	< 47	< 4.8

TABLE B-II.1

Concentrations of Tritium, Strontium, Gross Alpha and Gross Beta in Surface Water Samples Collected in the Vicinity of Zion Nuclear Power Station, 2017

Results in Units of pCi/liter ± 2 Sigma

SITE	COLLECTION DATE	H-3	Sr-90	Gr-A (Dis)	Gr-A (Sus)	Gr-B (Dis)	Gr-B (Sus)
SW-ZN-01	03/24/17	< 191	< 0.6	< 0.7	< 0.7	3.7 ± 0.8	< 1.6
SW-ZN-01	05/06/17	< 193	< 0.9	< 1.0	< 0.5	2.0 ± 0.8	< 1.4
SW-ZN-01	08/19/17	< 179	< 0.9	< 1.2	< 0.6	3.4 ± 0.8	< 1.5
SW-ZN-01	11/05/17	< 186	< 0.6	< 0.5	< 0.5	2.3 ± 0.7	< 1.6

TABLE B-II.2 **Concentrations of Gamma-Emitters in Surface Water Samples Collected in the Vicinity of Zion Nuclear Station, 2017**

Results in Units of pCi/liter ± 2 Sigma

SITE	COLLECTION DATE	K-40	Co-60	Nb-94	Sb-125	Cs-134	Cs-137
SW-ZN-01	03/18/17	< 48	< 2	< 2	< 6	< 2	< 2
SW-ZN-01	05/06/17	< 41	< 4	< 5	< 14	< 6	< 5
SW-ZN-01	08/18/17	< 102	< 5	< 5	< 14	< 6	< 5
SW-ZN-01	11/05/17	< 32	< 4	< 4	< 12	< 4	< 5

TABLE B-II.3 **Concentrations of Iron-55, Nickel-59, and Nickel-63 in Surface Water Samples Collected in the Vicinity of Zion Nuclear Station, 2017**

Results in Units of pCi/Liter ± 2 Sigma

SITE	COLLECTION DATE	Fe-55	Ni-59	Ni-63
SW-ZN-01	03/24/17	< 199	< 85	< 4.6
SW-ZN-01	05/06/17	< 191	< 137	< 3.3
SW-ZN-01	08/19/17	< 174	< 46	< 4.4
SW-ZN-01	11/05/17	< 133	< 35	< 4.9

APPENDIX F

ERRATA DATA

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APPENDIX F

ERRATA to 2012 to 2014 ANNUAL RADIOLOGICAL ENVIRONMENTAL OPERATING REPORTS (AREOR)

Statements made in the 2012 to 2014 AREORs erroneously identified sample results (for pathways including vegetation, sediment, fish, etc.) as being indistinguishable from background levels when these had either not been sampled for, or for which there were no control locations sampled in comparison with indicator locations.

Corrections with change bars are attached. 2012 AREOR correction:

INTRODUCTION

Units 1 and 2 of the Zion Station, located in Zion, Illinois adjacent to Lake Michigan, are 1100 MWe (3520 MWt) Westinghouse pressurized water reactors. The plant permanently ceased operation in February of 1998 and has been permanently defueled.

The station was designed to keep releases to the environment at levels below those specified in the regulations. Historical data has been established that Zion, as a fully operational facility, did not contribute appreciable doses to the surrounding public. Sampling results for 2012 showed minimal releases above background for a variety of monitored exposure pathways with control locations.

Liquid effluents from Zion Station are released to Lake Michigan in controlled batches after radioassay of each batch and continuously through a monitored pathway. There are no routine noble gas releases. Due to decay, iodine is no longer present. The only noble gas that remains is Kr85 captured in the spent fuel assemblies stored in the fuel pool in the fuel building The results of effluent analyses are summarized on a monthly basis and reported to the Nuclear Regulatory Commission as required per Technical Specifications. Airborne concentrations of noble gases and particulate radioactivity in offsite areas are calculated using effluent and meteorological data.

Environmental monitoring was conducted by sampling at indicator and control (background) locations in the vicinity of the Zion Station to measure changes in radiation or radioactivity levels that may be attributable to the station. If significant changes attributable to Zion Station are measured, these changes are correlated with effluent releases.

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2013 AREOR Correction:

INTRODUCTION

Units 1 and 2 of the Zion Station, located in Zion, Illinois adjacent to Lake Michigan, are 1100 MWe (3520 MWt) Westinghouse pressurized water reactors. The plant permanently ceased operation in February of 1998 and has been permanently defueled.

The station was designed to keep releases to the environment at levels below those specified in the regulations. Historical data has been established that Zion, as a fully operational facility, did not contribute appreciable doses to the surrounding public. Sampling results for 2013 showed minimal releases above background for a variety of monitored exposure pathways with control locations.

Liquid effluents from Zion Station are released to Lake Michigan in controlled batches after radioassay of each batch and continuously through a monitored pathway. There are no routine noble gas releases. Due to decay, iodine is no longer present. The only noble gas that remains is Kr-85 captured in the spent fuel assemblies stored in the fuel pool in the fuel building The results of effluent analyses are summarized on a monthly basis and reported to the Nuclear Regulatory Commission as required per Technical Specifications. Airborne concentrations of noble gases and particulate radioactivity in offsite areas are calculated using effluent and meteorological data.

Currently Zion Station is undergoing decommissioning. During the decommissioning process, containerized waste will be temporarily maintained at designated locations onsite. The designated locations are located in a manner to minimize the direct radiation exposure to the public at or near the site boundary.

Environmental monitoring was conducted by sampling at indicator and control (background) locations in the vicinity of the Zion Station to measure changes in radiation or radioactivity levels that may be attributable to the station. If significant changes attributable to Zion Station are measured, these changes are correlated with effluent releases or direct radiation from containerized waste.

2014 AREOR Correction:

INTRODUCTION

Units 1 and 2 of the Zion Station, located in Zion, Illinois adjacent to Lake Michigan, are 1100 MWe (3520 MWt) Westinghouse pressurized water reactors. The plant permanently ceased operation in February of 1998 and has been permanently defueled.

The station was designed to keep releases to the environment at levels below those specified in the regulations. Historical data has been established that Zion, as a fully operational facility, did not contribute appreciable doses to the surrounding public. Sampling results for 2014 showed minimal releases above background for a variety of monitored exposure pathways with control locations .

Liquid effluents from Zion Station are released to Lake Michigan in controlled batches after radioassay of each batch and continuously through a monitored pathway. There are no routine noble gas releases. Due to decay, iodine is no longer present. The only noble gas that remains is Kr-85 captured in the spent fuel assemblies stored in the fuel pool in the fuel building The results of effluent analyses are summarized on a monthly basis and reported to the Nuclear Regulatory Commission as required per Technical Specifications. Airborne concentrations of noble gases and particulate radioactivity in offsite areas are calculated using effluent and meteorological data.

Currently Zion Station is undergoing decommissioning. During the decommissioning process, containerized waste is temporarily maintained at designated locations onsite. The designated locations are located in a manner to minimize the direct radiation exposure to the public at or near the site boundary.

Environmental monitoring was conducted by sampling at indicator and control (background) locations in the vicinity of the Zion Station to measure changes in radiation or radioactivity levels that may be attributable to the station. If significant changes attributable to Zion Station are measured, these changes are correlated with effluent releases or direct radiation from containerized waste.

ISFSI operations were conducted in 2014 which attributed direct radiation dose in the form of gamma and neutron to members of the public. The results of the calculated dose from direct radiation from the ISFSI has been calculated and included in this report. In addition to the dose contributed to members of the public. A special case exists for members of the public working onsite in the switchyard area. Switchyard worker dose results are also included in this report.