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# ZION NUCLEAR POWER STATION

## Annual Radiological Environmental Operating Report

1 January through 31 December 2018

**Prepared By**  
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Zion Nuclear Power Station  
Zion, IL 60099

**May 2019**

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## I. Summary and Conclusions

This report on the Radiological Environmental Monitoring Program (REMP) conducted for the Zion Nuclear Power Station (ZNPS) by ZionSolutions (ZS) covers the period 1 January 2018 through 31 December 2018. During that time period, 574 analyses were performed on 525 samples. In assessing all the data gathered for this report and comparing these results with preoperational data, it was concluded that the operation of ZNPS had no adverse radiological impact on the environment.

Public water samples were analyzed for concentrations of gross beta, tritium and gamma-emitting nuclides. No fission or activation products were detected. Gross beta activities detected were consistent with those detected in previous years, and with levels of natural radioactivity typically observed in the environment.

Food product samples/vegetation were analyzed for concentrations of gamma-emitting nuclides. No fission or activation products were detected.

Fish (commercially and recreationally important species) and sediment samples were analyzed for concentrations of gamma-emitting nuclides. No Cesium-137 (Cs-137) activity was detected in fish or sediment samples. No plant-produced fission or activation products were found in fish or sediment.

Air particulate samples were analyzed for concentrations of gross beta and gamma-emitting nuclides. No fission or activation products were detected.

Environmental gamma radiation measurements were performed quarterly using thermoluminescent dosimeters.

The RETDAS Computer Model predicts concentrations of activation and fission products in off-site media (fish, vegetation, sediment, air and water) based on measured concentrations of sampled dust and permitted water discharges leaving the site. The results of these computer model predictions in 2018 indicated the projected concentrations in fish, sediment, vegetation, air and water were well below levels that can be measured with state of the art laboratory analysis.

This is why the concentrations off site and the resulting dose impact are calculated by computer. The levels are predicted to be too low to measure off site, as demonstrated by the results of environmental sampling summarized in this report.

Lastly, in Appendix E is the annual groundwater report summarizing the results of groundwater samples collected on site quarterly. In 2018, tritium was identified in groundwater for the first time since the station's 10CFR50 licenses were transferred from Exelon to Zion Solutions on September 1, 2010. Levels just above MDA were identified in well 08S for approximately six months, and then dropped below MDA, and have remained below MDA since then. This is reviewed and discussed in Appendix E.

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## II. Introduction

The Zion Nuclear Power Station (ZNPS), consisted of two 1,100 MWt pressurized water reactors, was owned and operated by Exelon Corporation, and 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 plant is in the final stages of decommissioning and the remaining sources of radioactive material on site include spent fuel stored in canisters on the Independent Spent Fuel Storage Installation (ISFSI), demolished building materials awaiting shipment to the low level waste and disposal facility in Utah, and trace amounts of radioactive material in backfilled structures and surface soil per the Station's License Termination Plan (LTP). The site is located in northeast Illinois on the western shore of Lake Michigan, approximately 50 miles north of Chicago, Illinois.

This report covers those analyses performed by Teledyne Brown Engineering (TBE) and Mirion Technologies on samples collected during the period 1 January 2018 through 31 December 2018.

### A. Objectives of the REMP

The objectives of the REMP are to:

1. Provide data on measurable levels of radiation and radioactive materials in the site environs
2. Evaluate the relationship between quantities of radioactive material released from the plant and resultant radiation doses to individuals from principal pathways of exposure
3. Validate the effluent computer model that predicts radioactive material concentrations at populated off-site sample locations.

### B. Implementation of the Objectives

The implementation of the objectives is accomplished by:

1. Identifying significant exposure pathways
2. Establishing baseline radiological data of media within those pathways
3. Continuously monitoring those media before, during and after Station operation to assess Station radiological impacts (if any) on man and the environment

### III. Program Description

#### A. Sample Collection

Samples for the ZNPS REMP were collected for Zion Solutions (ZS) by Environmental Inc. (Midwest Labs). This section describes the general collection methods used by Environmental Inc. (Midwest Labs) to obtain environmental samples for the ZNPS REMP in 2018. Sample locations and descriptions can be found in Table B-1 and Figures B-1 and B-2, Appendix B. The sampling methods used by Environmental Inc. (Midwest Labs) are listed in Table B-2.

#### Aquatic Environment

The aquatic environment was evaluated by performing radiological analyses on samples of public water, fish and sediment. Two gallon water samples were collected monthly from four public water locations (Z-14, Z-15, Z-16 and Z-18). Control locations were Z-14 and Z-18. All samples were collected in new unused plastic bottles, which were rinsed at least twice with source water prior to collection. Fish samples comprised of the edible flesh portion of white sucker, largemouth bass, common carp, brown trout, lake trout and burbot were collected semiannually at two locations, Z-26 and Z-27. Sediment samples composed of recently deposited substrate were collected at one location semiannually, Z-25.

#### Atmospheric Environment

The atmospheric environment was evaluated by performing radiological analyses on samples of air particulates. Airborne particulate samples were collected and analyzed weekly at four locations (Z-01, Z-02, Z-03, and Z-13). The control location was Z-13. Airborne particulate samples were obtained at each location, using a vacuum pump with glass fiber filters attached. The pumps were run continuously and sampled air at the rate of approximately one cubic foot per minute. The filters were replaced weekly and sent to the laboratory for analysis.

#### Terrestrial Environment

The terrestrial environment was evaluated by performing radiological analyses on food product samples. Food products were collected annually in August at three locations (Z-Control, Z-Quad 3 and Z-Quad 4). The control location was Z-Control. Various types of samples were collected and placed in new unused plastic bags and sent to the laboratory for analysis.

## Ambient Gamma Radiation

Direct radiation measurements were made with Panasonic Environmental TLD type 814 with 3 CaSO<sub>4</sub> elements. Each location consisted of 2 TLD sets. The TLD locations were placed on, around and surrounding the ZNPS site at the following locations:

Inner Ring: Z-01, Z-02, Z-03, Z-101, Z-102, Z-103, Z-104, Z-105, Z-106, Z-107, Z-108, Z-109, Z-121, Z-124, Z-125, Z-129, Z-130, Z-131

Special Interest: Z-112, Z-113, Z-114, Z-115

Outer Ring: Z-209, Z-211, Z-212, Z-213, Z-214, Z-215, Z-216

Control: Z-13

The specific TLD locations were determined by the following criteria:

1. The presence of relatively dense population;
2. Site meteorological data taking into account distance and elevation for each of the sixteen–22 1/2 degree sectors around the site, where estimated annual dose from ZNPS, if any, would be most significant;
3. On hills free from local obstructions and within clear line of sight to construction activities (where practical) and the ISFSI;
4. And near the closest dwelling to the demolition activities in the prevailing downwind direction and the ISFSI.

(Two TLDs – each comprised of three CaSO<sub>4</sub> elements enclosed in plastic – were placed at each location approximately four to eight feet above ground level. The TLDs were exchanged quarterly and sent to Mirion Technologies for analysis.

## B. Sample Analysis

This section describes the general analytical methodologies used by TBE to analyze the environmental samples for radioactivity for the ZNPS REMP in 2018. The analytical procedures used by the laboratories are listed in Table B-2.

In order to achieve the stated objectives, the current program includes the following analyses:

1. Concentrations of beta emitters in public water and air particulates using gross beta analysis with proportional detectors.
2. Concentrations of gamma emitters in public water, air particulates, vegetation, fish, and sediment using high purity germanium (HPGe) gamma spectroscopy.
3. Concentrations of tritium in public water using liquid scintillation analysis (LSC) with the energy window focused on the tritium emission energy.
4. Ambient gamma radiation levels at various locations on and off site up to 10 miles away using multi-chip thermoluminescent dosimeters (TLDs).

C. Data Interpretation

The radiological and direct radiation 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. In addition, data was compared to previous years' operational data for consistency and trending. Several factors were important in the interpretation of the data:

1. Lower Limit of Detection and Minimum Detectable Concentration

The lower limit of detection (LLD) is defined as the smallest concentration of radioactive material in a sample that would yield a net count (above background) that would be detected with only a 5% probability of falsely concluding that a blank observation represents a "real" signal. The LLD is intended as a before the fact estimate of a system (including instrumentation, procedure and sample type) and not as an after the fact criteria for the presence of activity. All analyses were designed to achieve the required ZNPS detection capabilities for environmental sample analysis.

The minimum detectable concentration (MDC) is defined above with the exception that the measurement is an after the fact estimate of the presence of activity.

2. Net Activity Calculation and Reporting of Results

Net activity for a sample was calculated by subtracting background activity from the sample activity. Since the REMP measures extremely small changes in radioactivity in the

environment, background variations may result in sample activity being lower than the background activity affecting a negative number. An MDC was reported in all cases where positive activity was not detected.

Gamma spectroscopy results for each type of sample were grouped as follows:

For public water, fish, vegetation, sediment and air particulates 11 nuclides, Mn-54, Co-58, Fe-59, Co-60, Zn-65, Nb-95, Zr-95, Cs-134, Cs-137, Ba-140, and La-140 were reported.

Means and standard deviations of the results were calculated. The standard deviations represent the variability of measured results for different samples rather than single analysis uncertainty.

D. Program Exceptions

For 2018 the ZNPS REMP had a sample recovery rate in excess of 98%. Sample anomalies and missed samples are listed in the tables below:

Table D-1 LISTING OF SAMPLE ANOMALIES

Sample Type	Location Code	Collection Date	Reason
PW	Z-18	01/24/18	Public water collected from Lake. Primary and back up location OOS due to demo.
AP	Z-03	03/07/18	No apparent reason for low reading; pump operating normally
TLD	Z-01, Z-02	03/21/18	Z-01 & Z-02 found on ground – reposted in a new bag and double-clipped
AP	Z-13	04/05/18	Air pump 264 found non-functional. Run time unknown. Pump changed out.
PW	Z-18	10/03/18	Primary collection point non-functional. Collected sample from back-up location.
SS	Z-25	10/04/18	Collection of sediments attempted at Z-25. Bad weather & choppy surf prevented collection. Sample collected on 10/24/18 from Z-26 as Z-25 conditions still prevented sample collection.

Table D-2 LISTING OF MISSED SAMPLES

Sample Type	Location Code	Collection Date	Reason
TLD	129-2	05/02/18	TLD Z-129-2 fell off fence and was run over by mower. Unable to read. Co-located TLD Z-129-1 was read and value used for this location.
WD	Z-15	07/05/18	No sample – collector could not gain entrance to water plant
TLD	Z-124-1	10/1/18	All three TLD chips provided error codes when read. No result obtained.
TLD	Z-103-1	12/26/18	TLD 101-1 was lost en route to Mirion and not read. Co-located TLD Z-103-2 was read and its value used for this location.

Each program exception was reviewed to understand the causes of the program exception. Sampling and maintenance errors were reviewed with the personnel involved to prevent recurrence. Occasional equipment breakdowns and power outages were unavoidable. The overall sample recovery rate indicates that the appropriate procedures and equipment are in place to assure reliable program implementation.

E. Program Changes

There were no program changes for 2018.

IV. Results and Discussion

A. Aquatic Environment

1. Public Water

Samples were taken weekly and composited monthly at four locations (Z-14, Z-15, Z-16 and Z-18). The following analyses were performed.

Gross Beta

Samples from all locations were analyzed for concentrations of gross beta. Gross beta was detected in 30 of 48 samples. The values ranged from 1.8 pCi/l to 4.9 pCi/l. Concentrations detected were consistent with those detected in previous years. (Table C-1.1, Appendix C) (Figures C-1 and C-2, Appendix C)

### Tritium

Quarterly composites of weekly collections were analyzed for tritium activity (Table C-I.2, Appendix C). No tritium was detected and the LLD was met (Figures C-3 and C-4, Appendix C).

### Gamma Spectrometry

Samples from both locations were analyzed for gamma-emitting nuclides. No nuclides were detected and all required LLDs were met. (Table C-I.3, Appendix C)

## 2. Fish

Fish samples comprised of white sucker, largemouth bass, common carp, brown trout, lake trout and burbot were collected at two locations (Z-26 and Z-27) semiannually. The following analysis was performed:

### Gamma Spectrometry

The edible portion of fish samples from both locations was analyzed for gamma-emitting nuclides. No nuclides were detected and all required LLDs were met. (Table C-II.1, Appendix C)

## 3. Sediment

Aquatic sediment samples are normally collected at one location (Z-25) semiannually. The fall sample was collected at Z-26 due to unsafe conditions at location Z-25 in October, 2018. The following analysis was performed:

### Gamma Spectrometry

Sediment samples from Z-25 and Z-26 were analyzed for gamma-emitting nuclides. No nuclides were detected and all required LLDs were met. (Table C-III.1, Appendix C)

## B. Atmospheric Environment

### 1. Airborne - Air Particulates

Continuous air particulate samples were collected from four locations on a weekly basis. Three locations were within the ZNPS site boundary (Z-01, Z-02 and Z-03) and the fourth is located 10 miles north and is the control location (Z-13). The

following analyses were performed:

#### Gross Beta

Weekly samples were analyzed for concentrations of beta emitters. Detectable gross beta activity was observed at all locations, except one control air sample (see Table C-IV.1). Comparison of results among the three groups aids in determining the effects, if any, resulting from the operation of ZNPS. The positive results from the three On-Site locations ranged from  $4\text{E-}3$  pCi/m<sup>3</sup> to  $41\text{E-}3$  pCi/m<sup>3</sup> with a mean of  $15\text{E-}3$  pCi/m<sup>3</sup>.

The results from the Control location ranged from  $7\text{E-}3$  pCi/m<sup>3</sup> to  $39\text{E-}3$  pCi/m<sup>3</sup> with a mean of  $16\text{E-}3$  pCi/m<sup>3</sup> and one result <LLD. Comparison of the 2018 air particulate data with previous year's data indicates there is no off site impact resulting from demolition activities at ZNPS. Concentrations detected were consistent with those detected in previous years. (Table C-IV.1 and C-IV.2, Appendix C)

#### Gamma Spectrometry

Weekly samples were composited quarterly and analyzed for gamma-emitting nuclides. No plant-related nuclides were detected and all required LLDs were met. Naturally occurring Be-7 was detected; the source of this is described later in this report. (Table C-IV.3, Appendix C)

### C. Terrestrial Environment

#### 1. Food Product

Food product samples were collected at three locations (Z-Control, Z-Quad 3 and Z-Quad 4) when available. The following analysis was performed:

#### Gamma Spectrometry

Samples from all locations were analyzed for gamma-emitting nuclides. No nuclides were detected and all required LLDs were met. (Table C-V.1, Appendix C)

### D. Ambient Gamma Radiation

Ambient gamma radiation levels were measured utilizing Panasonic Environmental Type 814 CaSO<sub>4</sub> thermoluminescent



dosimeters (TLD's). Sixty-four TLDs were mounted at 30 locations around the site. Results of TLD measurements are listed in Tables C-VI.1 to C-VI.3, Appendix C.

Most TLD measurements were below 25 mR/quarter, with a range of 13 mR/quarter to 32 mR/quarter. As there are duplicate TLDs posted at each location, the highest value is always reported in Appendix C for each location. The 13 mR/quarter reading was from the first quarter at location Z-101-1, but the higher value of 14 mR/quarter was reported (Z-101-2) in Appendix C.

When direct dose in 2018 is compared to direct dose the previous five years (2013-2018) at the four compass points surrounding decommissioning activities (Figure C-8) within the site boundary, there is a visible drop in direct dose. This is attributed to a steady reduction in source term over the same period, including demolition of structures inside the former protected area, and shipment by rail and truck of the debris to Energy Solutions low level waste facilities in Utah.

When looking at a more specific set of TLD's, those most likely to be impacted by direct radiation from the Independent Spent Fuel Storage Installation (ISFSI) by close proximity and line of site positioning inside the site boundary (Figure C-7), a significant increase in direct dose is evident in 2015 following completion of the transfer of spent fuel to the ISFSI. After 2015, a drop in direct dose is evident due in part to site source term reduction, and to a lesser extent, decay of the spent fuel.

#### E. Land Use Survey

A Land Use Census conducted during October 2018 around the Zion Nuclear Power Station (ZNPS) was performed by Zion Station Personnel for ZS to comply with Chapter 3 of the Zion Offsite Dose Calculation Manual. The purpose of the survey was to document the nearest resident, milk producing animal and garden of greater than 500 ft<sup>2</sup> in each of the sixteen 22 ½ degree sectors around the site. The results of this survey are summarized below:

Sector	Distance in Miles from ZS		
	Residence Miles	Garden Miles	Milk Farm Miles
N	2.5	3.4	>10
NNE	-	-	-
NE	-	-	-
ENE	-	-	-
E	-	-	-
ESE	-	-	-
SE	-	-	-
SSE	-	-	-
S	-	-	-
SSW	1.9	>10	>10
SW	1.1	4.8	>10
WSW	1.0	3.0	>10
W	1.1	2.9	>10
WNW	1.0	2.7	>10
NW	1.0	3.2	>10
NNW	1.3	3.5	>10

Source: Ill. Department of Agriculture and USGS recommended using google maps to locate garden areas due to gardens and milk animals are voluntary declarations, also aerial photographs on ARCGIS layers updated by government sources are 5-10 years old.

Gardens are located using Google Maps to narrow down areas that appeared to have been ploughed by aerial photographs, then visually verified by visiting these new locations.

Milk-producing animal located by internet search for dairies advertising the sale of milk for public consumption.

**F. Errata Data**

Minor errors were identified in the 2016 and 2017 AREORs. Corrections were made and the corrected pages with change bars are included in Appendix F.

In the 2016 AREOR, there were inconsistencies identified between Tables C-VI.1 through C-VI.3 in the data used to summarize TLD results and standard deviations reported by quarter and category. This was due to manual transcription and rounding errors. To alleviate these error sources, a verified and validated MS Excel workbook was created that permitted copying and pasting the raw TLD data supplied in a spreadsheet directly from Mirion into a worksheet. The workbook then calculated all averages, standard deviations, minimums and maximums reported from 254 analyses and populated all results in required

tabulated format for Appendix C with no transcription or rounding errors. As Teledyne creates the same tabulated data, it provides independent verification of the results.

In the 2017 AREOR, Figures C-7 and C-8 reported mrem per year between 2013 and 2017 but it was actually average quarterly dose per year and the y-axis labels were corrected.

G. Summary of Results – Inter-Laboratory Comparison Program

The TBE Laboratory analyzed Performance Evaluation (PE) samples of air particulate, air iodine, milk, soil, vegetation, and water matrices for various analytes. The PE samples supplied by Analytics Inc., Environmental Resource Associates (ERA) and Department of Energy (DOE) Mixed Analyte Performance Evaluation Program (MAPEP), were evaluated against the following pre-set acceptance criteria:

A. Analytics Evaluation Criteria

Analytics' evaluation report provides a ratio of TBE's result and Analytics' known value. Since flag values are not assigned by Analytics, TBE evaluates the reported ratios based on internal QC requirements based on the DOE MAPEP criteria.

B. ERA Evaluation Criteria

ERA's evaluation report provides an acceptance range for control and warning limits with associated flag values. ERA's acceptance limits are established per the USEPA, National Environmental Laboratory Accreditation Conference (NELAC), state-specific Performance Testing (PT) program requirements or ERA's SOP for the Generation of Performance Acceptance Limits, as applicable. The acceptance limits are either determined by a regression equation specific to each analyte or a fixed percentage limit promulgated under the appropriate regulatory document.

C. DOE Evaluation Criteria

MAPEP's evaluation report provides an acceptance range with associated flag values. MAPEP defines three levels of performance:

- Acceptable (flag = "A") - result within  $\pm 20\%$  of the reference value
- Acceptable with Warning (flag = "W") - result falls in the  $\pm 20\%$  to  $\pm 30\%$  of the reference value
- Not Acceptable (flag = "N") – bias is greater than 30% of the reference value

*Note: The Department of Energy (DOE) Mixed Analyte Performance Evaluation Program (MAPEP) samples are created to mimic conditions found at DOE sites which do not resemble typical environmental samples obtained at commercial nuclear power facilities.*

For the TBE laboratory, 166 out of 172 analyses performed met the specified acceptance criteria. Five analyses did not meet the specified acceptance criteria for the following reasons and were addressed through the TBE Corrective Action Program.

1. TBE was unable to report the February 2018 DOE MAPEP vegetation Sr-90 result due to QC failure and limited sample amount. (NCR 18-09)
2. The Analytics September 2018 milk Fe-59 result was evaluated as *Not Acceptable* (Ratio of TBE to known result at 132%). The reported value was  $158 \pm 17.6$  pCi/L and the known value was  $119 \pm 19.9$  pCi/L. No cause for the failure could be determined. TBE has passed 24 of the previous 27 milk cross-check results since 2012. This sample was run in duplicate on a different detector with comparable results ( $162 \pm 16$  pCi/L). *NOTE: TBE's 4<sup>th</sup> Qtr result passed at 105%* (NCR 18-20)
3. The Analytics September milk I-131 result was evaluated as *Not Acceptable* (Ratio of TBE to known result at 143%). Due to a personnel change in the gamma prep lab, the sample was not prepped/counted in a timely manner such as to accommodate the I-131 8-day half-life. Analysts have been made aware of the urgency for this analysis and it will be monitored more closely by QA. *NOTE: TBE's 4<sup>th</sup> Qtr result passed at 101%* (NCR 18-24)
4. The Analytics September soil Cr-51 result was evaluated as *Not Acceptable* (Ratio of TBE to known result at 131%). As with #3 above, the sample was not prepped/counted in a timely manner such as to accommodate the Cr-51 27-day half-life. The same corrective action applies here as in #3. (NCR 18-21)
5. The MAPEP November vegetation Sr-90 result of 0.338 Bq/sample was evaluated as *Not Acceptable* (Lower acceptable range was 0.554 Bq/sample). It appears that there has been incomplete dissolution of Sr-90 due to the composition of the MAPEP vegetation "matrix". To resolve this issue, the TBE-2018 procedure has been modified to add H<sub>2</sub>O<sub>2</sub> to assist in breaking down the organic material that comprises this "matrix". This corrective action will be monitored closely by QA. (NCR 18-25).
6. The ERA October 2017 water Sr-90 sample was evaluated as

*Not Acceptable.* TBE's initial reported result of 36.8 pCi/L exceeded the upper acceptance range (22.9 – 36.4 pCi/L). After reviewing the data for this sample, it was discovered that there was a typographical error at the time the results were entered at the ERA website. The correct result in LIMS of 36.2 should have been submitted instead. This result is within ERA's acceptance limits. In addition to the typo error, ERA's very stringent upper acceptance limit of 116% is not a reflection of TBE's ability to successfully perform this analysis. (NCR 18-23)

The Inter-Laboratory Comparison Program provides evidence of "in control" counting systems and methods, and that the laboratories are producing accurate and reliable data.

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## **APPENDIX A**

# **RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT SUMMARY**

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**TABLE A-1 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY FOR  
THE ZION NUCLEAR POWER STATION, 2018**

Name of Facility:		ZION NUCLEAR POWER STATION		DOCKET NUMBER:		50-295 & 50-304			
Location of Facility:		ZION, IL		REPORTING PERIOD:		2018			
MEDIUM OR PATHWAY SAMPLED (UNIT OF MEASUREMENT)	TYPES OF ANALYSIS PERFORMED	NUMBER OF ANALYSIS PERFORMED	REQUIRED LOWER LIMIT OF DETECTION (LLD)	INDICATOR LOCATIONS MEAN <sup>(M)</sup> (f) RANGE	CONTROL LOCATION MEAN <sup>(M)</sup> (f) RANGE	LOCATION WITH HIGHEST ANNUAL MEAN (M) MEAN <sup>(M)</sup> (f) RANGE	STATION # NAME DISTANCE AND DIRECTION	NUMBER OF NONROUTINE REPORTED MEASUREMENTS	
PUBLIC WATER (PCI/LITER)	GR-B	48	4	2.6 (15/24) 1.8 - 3.6	2.9 (15/24) 2 - 4.9	3.3 (7/12) 2 - 4.9	Z-14 CONTROL KENOSHA WATER WORKS 10.0 MILES N OF SITE	0	
	H-3	16	200	<LLD	<LLD	-		0	
	GAMMA	48							
		MN-54		15	<LLD	<LLD	-		0
		CO-58		15	<LLD	<LLD	-		0
		FE-59		30	<LLD	<LLD	-		0
		CO-60		15	<LLD	<LLD	-		0
		ZN-65		30	<LLD	<LLD	-		0
		NB-95		15	<LLD	<LLD	-		0
		ZR-95		15	<LLD	<LLD	-		0
		CS-134		15	<LLD	<LLD	-		0
		CS-137		18	<LLD	<LLD	-		0
		BA-140		NA	<LLD	<LLD	-		0
	LA-140		NA	<LLD	<LLD	-		0	
FISH (PCI/KG WET)	GAMMA	8							
		MN-54		130	<LLD	NA	-		0
		CO-58		130	<LLD	NA	-		0
		FE-59		260	<LLD	NA	-		0
		CO-60		130	<LLD	NA	-		0
		ZN-65		260	<LLD	NA	-		0
		NB-95		NA	<LLD	NA	-		0
		ZR-95		NA	<LLD	NA	-		0
		CS-134		100	<LLD	NA	-		0
		CS-137		100	<LLD	NA	-		0
	BA-140		NA	<LLD	NA	-		0	
	LA-140		NA	<LLD	NA	-		0	

<sup>(M)</sup> Mean and ranged based upon detectable measurements only. Fraction of detectable measurements at specified loactions is indicated in parentheses (f)

**TABLE A-1 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY FOR  
THE ZION NUCLEAR POWER STATION, 2018**

Name of Facility:		ZION NUCLEAR POWER STATION			DOCKET NUMBER:		50-295 & 50-304	
Location of Facility:		ZION, IL			REPORTING PERIOD:		2018	
MEDIUM OR PATHWAY SAMPLED (UNIT OF MEASUREMENT)	TYPES OF ANALYSIS PERFORMED	NUMBER OF ANALYSIS PERFORMED	REQUIRED LOWER LIMIT OF DETECTION (LLD)	INDICATOR LOCATIONS MEAN <sup>(M)</sup> (f) RANGE	CONTROL LOCATION MEAN <sup>(M)</sup> (f) RANGE	LOCATION WITH HIGHEST ANNUAL MEAN (M) MEAN <sup>(M)</sup> (f) RANGE	STATION # NAME DISTANCE AND DIRECTION	NUMBER OF NONROUTINE REPORTED MEASUREMENTS
<b>SEDIMENT</b> (PCI/KG DRY)	<b>GAMMA</b>	2						
		MN-54	NA	<LLD	NA	-		0
		CO-58	NA	<LLD	NA	-		0
		FE-59	NA	<LLD	NA	-		0
		CO-60	NA	<LLD	NA	-		0
		ZN-65	NA	<LLD	NA	-		0
		NB-95	NA	<LLD	NA	-		0
		ZR-95	NA	<LLD	NA	-		0
		CS-134	150	<LLD	NA	-		0
		CS-137	180	<LLD	NA	-		0
		BA-140	NA	<LLD	NA	-		0
	LA-140	NA	<LLD	NA	-		0	
<b>AIR PARTICULATE</b> (E-3 PCI/CU.METER)	<b>GR-B</b>	208	10	15 (156/156) 4 - 41	16 (51/52) 7 - 39	17 (52/52) 7 - 41	Z-03 INDICATOR ONSITE 3 0.2 MILES NNW OF SITE	0
	<b>GAMMA</b>	16						
		MN-54	NA	<LLD	<LLD	-		0
		CO-58	NA	<LLD	<LLD	-		0
		FE-59	NA	<LLD	<LLD	-		0
		CO-60	NA	<LLD	<LLD	-		0
		ZN-65	NA	<LLD	<LLD	-		0
		NB-95	NA	<LLD	<LLD	-		0
		ZR-95	NA	<LLD	<LLD	-		0
		CS-134	10	<LLD	<LLD	-		0
		CS-137	10	<LLD	<LLD	-		0
		BA-140	NA	<LLD	<LLD	-		0
		LA-140	NA	<LLD	<LLD	-		0

<sup>(M)</sup> Mean and ranged based upon detectable measurements only. Fraction of detectable measurements at specified loactions is indicated in parentheses (f)

**TABLE A-1 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY FOR  
THE ZION NUCLEAR POWER STATION, 2018**

Name of Facility:		ZION NUCLEAR POWER STATION		DOCKET NUMBER:		50-295 & 50-304		
Location of Facility:		ZION, IL		REPORTING PERIOD:		2018		
MEDIUM OR PATHWAY SAMPLED (UNIT OF MEASUREMENT)	TYPES OF ANALYSIS PERFORMED	NUMBER OF ANALYSIS PERFORMED	REQUIRED LOWER LIMIT OF DETECTION (LLD)	INDICATOR LOCATIONS MEAN <sup>(M)</sup> (f) RANGE	CONTROL LOCATION MEAN <sup>(M)</sup> (f) RANGE	LOCATION WITH HIGHEST ANNUAL MEAN (M) MEAN <sup>(M)</sup> (f) RANGE		NUMBER OF NONROUTINE REPORTED MEASUREMENTS
						STATION # NAME	DISTANCE AND DIRECTION	
<b>VEGETATION</b> (PCI/KGWET)	<b>GAMMA</b>	6						
	MN-54		NA	<LLD	<LLD	-		0
	CO-58		NA	<LLD	<LLD	-		0
	FE-59		NA	<LLD	<LLD	-		0
	CO-60		NA	<LLD	<LLD	-		0
	ZN-65		NA	<LLD	<LLD	-		0
	NB-95		NA	<LLD	<LLD	-		0
	ZR-95		NA	<LLD	<LLD	-		0
	CS-134		60	<LLD	<LLD	-		0
	CS-137		80	<LLD	<LLD	-		0
	BA-140		NA	<LLD	<LLD	-		0
	LA-140		NA	<LLD	<LLD	-		0
<b>DIRECT RADIATION</b> (MILLI-ROENTGEN/QTR.)	<b>TLD-QUARTERLY</b>	254	NA	18.6 (230/230) 13 - 32*	18.6 (24/24) 15 - 21*	29.3 (8/8) 26 - 32*	Z-131 INDICATOR  0.2 MIIES WSW	0

<sup>(M)</sup> Mean and ranged based upon detectable measurements only. Fraction of detectable measurements at specified loactions is indicated in parentheses (f)

\*Two TLDs are posted at each location for redundancy. The averages are based on the highest reading at each station. The ranges are based on all results.

The total number of analyses is based on all TLD results - there are 3 chips read in each TLD, so literally, there are 762 analytyses performed on 254 TLD's - the 2018 TLD results reflect 2 TLDs that were damaged/lost.

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## **APPENDIX B**

### **LOCATION DESIGNATION, DISTANCE & DIRECTION, AND SAMPLE COLLECTION & ANALYTICAL METHOD**

TABLE B-1: Radiological Environmental Monitoring Program - Sampling Locations, Distance and Direction, Zion Nuclear Power Station, 2017

Location	Location Description	Distance & Direction From Site
<u>A. Public Water</u>		
Z-14	Kenosha Water Works (control)	10.0 miles N
Z-15	Lake County Water Works (indicator)	1.4 miles NNW
Z-16	Waukegan Water Works (indicator)	6.1 miles S
Z-18	Lake Forest Water Works (control)	12.9 miles S
<u>B. Air Particulates</u>		
Z-01	Onsite 1 (indicator)	0.3 miles S
Z-02	Onsite 2 (indicator)	0.2 miles W
Z-03	Onsite 3 (indicator)	0.2 miles NNW
Z-13	Offsite Control	10 miles NW
<u>C. Fish</u>		
Z-26	Lake Michigan Nearsite (indicator)	At station
Z-27	Lake Michigan Farsite (indicator)	10.1 miles N
<u>D. Sediment</u>		
Z-25	Lake Michigan, Illinois Beach State Park (indicator)	0.2 miles S
<u>E. Vegetation</u>		
Z-Control	Control (control)	0.3 miles S
Z-Quad 3	Farm 3 (indicator)	0.2 miles W
Z-Quad 4	Farm 4 (indicator)	0.2 miles NNW
<u>F. Environmental Dosimetry - TLD</u>		
<u>Inner Ring</u>		
Z-101-1 and -2		0.2 miles N
Z-102-1 and -2		0.2 miles NNE
Z-103-1 and -2		0.2 miles NE
Z-104-1 and -2		0.1 miles ENE
Z-105-1 and -2		0.1 miles E
Z-106-1 and -2		0.1 miles ESE
Z-107-1 and -2		0.1 miles SE
Z-108-1 and -2		0.1 miles SSE
Z-109-1 and -2		0.2 miles SSE
Z-112-1 and -2		0.7 miles WSW
Z-113-1 and -2		0.6 miles W
Z-114-1 and -2		0.6 miles WNW
Z-115-1 and -2		0.4 miles NW
Z-121-1 and -2		0.2 miles NNW
Z-124-1 and -2		0.5 miles SW
Z-125-1 and -2		0.4 miles SSW
Z-129-1 and -2		0.2 miles NW
Z-130-1 and -2		0.2 miles WNW
Z-131-1 and -2		0.2 miles WSW
<u>Other</u>		
Z-01-1 and -2	Onsite 1 (indicator)	0.3 miles S
Z-02-1 and -2	Onsite 2 (indicator)	0.2 miles W
Z-03-1 and -2	Onsite 3 (indicator)	0.2 miles NNW
<u>Outer Ring</u>		
Z-209-1 and -2		5.1 miles S
Z-211-1 and -2		4.7 miles SW
Z-212-1 and -2		5.1 miles WSW
Z-213-1 and -2		5.1 miles W
Z-214-1 and -2		4.6 miles WNW
Z-215-1 and -2		4.0 miles NW
Z-216-1 and -2		3.0 miles NNW
<u>Control</u>		
Z-13-1 thru -6	Control	10 miles NW

TABLE B-2:

## Radiological Environmental Monitoring Program – Summary of Sample Collection and Analytical Methods, Zion Nuclear Power Station, 2017

Sample Medium	Analysis	Sampling Method	Analytical Procedure Number
Public Water	Gamma Spectroscopy	Monthly composite from weekly grab samples.	TBE, TBE-2007 Gamma emitting radioisotope analysis
Public Water	Gross Beta	Monthly composite from weekly grab samples.	TBE, TBE-2008 Gross Alpha and/or gross beta activity in various matrices
Public Water	Tritium	Quarterly composite from weekly grab samples.	TBE, TBE-2011 Tritium analysis in drinking water by liquid scintillation
Fish	Gamma Spectroscopy	Semi-annual samples collected via electroshocking or other techniques	TBE-2007 Gamma emitting radioisotope analysis
Sediment	Gamma Spectroscopy	Semi-annual grab samples	TBE, TBE-2007 Gamma emitting radioisotope analysis
Vegetation	Gamma Spectroscopy	Annual collection at harvest	TBE, TBE-2007 Gamma emitting radioisotope analysis
Air Particulates	Gross Beta	One-week composite of continuous air sampling through glass fiber filter paper	TBE, TBE-2008 Gross Alpha and/or gross beta activity in various matrices
Air Particulates	Gamma Spectroscopy	Quarterly composite of each station	TBE, TBE-2007 Gamma emitting radioisotope analysis
TLD	Thermo-luminescent Dosimetry	Quarterly TLDs comprised of two Panasonic Environmental TLD type 814 with 3 CaSO <sub>4</sub> elements at each location.	Mirion Technologies

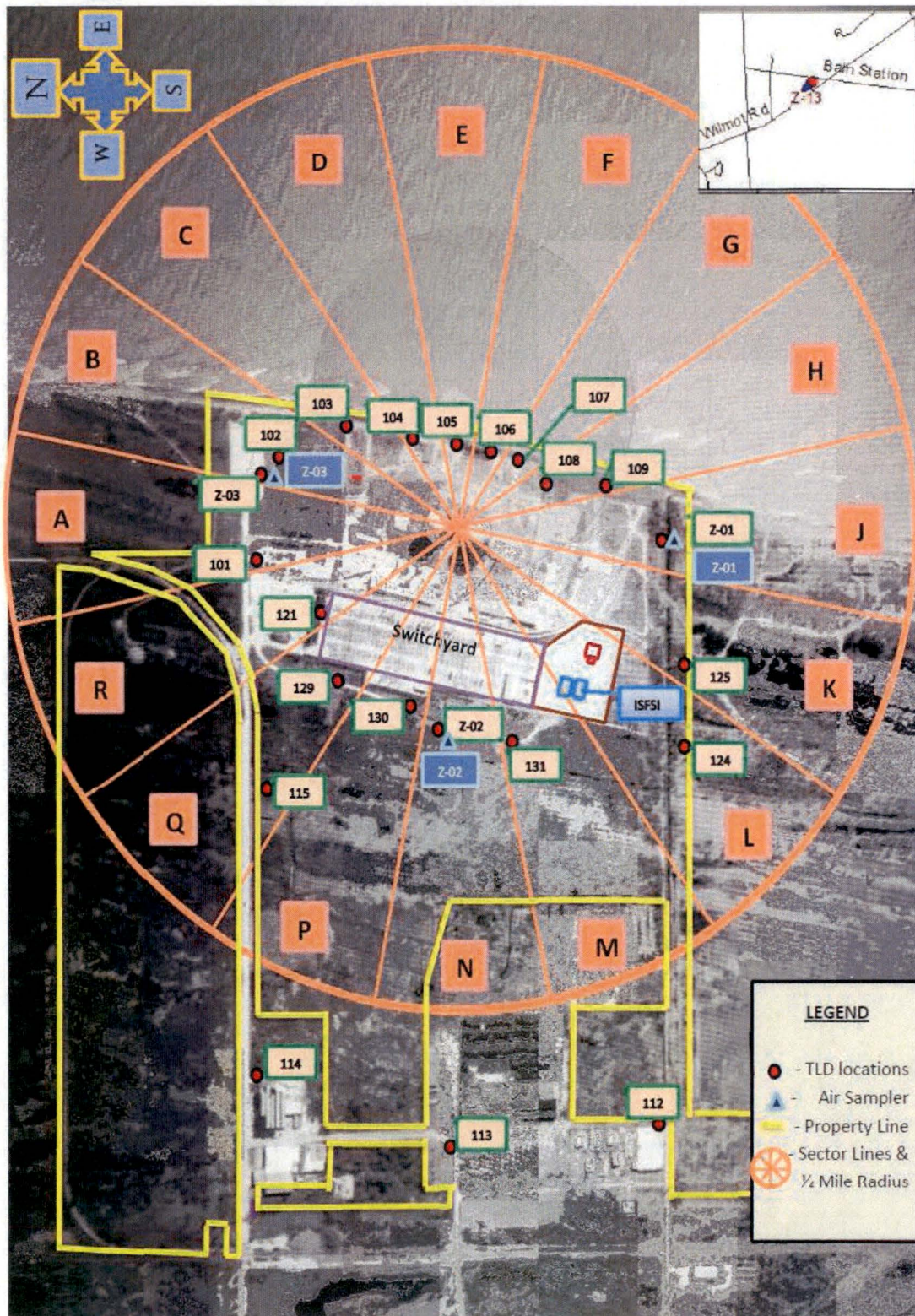


Figure B-1  
 Inner Ring TLD and Fixed Air Sampler Locations of the Zion Nuclear Power Station, 2017



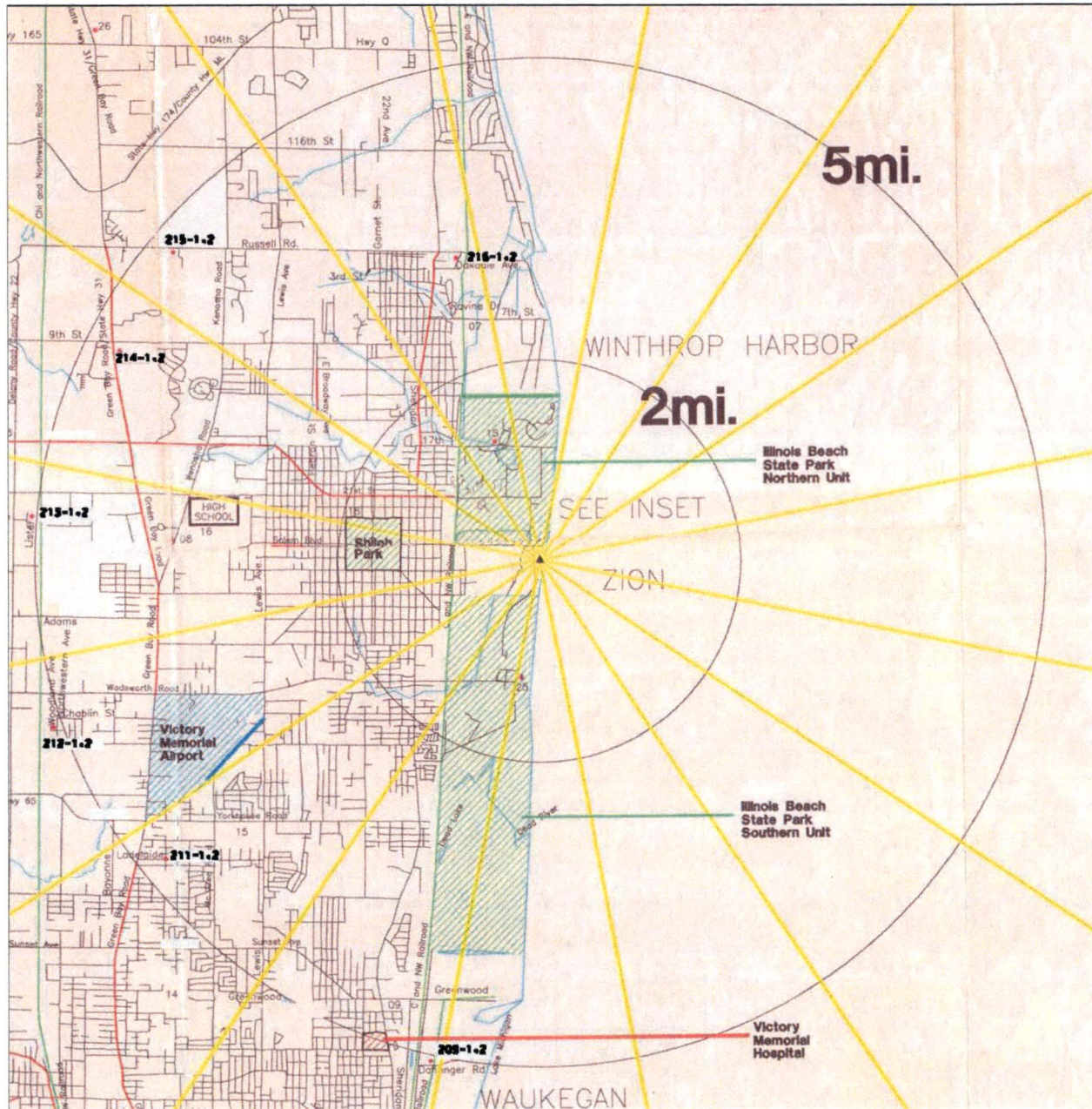


Figure B-2  
 Outer Ring TLD and Fixed Air Sampler Locations of the Zion Nuclear Power Station, 2017

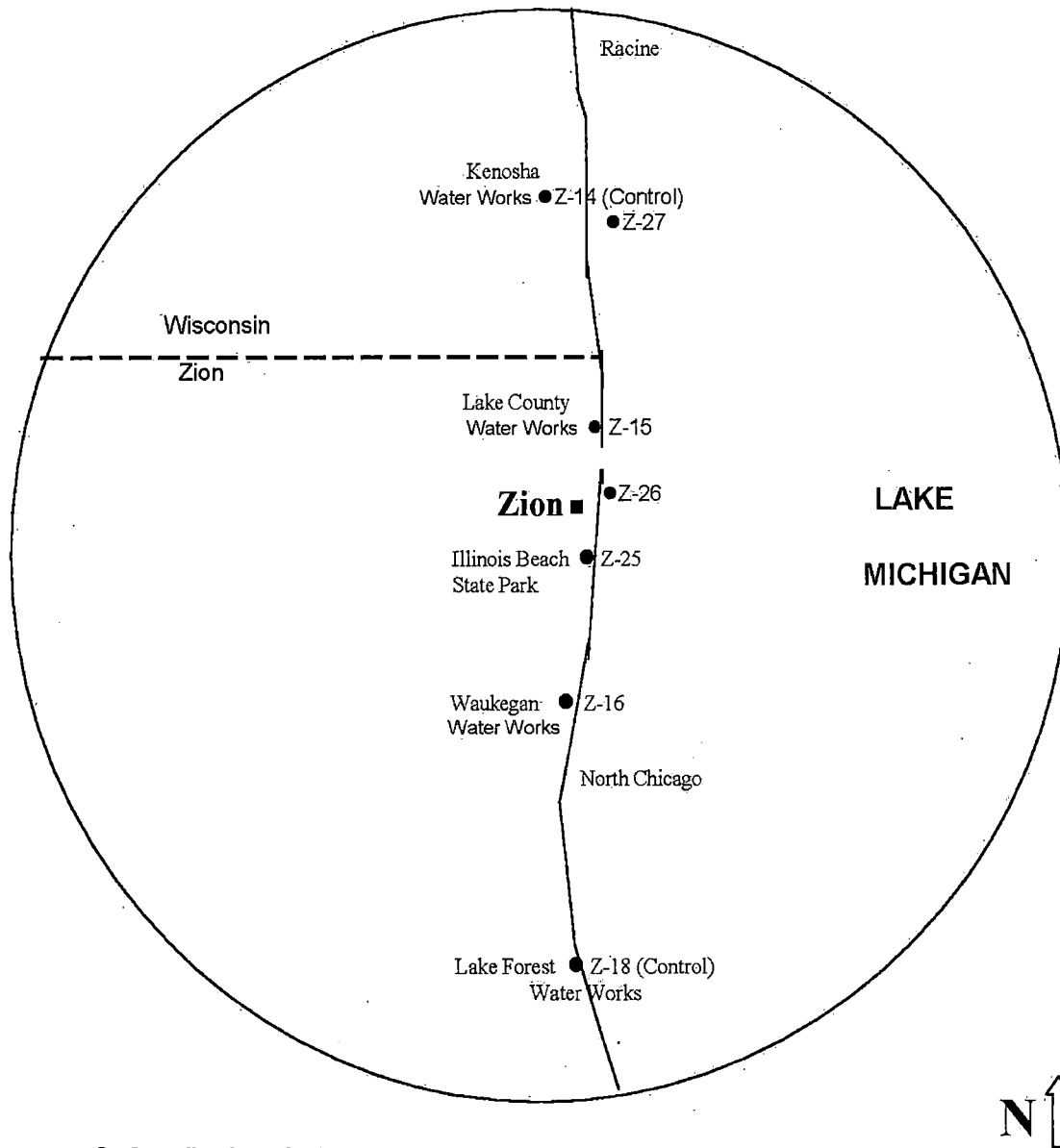


Figure B-3  
Fish, Water and Sediment Sampling Locations of the Zion Nuclear Power Station, 2017

**APPENDIX C**

**DATA TABLES AND FIGURES**

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**Table C-I.1 Concentrations of Gross Beta in Public Water Samples Collected in the Vicinity of Zion Nuclear Power Station, 2018**  
Results in Units of pCi/liter  $\pm$  2 Sigma

COLLECTION PERIOD	Z-14	Z-15	Z-16	Z-18
01/04/18 - 01/31/18	2.0 $\pm$ 1.3	< 1.8	< 1.8	< 1.9
02/07/18 - 02/28/18	4.9 $\pm$ 1.6	< 2.0	2.1 $\pm$ 1.4	< 2.1
03/07/18 - 03/28/18	< 1.8	3.1 $\pm$ 1.4	2.2 $\pm$ 1.3	2.4 $\pm$ 1.3
04/05/18 - 04/25/18	< 2.2	< 2.2	< 2.2	2.8 $\pm$ 1.6
05/03/18 - 05/30/18	2.8 $\pm$ 1.5	2.5 $\pm$ 1.5	3.6 $\pm$ 1.6	3.1 $\pm$ 1.5
06/06/18 - 06/27/18	3.3 $\pm$ 1.4	2.6 $\pm$ 1.4	< 1.9	2.3 $\pm$ 1.3
07/03/18 - 07/31/18	2.9 $\pm$ 1.5	2.2 $\pm$ 1.4	2.4 $\pm$ 1.5	3.0 $\pm$ 1.5
08/08/18 - 08/29/18	2.8 $\pm$ 1.4	< 2.0	< 2.0	2.4 $\pm$ 1.4
09/06/18 - 09/26/18	4.2 $\pm$ 1.4	1.8 $\pm$ 1.2	2.8 $\pm$ 1.4	< 1.8
10/03/18 - 10/31/18	< 2.1	< 2.1	2.8 $\pm$ 1.6	< 2.2
11/07/18 - 11/28/18	< 2.0	3.2 $\pm$ 1.5	3.2 $\pm$ 1.6	2.6 $\pm$ 1.5
12/05/18 - 12/26/18	< 2.0	2.7 $\pm$ 1.6	1.9 $\pm$ 1.1	2.7 $\pm$ 1.6
MEAN $\pm$ 2 STD DEV	3.3 $\pm$ 2.0	2.6 $\pm$ 1.0	2.6 $\pm$ 1.2	2.6 $\pm$ 0.6

**Table C-I.2 Concentrations of Tritium in Public Water Samples Collected in the Vicinity of Zion Nuclear Power Station, 2018**  
Results in Units of pCi/liter  $\pm$  2 Sigma

COLLECTION PERIOD	Z-14	Z-15	Z-16	Z-18
01/04/18 - 03/28/18	< 183	< 182	< 184	< 182
04/05/18 - 06/27/18	< 188	< 186	< 190	< 188
07/05/18 - 09/26/18	< 197	< 196	< 193	< 196
10/03/18 - 12/26/18	< 191	< 189	< 189	< 192
MEAN	-	-	-	-

THE MEAN AND TWO STANDARD DEVIATION ARE CALCULATED USING THE POSITIVE VALUES

Table C-I.3

**Concentrations of Gamma Emitters in Public Water Samples Collected in the  
Vicinity of Zion Nuclear Power Station, 2018**

Results in Units of pCi/liter  $\pm$  2 Sigma

SITE	COLLECTION		Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
	PERIOD												
Z-14	01/04/18 - 01/31/18		< 6	< 9	< 15	< 9	< 17	< 9	< 13	< 7	< 8	< 50	< 14
	02/07/18 - 02/28/18		< 4	< 4	< 7	< 3	< 7	< 4	< 7	< 4	< 4	< 32	< 10
	03/07/18 - 03/28/18		< 5	< 5	< 10	< 6	< 12	< 6	< 12	< 4	< 6	< 49	< 25
	04/05/18 - 04/25/18		< 2	< 2	< 5	< 2	< 4	< 2	< 4	< 2	< 2	< 17	< 5
	05/03/18 - 05/30/18		< 6	< 6	< 11	< 6	< 10	< 7	< 10	< 6	< 5	< 59	< 23
	06/06/18 - 06/27/18		< 2	< 2	< 5	< 2	< 4	< 2	< 4	< 2	< 2	< 18	< 6
	07/05/18 - 07/31/18		< 7	< 7	< 19	< 9	< 14	< 10	< 14	< 8	< 7	< 64	< 24
	08/08/18 - 08/29/18		< 6	< 7	< 18	< 6	< 13	< 9	< 14	< 7	< 7	< 64	< 23
	09/06/18 - 09/26/18		< 8	< 8	< 20	< 6	< 15	< 6	< 14	< 8	< 7	< 65	< 20
	10/03/18 - 10/31/18		< 5	< 5	< 12	< 4	< 12	< 6	< 10	< 5	< 6	< 43	< 10
	11/07/18 - 11/28/18		< 7	< 8	< 17	< 6	< 17	< 8	< 14	< 6	< 7	< 50	< 17
	12/05/18 - 12/26/18		< 7	< 7	< 13	< 8	< 13	< 8	< 10	< 7	< 7	< 33	< 12
		MEAN		-	-	-	-	-	-	-	-	-	-
Z-15	01/04/18 - 01/31/18		< 8	< 7	< 18	< 9	< 15	< 7	< 11	< 7	< 6	< 37	< 18
	02/07/18 - 02/28/18		< 4	< 4	< 8	< 4	< 7	< 4	< 7	< 4	< 3	< 31	< 11
	03/07/18 - 03/28/18		< 4	< 5	< 12	< 5	< 9	< 5	< 11	< 4	< 5	< 46	< 19
	04/05/18 - 04/25/18		< 3	< 3	< 6	< 3	< 6	< 3	< 5	< 3	< 3	< 20	< 6
	05/03/18 - 05/30/18		< 6	< 6	< 17	< 6	< 15	< 6	< 14	< 8	< 8	< 71	< 36
	06/06/18 - 06/27/18		< 2	< 2	< 5	< 2	< 4	< 2	< 4	< 2	< 2	< 17	< 7
	07/11/18 - 07/31/18		< 5	< 7	< 17	< 7	< 17	< 9	< 13	< 7	< 6	< 63	< 24
	08/08/18 - 08/29/18		< 4	< 4	< 10	< 5	< 9	< 5	< 8	< 5	< 5	< 40	< 13
	09/06/18 - 09/26/18		< 6	< 8	< 13	< 8	< 11	< 7	< 12	< 8	< 7	< 60	< 20
	10/03/18 - 10/31/18		< 5	< 7	< 16	< 7	< 14	< 6	< 14	< 8	< 7	< 47	< 15
	11/07/18 - 11/28/18		< 5	< 6	< 14	< 4	< 11	< 6	< 13	< 7	< 6	< 46	< 15
	12/05/18 - 12/26/18		< 4	< 4	< 8	< 5	< 10	< 4	< 7	< 5	< 4	< 25	< 9
		MEAN		-	-	-	-	-	-	-	-	-	-

Table C-I.3

**Concentrations of Gamma Emitters in Public Water Samples Collected in the  
Vicinity of Zion Nuclear Power Station, 2018**

Results in Units of pCi/liter  $\pm$  2 Sigma

SITE	COLLECTION		Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
	PERIOD												
Z-16	1/4/2018 - 01/31/18		< 6	< 6	< 10	< 6	< 14	< 6	< 13	< 7	< 7	< 37	< 10
	2/7/2018 - 02/28/18		< 3	< 3	< 6	< 3	< 5	< 3	< 5	< 3	< 3	< 25	< 9
	3/7/2018 - 03/28/18		< 6	< 7	< 21	< 7	< 11	< 9	< 15	< 6	< 7	< 66	< 19
	4/5/2018 - 04/25/18		< 2	< 2	< 6	< 3	< 4	< 2	< 4	< 2	< 2	< 16	< 8
	5/3/2018 - 05/30/18		< 7	< 8	< 20	< 6	< 14	< 9	< 14	< 7	< 7	< 68	< 23
	06/06/18 - 06/27/18		< 2	< 2	< 4	< 2	< 4	< 2	< 3	< 2	< 2	< 18	< 5
	07/05/18 - 07/31/18		< 7	< 8	< 20	< 9	< 18	< 9	< 15	< 9	< 8	< 70	< 29
	08/08/18 - 08/29/18		< 8	< 8	< 19	< 8	< 17	< 9	< 14	< 9	< 8	< 72	< 28
	09/06/18 - 09/26/18		< 6	< 7	< 18	< 7	< 15	< 8	< 13	< 8	< 7	< 65	< 23
	10/03/18 - 10/31/18		< 5	< 4	< 12	< 5	< 9	< 5	< 8	< 6	< 5	< 37	< 11
	11/07/18 - 11/28/18		< 5	< 5	< 16	< 8	< 12	< 6	< 11	< 6	< 5	< 44	< 15
	12/05/18 - 12/26/18		< 7	< 7	< 15	< 9	< 14	< 9	< 13	< 8	< 8	< 45	< 12
		MEAN		-	-	-	-	-	-	-	-	-	-
Z-18	01/04/18 - 01/31/18		< 7	< 7	< 15	< 7	< 16	< 7	< 12	< 8	< 7	< 43	< 13
	02/07/18 - 02/28/18		< 3	< 4	< 8	< 3	< 7	< 4	< 7	< 4	< 3	< 29	< 8
	03/07/18 - 03/28/18		< 5	< 5	< 12	< 4	< 12	< 7	< 11	< 6	< 6	< 55	< 13
	04/05/18 - 04/25/18		< 2	< 2	< 4	< 2	< 3	< 2	< 3	< 2	< 2	< 17	< 5
	05/03/18 - 05/30/18		< 7	< 7	< 14	< 6	< 12	< 6	< 14	< 7	< 6	< 60	< 23
	06/06/18 - 06/27/18		< 2	< 2	< 5	< 2	< 4	< 2	< 4	< 2	< 2	< 19	< 6
	07/05/18 - 07/31/18		< 5	< 8	< 17	< 8	< 8	< 8	< 12	< 8	< 6	< 57	< 22
	08/08/18 - 08/29/18		< 8	< 8	< 22	< 9	< 16	< 10	< 15	< 8	< 8	< 65	< 18
	09/06/18 - 09/26/18		< 6	< 8	< 13	< 7	< 13	< 9	< 12	< 7	< 7	< 75	< 16
	10/03/18 - 10/31/18		< 5	< 7	< 12	< 3	< 12	< 7	< 12	< 8	< 6	< 43	< 14
	11/07/18 - 11/28/18		< 5	< 6	< 12	< 3	< 13	< 6	< 11	< 6	< 6	< 36	< 11
	12/05/18 - 12/26/18		< 7	< 7	< 15	< 7	< 14	< 7	< 12	< 7	< 6	< 36	< 12
		MEAN		-	-	-	-	-	-	-	-	-	-

Table C-II.1

**Concentrations of Gamma Emitters in Fish Samples Collected in the  
Vicinity of Zion Nuclear Power Station, 2018**  
Results in Units of pCi/kilograms wet  $\pm$  2 Sigma

SITE	COLLECTION		Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
	PERIOD												
Z-26	(Predator)												
<i>White Sucker</i>	05/01/18		< 67	< 76	< 183	< 72	< 125	< 90	< 138	< 65	< 67	< 1217	< 287
<i>Largemouth Bass</i>	05/01/18		< 45	< 58	< 152	< 51	< 110	< 73	< 105	< 52	< 51	< 816	< 226
<i>Common carp</i>	10/04/18		< 44	< 72	< 202	< 43	< 120	< 74	< 98	< 64	< 55	< 906	< 318
<i>Brown trout</i>	10/04/18		< 65	< 76	< 175	< 41	< 130	< 69	< 139	< 77	< 69	< 1504	< 401
	MEAN		-	-	-	-	-	-	-	-	-	-	-
Z-27	(Predator)												
<i>Lake Trout</i>	05/15/18		< 92	< 86	< 219	< 81	< 170	< 98	< 142	< 89	< 98	< 837	< 236
<i>Burbot</i>	05/15/18		< 76	< 101	< 165	< 75	< 169	< 100	< 146	< 86	< 99	< 744	< 182
<i>Lake Trout</i>	10/26/18		< 51	< 51	< 83	< 43	< 107	< 54	< 93	< 56	< 46	< 342	< 103
<i>Burbot</i>	10/26/18		< 51	< 36	< 86	< 45	< 81	< 51	< 85	< 40	< 51	< 243	< 83
	MEAN		-	-	-	-	-	-	-	-	-	-	-



Table C-III.1

**Concentrations of Gamma Emitters in Sediment Samples Collected in the  
Vicinity of Zion Nuclear Power Station, 2018**  
Results in Units of pCi/kilograms Dry + 2 Sigma

SITE	COLLECTION	Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
	PERIOD											
Z-25	05/16/18	< 40	< 43	< 97	< 43	< 91	< 47	< 71	< 41	< 49	< 198	< 59
	10/24/18	< 54	< 52	< 140	< 70	< 129	< 60	< 112	< 65	< 66	< 240	< 30
	MEAN	-	-	-	-	-	-	-	-	-	-	-

**Table C-IV.1 Concentrations of Gross Beta in Air Particulate Samples Collected in the Vicinity of Zion Nuclear Power Station, 2018**  
Results in Units of E-3 pCi/cubic meter  $\pm$  2 Sigma

COLLECTION PERIOD	GROUP I			GROUP II
	Z-01	Z-02	Z-03	Z-13
12/27/17 - 01/04/18	29 $\pm$ 5	26 $\pm$ 4	27 $\pm$ 4	30 $\pm$ 5
01/04/18 - 01/10/18	20 $\pm$ 5	18 $\pm$ 5	20 $\pm$ 5	17 $\pm$ 5
01/10/18 - 01/17/18	13 $\pm$ 4	10 $\pm$ 4	11 $\pm$ 4	10 $\pm$ 4
01/17/18 - 01/24/18	14 $\pm$ 4	17 $\pm$ 4	19 $\pm$ 4	20 $\pm$ 4
01/24/18 - 01/31/18	14 $\pm$ 4	17 $\pm$ 4	14 $\pm$ 4	12 $\pm$ 4
01/31/18 - 02/07/18	20 $\pm$ 4	21 $\pm$ 4	21 $\pm$ 5	22 $\pm$ 4
02/07/18 - 02/14/18	27 $\pm$ 5	23 $\pm$ 5	26 $\pm$ 5	23 $\pm$ 5
02/14/18 - 02/21/18	17 $\pm$ 4	14 $\pm$ 4	16 $\pm$ 4	14 $\pm$ 4
02/21/18 - 02/28/18	12 $\pm$ 4	15 $\pm$ 4	13 $\pm$ 4	14 $\pm$ 4
02/28/18 - 03/07/18	12 $\pm$ 4	11 $\pm$ 4	14 $\pm$ 5	11 $\pm$ 4
03/07/18 - 03/14/18	10 $\pm$ 4	8 $\pm$ 4	17 $\pm$ 4	12 $\pm$ 4
03/14/18 - 03/21/18	15 $\pm$ 4	11 $\pm$ 4	19 $\pm$ 4	12 $\pm$ 4
03/21/18 - 03/28/18	11 $\pm$ 4	6 $\pm$ 4	20 $\pm$ 9	7 $\pm$ 4
03/28/18 - 04/05/18	14 $\pm$ 4	9 $\pm$ 3	19 $\pm$ 4	< 4
04/05/18 - 04/12/18	16 $\pm$ 4	9 $\pm$ 4	16 $\pm$ 4	13 $\pm$ 4
04/12/18 - 04/18/18	10 $\pm$ 4	9 $\pm$ 4	9 $\pm$ 4	7 $\pm$ 4
04/18/18 - 04/25/18	14 $\pm$ 4	13 $\pm$ 4	16 $\pm$ 4	14 $\pm$ 4
04/25/18 - 05/03/18	13 $\pm$ 3	11 $\pm$ 3	13 $\pm$ 3	12 $\pm$ 3
05/03/18 - 05/09/18	17 $\pm$ 5	11 $\pm$ 4	19 $\pm$ 5	15 $\pm$ 5
05/09/18 - 05/16/18	10 $\pm$ 4	7 $\pm$ 3	9 $\pm$ 3	10 $\pm$ 4
05/16/18 - 05/23/18	6 $\pm$ 3	10 $\pm$ 3	11 $\pm$ 4	8 $\pm$ 3
05/23/18 - 05/30/18	32 $\pm$ 8	26 $\pm$ 7	41 $\pm$ 8	39 $\pm$ 8
05/30/18 - 06/06/18	11 $\pm$ 4	7 $\pm$ 3	9 $\pm$ 3	8 $\pm$ 3
06/06/18 - 06/13/18	12 $\pm$ 4	7 $\pm$ 3	7 $\pm$ 3	12 $\pm$ 4
06/13/18 - 06/20/18	14 $\pm$ 4	11 $\pm$ 4	14 $\pm$ 4	18 $\pm$ 4
06/20/18 - 06/27/18	12 $\pm$ 4	6 $\pm$ 3	13 $\pm$ 4	11 $\pm$ 4
06/27/18 - 07/05/18	12 $\pm$ 4	7 $\pm$ 3	12 $\pm$ 4	12 $\pm$ 4
07/05/18 - 07/11/18	18 $\pm$ 5	13 $\pm$ 4	17 $\pm$ 5	17 $\pm$ 5
07/11/18 - 07/18/18	16 $\pm$ 4	11 $\pm$ 3	15 $\pm$ 4	14 $\pm$ 4
07/18/18 - 07/25/18	13 $\pm$ 4	8 $\pm$ 3	14 $\pm$ 4	13 $\pm$ 4
07/25/18 - 07/31/18	22 $\pm$ 5	13 $\pm$ 4	19 $\pm$ 4	19 $\pm$ 4
07/31/18 - 08/08/18	19 $\pm$ 4	11 $\pm$ 3	19 $\pm$ 4	21 $\pm$ 4
08/08/18 - 08/15/18	19 $\pm$ 4	9 $\pm$ 3	17 $\pm$ 4	19 $\pm$ 4
08/15/18 - 08/22/18	18 $\pm$ 4	17 $\pm$ 4	23 $\pm$ 4	23 $\pm$ 4
08/22/18 - 08/29/18	20 $\pm$ 4	14 $\pm$ 4	23 $\pm$ 4	21 $\pm$ 4
08/29/18 - 09/06/18	7 $\pm$ 3	4 $\pm$ 3	10 $\pm$ 3	9 $\pm$ 3
09/06/18 - 09/12/18	12 $\pm$ 4	12 $\pm$ 4	16 $\pm$ 4	13 $\pm$ 4
09/12/18 - 09/19/18	14 $\pm$ 4	9 $\pm$ 4	10 $\pm$ 4	13 $\pm$ 4
09/19/18 - 09/26/18	14 $\pm$ 4	10 $\pm$ 3	16 $\pm$ 4	13 $\pm$ 4
09/26/18 - 10/03/18	11 $\pm$ 4	10 $\pm$ 4	13 $\pm$ 4	14 $\pm$ 4
10/03/18 - 10/10/18	15 $\pm$ 4	12 $\pm$ 4	11 $\pm$ 4	13 $\pm$ 4
10/10/18 - 10/17/18	14 $\pm$ 4	10 $\pm$ 4	17 $\pm$ 4	13 $\pm$ 4
10/17/18 - 10/24/18	11 $\pm$ 4	8 $\pm$ 3	10 $\pm$ 3	13 $\pm$ 4
10/24/18 - 10/31/18	12 $\pm$ 4	8 $\pm$ 3	15 $\pm$ 4	15 $\pm$ 4
10/31/18 - 11/07/18	12 $\pm$ 4	6 $\pm$ 3	12 $\pm$ 4	12 $\pm$ 4
11/07/18 - 11/14/18	14 $\pm$ 4	8 $\pm$ 4	16 $\pm$ 4	14 $\pm$ 4
11/14/18 - 11/21/18	19 $\pm$ 4	15 $\pm$ 4	22 $\pm$ 4	20 $\pm$ 4
11/21/18 - 11/28/18	20 $\pm$ 4	15 $\pm$ 4	22 $\pm$ 5	22 $\pm$ 5
11/28/18 - 12/05/18	12 $\pm$ 4	11 $\pm$ 4	15 $\pm$ 4	14 $\pm$ 4
12/05/18 - 12/12/18	29 $\pm$ 5	23 $\pm$ 5	36 $\pm$ 5	30 $\pm$ 5
12/12/18 - 12/19/18	28 $\pm$ 5	24 $\pm$ 5	34 $\pm$ 6	38 $\pm$ 6
12/19/18 - 12/26/18	21 $\pm$ 4	17 $\pm$ 4	23 $\pm$ 4	26 $\pm$ 5
MEAN $\pm$ 2 STD DEV	16 $\pm$ 11	12 $\pm$ 11	17 $\pm$ 13	16 $\pm$ 14

THE MEAN AND TWO STANDARD DEVIATION ARE CALCULATED USING THE POSITIVE VALUES

**Table C-IV.2 Monthly and Yearly Mean Values of Gross Beta Concentrations in Air Particulate Samples Collected in the Vicinity of Zion Nuclear Power Station, 2018**

Results in Units of E-3 pCi/cubic meter  $\pm$  2 Sigma

GROUP I - ONSITE LOCATIONS				GROUP II - OFFSITE CONTROL LOCATION			
COLLECTION PERIOD	MIN	MAX	MEAN $\pm$ 2SD	COLLECTION PERIOD	MIN	MAX	MEAN $\pm$ 2SD
12/27/17 - 01/31/18	10	29	18 $\pm$ 11	12/27/17 - 01/31/18	10	30	18 $\pm$ 16
01/31/18 - 02/28/18	12	27	19 $\pm$ 10	01/31/18 - 02/28/18	14	23	18 $\pm$ 10
02/28/18 - 03/28/18	6	20	13 $\pm$ 9	02/28/18 - 03/28/18	7	12	10 $\pm$ 4
03/28/18 - 05/03/18	9	19	13 $\pm$ 7	04/05/18 - 05/03/18	7	14	12 $\pm$ 6
05/03/18 - 05/30/18	6	41	17 $\pm$ 22	05/03/18 - 05/30/18	8	39	18 $\pm$ 28
05/30/18 - 06/27/18	6	14	10 $\pm$ 6	05/30/18 - 06/27/18	8	18	12 $\pm$ 8
06/27/18 - 07/31/18	7	22	14 $\pm$ 8	06/27/18 - 07/31/18	12	19	15 $\pm$ 6
07/31/18 - 08/29/18	9	23	17 $\pm$ 8	07/31/18 - 08/29/18	19	23	21 $\pm$ 3
08/29/18 - 10/03/18	4	16	11 $\pm$ 6	08/29/18 - 10/03/18	9	14	12 $\pm$ 4
10/03/18 - 10/31/18	8	17	12 $\pm$ 6	10/03/18 - 10/31/18	13	15	13 $\pm$ 2
10/31/18 - 11/28/18	6	22	15 $\pm$ 10	10/31/18 - 11/28/18	12	22	17 $\pm$ 9
11/28/18 - 12/26/18	11	36	23 $\pm$ 16	11/28/18 - 12/26/18	14	38	27 $\pm$ 20
12/27/17 - 12/26/18	4	41	15 $\pm$ 12	12/27/17 - 12/26/18	7	39	16 $\pm$ 14

Table C-IV.3

**Concentrations of Gamma Emitters in Air Particulate Samples Collected  
in the Vicinity of Zion Nuclear Power Station, 2018**  
Results in Units of E-3 pCi/cubic meter + 2 Sigma

SITE	COLLECTION PERIOD	Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
Z-01	12/27/17 - 03/28/18	< 1	< 3	< 4	< 3	< 5	< 2	< 4	< 2	< 2	< 26	< 9
	03/28/18 - 06/27/18	< 2	< 2	< 6	< 3	< 4	< 3	< 6	< 3	< 2	< 21	< 9
	06/27/18 - 09/26/18	< 2	< 2	< 3	< 1	< 3	< 2	< 3	< 1	< 2	< 21	< 10
	09/26/18 - 12/26/18	< 2	< 2	< 7	< 3	< 5	< 3	< 5	< 3	< 2	< 24	< 10
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-02	12/27/17 - 03/28/18	< 2	< 3	< 6	< 2	< 5	< 3	< 5	< 3	< 2	< 28	< 13
	03/28/18 - 06/27/18	< 1	< 1	< 6	< 3	< 6	< 3	< 3	< 3	< 2	< 21	< 7
	06/27/18 - 09/26/18	< 3	< 5	< 10	< 5	< 10	< 5	< 8	< 4	< 3	< 72	< 24
	09/26/18 - 12/26/18	< 2	< 3	< 6	< 3	< 5	< 2	< 5	< 2	< 2	< 25	< 10
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-03	12/27/17 - 03/28/18	< 5	< 6	< 15	< 5	< 14	< 7	< 10	< 5	< 4	< 62	< 23
	03/28/18 - 06/27/18	< 2	< 2	< 7	< 3	< 5	< 3	< 5	< 3	< 2	< 28	< 9
	06/27/18 - 09/26/18	< 2	< 3	< 7	< 2	< 5	< 4	< 5	< 3	< 2	< 39	< 15
	09/26/18 - 12/26/18	< 2	< 2	< 4	< 2	< 3	< 3	< 5	< 2	< 2	< 20	< 10
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-13	12/27/17 - 03/28/18	< 2	< 3	< 5	< 3	< 6	< 2	< 4	< 2	< 2	< 24	< 13
	03/28/18 - 06/27/18	< 3	< 2	< 7	< 2	< 6	< 3	< 6	< 3	< 3	< 24	< 9
	06/27/18 - 09/26/18	< 2	< 2	< 8	< 5	< 5	< 3	< 5	< 3	< 2	< 37	< 18
	09/26/18 - 12/26/18	< 3	< 2	< 4	< 3	< 5	< 3	< 4	< 3	< 2	< 25	< 12
	MEAN	-	-	-	-	-	-	-	-	-	-	-

C-8

Table C-V.1

**Concentrations of Gamma Emitters in Vegetation Samples  
Collected in the Vicinity of Zion Nuclear Power Station, 2018**

Results in Units of pCi/kilograms wet  $\pm$  2 Sigma

SITE	COLLECTION		Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
	PERIOD												
<b>Z-CONTROL</b>													
<i>Potatoes</i>	09/19/18		< 21	< 17	< 42	< 23	< 51	< 23	< 42	< 26	< 19	< 104	< 28
<i>Cabbage</i>	09/19/18		< 20	< 20	< 40	< 26	< 38	< 22	< 33	< 17	< 21	< 89	< 21
	<i>MEAN</i>		-	-	-	-	-	-	-	-	-	-	-
<b>Z-QUAD 3</b>													
<i>Cabbage</i>	09/19/18		< 15	< 14	< 32	< 15	< 34	< 18	< 25	< 14	< 16	< 75	< 22
<i>Carrots</i>	09/19/18		< 20	< 28	< 54	< 27	< 56	< 29	< 48	< 29	< 31	< 127	< 29
	<i>MEAN</i>		-	-	-	-	-	-	-	-	-	-	-
<b>Z-QUAD 4</b>													
<i>Cauliflower</i>	09/19/18		< 18	< 18	< 40	< 19	< 42	< 22	< 26	< 21	< 20	< 83	< 13
<i>Sweet potatoes</i>	09/19/18		< 18	< 16	< 36	< 20	< 41	< 17	< 35	< 18	< 21	< 81	< 15
	<i>MEAN</i>		-	-	-	-	-	-	-	-	-	-	-

**Table C-VI.1**

**Quarterly TLD Results for Zion Nuclear Power Station, 2018**

Results in Units of Milli-Roentgen/Quarter  $\pm$  2 Standard Deviations

STATION CODE	MEAN $\pm$ 2 S.D.	JAN - MAR	APR - JUN	JUL - SEP	OCT - DEC
Z-01	18 $\pm$ 4	16	17	20	19
Z-02	17 $\pm$ 2	15	17	17	17
Z-03	17 $\pm$ 3	15	17	19	18
Z-13	19 $\pm$ 4	16	19	21	20
Z-101	16 $\pm$ 3	14	16	18	17
Z-102	18 $\pm$ 3	16	18	19	18
Z-103	17 $\pm$ 3	15	17	18	17
Z-104	17 $\pm$ 4	14	18	18	18
Z-105	17 $\pm$ 3	15	17	18	18
Z-106	17 $\pm$ 4	15	16	18	19
Z-107	17 $\pm$ 2	16	17	17	18
Z-108	18 $\pm$ 3	16	19	18	20
Z-109	19 $\pm$ 3	16	19	20	19
Z-112	19 $\pm$ 4	16	18	20	20
Z-113	17 $\pm$ 5	14	17	19	19
Z-114	18 $\pm$ 4	15	18	19	19
Z-115	18 $\pm$ 4	15	19	20	18
Z-121	17 $\pm$ 3	14	17	18	17
Z-124	17 $\pm$ 5	14	17	20	18
Z-125	20 $\pm$ 6	24	17	19	18
Z-129	17 $\pm$ 4	14	17	18	18
Z-130	19 $\pm$ 5	15	19	20	20
Z-131	30 $\pm$ 5	26	30	32	30
Z-209	17 $\pm$ 3	15	17	19	18
Z-211	21 $\pm$ 5	18	21	24	22
Z-212	21 $\pm$ 5	18	21	24	22
Z-213	23 $\pm$ 5	19	23	25	23
Z-214	21 $\pm$ 5	17	21	23	21
Z-215	21 $\pm$ 6	17	22	24	21
Z-216	18 $\pm$ 3	15	18	19	18

**Table C-VI.2 MEAN QUARTERLY TLD RESULTS FOR INNER RING, OUTER RING, SPECIAL INTEREST, AND CONTROL STATIONS FOR ZION NUCLEAR POWER STATION, 2018**  
Results in Units of Milli-Roentgen/Quarter  $\pm$  2 Standard Deviations of the Station Data

COLLECTION PERIOD	INNER RING $\pm$ 2 S.D.	OUTER RING $\pm$ 2 S.D.	SPECIAL INTEREST $\pm$ 2 S.D.	CONTROL $\pm$ 2 S.D.
JAN-MAR	16 $\pm$ 7	17 $\pm$ 3	15 $\pm$ 2	16 $\pm$ 1
APR-JUN	18 $\pm$ 6	20 $\pm$ 5	18 $\pm$ 2	19 $\pm$ 1
JUL-SEP	19 $\pm$ 7	23 $\pm$ 5	20 $\pm$ 1	21 $\pm$ 1
OCT-DEC	19 $\pm$ 6	21 $\pm$ 4	19 $\pm$ 2	20 $\pm$ 1

**Table C-VI.3**

**SUMMARY OF THE AMBIENT DOSIMETRY PROGRAM  
FOR ZION NUCLEAR POWER STATION, 2018  
RESULTS IN UNITS OF MILLI-ROENTGEN/QUARTER**

LOCATION	SAMPLES ANALYZED	PERIOD MINIMUM	PERIOD MAXIMUM	PERIOD MEAN $\pm$ 2 S.D.
INNER RING	142	13	32	18 $\pm$ 7
OUTER RING	56	14	25	20 $\pm$ 6
SPECIAL INTEREST	32	14	20	18 $\pm$ 4
CONTROL	24	15	21	19 $\pm$ 4

INNER RING STATIONS - Z-01, Z-02, Z-03, Z-101, Z-102-1, Z-103-1, Z-104, Z-105, Z-106, Z-107, Z-108, Z-109, Z-121, Z-124, Z-125, Z-129, Z130, Z-131

SPECIAL INTEREST STATIONS - Z-112, Z-113, Z-114, Z-115

OUTER RING STATIONS - Z-209, Z-211, Z-212, Z-213, Z-214, Z-215, Z-216

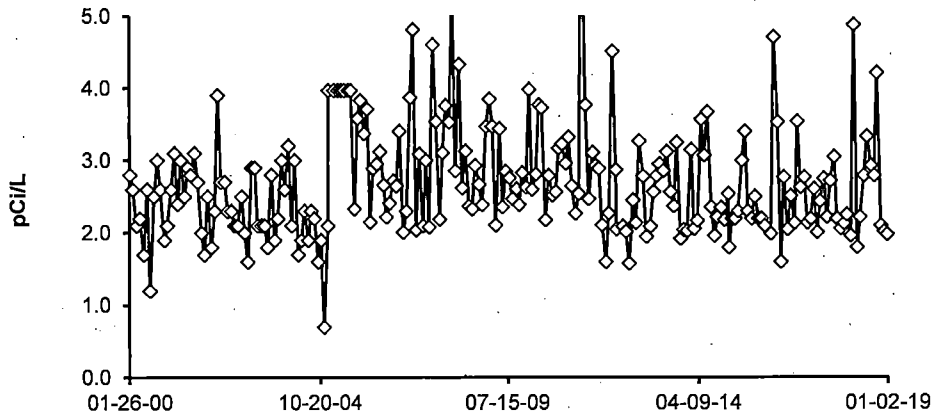
CONTROL STATION - Z-13

\*Note: There are 2 TLDs posted at each indicator station for redundancy and data recovery. In reporting results, the higher of the two readings are reported, except when reporting minimums, which are based on all results. There are six (6) TLDs posted at the control location, and that value is based on an average of all six results each quarter.

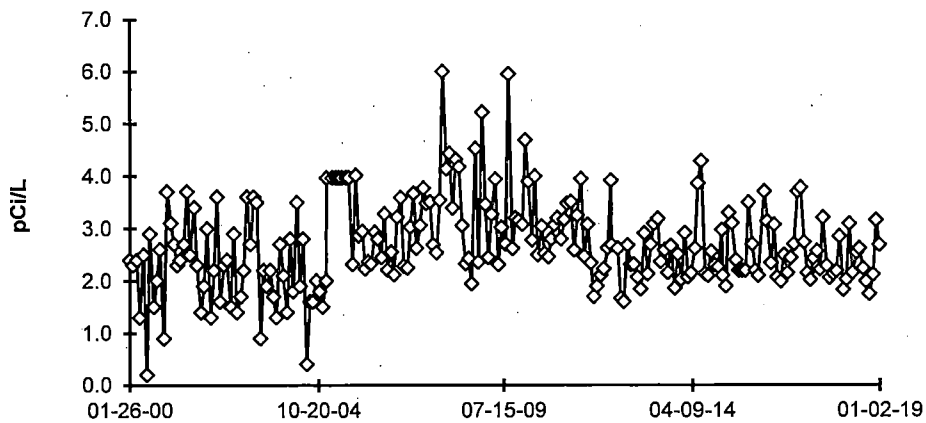
The period minimum in Table C-VI.3, above, was 13 mR/quarter at location Z-101. It was the single lowest result of all 254 TLD's analyzed during the year.

**FIGURE C-1  
PUBLIC WATER - GROSS BETA - STATIONS Z-14 AND  
Z-15 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2018**

**Z-14 (C) Kenosha Water Works**



**Z-15 Lake County Water Works**

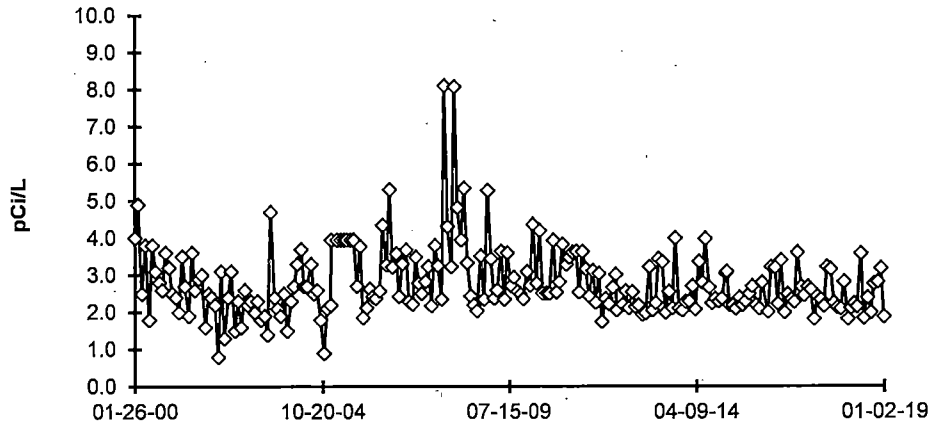


DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

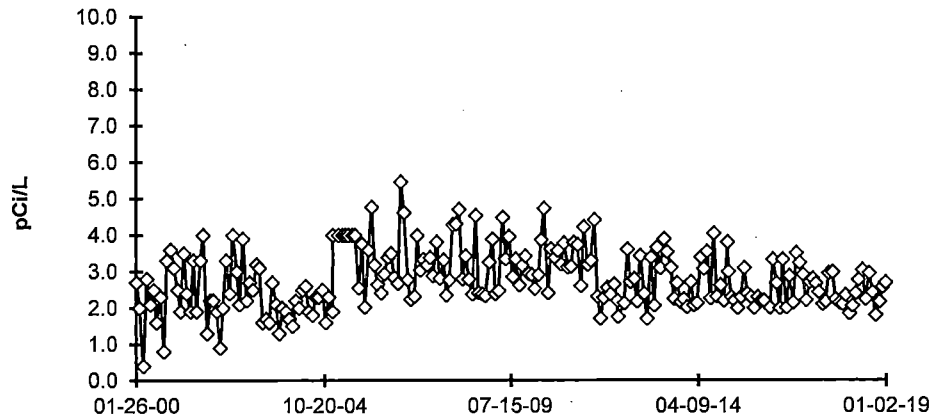


**FIGURE C-2  
PUBLIC WATER - GROSS BETA - STATIONS Z-16 AND  
Z-18 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2018**

**Z-16 Waukegan Water Works**



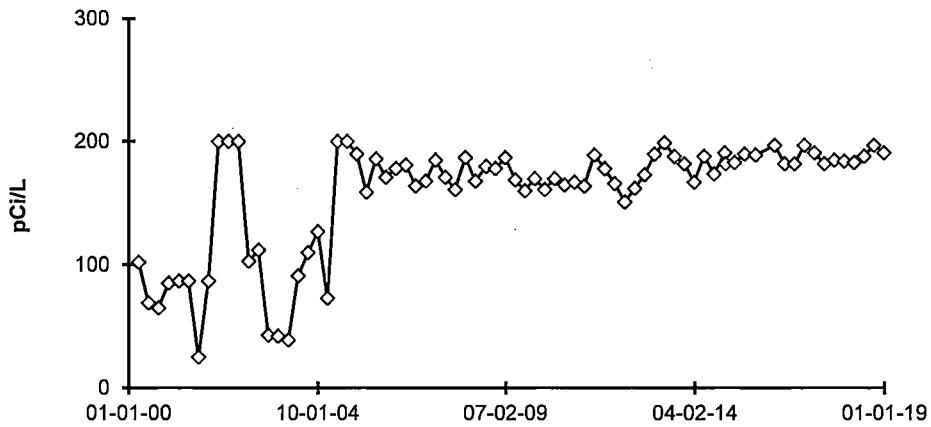
**Z-18 (C) Lake Forest Water Works**



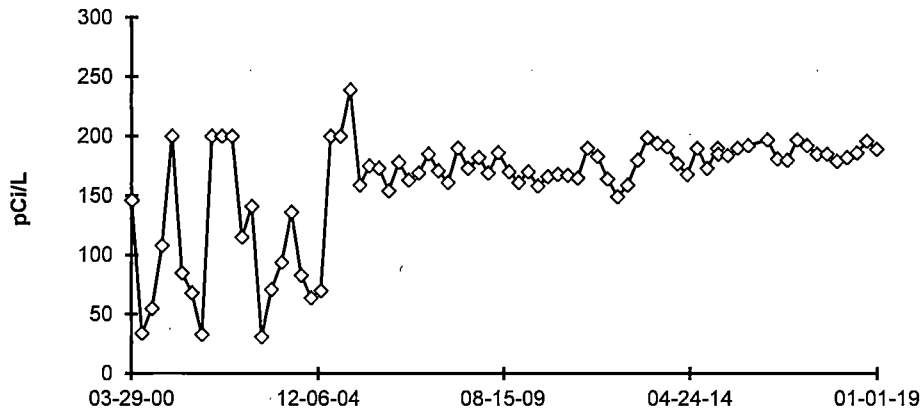
DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

**FIGURE C-3  
PUBLIC WATER - TRITIUM - STATION Z-14 AND Z-15  
COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2018**

**Z-14 (C) Kenosha Water Works**



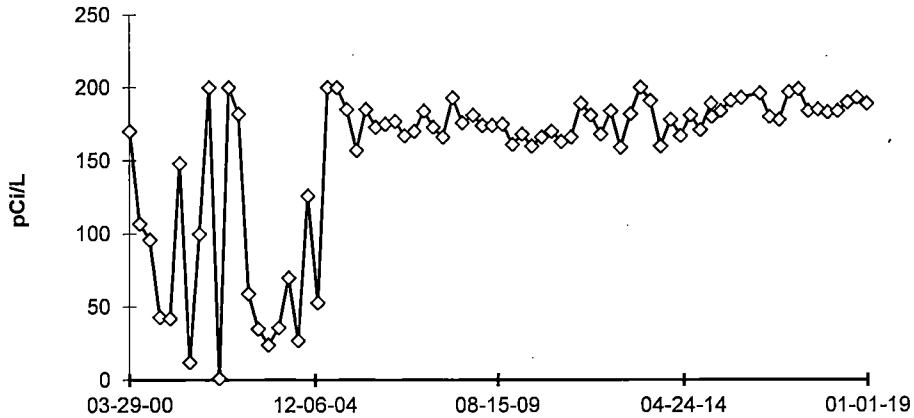
**Z-15 Lake County Water Works**



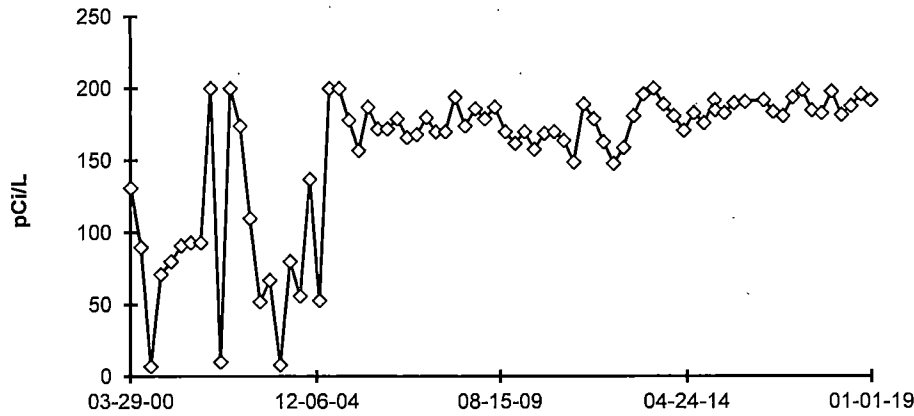
DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

**FIGURE C-4  
PUBLIC WATER - TRITIUM - STATION Z-16 AND Z-18  
COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2018**

**Z-16 Waukegan Water Works**



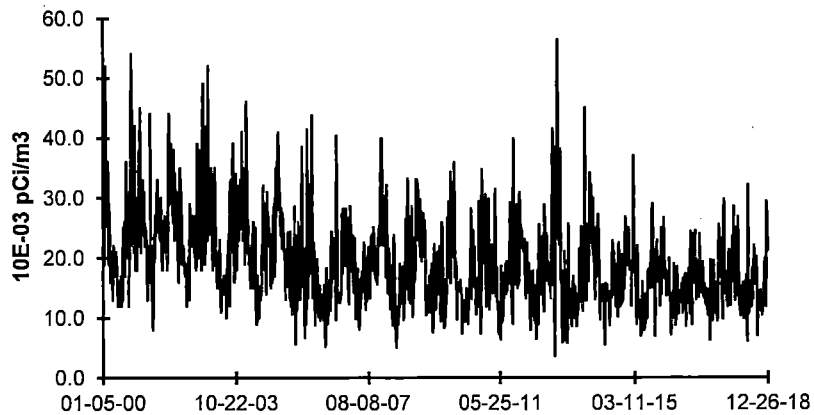
**Z-18 (C) Lake Forest Water Works**



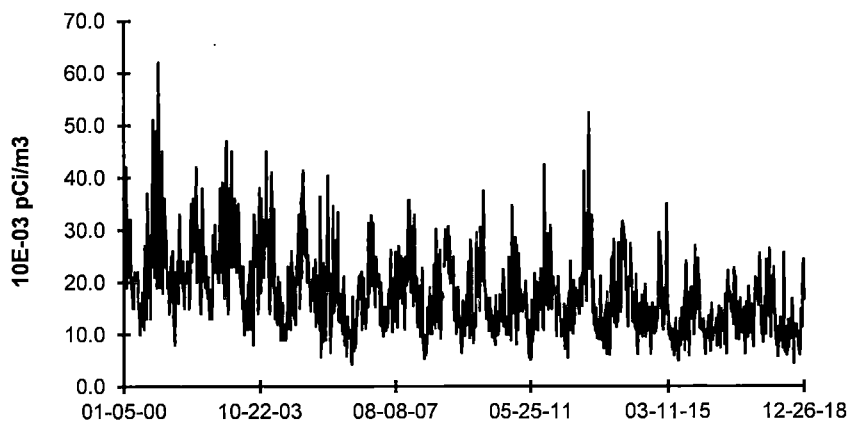
DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

**FIGURE C-5**  
**AIR PARTICULATES - GROSS BETA - STATIONS Z-01 AND**  
**Z-02 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2018**

**Z-01 Onsite No. 1, Southside**

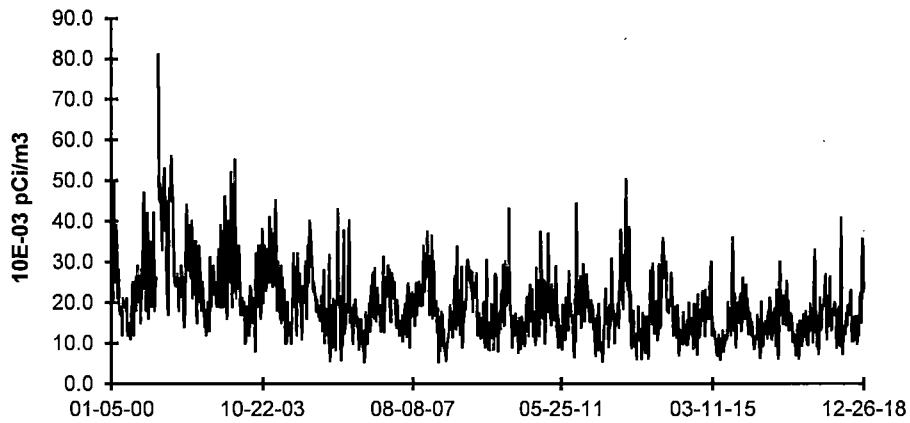


**Z-02 Onsite No. 2, Westside**



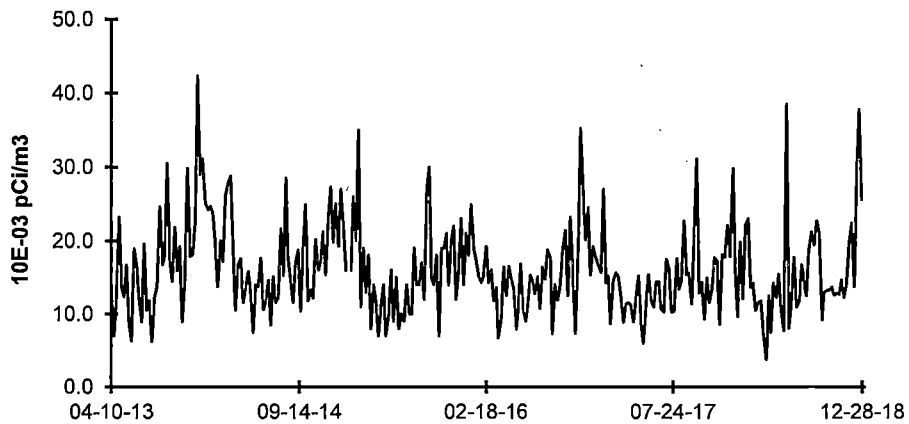
**FIGURE C-6**  
**AIR PARTICULATES - GROSS BETA - STATIONS Z-03**  
**COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2018**

**Z-03 Onsite No. 3, Northside**

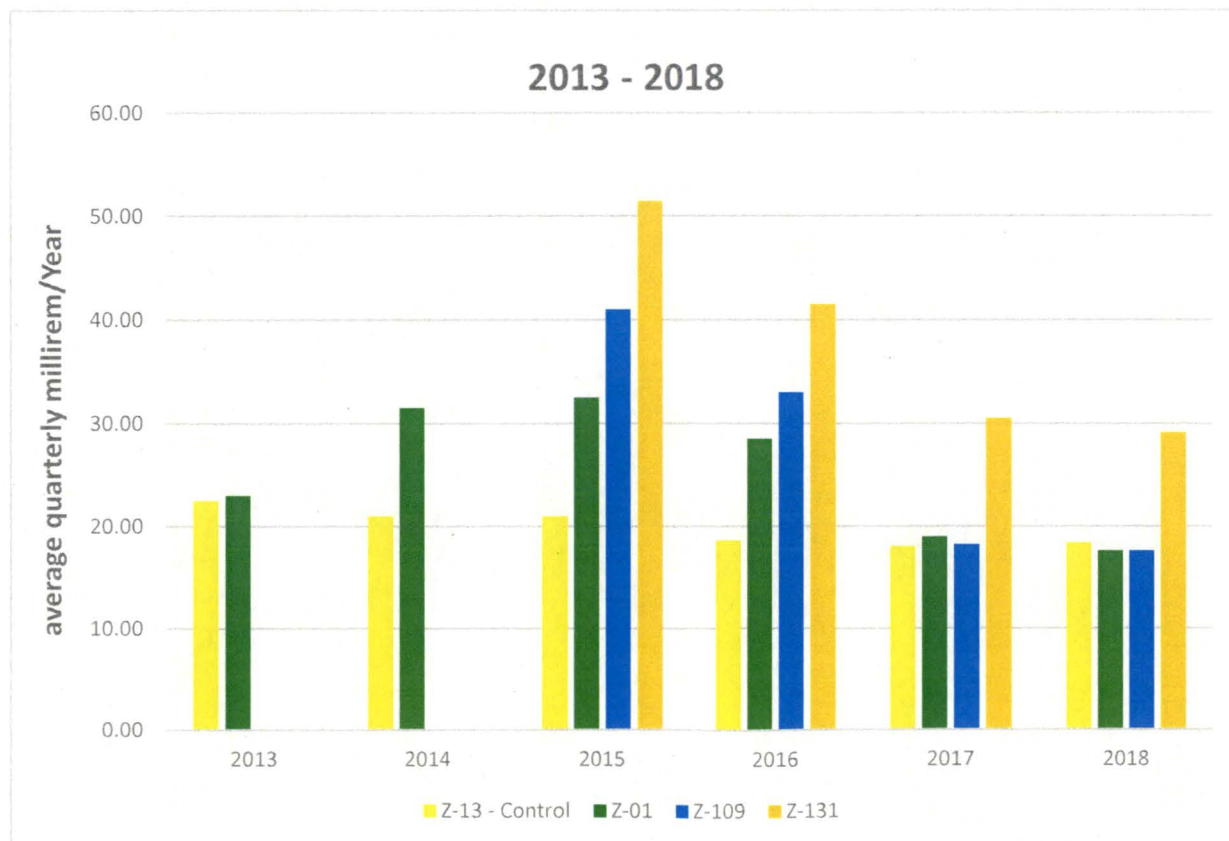
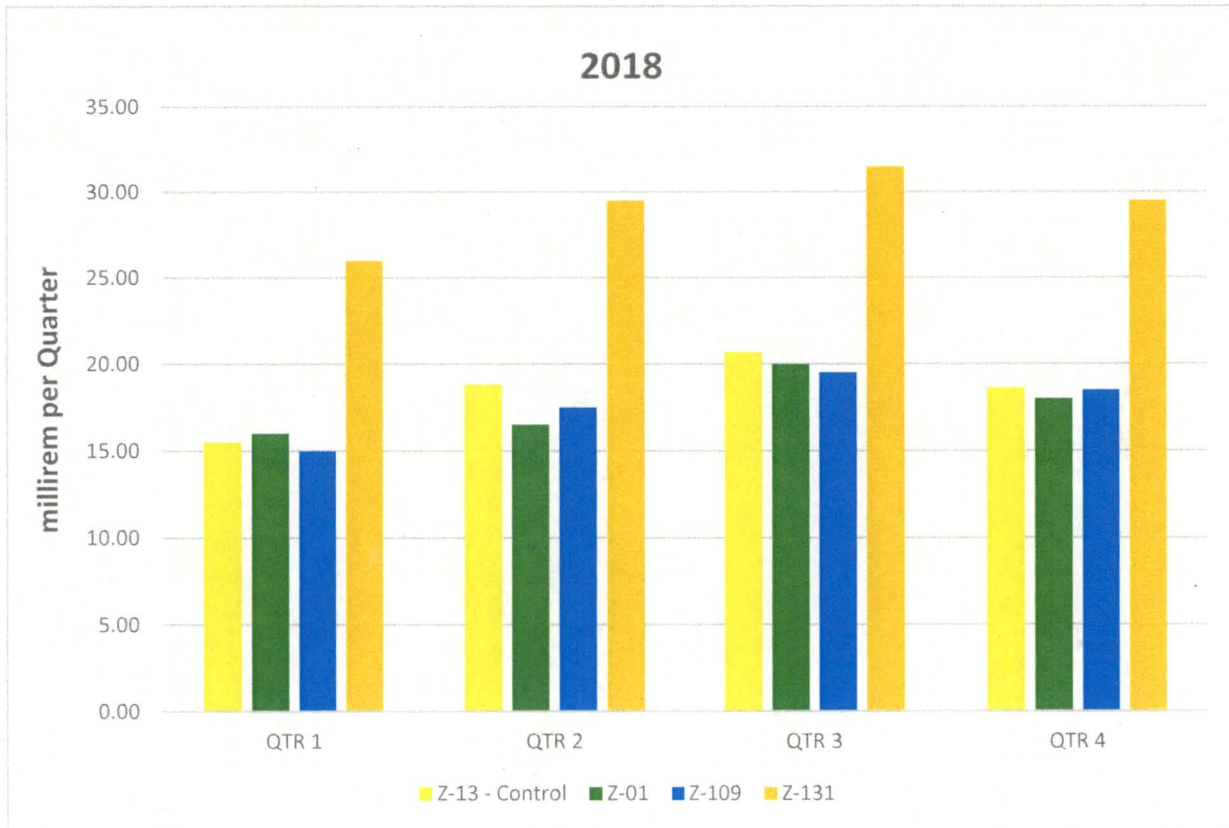


**AIR PARTICULATES - GROSS BETA - STATION Z-13**  
**COLLECTED IN THE VICINITY OF ZNPS, 2013 - 2018**

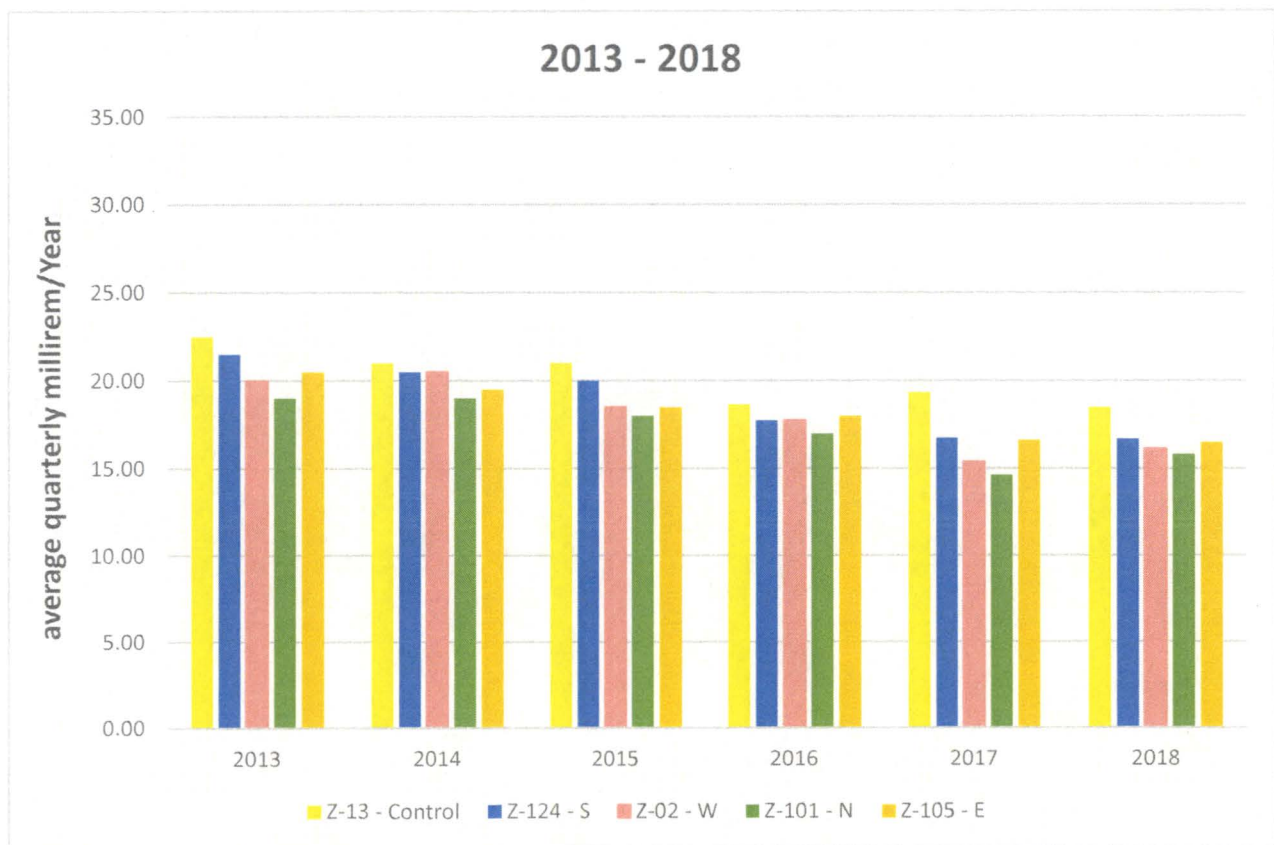
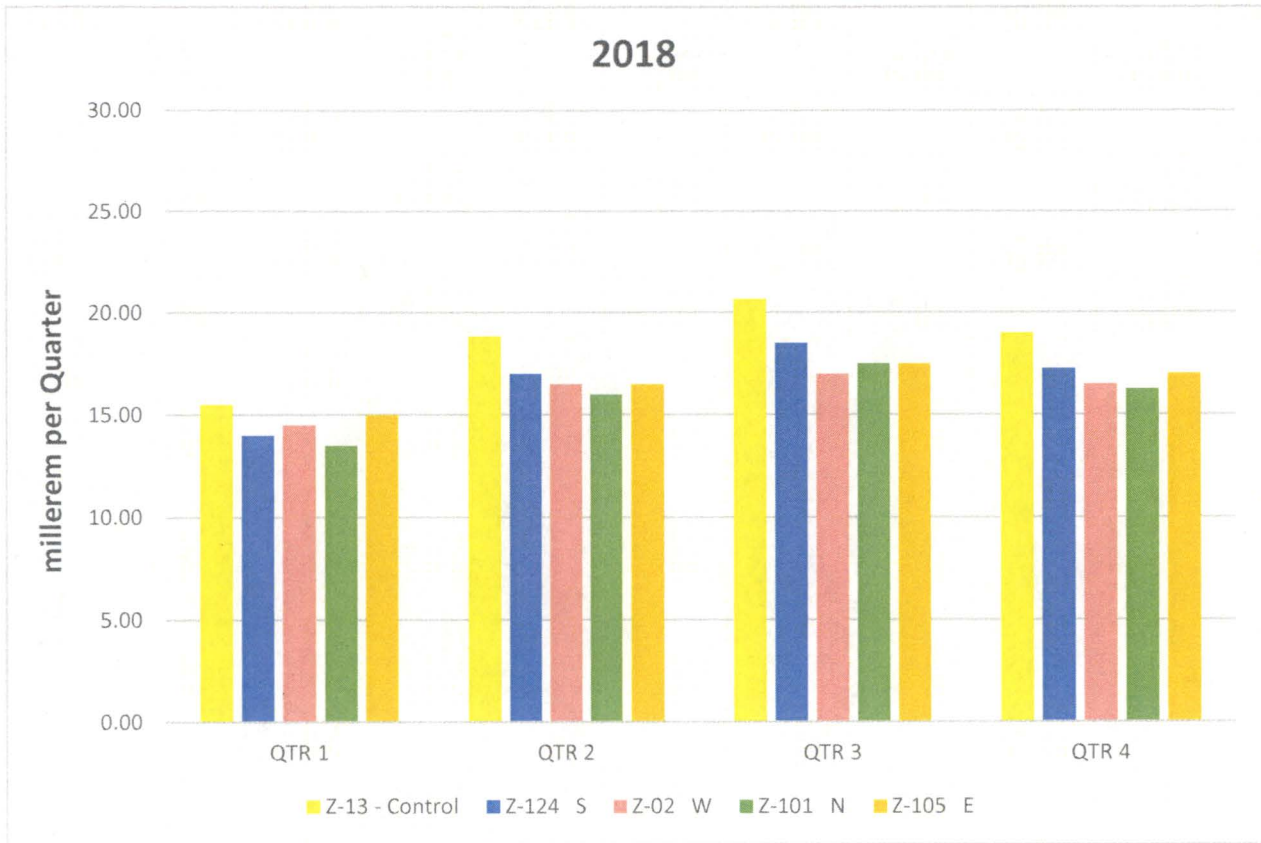
**Z-13 Offsite Control**



**FIGURE C-7**  
**ZNPS INNER RING TLD'S POTENTIALLY IMPACTED BY ISFSI**



**FIGURE C-8  
ZNPS AREA BOUNDARY TLD'S AT 4 COMPASS POINTS**



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**APPENDIX D**

**INTER-LABORATORY COMPARISON  
PROGRAM**

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TABLE D.1

**Analytics Environmental Radioactivity Cross-Check Program  
Teledyne Brown Engineering Environmental Services**

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value <sup>(a)</sup>	Ratio of TBE to Analytics Result	Evaluation <sup>(b)</sup>			
March 2018	E12133	Milk	Sr-89	pCi/L	76.1	90.1	0.84	A			
			Sr-90	pCi/L	12.2	12.5	0.98	A			
March 2018	E12134	Milk	Ce-141	pCi/L	77.8	77.0	1.01	A			
			Co-58	pCi/L	105	114	0.92	A			
			Co-60	pCi/L	181	187	0.97	A			
			Cr-51	pCi/L	298	326	0.92	A			
			Cs-134	pCi/L	150	180	0.84	A			
			Cs-137	pCi/L	164	172	0.95	A			
			Fe-59	pCi/L	140	139	1.01	A			
			I-131	pCi/L	105	108.0	0.97	A			
			Mn-54	pCi/L	133	131	1.01	A			
			Zn-65	pCi/L	242	244	0.99	A			
			E12135	Charcoal	I-131	pCi	93.7	95.4	0.98	A	
			March 2018	E12136	AP	Ce-141	pCi	92.6	85.3	1.09	A
						Co-58	pCi	130	126	1.03	A
Co-60	pCi	237				207	1.14	A			
Cr-51	pCi	411				361	1.14	A			
Cs-134	pCi	194				199	0.98	A			
Cs-137	pCi	200				191	1.05	A			
Fe-59	pCi	160				154	1.04	A			
Mn-54	pCi	152				145	1.05	A			
Zn-65	pCi	267	271	0.99	A						
March 2018	E12137	Water	Fe-55	pCi/L	1990	1700	1.17	A			
March 2018	E12138	Soil	Ce-141	pCi/g	0.148	0.118	1.26	W			
			Co-58	pCi/g	0.171	0.174	0.98	A			
			Co-60	pCi/g	0.297	0.286	1.04	A			
			Cr-51	pCi/g	0.537	0.498	1.08	A			
			Cs-134	pCi/g	0.274	0.275	1.00	A			
			Cs-137	pCi/g	0.355	0.337	1.05	A			
			Fe-59	pCi/g	0.243	0.212	1.15	A			
			Mn-54	pCi/g	0.228	0.201	1.14	A			
Zn-65	pCi/g	0.395	0.374	1.06	A						

(a) The Analytics known value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation

(b) Analytics evaluation based on TBE internal QC limits:

A = Acceptable - reported result falls within ratio limits of 0.80-1.20

W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30

N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

TABLE D.1

**Analytics Environmental Radioactivity Cross Check Program  
Teledyne Brown Engineering Environmental Services**

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value <sup>(a)</sup>	Ratio of TBE to Analytics Result	Evaluation <sup>(b)</sup>
June 2018	E12205	Milk	Sr-89	pCi/L	74.9	84.6	0.89	A
			Sr-90	pCi/L	10.5	11.4	0.92	A
	E12206	Milk	Ce-141	pCi/L	89.2	82.2	1.08	A
			Co-58	pCi/L	94.8	89	1.07	A
			Co-60	pCi/L	125	113	1.10	A
			Cr-51	pCi/L	256	239	1.07	A
			Cs-134	pCi/L	112	114	0.99	A
			Cs-137	pCi/L	107	98.8	1.08	A
			Fe-59	pCi/L	95.9	86.0	1.12	A
			I-131	pCi/L	69.8	71.9	0.97	A
			Mn-54	pCi/L	138	130	1.06	A
			Zn-65	pCi/L	186	157	1.18	A
	E12207	Charcoal	I-131	pCi	69.6	72.2	0.96	A
	E12208	AP	Ce-141	pCi	151	165	0.92	A
			Co-58	pCi	174	178	0.98	A
			Co-60	pCi	290	227	1.28	W
			Cr-51	pCi	452	478	0.95	A
			Cs-134	pCi	215	227	0.95	A
			Cs-137	pCi	206	198	1.04	A
			Fe-59	pCi	180	172	1.05	A
Mn-54			pCi	265	260	1.02	A	
E12209	Water	Fe-55	pCi/L	1790	1740	1.03	A	
E12210	AP	Sr-89	pCi	77.8	90.3	0.86	A	
		Sr-90	pCi	9.54	12.2	0.78	W	

(a) The Analytics known value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation

(b) Analytics evaluation based on TBE internal QC limits:

A = Acceptable - reported result falls within ratio limits of 0.80-1.20

W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30

N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

TABLE D.1

**Analytics Environmental Radioactivity Cross Check Program  
Teledyne Brown Engineering Environmental Services**

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value <sup>(a)</sup>	Ratio of TBE to Analytics Result	Evaluation <sup>(b)</sup>
September 2018	E12271	Milk	Sr-89	pCi/L	79.4	81.7	0.97	A
			Sr-90	pCi/L	12.2	14.8	0.82	A
	E12272	Milk	Ce-141	pCi/L	152	128	1.19	A
			Co-58	pCi/L	161	144	1.12	A
			Co-60	pCi/L	208	190	1.10	A
			Cr-51	pCi/L	244	265	0.92	A
			Cs-134	pCi/L	124	123	1.01	A
			Cs-137	pCi/L	166	147	1.13	A
			Fe-59	pCi/L	158	119	1.32	N <sup>(1)</sup>
			I-131	pCi/L	83.1	58.2	1.43	N <sup>(2)</sup>
			Mn-54	pCi/L	191	167	1.14	A
			Zn-65	pCi/L	229	201	1.14	A
			E12273	Charcoal	I-131	pCi	83.0	80.7
	E12274	AP	Ce-141	pCi	101	85.6	1.18	A
			Co-58	pCi	92.7	96.0	0.97	A
			Co-60	pCi	142	127	1.12	A
			Cr-51	pCi	218	177	1.23	W
			Cs-134	pCi	81.2	81.9	0.99	A
			Cs-137	pCi	99.0	98.5	1.01	A
			Fe-59	pCi	93.7	79.7	1.18	A
			Mn-54	pCi	116	112	1.04	A
			Zn-65	pCi	139	134	1.04	A
	E12302	Water	Fe-55	pCi/L	2120	1820	1.17	A
	E12276	Soil	Ce-141	pCi/g	0.259	0.221	1.17	A
			Co-58	pCi/g	0.279	0.248	1.12	A
			Co-60	pCi/g	0.367	0.328	1.12	A
			Cr-51	pCi/g	0.597	0.457	1.31	N <sup>(3)</sup>
Cs-134			pCi/g	0.261	0.212	1.23	W	
Cs-137			pCi/g	0.376	0.330	1.14	A	
Fe-59			pCi/g	0.248	0.206	1.20	A	
Mn-54			pCi/g	0.317	0.289	1.10	A	
Zn-65			pCi/g	0.407	0.347	1.17	A	

(a) The Analytics known value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation

(b) Analytics evaluation based on TBE internal QC limits:

A = Acceptable - reported result falls within ratio limits of 0.80-1.20

W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30

N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

(1) See NCR 18-20

(2) See NCR 18-24

(3) See NCR 18-21

TABLE D.1

**Analytics Environmental Radioactivity Cross Check Program  
Teledyne Brown Engineering Environmental Services**

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value <sup>(a)</sup>	Ratio of TBE to Analytics Result	Evaluation <sup>(b)</sup>
December 2018	E12313	Milk	Sr-89	pCi/L	71.9	91.9	0.78	W
			Sr-90	pCi/L	12.1	13.3	0.91	A
	E12314	Milk	Ce-141	pCi/L	124	133	0.93	A
			Co-58	pCi/L	110	119	0.93	A
			Co-60	pCi/L	202	212	0.95	A
			Cr-51	pCi/L	292	298	0.98	A
			Cs-134	pCi/L	146	171	0.85	A
			Cs-137	pCi/L	118	121	0.98	A
			Fe-59	pCi/L	120	114	1.05	A
			I-131	pCi/L	94.2	93.3	1.01	A
			Mn-54	pCi/L	151	154	0.98	A
			Zn-65	pCi/L	266	264	1.01	A
	E12315	Charcoal	I-131	pCi	94.8	89.9	1.05	A
	E12316A	AP	Ce-141	pCi	92.3	94.0	0.98	A
			Co-58	pCi	73.4	83.8	0.88	A
			Co-60	pCi	137	150	0.91	A
			Cr-51	pCi	202	210	0.96	A
			Cs-134	pCi	115	121	0.95	A
			Cs-137	pCi	85.0	85.4	1.00	A
			Fe-59	pCi	83.1	80.8	1.03	A
			Mn-54	pCi	104	109	0.96	A
			Zn-65	pCi	168	187	0.90	A
	E12317	Water	Fe-55	pCi/L	2110	1840	1.15	A
	E12318	AP	Sr-89	pCi	81.1	83.0	0.98	A
			Sr-90	pCi	11.4	12.0	0.95	A

(a) The Analytics known value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation

(b) Analytics evaluation based on TBE internal QC limits:

A = Acceptable - reported result falls within ratio limits of 0.80-1.20

W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30

N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

TABLE D.2

**DOE's Mixed Analyte Performance Evaluation Program (MAPEP)  
Teledyne Brown Engineering Environmental Services**

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value <sup>(a)</sup>	Acceptance Range	Evaluation <sup>(b)</sup>
February 2018	18-MaS38	Soil	Ni-63	Bq/kg	9.94		(1)	A
			Sr-90	Bq/kg	0.846		(1)	A
	18-MaW38	Water	Am-241	Bq/L	0.785	0.709	0.496 - 0.922	A
			Ni-63	Bq/L	12.6	14.0	9.8 - 18.2	A
			Pu-238	Bq/L	0.0214	0.023	(2)	A
			Pu-239/240	Bq/L	0.544	0.600	0.420 - 0.780	A
	18-RdF38	AP	U-234/233	Bq/sample	0.111	0.124	0.087 - 0.161	A
			U-238	Bq/sample	0.123	0.128	0.090 - 0.166	A
	18-RdV38	Vegetation	Cs-134	Bq/sample	2.46	3.23	2.26 - 4.20	W
			Cs-137	Bq/sample	3.14	3.67	2.57 - 4.77	A
			Co-57	Bq/sample	4.12	4.42	3.09 - 5.75	A
			Co-60	Bq/sample	1.86	2.29	1.60 - 2.98	A
			Mn-54	Bq/sample	2.21	2.66	1.86 - 3.46	A
			Sr-90	Bq/sample				NR <sup>(3)</sup>
Zn-65			Bq/sample	-0.201		(1)	A	
November 2018	18-MaS39	Soil	Ni-63	Bq/kg	703	765	536 - 995	A
			Sr-90	Bq/kg	137	193	135 - 251	W
	18-MaW39	Water	Am-241	Bq/L	0.0363		(1)	A
			Ni-63	Bq/L	6.18	7.0	4.9 - 9.1	A
			Pu-238	Bq/L	0.73	0.674	0.472 - 0.876	A
			Pu-239/240	Bq/L	0.89	0.928	0.650 - 1.206	A
	18-RdF39	AP	U-234/233	Bq/sample	0.159	0.152	0.106 - 0.198	A
			U-238	Bq/sample	0.162	0.158	0.111 - 0.205	A
	18-RdV39	Vegetation	Cs-134	Bq/sample	1.85	1.94	1.36 - 2.52	A
			Cs-137	Bq/sample	2.5	2.36	1.65 - 3.07	A
			Co-57	Bq/sample	3.53	3.31	2.32 - 4.30	A
			Co-60	Bq/sample	1.6	1.68	1.18 - 2.18	A
			Mn-54	Bq/sample	2.61	2.53	1.77 - 3.29	A
			Sr-90	Bq/sample	0.338	0.791	0.554 - 1.028	N <sup>(4)</sup>
Zn-65			Bq/sample	1.32	1.37	0.96 - 1.78	A	

(a) The MAPEP known value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation

(b) DOE/MAPEP evaluation:

A = Acceptable - reported result falls within ratio limits of 0.80-1.20

W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30

N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

(1) False positive test

(2) Sensitivity evaluation

(3) See NCR 18-09

(4) See NCR 18-25

TABLE D.3

**ERA Environmental Radioactivity Cross Check Program  
Teledyne Brown Engineering Environmental Services**

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value <sup>(a)</sup>	Acceptance Limits	Evaluation <sup>(b)</sup>
March 2018	MRAD-28	AP	GR-A	pCi/sample	65.7	43.4	22.7 - 71.5	A
			GR-B	pCi/sample	57.2	52	31.5 - 78.6	A
April 2018	RAD-113	Water	Ba-133	pCi/L	91.2	91.5	77.1 - 101	A
			Cs-134	pCi/L	70.4	75.9	62.0 - 83.5	A
			Cs-137	pCi/L	122	123	111 - 138	A
			Co-60	pCi/L	64.8	64.3	57.9 - 73.2	A
			Zn-65	pCi/L	98.6	86.7	78.0 - 104	A
			GR-A	pCi/L	32.8	28.6	14.6 - 37.5	A
			GR-B	pCi/L	62.9	73.7	51.4 - 81.1	A
			U-Nat	pCi/L	6.7	6.93	5.28 - 8.13	A
			H-3	pCi/L	17100	17200	15000 - 18900	A
			Sr-89	pCi/L	38.6	48.8	38.3 - 56.2	A
			Sr-90	pCi/L	27.1	26.5	19.2 - 30.9	A
	I-131	pCi/L	26.7	24.6	20.4 - 29.1	A		
September 2018	MRAD-29	AP	GR-A	pCi/sample	49.7	55.3	28.9 - 91.1	A
			GR-B	pCi/sample	75.3	86.5	52.4 - 131	A
October 2018	RAD-115	Water	Ba-133	pCi/L	15.2	16.3	11.9 - 19.4	A
			Cs-134	pCi/L	85.9	93.0	76.4 - 102	A
			Cs-137	pCi/L	229	235	212 - 260	A
			Co-60	pCi/L	81.9	80.7	72.6 - 91.1	A
			Zn-65	pCi/L	348	336	302 - 392	A
			GR-A	pCi/L	38.9	60.7	31.8 - 75.4	A
			GR-B	pCi/L	36.5	41.8	27.9 - 49.2	A
			U-Nat	pCi/L	17.48	20.9	16.8 - 23.4	A
			H-3	pCi/L	2790	2870	2410 - 3170	A
			I-131	pCi/L	26.9	27.2	22.6 - 32.0	A
			Sr-89	pCi/L	57.2	56.9	45.5 - 64.6	A
Sr-90	pCi/L	36.8	31.4	22.9 - 36.4	N <sup>(1)</sup>			

(a) The ERA known value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation.

(b) ERA evaluation:

A = Acceptable - Reported value falls within the Acceptance Limits

N = Not Acceptable - Reported value falls outside of the Acceptance Limits

(1) See NCR 18-23



## **APPENDIX E**

# **ANNUAL RADIOLOGICAL GROUNDWATER PROTECTION PROGRAM REPORT (ARGPPR)**

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