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10 CFR 50, Appx. I

May 11, 2021

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

Subject: **Docket Nos. 50-206, 50-361, 50-362 and 72-41**
2020 Annual Radiological Environmental Operating Report
San Onofre Nuclear Generating Station (SONGS), Units 1, 2 and 3 and Independent Spent Fuel Storage Installation

In accordance with the San Onofre Nuclear Generating Station (SONGS) Licensee Controlled Specification 5.7.1.2, Southern California Edison (SCE) is submitting the 2020 Annual Radiological Environmental Operating Report (AREOR) for SONGS Units 1, 2 and 3. The AREOR covers the operation of SONGS during January 1, 2020 through December 31, 2020 and includes summaries, interpretations, and analyses of trends of the results of the Radiological Environmental Monitoring Program (REMP).

In addition, the AREOR includes the results for direct radiation monitoring near the Independent Spent Fuel Storage Installation.

There are no commitments in this letter or the enclosure.

If you have any questions, please contact me at (949) 368-7024.

Sincerely,

Enclosure: 2020 San Onofre Nuclear Generating Station Annual Radiological Environmental Operating Report

cc: S. A. Morris, Regional Administrator, NRC Region IV
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ENCLOSURE

2020 San Onofre Nuclear Generating Station
Annual Radiological Environmental Operating Report

San Onofre Nuclear Generating Station
2020
Annual Radiological Environmental Operating Report

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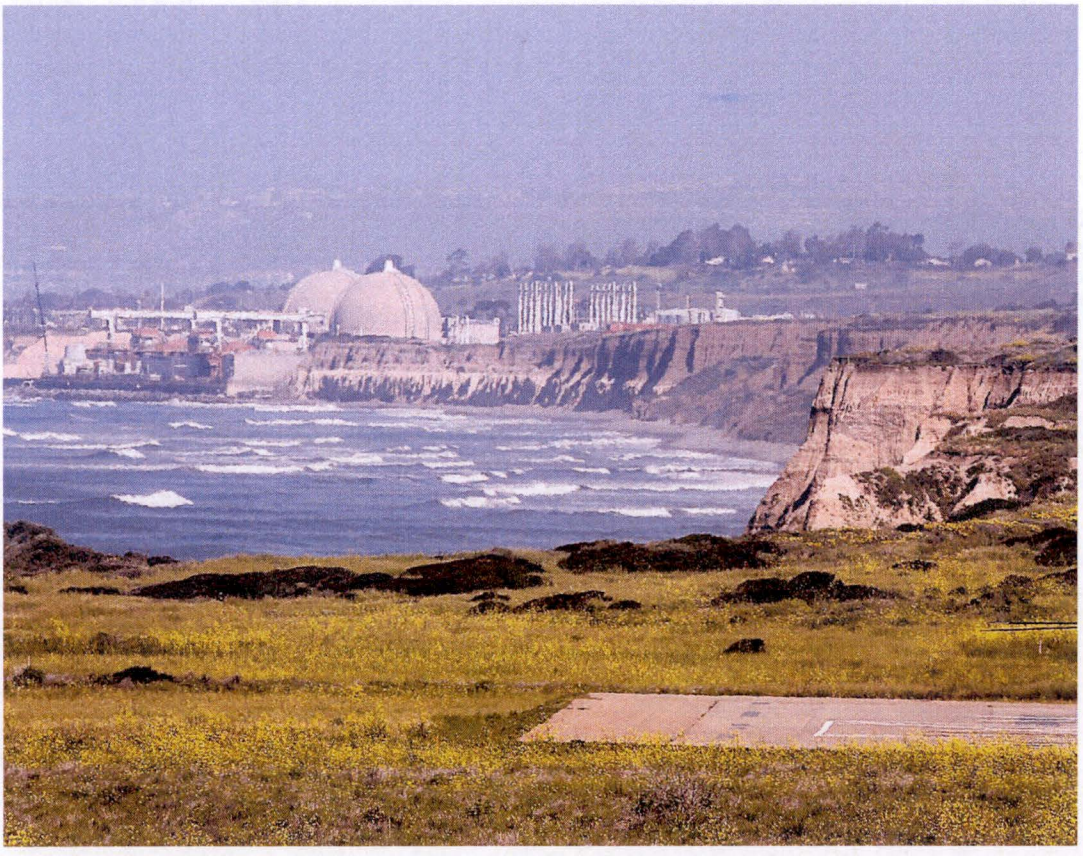

This 2020 Annual Radiological Environmental Operating Report (AREOR) for the San Onofre Nuclear Generating Station (SONGS) fulfills the requirements of the SONGS Licensee Controlled Specification 5.7.1.2 and the Independent Spent Fuel Storage Installation (ISFSI) facility. The 2020 AREOR covers the results of the environmental monitoring performed around SONGS during the time period January 1, 2020 through December 31, 2020.

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Acronyms

AREOR	Annual Radiological Environmental Operating Report
ARERR	Annual Radioactive Effluent Release Report
CDPH	California Department of Public Health
CEAL	Contracted Environmental Analysis Laboratory
DOE	Department of Energy
EAB	Exclusion Area Boundary
EPA	U.S. Environmental Protection Agency
ISFSI	Independent Spent Fuel Storage Installation
LCS	Licensee Controlled Specifications
LLD	Lower Limit of Detection
LUC	Land Use Census
MDC	Minimum Detectable Concentration
MDD	Minimum Differential Dose
ND	Not Detected
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
ODCM	Offsite Dose Calculation Manual
QA	Quality Assurance
QC	Quality Control
REMP	Radiological Environmental Monitoring Program
TLD	Thermoluminescent Dosimeter

1 Executive Summary

On June 12, 2013, Southern California Edison notified the Nuclear Regulatory Commission (NRC) that it had permanently ceased operation for both Units 2 and 3 on June 7, 2013. While all power operations have ceased, spent fuel remains stored on site. San Onofre Nuclear Generating Station (hereafter referred to as San Onofre or SONGS) continues to fulfill its regulatory commitment to monitor the environment and potential exposure pathways. The Radiological Environmental Monitoring Program (REMP) supports the conclusion that San Onofre has had an inconsequential radiological impact on the environment and that it is well within applicable state and federal regulations.

The REMP includes the sampling of environmental media and measuring radiation levels in the environment surrounding SONGS. Its purpose is to identify any levels of radioactivity or radiation associated with SONGS that have a potential exposure to a member of the general public. This is accomplished through the measurement of direct radiation and by the sampling and analyses of various environmental media, including:

- soil
- shoreline sediment (beach sand)
- air (particulate)
- local crops
- non-migratory marine species
- kelp
- drinking water
- ocean water
- ocean bottom sediments

Samples are analyzed for both naturally occurring and SONGS plant related radionuclides. A detailed description of the 2020 sampling locations and location maps are included in Appendix A of this report.

The California Department of Public Health (CDPH) Drinking Water and Sanitation Laboratory participated in an inter-laboratory split sampling program with SONGS, including ocean water tritium samples and gamma isotopic samples from various environmental media. The results are discussed in Appendix C. The CDPH also conducted a direct radiation (TLD) monitoring program in conjunction with SONGS. Refer to Appendix H.

This report describes the REMP as conducted at SONGS during the period from January 1, 2020 through December 31, 2020. The REMP produces scientifically defensible data indicating SONGS had no significant radiological environmental impact in 2020. This report fulfills applicable license commitments, as described in the Offsite Dose Calculation Manual (ODCM), submitted to the NRC as part of the 2020 Annual Radioactive Effluent Release Report (ARERR).

Beyond the immediate area of the ISFSI, the REMP data collected during 2020, as in previous years, continues to be representative of background levels. The data is summarized in the Statistical Summary of REMP Data found in Appendix B. As in previous years, cesium-137 (Cs-137) was identified in soil and fish. Cs-137 in soil is attributable to fallout from nuclear weapons testing and sources external to SONGS, such as the Chernobyl accident. The Cs-137 in fish is consistent with concentrations detected in other west coast marine species and may be attributable to the legacy Pacific Ocean discharges from Fukushima. Cs-137 has been detected at indicator locations, as well as at control locations, in past years. Naturally occurring radionuclides, including beryllium-7 (Be-7), potassium-40 (K-40), thorium-228 (Th-228) and thorium-230 (Th-230) were detected in both control and indicator locations at similar

concentrations and are not related to SONGS. Refer to Appendix B for a more detailed discussion.

There is a natural and manmade radiation background. Natural background is comprised of the terrestrial and cosmic radiation sources while manmade background results from past weapons testing fallout and routine medical applications. Prior to the construction of SONGS, environmental samples and measurements were collected and analyzed to determine the baseline natural radiation levels. The results from the indicator stations are compared to this pre-operational data, as well as control samples, to evaluate if changes in any radiation levels can be attributed to SONGS or other causes such as natural variations in the environment or manmade contributions external to SONGS.

In summary, the environmental monitoring data collected during 2020 supports a conclusion of no adverse effect on the population or the environment from SONGS. The radiation exposures to people living in the surrounding area from SONGS remains less than the detection level, and is a small fraction of the radiation exposures in the environment from the natural background from terrestrial and cosmic radiation.

2 Radiological Environmental Monitoring Program

Program Overview

The purpose of the REMP is to characterize the radiological environment outside of the Site Boundary and to detect potential radiological impacts resulting from activities at SONGS Units 2 and 3. The REMP monitors credible pathways of exposure to the public and fulfills the radiological environmental monitoring requirements of the ODCM.

Exposure pathways are the different routes by which people can potentially be exposed to radiation or radioactive materials. The pathways may be characterized into four general types, shown below along with a brief description of the monitoring as performed at SONGS:

- **AIRBORNE**. The airborne pathway represents the inhalation intake of airborne radioactive materials. This pathway is sampled in areas around SONGS by continuously drawing air through specialized filters 24 hours a day, 7 days a week. Although both units at SONGS ceased operation in June 2013, these air samples continue to be collected on a weekly basis.
- **WATERBORNE**. The waterborne pathways include the exposure to radioactive materials accumulated in aquatic biota (fish, shellfish) and in shoreline sediments. These pathways are assessed through the collection of fish and shellfish samples in the environment around the plant. Sediment samples are also collected to evaluate any long-term buildup in the environment.
- **INGESTION**. The ingestion pathway includes broadleaf vegetation, agricultural products, and food products. Atmospheric releases from the plant can deposit on these food products, representing an intake exposure pathway through the consumption of these food products. Samples of crops (e.g., tomato, lettuce, sorrel) are collected from the local area around the plant to evaluate any impact on this pathway.
- **DIRECT RADIATION**. The direct radiation pathway represents the external exposure from sources on the plant site and directly from any radioactive effluents released to the air or water. This direct environmental radiation dose is measured through the use of direct measurement dosimeters, such as thermoluminescent dosimeters (TLDs) that are placed around the plant site and in the local environment.

Site Area and Description

San Onofre Nuclear Generating Station is located next to San Onofre State Beach, adjoining Camp Pendleton Marine Corps Base, in San Diego County, 64 miles south of Los Angeles, California. At this time there are no operating reactors, but in the past, there were three operating pressurized water reactors with a total rated capacity of 2664 net megawatts electrical.

Figure 1 - SONGS 45 mile REMP Radius

Unit 1, rated at 410 net megawatts electrical, was supplied by Westinghouse Electric Company. Unit 1 began commercial operation on January 1, 1968. The unit was permanently shut down on November 30, 1992, and all above-ground structures have been dismantled. By August 31, 2004, all fuel was transferred to the ISFSI. By November 29, 2006, all remaining monitored effluent pathways were permanently removed from service or routed to Unit 2 discharge to the outfall. The remaining portions of Unit 1 are owned by Southern California Edison (80%) and San Diego Gas and Electric (20%).

Unit 2 and Unit 3 were supplied by Combustion Engineering, Inc., with turbine generators supplied by G.E.C. Turbine Generators, Ltd., of England. The units began commercial operation in August 1983, and April 1984, respectively, and were rated at 1127 net megawatts electrical each. The twin units are owned by Southern California Edison (78.21%), San Diego Gas and Electric (20%), and the City of Riverside (1.79%).

Figure 2 - SONGS Location

Effective December 29, 2006, the City of Anaheim transferred its ownership interests in San Onofre Units 2 and 3 and the entitlement to the Units 2 and 3 output to Southern California Edison Company, except that it retains its ownership interests in its spent nuclear fuel and Units 2 and 3's ISFSI located on the facility's site. In addition, the City of Anaheim retains financial responsibility for its spent fuel and for a portion of the Units 2 and 3 decommissioning costs. The City of Anaheim remains a licensee for purposes of its retained interests and liabilities. Southern California Edison notified the NRC on June 12, 2013, that it had permanently ceased operation of Units 2 and 3 on June 7, 2013. The NRC notification, called a Certification of Permanent Cessation of Power Operations, sets the stage for SCE to begin preparations for decommissioning. In a letter to the NRC dated August 7, 2020, SCE certified that all spent fuel has been removed from the Spent Fuel Pools of Units 2 and 3 and on August 10, 2020 had put in place programmatic changes that were previously approved by the NRC for ISFSI-Only operation. SCE continues to monitor environmental conditions in accordance with 10 CFR 50, Appendix I.

Sample Collection and Analyses

Samples of environmental media were obtained in accordance with the requirements of the ODCM to meet the regulatory requirements. Refer to Appendix A for a complete list of REMP sample locations as described in Table 5-4 of the ODCM.

Indicator samples close to SONGS are compared to control samples located in areas that are beyond the measurable influence of San Onofre. The control sample results are considered representative of background levels with no potential for contribution from releases and sources at SONGS. The control stations also serve as indicators of radioactive sources unrelated to activities at SONGS, such as remote sewage plant discharges of nuclear medicine applications or nuclear fallout attributable to external sources (legacy fallout from nuclear weapons, the nuclear accident at Chernobyl, and the nuclear accident at Fukushima). The indicator location samples are used to detect environmental radioactivity attributable to SONGS. Indicator sample locations can be located either onsite or offsite.

The SONGS REMP is conducted in accordance with a Quality Assurance Program, meeting the requirements of NRC Regulatory Guide 4.15, Rev. 1. Samples are collected using approved methods; radiochemical analyses of these samples are performed using standardized analytical methods. The Contracted Environmental Analysis Laboratory (CEAL) participates in an inter-laboratory comparison program in partial fulfillment of the quality assurance requirements for environmental monitoring. The CEAL participated in cross check programs which meet the intent of Reg. Guide 4.15. See Appendix C for additional details.

Detection Limit Terminology

The NRC requires that equipment and analytical methods used for radiological monitoring must be able to detect specified minimum limits for the type sample and the radionuclide of the analysis. The *a priori* detection capability for the analytical system used for the measurement is referred to as the Lower Limit of Detection (LLD). This LLD ensures that radiation measurements are sufficiently sensitive to detect any levels of concern and small changes in the environment. Samples with no detectable radiation levels are typically referred to as less than the Minimum Detectable Concentration (MDC). The MDC is evaluated for each sample and is used to ensure that the specific analysis has sufficient sensitivity to detect levels consistent with the requirements for analysis by the system LLD. For a more thorough discussion, refer to NUREG/CR-4007.

- **Lower Limit of Detection (LLD)** - The LLD is the *a priori* (before the fact) lower limit of detection for the method used for the analysis. It is a measure of the detection capability for the analytical method and not for any single sample analysis. This value is calculated for each isotope and every matrix based on typical or expected values of decay time, sample size, counter efficiency, etc. The LLD values are listed in the ODCM and represent the detection capability that the analytical methods must meet for each the specified sample media.
- **Minimum Detectable Concentration (MDC)** - The MDC is the *a posteriori* (after the fact) lower limit of detection based on actual decay time, measured sample size, and counting efficiency for an individual sample analysis. The MDC is compared to the LLD to verify that the measurement met the ODCM requirements for the maximum value of the LLD for the listed radionuclides. Values flagged by the CEAL as being confirmed above the MDC are presumed to be valid detected levels of radioactivity.
- **Not Detected (ND)** - The term ND refers to TLD data analyzed per ANSI N13.37-2014 (Environmental Dosimetry-Criteria for System Design and Implementation) that is less than the ANSI calculated detection limit above a specific location's baseline. A baseline is calculated per ANSI methods for each specific location because the direct radiation

signal is a strong function of very local conditions. If the TLD data for a specific location is less than that specific location's baseline plus the ANSI calculated detection limit, then the value is "ND" for that specific measurement.

The sampling and analyses for the REMP are conducted in accordance with the ODCM and the applicable regulatory requirements.

Regulations and Guidance

10 CFR 50, Appendix I

10 CFR 50, Appendix I establishes the per unit limits on releases of radioactivity to the environment and the resulting dose to the public. These limits are more restrictive than the 10 CFR 20 limits. The 10 CFR 50, Appendix I limits are:

Source	NRC Limits for SONGS
Liquid Effluent	Less than or equal to 3 mrem/yr to whole body from all pathways of exposure
	Less than or equal to 10 mrem/yr to any organ from all pathways of exposure
Gaseous Effluents – Noble Gases	Less than or equal to 10 mrad/yr gamma air dose
	Less than 20 mrad/yr, beta air dose
	Less than 5 mrem/yr, total body dose to an offsite exposed individual of the public
Tritium and particulates with half-life greater than 8 days	Less than or equal to 15 mrem to any organ for an offsite individual from all pathways of exposure

40 CFR 190

The Environmental Protection Agency (EPA) has established environmental radiation protection standards in 40 CFR 190 for the uranium fuel cycle that includes nuclear power plants. These limits are applicable to the sum of liquid effluent, gaseous effluents and direct radiation.

The dose limits from all applicable pathways to any offsite individual are:

- 25 mrem/year to the whole body
- 75 mrem/year to the thyroid
- 25 mrem to any other organ

As discussed in the 2020 SONGS ARERR, the calculated dose to a member of the public as a result of SONGS is a small fraction of the dose standard established by the EPA. This conclusion is supported by the results of the REMP, as reflected by the absence of measurable levels of radiation or radioactive materials in the offsite environment attributable to SONGS.

The following regulatory and industry guidance has been identified as applicable to the SONGS REMP.

- US NRC Regulatory Guide 4.1, Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants, 1975

- US NRC Regulatory Guide 4.2, Preparation of Environmental Reports for Nuclear Power Stations, 1976
- US NRC Regulatory Guide 1.109, Calculation of Annual Doses to Man from Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I, 1977
- NUREG-1301, Offsite Dose Calculations Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors, Generic Letter 89-01, Supplement No. 1, 1991
- US NRC Regulatory Guide 4.13, Revision 2, June 2019, Environmental Dosimetry Performance Specifications, Testing, and Data Analysis
- ANSI/HPS N13.37, "Environmental Dosimetry – Criteria for System Design and Implementation", 2014
- US NRC Regulatory Guide 4.15, Rev. 1, Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment, 1979
- NUREG-1576, Multi-agency Radiological Laboratory Analytical Protocols
- NUREG/CR-4007, Lower Limit of Detection: Definition and Elaboration of a Proposed Position for Radiological Effluent and Environmental Measurements, 1984

NRC Reporting Limits

The NRC has established required reporting levels that represent thresholds above which an investigation is needed to evaluate and ensure compliance with radiation safety standards for the public. Licensed nuclear facilities must prepare a special report if any environmental sample value exceeds the corresponding reporting limit. SONGS did not submit any special reports to the NRC in 2020 as no reporting limits were exceeded.

Summary of Analysis of Results and Trends

The 2020 SONGS REMP was conducted in accordance with 10 CFR 50, Appendix I, the SONGS LCS and Section 5.0 of the SONGS ODCM. The REMP sample data have been summarized in the format specified in NUREG-1301. Data have been evaluated to identify the levels of any plant related environmental radioactivity above background levels (i.e., plant related contributions that are distinguishable from background). For data distinguishable from background, a comparison has been made between current environmental monitoring results and pre-operational or previous operational data as appropriate, for trending environmental radioactivity.

To conform with 10 CFR 50, Appendix I, Section IV B.2, data on measurable levels of radiation and radioactive materials in the environment are provided to allow for a comparison to the predicted (calculated) values in the environment from radioactive material released in effluents.

The tabulated means, ranges, and standard deviations are presented in Appendix B. Comparisons with background and pre-operational baseline data are presented in Appendix D.

The REMP data are reviewed for accuracy and are compared against NRC reporting levels. Measurements exceeding the administrative levels (10% of the NRC reporting levels) are flagged. Analyses are performed using instrumentation and methods that provide analytical results with a level of detection as required by the ODCM. The *a posteriori* MDC is compared to the maximum value for the *a priori* LLD specified in the ODCM. This ensures that regulatory limits for the maximum LLD are met.

Table 1 - Maximum LLDs as Specified in SONGS ODCM

Analysis	Water (pCi/L)	Airborne Particulate or Gases (pCi/m^3)	Marine Animals (pCi/kg, wet)	Local Crops (pCi/kg, wet)	Sediment (pCi/kg, dry)
Gross beta	4	1E-02			
H-3	2000				
Mn-54	15		130		
Fe-59	30		260		
Co-58, 60	15		130		
Zn-65	30		260		
Zr-95, Nb-95	15				
I-131	1	7E-02		60	
Cs-134	15	5E-02	130	60	150
Cs-137	18	6E-02	150	80	180
Ba-140, La-140	15				

The impact of SONGS on the surrounding environment is assessed through a series of analyses. These analyses include: comparisons of indicator to control locations (Appendix B); comparison of 2020 REMP data to historical environmental data (Appendix D); and the summary of deviations from sampling requirements and corrective actions taken (Appendix E).

A detailed discussion of the 2020 analytical results is presented in this report. Analytical values from offsite indicator sample stations continue to trend with the control stations. The data indicate that SONGS had no significant radiological impact on the environment during 2020. In addition, dose to members of the public attributable to SONGS related radiological activities remain well below regulatory limit of 100 mrem per year, as specified in 10 CFR 20, § 20.1301 and in keeping with the philosophy of "as low as is reasonably achievable" (ALARA), as specified in 10 CFR 20.1101(b).

The data are summarized in the Statistical Summary of REMP Data found in Appendix B. The level of Cs-137 found in control and indicator samples is consistent with historical and expected data. The Cs-137 is attributable to fallout from legacy atmospheric nuclear weapons testing, to fallout from Chernobyl, and to the legacy Fukushima discharges into the Pacific Ocean. Naturally occurring radionuclides, including beryllium-7 (Be-7), potassium-40 (K-40), thorium-228 (Th-228) and thorium-230 (Th-230) were detected in both control and indicator locations at similar concentrations and are not related to SONGS. Refer to Appendix B for a more detailed discussion.

3 Land Use Census Results

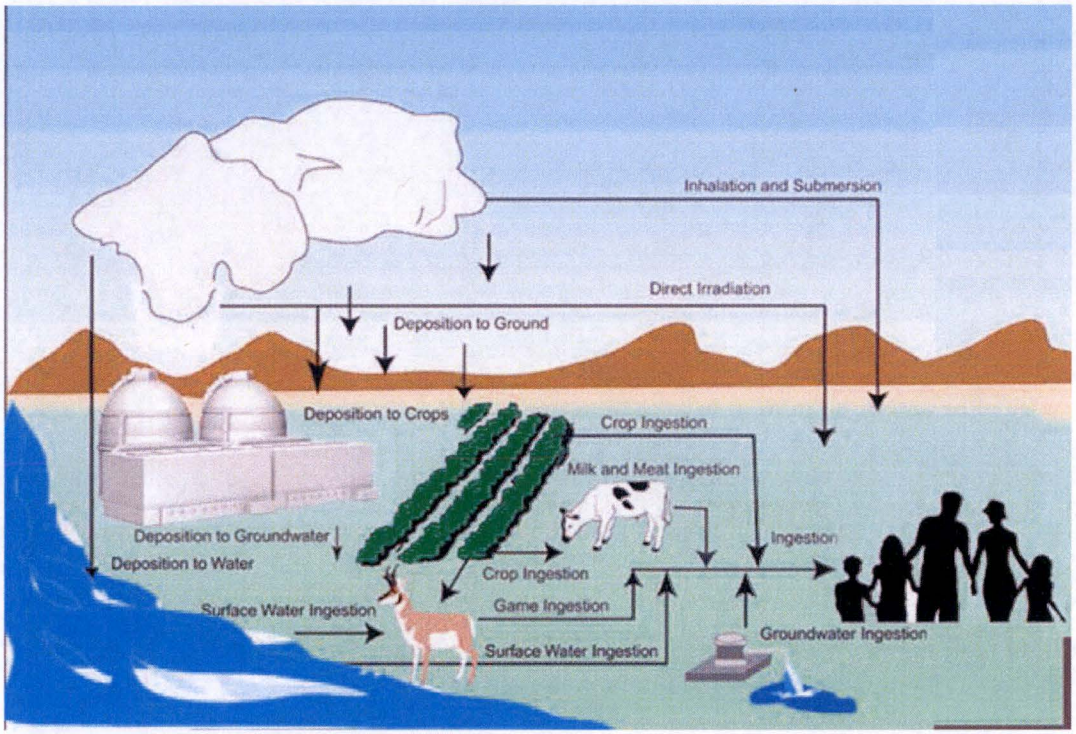

Figure 3 - Examples of Exposure Pathways

In accordance with the ODCM, each year a Land Use Census (LUC) is performed to identify any changes in the use of areas at and beyond the site boundary. Modifications to the monitoring program may be made if the LUC identifies either new pathways of exposure, or significant changes to the existing pathways around the plant. The 2020 LUC did not identify any new pathways.

Summary of Changes to the LUC:

The 2020 LUC did identify some minor changes to the occupancy and location of some existing receptors. Based on data from the Camp Pendleton base Game Warden the distance to the closest deer habitat range was adjusted for each sector. The occupancy of some employment locations changed because of impacts from the COVID pandemic. The findings of the 2020 LUC did not require any changes to the sampling media or the sample locations listed in the current monitoring program.

Land Use Changes identified in the 2020 LUC report:

- The 2019 LUC reported the distance between SONGS and the area closest to SONGS containing vegetation that may be consumed by deer. The 2020 LUC reports the distance between SONGS and the area closest to SONGS containing deer habitat as reported by the Camp Pendleton Base Game Warden. This revision changes the location for the deer consumption pathway in all landward sectors.
- The occupancy for the State Parks Surfing Beach entrance structure changed from 1500 hours to 2000 hours.

- The occupancy for the State Parks Surfing Beach life-guard tower changed from 800 hours to 1000 hours.
- The Endless Summer Surf Camp overnight activity did not occur in 2020 because of the COVID pandemic.
- LUC # R-G1 (San Onofre State Park campground host) occupied spaces 103 to 104 in 2020. Two hosts occupied this location for six months each. The Campground host (located adjacent to the former Endless Summer Surf Camp) was occupied by two hosts each on site for six months in 2020. Occupancy changed to 4380 hours for 2020 - adult only. No other age group occupied this location. In 2019 this location was reported as Full Time Residence "FTR."
- Deleted LUC # 22 (SCE land uses). This location referred to the SONGS Mesa facility. Members of the general public are not allowed on the SONGS Mesa and there is no specific location to map.

4 Quality Assurance

A portion of REMP sampling activity is devoted to quality assurance. All REMP activities, including support contractors, are assessed as defined in Regulatory Guide 4.15, Rev. 1. The quality assurance program's main aspects include process quality control, instrument quality control, comprehensive data reviews, cross-check analyses, and audits. Routine REMP assessments ensure that the program, procedures and personnel are performing satisfactorily. Samples are collected using approved methods; radiochemical analyses of these samples are performed using standardized analytical methods. Quality audits and independent technical reviews help determine areas that need attention. These areas are addressed in accordance with the station's Corrective Action Program.

The CDPH participates in a split sampling program in accordance with the site's REMP procedures. Duplicate radiological split sampling is performed by SONGS to demonstrate repeatability of the sample collection, preparation, and analysis process. Split sample analysis is performed for the evaluation of the precision and bias trends of the method of analysis without the added variables introduced by sampling. The 2020 CDPH data resulted in similar conclusions to the 2020 SONGS REMP data.

GEL Laboratories, LLC (GEL) performs the radiochemistry analysis of samples noted within this report. GEL performs the requested analysis under its Quality Assurance Program, which meets the requirements of 10 CFR 50, Appendix B, ASME NQA-1 and Regulatory Guide 4.15 Revision 1. The measurement capabilities of the radiological laboratory are demonstrated by participating in an inter-laboratory measurement assurance program and performing duplicate and split sample analyses. Approximately 10% of the analyses performed are quality control samples, consisting of inter-laboratory measurement assurance program samples, duplicate samples, and split samples. The inter-laboratory measurement assurance program provides samples that are similar in matrix and size to those sampled and measured by the REMP. This program assures that equipment calibrations and sample preparation methods accurately measure radioactive material in samples. See Appendix C for detailed QA measurement data.

Stanford Dosimetry performs the environmental TLD analyses noted in this report. Stanford Dosimetry performs the requested analyses under its Quality Assurance Program which meets the requirement of 10 CFR 50, Appendix B, ASME NQA-1, Regulatory Guide 4.15 Revision 1 and Regulatory Guide 4.13 Revision 2 (Environmental Dosimetry – Performance Standards, Testing and Data Analysis).

5 Program Deviations

Any deviation in the conduct of the program as required, either in terms of sample collection or analysis, requires an investigation as to the cause and identification of measures to prevent recurrence. Deviations from the sampling program or sensitivity requirements are acknowledged and explained in Appendix E to this report.

6 Conclusion

Radiological environmental data collected throughout 2020 have been evaluated to determine if SONGS had any measurable impact on the surrounding environment.

The Cs-137 detected in soil and fish is due to factors external to SONGS. The Cs-137 in soil is attributable to the legacy fallout from nuclear weapons testing and to the fallout from the Chernobyl accident. The Cs-137 in fish is attributable to the legacy discharges to the Pacific Ocean from Fukushima. The work process at SONGS during 2020 had an insignificant radiological impact on the environment.

7 References

1. SONGS Offsite Dose Calculation Manual (ODCM), Section 5.0.
2. SONGS Radiological Monitoring (RM) Procedures established for the Radiological Environmental Monitoring Program.
3. NUREG/CR-4007, "Lower Limit of Detection: Definition and Elaboration of a Proposed Position for Radiological Effluent and Environmental Measurements," August 1984.
4. The Procedures Manual of the Environmental Measurements Laboratory (US DOE HASL-300)

APPENDIX A. SAMPLE TYPE AND SAMPLING LOCATIONS

Table 2 - Direct Radiation Measuring Locations

DIRECT RADIATION MEASURING LOCATION		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
1	City of San Clemente (Former SDG&E Offices) (Control)	5.7	NW
2	Camp San Mateo – (MCB, Camp Pendleton)	3.6	N
3	Camp San Onofre – (MCB, Camp Pendleton)	2.8	NE
4	Camp Horno – (MCB, Camp Pendleton)	4.4	E
6	Old El Camino Real (AKA Old Highway 101)	3.0	ESE
8	Noncommissioned Officers Beach Club	1.4	NW
10	Bluff	0.7	WNW
11	Former Visitors Center	0.4[b]	NW
12	South Edge of Switchyard	0.2[b]	E
13	Southeast Site Boundary (Bluff)	0.4[b]	ESE
15	Southeast Site Boundary (Office Building)	0.1[b]	SSE
16	East Southeast Site Boundary	0.4[b]	ESE
19	San Clemente Highlands	4.9	NNW
22	Former US Coast Guard Station - San Mateo Point	2.7	WNW
23	SDG&E Service Center Yard (Control)	8.1	NW
31	Aurora Park - Mission Viejo (Control)	18.6	NNW
33	Camp Talega – (MCB, Camp Pendleton) (Control)	5.9	N
34	San Onofre School – (MCB, Camp Pendleton)	1.9	NW
35	Range 312 – (MCB, Camp Pendleton)	4.8	NNE
36	Range 208C – (MCB, Camp Pendleton)	4.1	NE
38	San Onofre State Beach Park	3.4	SE
40	SCE Training Center – Mesa	0.7	NNW
41	Old Route 101 – East	0.3[b]	E
44	Fallbrook Fire Station (Control)	17.7	E
46	San Onofre State Beach Park	1.0	SE
47	Camp Las Flores – (MCB, Camp Pendleton) (Control)	8.6	SE
49	Camp Chappo – MCB (Control)	12.9	ESE
50	Oceanside Fire Station (Control)	15.6	SE
53	San Diego County Operations Center (Control)	44.2	SE
54	Escondido Fire Station (Control)	31.8	ESE

DIRECT RADIATION MEASURING LOCATION		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
55	San Onofre State Beach (U1 West)	0.2 [b]	WNW
56	San Onofre State Beach (U1 West)	0.2 [b]	W
57	San Onofre State Beach (Unit 2)	0.1 [b]	SW
58	San Onofre State Beach (Unit 3)	0.1 [b]	S
59	SONGS Meteorological Tower	0.3 [b]	WNW
61	Mesa - East Boundary	0.7	N
62	MCB - Camp Pendleton	0.7	NNE
63	MCB - Camp Pendleton	0.6	NE
64	MCB - Camp Pendleton	0.6	ENE
65	MCB - Camp Pendleton	0.7	E
66	San Onofre State Beach	0.6	ESE
67	Former SONGS Evaporation Pond	0.6	NW
68	Range 210C – (MCB, Camp Pendleton)	4.4	ENE
73	South Yard Facility	0.4 [b]	ESE
74	Oceanside City Hall (Backup Control)	15.6	SE
75	Gate 25 MCB	4.6	SE
76	Former El Camino Real Mobil Station	4.6	NW
77	Area 62 Heavy Lift Pad	4.2	N
78	Horno Canyon (AKA Sheep Valley)	4.4	ESE

Table 3 – Airborne Radioactivity Sampling Locations

AIRBORNE (AP and AC) SAMPLING LOCATION		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
1	City of San Clemente (City Hall)	5.1	NW
7 [e]	AWS Roof	0.18 [b]	NW
9	State Beach Park	0.6	ESE
10 [e]	Bluff	0.7	WNW
11 [e]	Mesa EOF	0.7	NNW
12	Former SONGS Evaporation Pond	0.6	NW
13	Marine Corp Base (Camp Pendleton East)	0.7	E
16	San Luis Rey Substation (Control)	16.7	SE

Table 4 – Soil Sampling Locations

SOIL (TSC SO) SAMPLING LOCATION[c]		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
1	Camp San Onofre	2.8	NE
2	Old Route 101 – (East Southeast)	3.0	ESE
3	Basilone Road / I-5 Freeway Off ramp	2.0	NW
5	Former Visitors Center	0.4 [b]	NW
7	Prince of Peace Abbey – Oceanside (Control)	15	SE

Table 5 – Ocean Water Radioactivity Sampling Locations

OCEAN WATER (SW) SAMPLING LOCATION		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
A	Station Discharge Outfall - Unit 1	0.6	SW
B	Outfall - Unit 2	1.5	SW
C	Outfall - Unit 3	1.2	SSW
D	Newport Beach (Control)	30.0	NW

Table 6 – Drinking Water Radioactivity Sampling Locations

DRINKING WATER (WGC DW) SAMPLING LOCATION		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
4	Camp Pendleton Drinking Water Reservoir	2.0	NW
5	Oceanside City Hall (Control)	15.6	SE

Table 7 – Shoreline Sediment Radioactivity Sampling Locations

SHORELINE SEDIMENT (SSA SO) SAMPLING LOCATION		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
1	San Onofre State Beach (Southeast)	0.6	SE
2	San Onofre Surfing Beach	0.8	WNW
3	San Onofre State Beach (Southeast)	3.5	SE
4	Newport Beach North End (Control)	29.2	NW

Table 8 – Local Crops Sampling Locations

LOCAL CROPS SAMPLING (TFB VG) LOCATION		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
2	Oceanside (Control)	15 to 25	SE to ESE
6	SONGS Garden Mesa EOF	0.7	NNW

Table 9 – Non-Migratory Marine Animal Sampling Locations

MARINE ANIMAL (MOA) SAMPLING LOCATION		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
A	Unit 1 Outfall	0.9	WSW
B	Units 2/3 Outfall	1.5	SSW
C	Laguna Beach (Control)	20 to 25	WNW to NW

Table 10 – Kelp Sampling Locations

KELP (VG) SAMPLING LOCATION [d]		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
A	San Onofre Kelp Bed	1.5	S
B	San Mateo Kelp Bed	3.8	WNW
C	Barn Kelp Bed	6.3	SSE to SE
E	Salt Creek (Control)	11 to 13	WNW to NW

Table 11 – Ocean Bottom Sediment Sampling Locations

OCEAN BOTTOM (SEB SO) SAMPLING LOCATION		DISTANCE [a] (miles)	DIRECTION [a] (Sector)
B	Unit 1 Outfall	0.8	SSW
C	Unit 2 Outfall	1.6	SW
D	Unit 3 Outfall	1.2	SSW
E	Laguna Beach (Control)	20-25	NW
F	SONGS Up-coast	0.9	WSW

NOTES for TABLES 3 - 11:

a Distance (miles) and Direction (sector) are measured relative to Units 2/3 midpoint as described in the ODCM. Direction determined from degrees true north.

b Distances are within the Units 2/3 Exclusion Area Boundary (EAB)

c Soil samples are not required by the SONGS ODCM.

d Kelp samples are not required by the SONGS ODCM.

e Not required by the SONGS ODCM.

MCB = Marine Corps Base (Camp Pendleton)

Table 12 - Sector and Direction Designations

DEGREES TRUE NORTH FROM SONGS 2 AND 3 MIDPOINT			NOMENCLATURE	
Sector Limit	Center Line	Sector Limit	22.5° Sector	Direction
348.75	0 & 360	11.25	A	N
11.25	22.5	33.75	B	NNE
33.75	45.0	56.25	C	NE
56.25	67.5	78.75	D	ENE
78.75	90.0	101.25	E	E
101.25	112.0	123.75	F	ESE
123.75	135.0	146.25	G	SE
146.25	157.0	168.75	H	SSE
168.75	180.0	191.25	J	S
191.25	202.5	213.75	K	SSW
213.75	225.0	236.25	L	SW
236.25	247.5	258.75	M	WSW
258.75	270.0	281.25	N	W
281.25	292.5	303.75	P	WNW
303.75	315.0	326.25	Q	NW
326.25	337.5	348.75	R	NNW

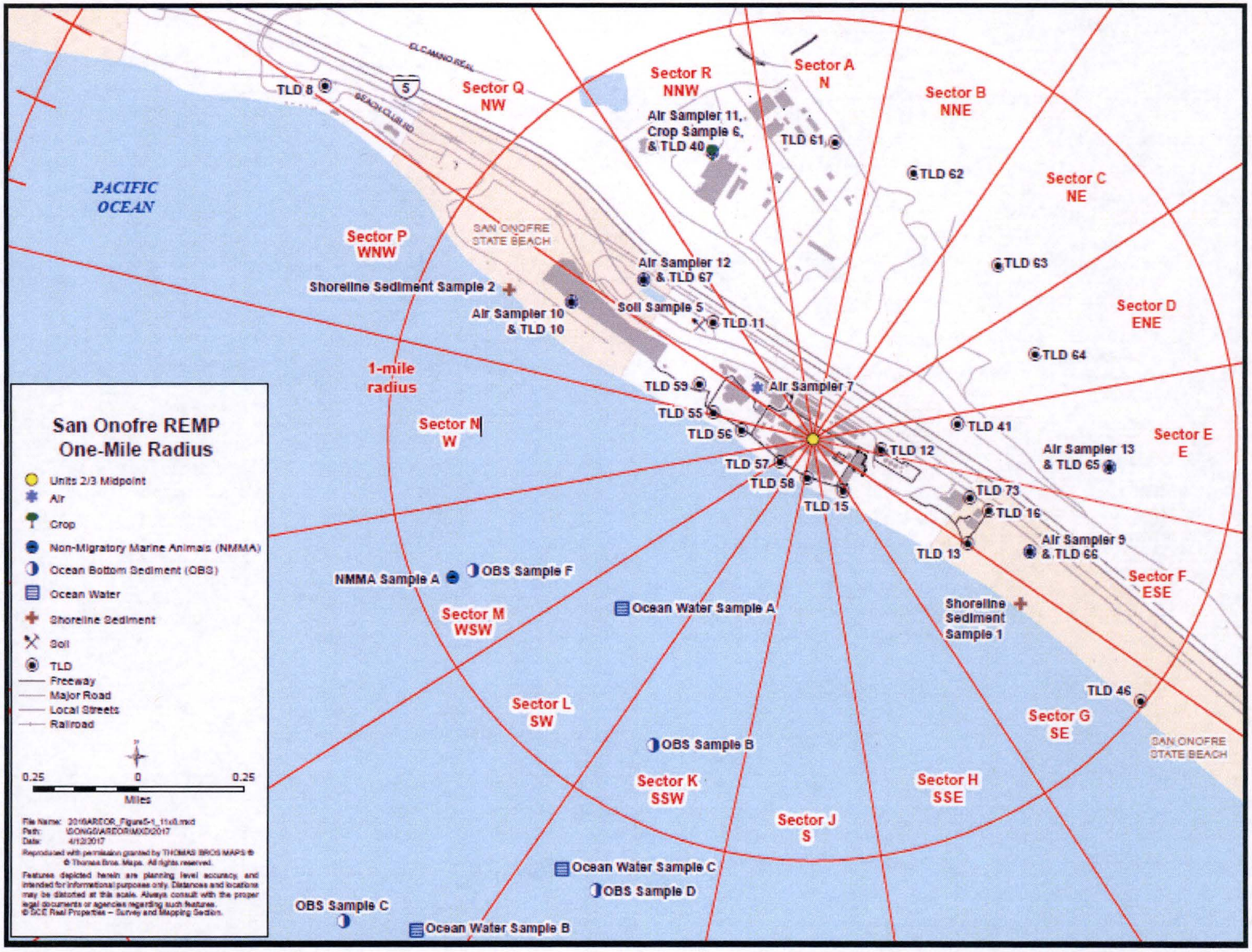

Figure 4 - SONGS REMP One Mile Radius

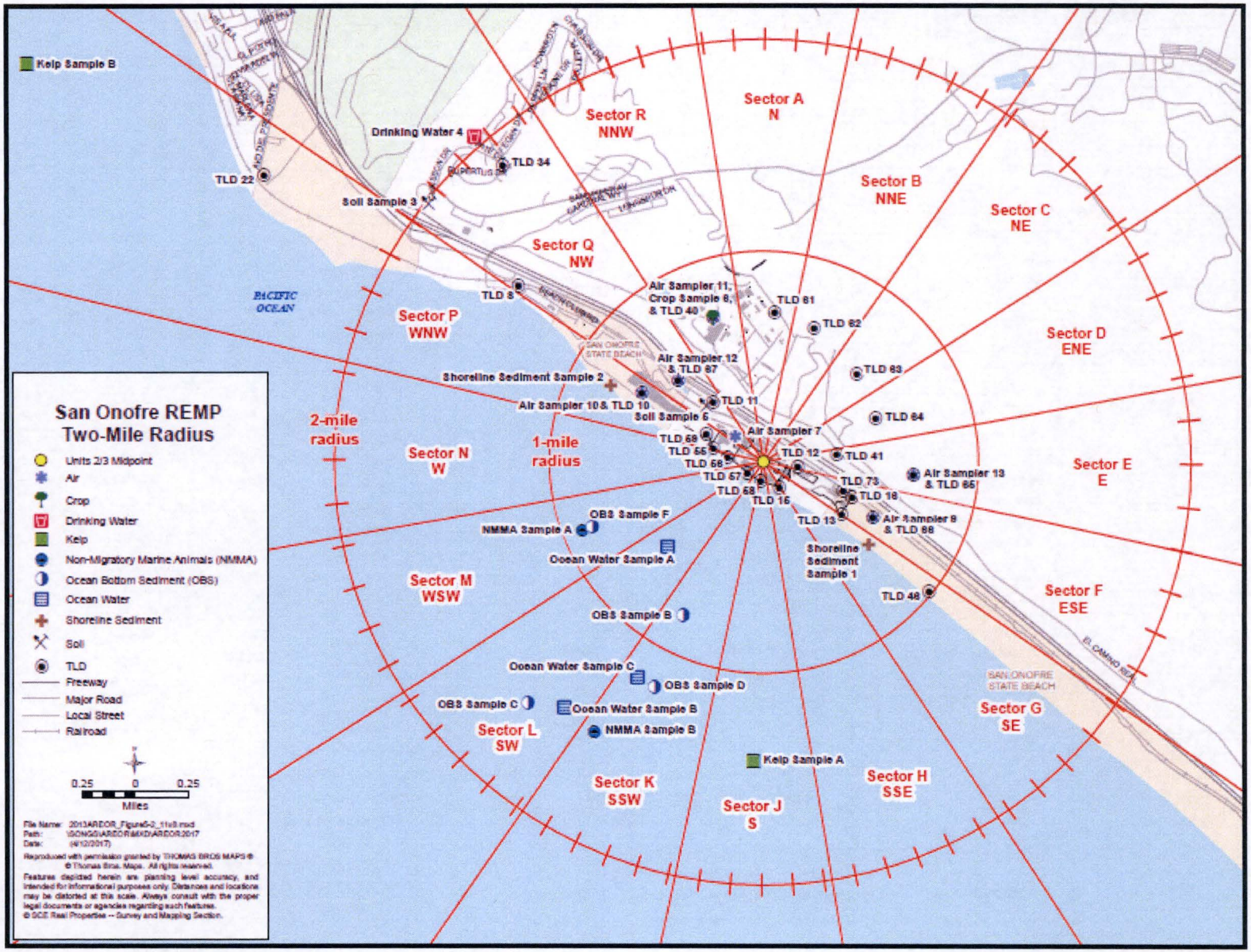

Figure 5 - SONGS REMP Two Mile Radius

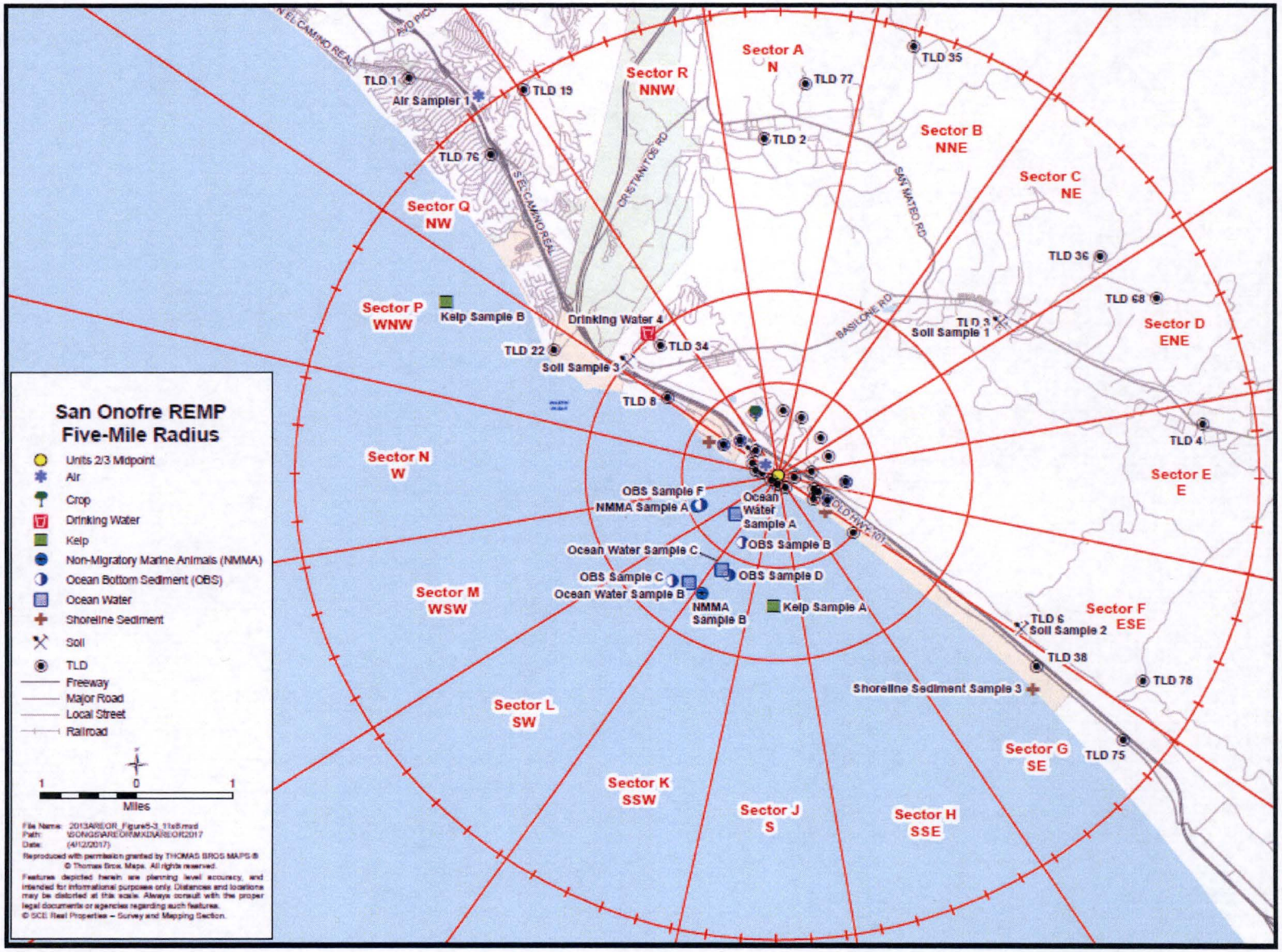

Figure 6 - SONGS REMP Five Mile Radius

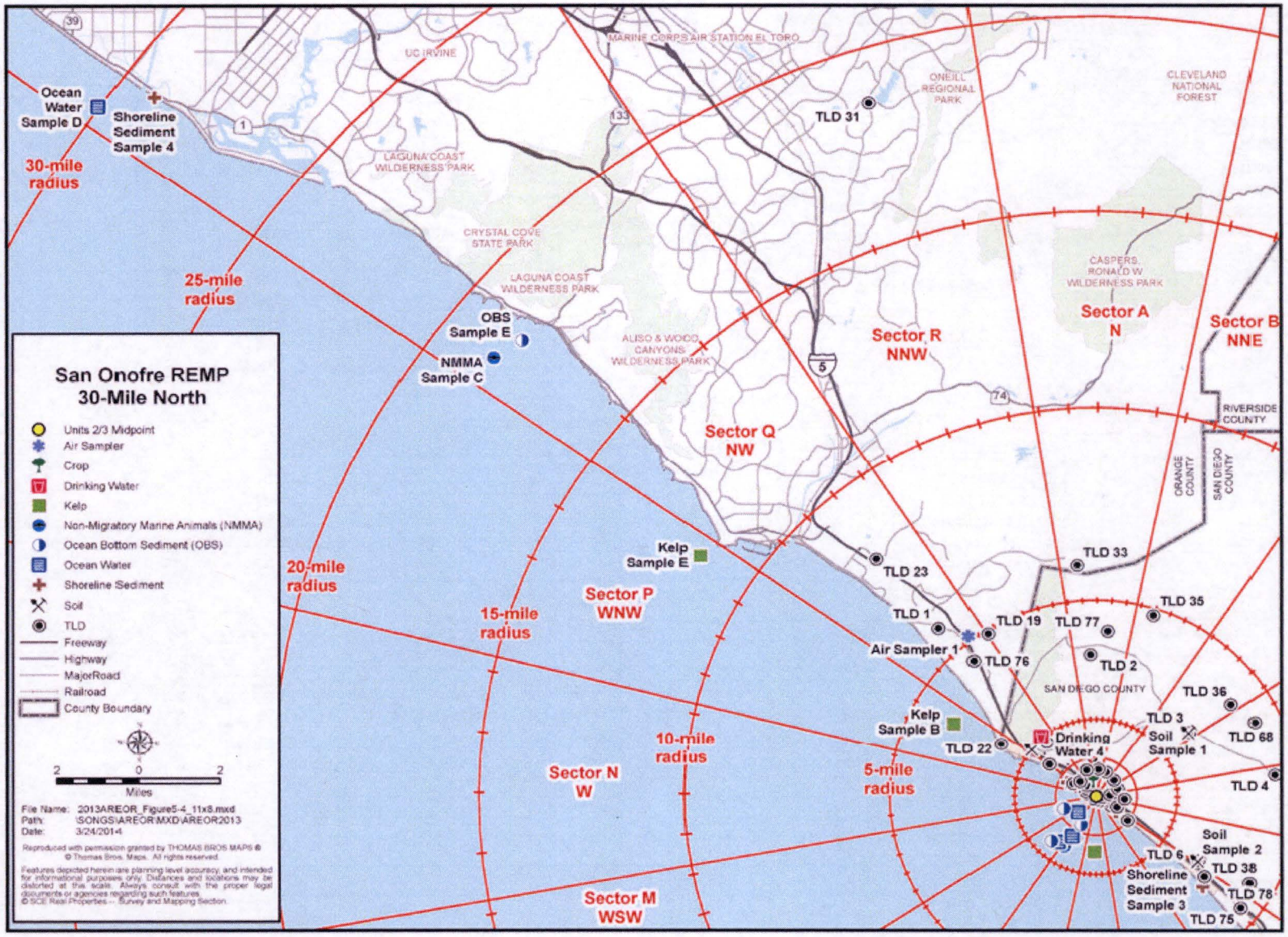

Figure 7 - SONGS REMP 30-mile Radius North

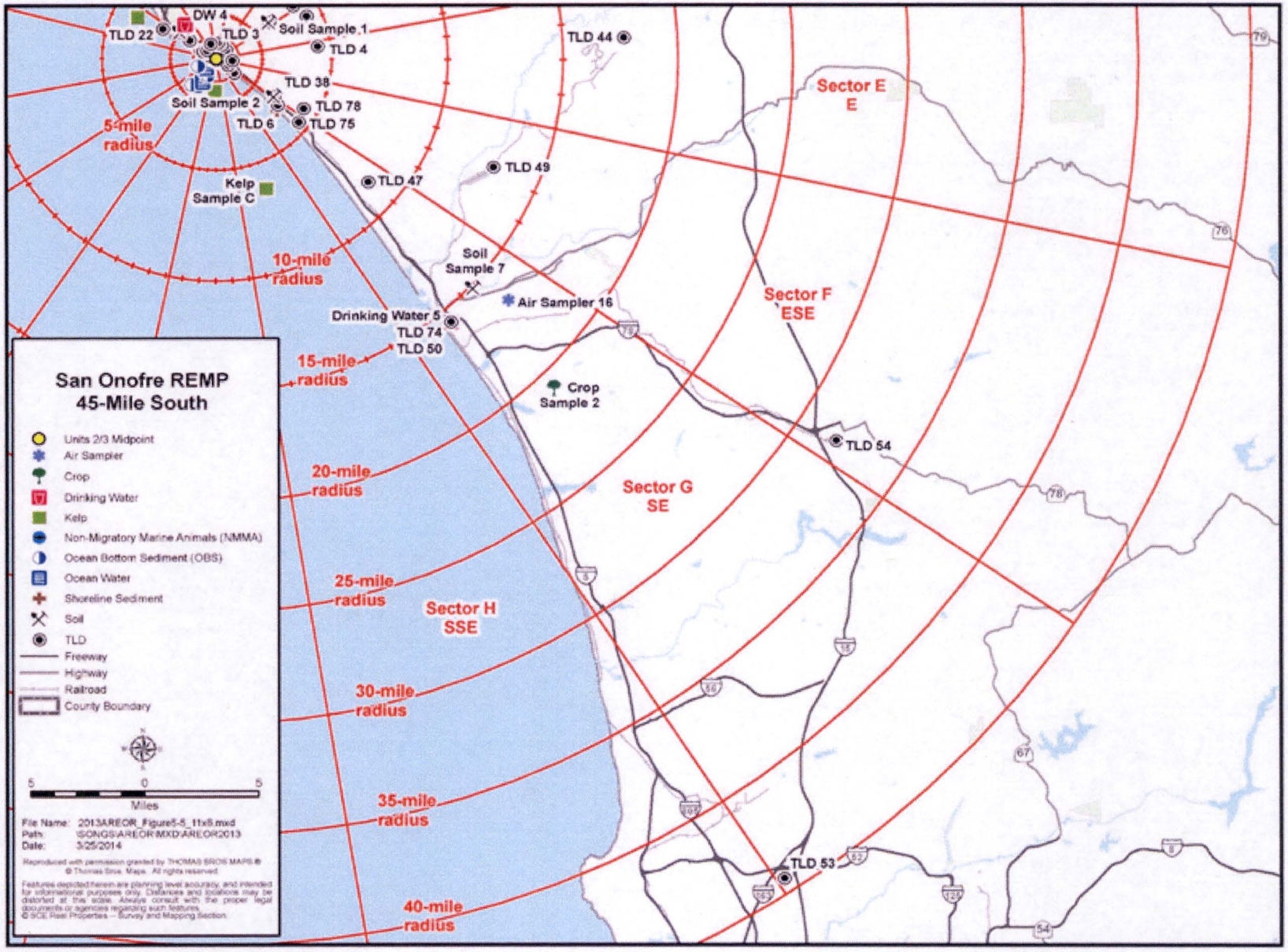

Figure 8 - SONGS REMP 45-mile Radius South

APPENDIX B. RESULTS AND DISCUSSIONS OF 2020 ENVIRONMENTAL DATA

Summary

The 2020 REMP analysis results support the conclusion that the measured levels of radioactivity in samples collected are attributable to sources external to SONGS (fallout and ongoing liquid discharges to the Pacific Ocean from the nuclear accident at the Fukushima Daiichi Nuclear Power Station, Chernobyl, and residual fallout from legacy atmospheric nuclear weapons testing). Cs-137 has been intermittently detected in the indicator and in the control soil samples in past years and no correlation between Cs-137 level in soil and proximity to the plant has been observed. The CS-137 detected in both indicator and control samples of non-migratory marine animals is attributable to sources external to SONGS. The direct radiation results (from TLD data) are ND (not detected) outside the immediate area of the ISFSI.

Results and Discussions of 2020 Environmental Data

Direct Radiation

Direct gamma radiation is monitored in the environment by calcium sulfate ($CaSO_4$) TLDs placed at 49 locations and analyzed quarterly per the methodology described in Regulatory Guide 4.13 revision 2 (based on ANSI/HPS N13.37-2014, "Environmental Dosimetry – Criteria for System Design and Implementation"). The Annual Public Dose, as referenced in Table 13, is based on the potential member of the public exposure at the listed locations. For onsite locations, at or near the EAB, the occupancy factor is determined per site procedure for Direct Radiation Exposure Controls and Monitoring. The hypothetical maximum associated exposure to a member of the general public, adjusted for occupancy, is less than the minimum detectable dose as calculated using the ANSI method.

The 2020 quarterly dose measurements (accounting for background) at all TLD locations outside the SONGS EAB were ND. The criteria for establishing a detectable dose, in accordance with Reg. Guide 4.13, is 5 mrem per quarter above the baseline and 10 mrem per year. Dose measurements less than these values are reported as ND. In accordance with ANSI N13.37, the annual facility dose is calculated using the sum of the four quarterly dose measurements and subtracting the annual baseline. Refer to Table 13 for a summary of all 2020 SONGS REMP TLD data. The data for offsite locations indicate no significant change since 2019.

The 2020 REMP quarterly dose measurements within the EAB were detectable at TLD 55 and at TLD 13. REMP TLD 13, Southeast Site Boundary (Bluff) is within the EAB at the southwest corner of SONGS facility footprint and has been used for radioactive equipment and materials storage for a number of years; TLD location 13 is not readily accessible to the public. REMP TLD 55, (located on the beach walkway between the ISFSI and the ocean), is readily accessible to the general public and had detectable quarterly dose measurements during the first three quarters of 2020 when TLD 55 data was available. REMP TLD 55 data includes the estimated neutron dose. In 2020, the measurable doses at REMP TLD 55 are attributable to the loading operation of the SONGS ISFSI located in the near vicinity.

The annual dose measurements at TLD 13, TLD 55, TLD 56, TLD 59, and TLD 73 were also detectable. The detectable dose measurement at TLD 73 (located close to TLD 13) is also attributable to the transport, loading and storage of radioactive materials at SONGS. The detectable dose measurements at TLDs 56 (located close to 55) is also attributable to the operation of the ISFSI. The measured dose rates at TLD 59 can be attributed to a locally elevated baseline dose rate at this location. There are no SONGS related activities near TLD

59 that could account for the elevated dose rate observed here. The area around TLD 59 is not accessible to members of the general public.

Separate TLDs are used to compensate for transit dose and a fade TLD is used to evaluate for the time and temperature dependent "fade" that may affect dosimeter data. After the samples were analyzed, the measured doses were corrected for pre and post field exposure times.

A neutron dosimeter package was co-located with REMP TLD 55 and at selected ISFSI TLD locations around the ISFSI. Any detected neutron dose was added to the gamma dose to report a total dose for each station with a neutron package. The maximum detected neutron dose in any quarter of 2020 was 3.0 mrem at some of the SONGS ISFSI locations. This was due to the increased movement and storage of spent fuel at the SONGS ISFSI.

The fourth quarter 2020 data for TLDs 55 and 56 was not available. In accordance with the ANSI guidance, a normalized annual dose to members of the general public was calculated for TLDs 55 and 56 based on the three quarters of available data. In addition, two supplemental dosimeters were deployed at two locations between TLD 55 and 56 along the seawall. Data from the supplemental locations was available for all of 2020. The empirical data gathered from these four locations immediately adjacent to the ISFSI indicate that dose to a member of the general public was less than one millirem per year based on the estimated occupancy at this location as per the ANSI guidance.

Direct Radiation baseline evaluation and estimation of natural background

An in-depth baseline exposure analysis of the environmental radiation results for the period of 2001 through 2010 was completed for all the REMP TLD monitoring locations. It was determined that if the standard deviation was low and no additional exposure above background was identified at a particular station, the average of that station's radiation exposure results should be equal to natural background (baseline) at that location. The baseline results for REMP TLDs have been summarized with the annual and quarterly values in Table 13.

Natural background radiation is variable and a minor shift in location can yield a measurable change in background radiation. Therefore, if a TLD is moved, the baseline (background) for that location may be affected. The natural direct gamma radiation varies according to location because of differences in the natural radioactive materials in the soil, soil moisture content, buildings, and other factors.

The baseline environmental exposure analysis included an assessment of the standard deviation of the quarterly results and annual totals at each location. This is an appropriate methodology to determine the ability to detect radiation exposure above background, described in ANSI/HPS N13.37-2014. The 2020 quarterly and annual results expressed in Table 13 are positive exposures if they exceed either 5 mrem above the baseline quarterly or 10 mrem above the baseline annually. If not, the measurement is noted as ND.

In 1980 the Department of Energy (DOE) conducted an Aerial Radiological Survey of SONGS and the surrounding area. The currently used baseline/background value of 15.8 mrem per standard quarter within the SONGS EAB is consistent with the 1980 gamma exposure rates reported by the DOE for the areas immediately north and south of SONGS, taking into account the reduction in environmental radioactivity and background dose rates caused by the decay of atmospheric nuclear weapons testing fallout since 1980.

An empirical determination of the background baseline for stations within the EAB is not possible due to the known plant related radiological activities (e.g., storage and transport of radioactive materials) that occurred during the baseline calculation study period. The average of nearby proxy locations outside the EAB was used to estimate the baseline within the EAB. A value of 15.8 mrem per quarter was determined as the appropriate baseline for the REMP

stations located within the EAB. However, local baseline variations within the EAB are possible because the baseline study period did not predate the introduction of licensed material to the REMP TLD locations within the EAB.

Table 13 - SONGS REMP TLD Data

TLD (SCE-##)	Location	Distance (miles)	Qtr. Baseline (mrem)	2020 Quarterly Results (mrem)				Baseline Adjusted Quarterly Results (mrem)				Annual Baseline (mrem)	Annual Total (mrem)	Annual Facility Dose (mrem)	Annual Public [e f] Dose (mrem)
				1	2	3	4	1	2	3	4				
1	City of San Clemente	5.7	18.4	18.4	17.9	18.0	19.2	ND	ND	ND	ND	73.6	73.5	ND	ND
2	Camp San Mateo – MCB	3.6	19.6	18.4	20.0	18.5	21.0	ND	ND	ND	ND	78.2	77.9	ND	ND
3	Camp San Onofre – MCB	2.8	17.2	16.7	18.1	17.8	18.7	ND	ND	ND	ND	69.0	71.2	ND	ND
4	Camp Horno – MCB	4.4	19.0	17.5	18.7	17.8	20.1	ND	ND	ND	ND	76.1	74.2	ND	ND
6	Old Route 101 (ESE)	3.0	12.0	10.0	12.4	9.9	12.7	ND	ND	ND	ND	47.9	45.0	ND	ND
8	Noncommissioned Officers' Beach Club	1.4	16.2	15.2	15.7	15.1	16.7	ND	ND	ND	ND	64.8	62.7	ND	ND
10	Bluff	0.7	17.2	16.6	16.1	16.2	17.6	ND	ND	ND	ND	69.0	66.6	ND	ND
19	San Clemente Highlands	4.9	18.7	19.0	19.1	18.9	19.2	ND	ND	ND	ND	74.8	76.2	ND	ND
22	Former US Coast Guard Station	2.7	18.8	18.4	18.7	19.0	20.2	ND	ND	ND	ND	75.3	76.2	ND	ND
23	SDG&E Service Center Yard (Control)	8.1	16.6	16.0	16.4	15.7	16.6	ND	ND	ND	ND	66.4	64.8	ND	ND
31	Aurora Park - Mission Viejo (Control)	18.6	19.4	20.3	19.8	19.4	20.0	ND	ND	ND	ND	77.8	79.5	ND	ND
33	Camp Talega – MCB (Control)	5.9	19.9	18.5	19.8	18.4	20.4	ND	ND	ND	ND	79.5	77.1	ND	ND
34	San Onofre School – MCB	1.9	17.0	16.9	17.3	16.8	17.4	ND	ND	ND	ND	68.1	68.4	ND	ND
35	Range 312 – MCB	4.8	17.8	15.3	16.8	14.8	16.9	ND	ND	ND	ND	71.1	63.8	ND	ND
36	Range 208C – MCB	4.1	20.5	18.8	21.0	19.1	21.1	ND	ND	ND	ND	82.0	79.9	ND	ND
38	San Onofre State Beach Park	3.4	15.0	12.4	14.9	13.0	13.9	ND	ND	ND	ND	60.1	54.2	ND	ND
40	SCE Training Center – Mesa	0.7	18.0	17.4	18.6	17.6	18.7	ND	ND	ND	ND	71.9	72.2	ND	ND
44	Fallbrook Fire Station (Control)	17.7	14.7	15.4	15.5	15.4	15.8	ND	ND	ND	ND	58.9	62.2	ND	ND
46	San Onofre State Beach Park	1.0	12.8	12.9	14.8	13.0	14.3	ND	ND	ND	ND	51.3	54.9	ND	ND
47	Camp Las Flores – MCB (Control)	8.6	14.0	15.8	15.6	16.0	17.0	ND	ND	ND	ND	55.9	64.4	ND	ND
49	Camp Chappo – MCB (Control)	12.9	14.9	15.5	15.0	15.3	16.4	ND	ND	ND	ND	59.7	62.3	ND	ND
50	Oceanside Fire Station (Control)	15.6	17.4	17.5	17.3	16.4	18.3	ND	ND	ND	ND	69.8	69.5	ND	ND
53	San Diego County Operations Center (Control)	44.2	19.1	19.8	20.1	19.3	20.0	ND	ND	ND	ND	76.5	79.3	ND	ND
54	Escondido Fire Station (Control)	31.8	16.9	18.7	18.6	18.8	19.8	ND	ND	ND	ND	67.7	75.9	ND	ND
61	Mesa - East Boundary	0.7	16.2	15.3	16.3	14.8	16.5	ND	ND	ND	ND	64.8	62.9	ND	ND
62	Camp Pendleton	0.7	13.9	12.4	14.1	12.0	13.7	ND	ND	ND	ND	55.5	52.2	ND	ND
63	Camp Pendleton	0.6	14.6	13.2	15.1	13.9	14.7	ND	ND	ND	ND	58.4	57.0	ND	ND
64	Camp Pendleton	0.6	15.8	15.0	15.9	14.3	16.3	ND	ND	ND	ND	63.1	61.5	ND	ND

TLD (SCE-##)	Location	Distance (miles)	Qtr. Baseline (mrem)	2020 Quarterly Results (mrem)				Baseline Adjusted Quarterly Results (mrem)				Annual Baseline (mrem)	Annual Total (mrem)	Annual Facility Dose (mrem)	Annual Public [e f] Dose (mrem)
				1	2	3	4	1	2	3	4				
65	Camp Pendleton	0.7	14.1	13.0	14.3	12.5	14.7	ND	ND	ND	ND	56.3	54.5	ND	ND
66	San Onofre State Beach	0.6	14.7	14.1	14.7	14.1	16.2	ND	ND	ND	ND	58.9	59.1	ND	ND
67	Former SONGS Evaporation Pond	0.6	17.8	17.7	17.4	17.2	19.0	ND	ND	ND	ND	71.1	71.3	ND	ND
68	Range 210C – MCB	4.4	15.8	15.6	17.8	15.7	18.0	ND	ND	ND	ND	63.1	67.2	ND	ND
74	Oceanside City Hall (Backup Control)	15.6	14.0	13.5	13.9	13.5	14.8	ND	ND	ND	ND	55.9	55.6	ND	ND
75	Gate 25 MCB	4.6	16.7	15.9	17.7	15.9	17.9	ND	ND	ND	ND	66.9	67.3	ND	ND
76	El Camino Real Mobil Station	4.6	18.2	17.8	18.2	18.4	19.0	ND	ND	ND	ND	72.7	73.4	ND	ND
77	Area 62 Heavy Lift Pad	4.2	20.2	17.8	20.4	18.6	20.4	ND	ND	ND	ND	80.7	77.1	ND	ND
78 [b]	Horno Canyon	4.4	11.7	11.5	-	-	-	ND	-	-	-	46.7	-	-	-
11	Former Visitors' Center	0.4*	15.8	16.4	16.0	16.4	17.5	ND	ND	ND	ND	63.1	66.3	ND	ND
12 [a]	South Edge of Switchyard	0.2*	15.8	18.4	17.9	16.6	19.4	ND	ND	ND	ND	63.1	72.3	ND	ND
13 [e]	Southeast Site Boundary (Bluff) [a]	0.4*	15.8	21.8	21.4	20.7	20.8	6.0	5.6	ND	5.0	63.1	84.7	21.6	ND
15 [a b]	Southeast Site Boundary (Office Bldg) [a]	0.1*	15.8	17.4	18.2	17.5	18.6	ND	ND	ND	ND	63.1	71.7	ND	ND
16 [c]	East Southeast Site Boundary [a]	0.4*	15.8	17.3	17.1	16.8	17.0	ND	ND	ND	ND	63.1	68.2	ND	ND
41 [c]	Old Route 101 – East	0.3*	15.8	15.6	17.3	15.0	17.1	ND	ND	ND	ND	63.1	64.9	ND	ND
55 [a b d]	San Onofre State Beach (U1 West)	0.2*	15.8	21.0	22.5	21.7	-	5.2	6.8	5.9	-	63.1	86.9	23.8	ND
56 [a b]	San Onofre State Beach (U1 West)	0.2*	15.8	19.2	18.5	18.7	-	ND	ND	ND	-	63.1	75.2	12.2	ND
57 [a]	San Onofre State Beach (Unit 2)	0.1*	15.8	18.3	17.2	17.6	17.7	ND	ND	ND	ND	63.1	70.8	ND	ND
58 [a]	San Onofre State Beach (Unit 3)	0.1*	15.8	18.0	17.8	18.0	18.1	ND	ND	ND	ND	63.1	71.9	ND	ND
59 [c]	SONGS Meteorological Tower	0.3*	15.8	20.1	20.0	19.4	19.9	ND	ND	ND	ND	63.1	79.5	16.4	ND
73 [c]	South Yard Facility	0.4*	15.8	19.0	18.8	17.8	19.4	ND	ND	ND	ND	63.1	75.0	11.9	ND

* Indicates that the station is within the EAB. The baseline has been estimated to be 15.8 mrem per standard 91-day quarter within the EAB.

a The dose to members of the public is based on a default non-office area annual occupancy time of 300 hours per year.

b TLD 55 and TLD 56 were not on station for the fourth quarter 2020. The annual dose was estimated based on the remaining three quarter's data per ANSI guidance. TLD 78 data was not available for three quarters due to construction activity. An annual dose for TLD 78 is not available due to the limited amount of data.

c This location is not accessible to members of the general public

d A neutron dosimeter was co-located with REMP TLD 55 and selected ISFSI TLDs. The estimated neutron dose was added to the gamma dose.

e Adjusted for occupancy in accordance with Radiation Monitoring and Exposure Controls procedure.

f For off-site locations with no available occupancy the public dose is ND.

Quality Control Duplicate Direct Radiation Samples

Duplicate Quality Control (QC) TLD was installed adjacent to TLD 66 and TLD 67. The duplicate TLDs agreed closely with the indicator TLDs, see Appendix C for results. These TLDs were not required by the ODCM and are not included in the Statistical Summary of REMP Data.

ISFSI Direct Radiation Samples

ISFSI TLDs were placed in the vicinity of the ISFSI. Though data from these TLDs are not included in the statistical summary of REMP data because they are not part of the ODCM, the ISFSI data are listed and discussed in Appendix I.

Airborne Particulate, Iodine, and Composite Isotopic Analyses

Air particulate samples were collected from the control location (#16) and seven indicator stations, including four stations required by the ODCM (#1, #9, #12, and #13) and three optional stations (#7, #10, and #11) not required by the ODCM. The data from these eight stations are included in the statistical summary. The samples were analyzed for gross beta activity, I-131, and composited quarterly for gamma isotopic analysis. Air Sampler #7 (AWS roof) was permanently removed from service in November 2020 due to planned demolition of the AWS building.

Gross beta analysis is a measure of total radioactivity of beta-emitting radionuclides in a sample. Beta radiation is emitted by many radionuclides and the gross beta measurements are used to identify samples with elevated levels of beta activity that would warrant further analysis. All of the weekly gross beta activity analysis results were above the MDC. The indicator data trends closely with the control data. The seasonal variability observed in the data is attributable to a factor external to SONGS. The 2020 gross beta data is similar to the gross beta data from the past few years.

The gross beta analysis does not identify specific radionuclides. To identify specific radionuclides, the weekly particulate media is composited quarterly and is analyzed for gamma emitters. During 2020, only naturally occurring radionuclides were identified and no SONGS related radionuclides were detected. Beryllium-7 (a naturally occurring radionuclide) was present in all of the quarterly composites.

I-131 is a fission product and can no longer be produced at SONGS with the reactor incapable of operation. As in previous years since SONGS power operation has halted, all samples analyzed for I-131 were below the MDC. Based on the station no longer being capable of generating I-131, the ODCM was revised in November 2020 to discontinue its inclusion in the program. Therefore, sampling and analysis was performed for iodine throughout 2020. However, it will no longer be included in the AREOR going forward.

Ocean Water

Monthly ocean water samples were collected from three indicator locations near each station discharge and from the control location at Newport Beach. The samples were analyzed for naturally occurring and SONGS related gamma-emitting radionuclides, including tritium. Quarterly composite ocean water samples were analyzed for tritium according to ODCM requirements.

Throughout 2020, only naturally occurring radionuclides were detected in the monthly gamma spectral analyses of ocean water. Monthly ocean water samples were also analyzed for tritium, consistent with the CDPH split sample program. During 2020, all the SONGS REMP and the duplicate CPDH tritium ocean water sample results were less than detectable.

The data indicate that SONGS had no measurable impact on the environment as measured by ocean water.

Drinking Water

In 2020, monthly drinking water samples were collected from one indicator location and from the Oceanside control location. Samples were analyzed for tritium, gross beta, naturally occurring radionuclides, and SONGS related gamma emitting radionuclides. There is no drinking water pathway for liquid effluent at SONGS.

No station related radionuclides were detected in drinking water during 2020. Gross beta activity was identified in some samples, but gamma spectroscopy identified only natural radionuclides. SONGS had no impact on the environment as measured by drinking water.

Shoreline Sediment (Beach Sand)

Beach sand was collected semiannually in 2020 from three indicator locations and from a control location situated in Newport Beach. After collection, the samples were analyzed for plant related and naturally occurring radionuclides. Only naturally occurring radionuclides were detected in all samples. No plant related radionuclides were reported above the MDC. SONGS had no impact on the environment as measured in beach sand.

Ocean Bottom Sediments

Ocean bottom sediments were collected from four indicator locations and the Laguna Beach control location. The samples were analyzed by gamma spectral analysis for naturally occurring and station related radionuclides. Only naturally occurring radionuclides were detected in ocean bottom sediment samples collected during 2020. The Ocean Bottom Sediments analyzed in 2020 did not yield any radionuclides attributable to SONGS.

Marine Species (Flesh)

Species of adult fish, crustacean and mollusks were collected on a semi-annual basis at the SONGS Unit 1 outfall, the SONGS Units 2/3 outfall, and from the Laguna Beach control location. The edible portion of each sample type was analyzed for gamma-emitting station related and naturally occurring radionuclides. The results were subsequently reported to SONGS in terms of wet sample weights. Because results based on a wet sample weight are most useful for calculating doses, the results of sample analyses are summarized in terms of "as received" wet weights. Cs-137 was detected in indicator and control samples above the MDC and below the LLD. This is consistent with the conclusion that the Cs-137 is attributable to sources external to SONGS. Some samples were split with the CDPH and the Cs-137 result (greater than the MDC but less than the LLD) is consistent with results from other marine species samples collected at other west coast locations. Publicly available research from scientific organizations indicates that the presence of Cs-137 in Pacific Ocean sea creatures is attributable to the legacy radioactive contamination from Global weapons testing, Chernobyl, and Fukushima (Woods Hole Oceanographic Institution website 3-30-2021). Naturally occurring radionuclides, such as K-40, were also detected in marine species samples collected during 2020, (refer to Table 28 for comparison results). SONGS had no measurable impact on the environment as measured by this sample medium.

Local Crops

Fleshy and leafy crops were collected semiannually in 2020 from the SONGS garden and from the control location 21 miles SE from SONGS Units 2/3 midpoint. Only naturally occurring radionuclides were identified and no plant related radioactivity was detected during 2020. SONGS had no measurable impact on local crops.

Soil

To determine if there is evidence of a build-up of radionuclides in the land near SONGS, indicator soil samples were collected from Camp San Onofre, Old Route 101, Basilone Road and the East Site Boundary (Former Visitors Center). A control sample was obtained from Prince of Peace Abbey in Oceanside. Surface soil was collected from all indicator and control locations at the depth of three inches. The sampling protocol is consistent with the procedure described in HASL-300. Soil sampling is not required by the ODCM.

Soil samples were analyzed for naturally occurring and SONGS related gamma-emitting radionuclides using gamma spectral analysis. The 2020 soil samples showed measurable levels of naturally occurring radionuclides and measurable Cs-137 which is consistent with the decay of legacy Cs-137 in soil attributable to factors external to SONGS (e.g., residual nuclear weapons testing fallout and the Chernobyl accident).

Cs-137 and strontium-90 (Sr-90) were detected in soil profile analyses conducted in previous years. These radionuclides are attributable to the nuclear weapons testing fallout depositing on soil and retention of these radionuclides due to their long half-lives. The presence of Cs-137 in indicator and in control samples at similar levels supports the conclusion that the source of this radionuclide to a factor external to SONGS (fallout deposition). During 2020, SONGS did not have a detectable effect on the environment as measured by soil samples.

Kelp

Only one Kelp sample was collected during 2020, at Salt Creek control station. The kelp canopy was absent at all the other locations and was only present at the Salt Creek control location in October 2020. No plant related radionuclides were detected. Kelp sampling is not required by the ODCM.

Correlation of Effluent Concentration to Concentrations in the Environment

In accordance with 10 CFR 50 Appendix I, Section IV, B.2, data on measurable levels of radiation and radioactive materials in the environment have been evaluated to determine the relationship between quantities of radioactive material released in effluents and resultant radiation doses to individuals from principal pathways of exposure.

REMP samples, both terrestrial and marine, indicated no accumulation of plant related radioactivity in the environs. Samples with detectable activity were not statistically different from control samples. Plant related radionuclides detected during 2020 were attributed to sources external to SONGS (past nuclear weapons fallout, Chernobyl, and Fukushima). The regulatory requirement to evaluate the relationship between quantities of radioactive materials released in effluents and the resultant radiation doses to individuals may be summarized by the following conclusion:

Effluent program releases are evaluated annually to determine the receptor(s) with the highest hypothetical dose. The 2020 REMP sample data indicated no accumulation of plant related radionuclides in the environment attributable to SONGS, thereby lending confirmation to the adequacy of the in-plant effluent controls program and dose assessments. Furthermore, the SONGS REMP data are consistent with the conclusion that SONGS has had an insignificant radiological impact on the environment in 2020.

Statistical Summary of REMP Data for 2020

For the tables below, the numbers in parentheses next to the mean value indicate the number of samples with positive results compared to the total number of samples. The smaller font numbers in parentheses indicate the range of results.

Table 14 – Weekly Airborne Particulates Gross Beta

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]	Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Air Filter Inhalation (pCi/m³)	Gross Beta 410	0.01	0.034 (358/358) (0.012 – 0.090)	Mesa EOF 0.7 Mi. NNW	0.039 (52/52) (0.015 – 0.090)	0.039 (52/52) (0.017 – 0.083)	0

NOTES:

a. Though not required by the ODCM, data for optional Air Samplers #7, #10, #11 are included since valid samples were collected for 2020. Air Sampler #7 was permanently discontinued in November 2020 due to the planned dismantlement of the nearby AWS building.

Table 15 – Weekly Radioiodine I-131 Activity

Pathway [a] (Measurement Unit)	Type and Number of Analysis Performed [d]	Lower Limit of Detection (LLD) [b]	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Activated Charcoal Inhalation (pCi/m³)	I-131 410	0.07	< MDC [c] (0/358)	All locations	< MDC	< MDC (0/52)	0

NOTES:

a This table summarizes the weekly air iodine-131 cartridge data above the MDC. Iodine-131 has an 8-day half-life. With reactor shutdown, it is no longer a radionuclide attributable to SONGS.

b LLD is the a priori limit as prescribed by the ODCM.

c The Term <MDC as used means that results had no activity above the minimum detectable activity.

d Though not required by the ODCM, data for optional Air Samplers #7, #10, #11 are included since valid samples were collected for 2020. Air Sampler #7 was discontinued in November 2020.

Table 16 – Quarterly Composite Airborne Particulate Gamma Activity

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Air Filter Inhalation (pCi/m^3)	Cs-134	32	0.05	< MDC (0/28)	< MDC	< MDC	< MDC (0/4)	0
	Cs-137	32	0.06	< MDC (0/28)	< MDC	< MDC	< MDC (0/4)	0

NOTES:

a As expected, natural occurring Be-7 was detected in all quarterly composite air particulate samples. Other naturally occurring radionuclides (such as K-40) were observed in some 2020 quarterly composite air samples. Though not required by the ODCM, data for optional Air Sampler's #7, #10, #11 are included since valid samples were collected for 2020.

Table 17 - Monthly Ocean Water Activity

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Ocean Water (pCi/L)	Ba-140	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Cs-134	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Cs-137	48	18	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Co-58	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Co-60	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	I-131	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Fe-59	48	30	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	La-140	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Mn-54	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Nb-95	48	15	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Tritium	48	2000	< MDC(0/36)	< MDC	< MDC	< MDC (0/12)	0
	Zn-65	48	30	< MDC(0/36)	< MDC	< MDC	< MDC(0/12)	0
	Zr-95	48	15	< MDC(0/36)	< MDC	< MDC	< MDC (0/12)	0

NOTES:

a Naturally occurring K-40 was observed in most 2020 ocean water samples.

Table 18 - Quarterly Ocean Water Tritium

Pathway (Measurement Unit)	Type and Number of Analysis Performed	Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Ocean Water (pCi/L)	Tritium 16	2000	< MDC (0/12)	< MDC	< MDC	< MDC (0/4)	0

Table 19 – Monthly Drinking Water Activity

Pathway (Measurement Unit)	Type and Number of Analysis Performed	Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Drinking Water (pCi/L)	Gross Beta 24	4	< MDC (0/12)	Oceanside City Hall (Control) 15.6 Mi SE	3.83 (2/12) (3.82 – 3.85)	3.83 (2/12) (3.82 – 3.85)	0
	Ba-140 24	15	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	Cs-134 24	15	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	Cs-137 24	18	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	Co-58 24	15	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	Co-60 24	15	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	I-131 24	15	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	Fe-59 24	30	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	La-140 24	15	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	Mn-54 24	15	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	Nb-95 24	15	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	Tritium 24	2000	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	Zn-65 24	30	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0
	Zr-95 24	15	< MDC (0/12)	< MDC	< MDC	< MDC (0/12)	0

Table 20 – Semi-annual Shoreline Sediment Gamma Activity (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Beach Sand Direct Exposure (pCi/g)	Cs-134	8	0.150	< MDC (0/6)	< MDC	< MDC	< MDC (0/2)	0
	Cs-137	8	0.180	< MDC (0/6)	< MDC	< MDC	< MDC (0/2)	0

NOTES:

a Naturally occurring radionuclides (K-40 and others) were detected in the 2020 shoreline sediment samples.

Table 21 – Semi-annual Ocean Bottom Sediment Gamma Activity (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Waterborne Ocean Bottom Sediment (pCi/g)	Cs-134	10	0.150	< MDC (0/8)	< MDC	< MDC	< MDC (0/2)	0
	Cs-137	10	0.180	< MDC (0/8)	< MDC	< MDC	< MDC (0/2)	0

NOTES:

a Naturally occurring radionuclides (K-40 and others) were detected in the 2020 ocean bottom sediment samples.

Table 22 – Semi-annual Marine Animal Gamma Activity (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Non-Migratory Marine Animals (pCi/g)	Cs-134	24	0.130	< MDC (0/16)	< MDC	< MDC	< MDC (0/8)	0
	Cs-137	24	0.150	0.0063 (2/16) (0.0052 – 0.0075)	Laguna Beach 20 - 25 Mi NW	0.0112 (1/8) (0.0112 – 0.0112)	0.0112 (1/8) (0.0112 – 0.0112)	0
	Co-58	24	0.130	< MDC	< MDC	< MDC	< MDC	0
	Co-60	24	0.130	< MDC	< MDC	< MDC	< MDC	0
	Fe-59	24	0.260	< MDC	< MDC	< MDC	< MDC	0
	Mn-54	24	0.130	< MDC	< MDC	< MDC	< MDC	0
	Zn-65	24	0.260	< MDC	< MDC	< MDC	< MDC	0

NOTES:

a Naturally occurring radionuclides (K-40 and others) were detected in the 2020 non-migratory marine animal samples.

Table 23 – Semi-annual Local Crops Gamma Activity (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Local Crops ingestion (pCi/g)	Cs-134	8	0.06	< MDC (0/4)	< MDC	< MDC	< MDC (0/4)	0
	Cs-137	8	0.08	< MDC (0/4)	< MDC	< MDC	< MDC (0/4)	0
	I-131	8	0.06	< MDC (0/4)	< MDC	< MDC	< MDC (0/4)	0

NOTES:

a Naturally occurring radionuclides (K-40 and others) were observed in the 2020 local crop samples.

Table 24 –Annual Soil Gamma Activity, 3" Depth (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [a]	Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Soil Direct Exposure (pCi/g)	Cs-134 5	0.150	< MDC	< MDC	< MDC	< MDC	0
	Cs-137 [b] 5	0.180	0.0834 (2/4) (0.0576 – 0.109)	Camp San Onofre 2.8 Mi. NE	0.109 (2/4) (0.109 – 0.109)	0.0868 (1/1) (0.0868 – 0.0868)	0

NOTES:

a K-40 and other naturally occurring radionuclides were detected in the 2020 REMP soil samples.

b The Cs-137 detected in the control and in two indicator samples at the same level (approximately 0.1 pCi/g). This is due to factors external to SONGS (legacy fallout from nuclear weapons testing and Chernobyl) and are not attributable to SONGS. All indicator sample results have been included in the statistical summary above.

Table 25 –Semi-Annual Kelp Gamma Activity (pCi/g)

Pathway (Measurement Unit)	Type and Number of Analysis Performed [b]	Lower Limit of Detection (LLD)	All Indicator Locations Mean (Range)	Location with Highest Annual Mean		Control Locations Mean (Range)	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Kelp Ingestion (pCi/g)	I-131 [a] 1	0.06	NA	< MDC	< MDC	< MDC (0/1)	0

NOTES:

a I-131 in kelp was not detected above the MDC during 2020.

b Only one kelp sample at the control location (Salt Creek) was available during all of 2020. No indicator samples were available.

APPENDIX C. SUMMARY OF QUALITY CONTROL PROGRAMS

Summary

All REMP samples are collected, shipped, and analyzed in accordance with Regulatory Guide 4.15. Marine radiological environmental samples are collected by a vendor, MBC Environmental, per the vendor's Quality Assurance manual. REMP sample analysis is performed by GEL in accordance with GEL's Laboratory Quality Assurance Plan. The CEAL for REMP TLDs was Stanford Dosimetry. The raw data for TLDs was reported as milli-Roentgen/standard quarter and converted to millirem per standard quarter using conversion factors in ANSI N13.37.

Quarterly Duplicate TLDs

SONGS deployed a duplicate TLD package, TLD 200, in the same canister as TLD 66. The quarterly dose measured by the duplicate TLD package was statistically equivalent.

Table 26 - 2020 Quarterly Duplicate TLD Data Comparison

TLD #	1ST QUARTER (mrem) +/- 1 sigma	2ND QUARTER (mrem) +/- 1 sigma	3RD QUARTER (mrem) +/- 1 sigma	4TH QUARTER (mrem) +/- 1 sigma
TLD 66	14.05 ± 0.68 [a]	14.74 ± 0.64	14.14 ± 0.90	16.19 ± 1.05
TLD 200	13.73 ± 0.68	14.68 ± 0.60	14.46 ± 0.75	15.05 ± 0.91

NOTES:
a Data is reported as mrem per standard quarter ± 1 sigma

Annual Duplicate TLDs

SONGS deployed an annual duplicate TLD package, TLD 201, in the same location and canister as REMP TLD 67. The average of four the quarterly TLD 67 exposure results is statistically equal to the annual TLD 201 results for 2020 expressed as mrem/91 days.

Table 27 - 2020 Annual Duplicate TLD Data compared to data from the same canister

TLD #	January 2020 to December 2020 Average of the quarterly values (mrem/91 days +/- 1 sigma)
TLD 67	17.82 ± 0.84
TLD 201	17.70 ± 0.63

Calibration of Air Sampler Volume Meters

All REMP air sampler volume meters are calibrated annually using standards referenced to National Institute of Standard and Technology. Calibration of REMP air samplers that are required by the ODCM is verified quarterly to ensure the volume meters remain within limits. Meters are removed from service if they fail the quarterly test. This is an *a posteriori* review of the volume meter performance to evaluate method bias and to identify possible outlier analysis results. A bias was not detected in 2020. A review of the air particulate beta results over the course of the year did not indicate a particular bias for any particular sampler. The trends in the beta results over the course of the year were consistent, within the limitations of the gross beta method of analysis.

Interlaboratory Cross-Check Program

The CDPH participates in a comprehensive radiological environmental split sampling program in conjunction with SONGS. In 2020, the CDPH acquired split samples, collected by an independent third party, from the following SONGS media: atmospheric radioactivity, non-migratory marine animals, kelp, ocean bottom sediments, ocean water gamma emitters, and ocean water tritium. The CDPH also conducts a parallel terrestrial direct radiation (TLD) measurement effort at SONGS, (refer to Appendix H for a discussion of the CDPH TLD data).

CDPH Atmospheric Radioactivity Gross Beta, I-131 and quarterly gamma analysis results were substantially similar to the SONGS results for the same media. As expected, both the CDPH Drinking Water and Radiation Laboratory (DWRL) and the SONGS contracted GEL found a gross beta signal above the detection limit. Both labs detected naturally occurring Be-7 in the quarterly composite gamma particulate media samples. Both labs did not detect anthropogenic radionuclides in the split samples with the exception of non-migratory marine animals.

Since ocean water tritium and non-migratory marine animals have the potential for human consumption, their raw data are tabulated below. Fourteen split sample analyses for marine species was conducted. Analysis methodologies are different in that the SONGS contracted laboratory reported a wet weight result, where the CDPH lab reported a dry weight result. The low level Cs-137 was detected in some samples. The variability in the detection of positive results is due to the low activity of the samples, the differences in sample processing, the uncertainty of isotope detection and detection limits at low concentrations. (For a discussion on the presence of Cs-137 in fish, refer to Appendix B.)

Table 28 - Non-migratory marine animals analysis results

SPLIT SAMPLE LOCATION		Sample Date / Time	SONGS data (wet weight)		CDPH data (dry weight)	
			gamma result +/- 2 sigma (pCi/g)	MDC	Gamma result +/- uncertainty (pCi/g)	MDC
A	Station Discharge Outfall - Unit 1	12-Oct-20 / 1145	K-40 1.30 +/- 0.224	7.47E-02	8.58 +/- 0.526 Dry / wet ratio 0.194	6.20E-01
			Cs-137 1.48E-3 +/- 5.23E-3	9.23E-03	1.34E-2 +/-7.82E-3 Dry / wet ratio 0.194	1.93E-02
		28-Oct-20 / 1200	K-40 4.15 +/- 0.349	5.52E-02	20.3 +/- 0.917 Dry / wet ratio 0.220	5.33E-01
			Cs-137 9.68E-4 +/- 6.40E-3	1.06E-02	4.22E-2+/- 1.16E-2 Dry / wet ratio 0.220	2.46E-02
B	Outfall - Unit 2	20-Apr-20 / 0900	K-40 2.80 +/- 0.313	9.57E-02	19.4 +/- 0.988 Dry / wet ratio 0.219	4.64E-01
			Cs-137 4.05E-3 +/- 1.05E-2	9.25E-03	3.67E-2+/- 1.03E-2 Dry / wet ratio 0.219	2.17E-02
		20-Apr-20 / 0925	K-40 2.22 +/- 0.252	7.69E-02	11.4 +/- 0.748 Dry / wet ratio 0.191	7.17E-01
			Cs-137 5.78E-4 +/- 4.81E-3	8.16E-03	7.82E-3 +/- 1.21E-2 Dry / wet ratio 0.191	2.86E-02
		20-Apr-20 / 1055	K-40 3.38 +/- 0.320	7.62E-02	14.1 +/- 0.639 Dry / wet ratio 0.276	3.75E-01
			Cs-137 3.76E-3 +/- 5.29E-3	9.70E-03	1.87E-2 +/-6.74E-3 Dry / wet ratio 0.276	1.45E-02
		20-Apr-20 / 1115	K-40 2.09 +/- 0.136	3.18E-01	19.6 +/- 0.852 Dry / wet ratio 0.239	4.15E-01
		20-Apr-20 / 1115	Cs-137 (UI) 7.48E-3 +/- 6.33E-3	4.99E-03	3.23E-2+/- 8.50E-3 Dry / wet ratio 0.239	1.78E-02

SPLIT SAMPLE LOCATION		Sample Date / Time	SONGS data (wet weight)		CDPH data (dry weight)	
			gamma result +/- 2 sigma (pCi/g)	MDC	Gamma result +/- uncertainty (pCi/g)	MDC
		12-Oct-20 / 0955	K-40 3.89 +/- 0.307	5.94E-02	17.9 +/- 0.959 Dry / wet ratio 0.239	7.14E-01
			Cs-137 1.33E-3 +/- 5.25E-3	9.15E-03	2.53E-2 +/-1.22E-2 Dry / wet ratio 0.239	2.72E-02
		12-Oct-20 / 1000	K-40 3.54+/- 0.407	1.08E-01	1.47E-1+/-8.31E-2 Dry / wet ratio 0.259	1.97E-01
			Cs-137 -2.26E-4 +/- 7.58E-3	1.29E-02	1.33E-2+/- 6.97E-3 Dry / wet ratio 0.259	1.54E-02
C	Laguna Beach - Control	14-Apr-20 / 1040	K-40 3.62 +/- 0.335	7.99E-02	16.6 +/- 0.920 Dry / wet ratio 0.233	5.78E-01
			Cs-137 2.77E-3 +/- 7.15E-3	1.13E-02	3.02E-2 +/-1.58E-2 Dry / wet ratio 0.233	3.51E-02
		14-Apr-20 / 1110	K-40 3.63 +/- 0.235	5.32E-02	13.8 +/- 0.770 Dry / wet ratio 0.243	4.94E-01
			Cs-137 -6.26E-4 +/- 4.10E-3	6.79E-03	1.74E-2+/- 1.18E-2 Dry / wet ratio 0.243	2.66E-02
		14-Apr-20 / 1315	K-40 1.10 +/- 0.189	9.31E-02	8.99 +/- 0.708 Dry / wet ratio 0.161	1.00
			Cs-137 9.20E-3 +/- 8.27E-3	7.87E-03	8.48E-3+/- 1.21E-2 Dry / wet ratio 0.161	2.87E-02
		20-Oct-20 / 0900	K-40 1.79 +/- 0.166	5.78E-02	9.71 +/- 64.7 Dry / wet ratio 0.676	6.41E-01
			Cs-137 2.27E-3 +/- 3.92E-3	4.46E-03	1.51E-2+/- 1.00E-2 Dry / wet ratio 0.676	2.48E-02
		20-Oct-20 / 1100	K-40 3.41 +/- 0.263	8.18E-02	15.9 +/- 0.717 Dry / wet ratio 0.254	4.07E-01
			Cs-137 -1.71E-3 +/- 5.13E-3	7.99E-03	1.33E-2 +/-9.25E-3 Dry / wet ratio 0.254	2.10E-02
		20-Oct-20 / 1230	K-40 3.42 +/- 0.207	3.79E-02	15.4 +/- 0.827 Dry / wet ratio 0.72	4.47E-01
			Cs-137 (UI) 5.70E-3 +/- 5.39E-3	4.80E-03	2.89E-2 +/-1.15E-2 Dry / wet ratio 0.72	2.48E-02

UI - Uncertain identification for gamma spectroscopy

MDC - minimum detectable concentration (SONGS lab)

Table 29 below shows the results from ocean water tritium samples. All the SONGS and the available CDPH results for 2020 tritium in ocean water were less than detectable. The December 2020 CDPH data was not available.

NOTE: When sample results are analyzed to be lower in activity than the laboratory background result, the result is depicted as a negative value.

Table 29 - CDPH and SONGS split sample tritium in ocean water

SPLIT SAMPLE LOCATION		Sample Date	SONGS tritium data		CDPH tritium data	
			H-3 result +/- 2 sigma (pCi/L)	MDC	H-3 result +/- uncertainty (pCi/L)	MDC
A	Station Discharge Outfall - Unit 1	15-Jan-20	-70.1 +/- 114	215	-11.0 +/- 180	307
		18-Feb-20	-112 +/- 357	619	-115 +/- 128	226
		20-Mar-20	81.9 +/- 313	511	-3.65 +/- 131	226
		15-Apr-20	366 +/- 309	461	-13.3+/- 134	230
		21-May-20	234 +/- 323	508	133 +/- 138	230
		15-Jun-20	-427 +/- 362	685	-15.3 +/- 137	236
		15-Jul-20	-79.8 +/- 414	709	-57.3 +/- 136	236
		17-Aug-20	-141 +/- 411	717	-84.9 +/- 135	236
		17-Sep-20	59.1 +/- 356	589	57.9 +/- 139	236
		19-Oct-20	151 +/- 307	493	-43.6 +/- 129	224
		17-Nov-20	225 +/- 328	515	-24.7 +/- 130	224
		16-Dec-20	-310 +/- 302	558	Data not available (b)	-
B	Outfall - Unit 2	15-Jan-20	-68.5 +/- 124	232	-82.2 +/-.179	307
		18-Feb-20	.0933 +/- 351	588	-85.8 +/- 129	226
		20-Mar-20	-13.5 +/- 283	477	-27.4 +/- 131	226
		15-Apr-20	99.3 +/- 289	469	-58.9 +/- 132	230
		21-May-20	152 +/- 318	512	-20.9 +/- 133	230
		15-Jun-20	-282 +/- 387	699	-95.6 +/- 135	236
		15-Jul-20	146 +/- 442	715	-59.2 +/- 136	236
		17-Aug-20	1.61 +/- 422	707	-27.0 +/- 137	236
		17-Sep-20	280 +/- 378	592	15.4 +/- 138	236
		19-Oct-20	12.1 +/- 295	494	43.6 +/- 131	224
		17-Nov-20	18.1 +/- 312	521	85.4 +/- 133	224
		16-Dec-20	-315 +/- 304	562	Data not available (b)	-

SPLIT SAMPLE LOCATION		Sample Date	SONGS tritium data		CDPH tritium data	
			H-3 result +/- 2 sigma (pCi/L)	MDC	H-3 result +/- uncertainty (pCi/L)	MDC
C	Outfall - Unit 3	15-Jan-20	88.6 +/- 154	231	98.6 +/- 182	307
		18-Feb-20	-240 +/- 323	585	-51.1 +/- 130	226
		20-Mar-20	16.1 +/- 293	489	-29.2 +/- 131	226
		15-Apr-20	82.2 +/- 280	456	38.0 +/- 135	230
		21-May-20	167 +/- 322	517	-53.2 +/- 133	230
		15-Jun-20	-92.1 +/- 430	737	-24.8 +/- 137	236
		15-Jul-20	135 +/- 431	698	-112.8 +/- 134	236
		17-Aug-20	-154 +/- 394	691	-81.0 +/- 135	236
		17-Sep-20	-182 +/- 325	574	-84.9 +/- 135	236
		19-Oct-20	318 +/- 321	493	17.1 +/- 131	224
		17-Nov-20	12.7 +/- 315	527	24.7 +/- 131	224
		16-Dec-20	229 +/- 346	545	Data not available (b)	-
D	Newport Beach (Control)	15-Jan-20	255 +/- 334	525	159 +/- 183	307
		18-Feb-20	-208 +/- 330	590	40.2 +/- 132	226
		20-Mar-20	216 +/- 312	488	-55.6 (a)	226
		15-Apr-20	200 +/- 298	468	28.5 +/- 135	230
		21-May-20	-157 +/- 295	520	38.0 +/- 135	230
		15-Jun-20	-325 +/- 379	693	-89.8 +/- 135	236
		15-Jul-20	98.7 +/- 414	677	17.2 +/- 138	236
		17-Aug-20	-73.5 +/- 398	682	-3.86 +/- 137	236
		17-Sep-20	-171 +/- 342	601	3.86 +/- 137	236
		19-Oct-20	164 +/- 307	490	64.5 +/- 132	224
		17-Nov-20	325 +/- 330	504	30.4 +/- 131	224
		16-Dec-20	-239 +/- 314	566	Data not available (b)	-

Note that the EPA drinking water maximum permissible tritium activity is 20,000 pCi / liter. Both labs only detected naturally occurring radionuclides in ocean bottom sediments and ocean water. No plants related radionuclides were reported above the MDC.

Notes:

(a) The uncertainty for this sample is not available
(b) The December 2020 CDPH data is not available per the CDPH

GEL participates in three independent cross check programs. GEL's QA programs consists of these testing vendors: Eckert & Ziegler Analytics, U.S. DOE MAPEP, and ERA's MARD Proficiency Testing Program. Non-agreement results were resolved in accordance with GEL's corrective action program.

In 2020, the environmental TLDs, routine quality control (QC) testing was performed for the types of dosimeters issued by the Environmental Dosimetry Company (EDC). During 2020, 100% (72/72) of individual dosimeters evaluated against the EDC internal performance acceptance criteria (high-energy photons only) met the criterion for accuracy and 100% (72/72) met the criterion for precision.

The GEL and Stanford Dosimetry performance meets the criteria described in Reg. Guide 4.15 and ANSI/HPS N13.37-2014.

APPENDIX D. COMPARISON OF 2020 REMP DATA TO HISTORICAL DATA

Comparison of 2020 REMP data to Historical Data and Analysis of Trends

Unit 1 achieved criticality on June 14, 1967 and was permanently retired from service on November 30, 1992. Unit 2 attained initial criticality on July 26, 1982 and Unit 3 on August 29, 1983.

A variety of environmental samples were analyzed and the analytical results (January 1, 1979 to July 31, 1982) were compared with the 2020 REMP data obtained for SONGS Units 2/3.

The following media were evaluated and compared with the operational data of SONGS Units 1, 2 and 3:

- External Radiation
- Air Particulates
- Radioiodine
- Ocean Water
- Shoreline Sediment (Sand)
- Ocean Bottom Sediments
- Marine Species
- Local Crops
- Soil
- Kelp
- Drinking Water

The measurements obtained from the SONGS Unit 1 operational Radiological Environmental Monitoring Program (REMP) during the period from January 1979 to July 1982 are used as the pre-operational baseline for SONGS Units 2/3. This is in accordance with San Onofre Units 2/3, Environmental Report, Operating License Stage, Appendix 6A, Pre-operational Radiological Environmental Monitoring, May 31, 1978. Comparisons of pre-operational data to 2020 REMP data are possible for each of the following exposure pathways: (1) direct radiation, (2) air particulates (inhalation), and (3) ocean water (marine pathway for ingestion). Comparisons can also be made between pre-operational and 2020 REMP data for ocean bottom sediment data to ascertain if there has been any significant increase in radioactivity in ocean bottom sediments near the SONGS Units 2/3 outfalls.

Currently the pre-operational data are higher than the 2020 REMP data. The decrease in radioactivity is due primarily to the cessation of atmospheric nuclear weapons testing and to the decay of fallout radionuclides. There is a close correlation between indicator and control data over several decades. There are no indications of adverse effects from SONGS on the environment.

Direct Radiation

The direct radiation measurements for the SONGS REMP were made by TLDs on a quarterly collection cycle at 49 locations in 2020. (See Appendix I for ISFSI TLD data). The TLDs were located at inner and outer ring locations as specified by the ODCM. During the pre-operational period from January 1979 to July 31, 1982, the indicator stations ranged from 16.1 to 46.6 mrem. The preoperational indicator average was 25.3 mrem. The pre-operational control range was 19.3 to 30.1 and the control mean was 23.1 mrem. During the 2020 REMP year for Units 2/3, the SONGS REMP TLD data was processed in accordance with ANSI/HPS N13.37-2014. Accordingly, the data from individual REMP TLD locations are evaluated against the baseline for each location. The individual REMP TLD locations are not compared with distant control locations for evaluation per the current regulatory guidance, Reg. Guide 4.13 Revision 2, 2019 (Environmental Dosimetry – Performance Specifications, Testing, and Data Analysis). Refer to Appendix B for a detailed discussion of the REMP TLD data evaluation process.

Factors such as meteorology, local geology, the fallout from atmospheric nuclear weapons testing, and seasonal fluctuations account for the variability in the data as observed during the preoperational period for each location. The decrease in radiation levels at all TLD sample locations is attributable to the curtailment of the atmospheric nuclear weapons testing, and the continued decay of the manmade background from fallout from past nuclear weapons tests.

Simultaneous variation in the radiation levels at both the control and indicator locations shows that the variations are due to factors external to SONGS. Outside the EAB there were no measurable levels of increased direct radiation associated with SONGS as measured by TLDs.

Airborne Particulates

From January 1979 through December 1982 (considered to be the pre-operational period for SONGS Units 2/3), there was a noticeably higher gross beta activity in air at all sample locations. This period extends from the fourth quarter of 1980 through the fourth quarter of 1981. These higher activity levels were attributable to the Chinese atmospheric nuclear weapons test conducted on October 15, 1980.

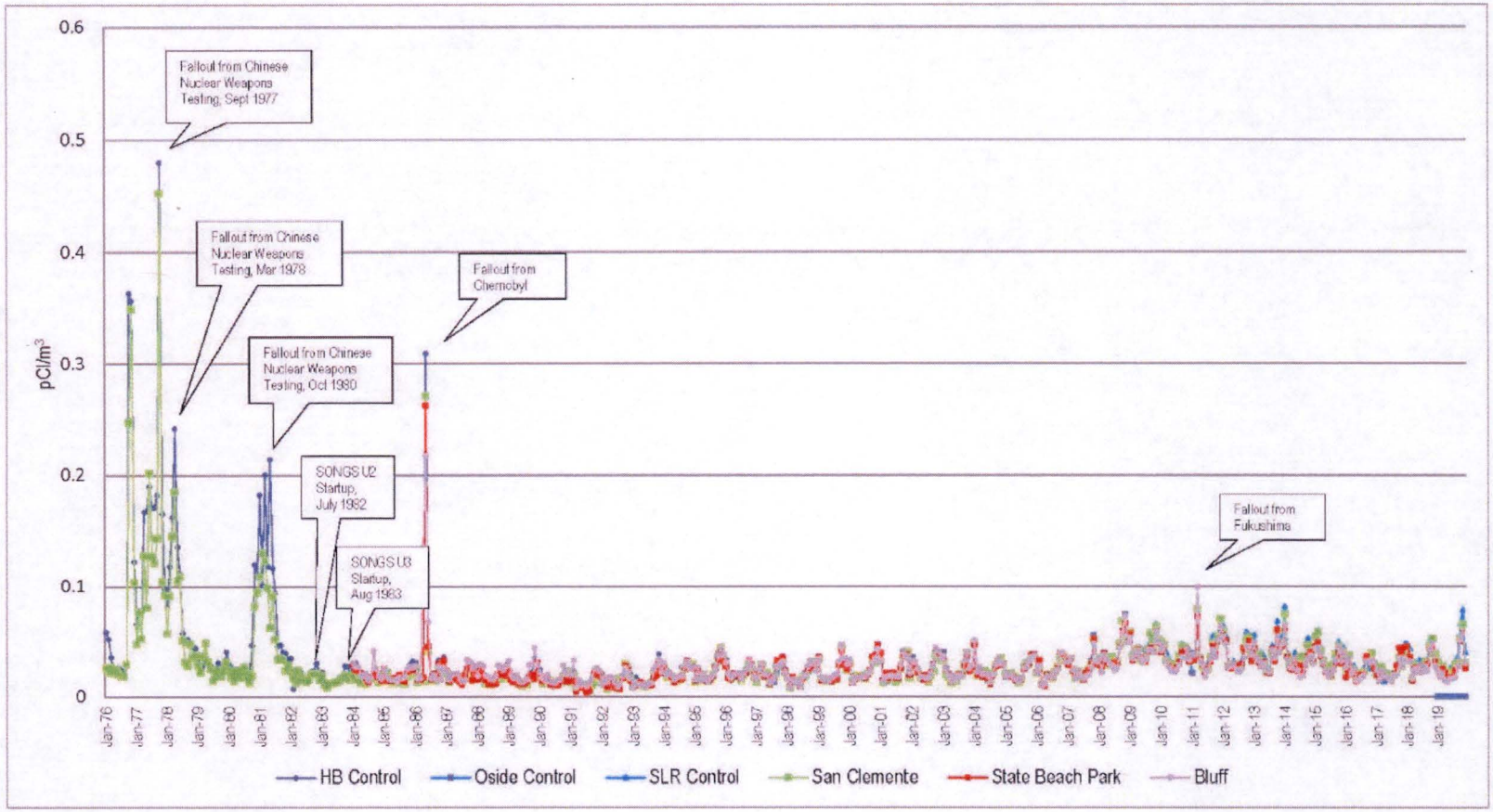

Figure 9 - Monthly Average Airborne Particulate Gross Beta Preoperational and Operational Data for Units 2 and 3, (1976 – Jan 2020)

For 2020, the maximum average annual airborne particulate gross beta result was 0.039 pCi/m^3. This result is in line with recent history.

Radioiodine

Most of the preoperational data for I-131 level was below the detection limit. All the 2020 REMP I-131 data were below the detection limit. This is expected, as the shutdown and defueled SONGS is no longer producing I-131, and all previously produced I-131 has decayed away. SONGS had no effect on the environment as measured by the radioiodine cartridge data in 2020.

Ocean Water

Monthly ocean water samples were collected near each of the Station discharge outfalls, and from the Newport Beach control location. The ocean water samples are analyzed for naturally occurring and station-related gamma-emitting radionuclides. Samples were composited quarterly and analyzed for tritium.

During the pre-operational period, naturally occurring potassium-40 was detected in each of the samples collected from both indicator and control locations. Other gamma-emitting radionuclides were detected in only one ocean water sample. In May 1980, Co-58, Co-60, Cs-134, and Cs-137 were detected in an ocean water sample collected from the SONGS Unit 1 outfall. Concentrations of the radionuclides in this sample were 11, 6, 380, and 430 pCi/l respectively. Tritium was also detected in two of the ocean water samples collected in May 1980 from the SONGS Unit 2 outfall and in and from the Newport Beach control location.

No plant related radionuclides were detected in ocean water during 2020. SONGS had no impact on the environment as measured by this exposure pathway in 2020.

Drinking Water

Due to its location near the beach, there is no drinking water pathway for SONGS. Nonetheless, drinking water samples from Oceanside and Camp Pendleton were collected and analyzed. No plant related radionuclides were detected in drinking water in 2020. Gross beta activity (from natural radionuclides) was detected during 2020 and during the pre-operational periods at both the indicator and the control locations. No trends have been noted. SONGS had no impact on the environment as measured by this exposure pathway.

Shoreline Sediments (Sand)

Beach sand is collected semiannually from three indicator locations and from a control location situated at Newport Beach. The samples are analyzed for naturally occurring and plant related radionuclides.

To assess the impact of SONGS operations on this environmental medium, pre-operational data were compared to the 2020 REMP data (refer to Table 30). The radionuclide detected in shoreline sediment in the preoperational time frame was Cs-137 with a range of 0.012 to 0.022 pCi/g, averaging 0.019 in five sediment samples. One control sample with a Cs-137 activity of 0.032 pCi/g was observed in July 1979. The presence of Cs-137 in both control and indicator locations during the preoperational period leads to the conclusion that the activity is external to SONGS and is most likely attributable to atmospheric nuclear weapons testing. No SONGS related radionuclides were detected in shoreline sediment during 2020. SONGS had no impact on the environment as measured by this exposure pathway in 2020.

Table 30 - Shoreline Sediment Concentration

		INDICATOR		CONTROL	
Radionuclide	**Period [a]**	**Range [b] (pCi/g, wet)**	**Average (pCi/g, wet)**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**
Cs-137	PreOp 2020 [c]	0.012 - 0.022 < LLD	0.019 < LLD	< LLD - 0.032 < LLD	< LLD < LLD
All other SONGS radionuclides	PreOp 2020 [c]	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD

NOTES:

a Preoperational period is January 1979 – July 1982.

b LLD for operational data are listed in Appendix B

c During 2020, all station related radionuclides from all sample locations were < LLD

Ocean Bottom Sediments

In 2020 and during the pre-operational periods, representative samples of ocean bottom sediments were collected semiannually from each of the Station discharge outfalls and from a control station in Laguna Beach. The samples were analyzed for naturally occurring and SONGS related radionuclides.

Table 31 compares historical information versus 2020 sample results. During the pre-operational period, manganese-54 (Mn-54) was detected in 5 of the 28 samples. Cobalt-58 (Co-58) was detected in nine samples. Cobalt-60 (Co-60) was measured in 15 of the 28 samples. Cs-137 was also detected in 16 of the 28 samples. The concentrations of Cs-137 in the samples ranged from 0.014 to 0.090 pCi/g, averaging 0.039 pCi/g. Cerium-144 (Ce-144) was found in two samples.

The concentration of station related radionuclides in all ocean bottom sediment samples analyzed in 2020 was below the MDC. SONGS had no impact on the environment as measured by this exposure pathway in 2020.

Table 31 - Ocean Bottom Sediment Concentration

		INDICATOR		CONTROL	
Radionuclide	**Period [a]**	**Range [b] (pCi/g, wet)**	**Average [b] (pCi/g, wet)**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**
Mn-54	PreOp 2020	0.015 - 0.49 < LLD	0.129 < LLD	< LLD < LLD	< LLD < LLD
Co-58	PreOp 2020	0.013 - 1.160 < LLD	0.199 < LLD	< LLD < LLD	< LLD < LLD
Co-60	PreOp 2020	0.014 - 8.100 < LLD	0.788 < LLD	< LLD < LLD	< LLD < LLD
Ag-110m	PreOp 2020	< LLD - 0.020 < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD
Cs-137	PreOp 2020	0.014 - 0.090 < LLD	0.039 < LLD	< LLD < LLD	< LLD < LLD
Ce-144	PreOp 2020	0.060 - 0.260 < LLD	0.160 < LLD	< LLD < LLD	< LLD < LLD
All other SONGS radionuclides	PreOp 2020	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD

NOTES:

a Preoperational period is January 1979 – July 1982.

b LLD for operational data are listed in Appendix B

Marine Species (Flesh)

Non-migratory marine species are collected semi-annually near SONGS. Non-migratory marine animals are collected near the SONGS outfalls and from Laguna Beach and analyzed for gamma-emitting radionuclides as specified in the ODCM. The results are subsequently reported as pCi/g, wet weight.

Results for several marine species for both 2020 and for the pre-operational period for Units 2/3 are summarized in Table 32. The marine species used for purposes of comparison include: two species of fish, Bay Mussel (a mollusk), and Spiny Lobster (a crustacean). Radionuclides analyzed, but not included in Table 32, were below the lower limits of detection for both the pre-operational and operational periods.

During 2020 several samples (both indicator and control) had low level Cs-137 activity > MDC and < LLD. This is consistent with other Pacific Ocean marine organism samples at other locations and is consistent with the levels of Cs-137 in marine samples that may be attributable to the ocean water discharges from Fukushima. The data indicate no accumulation trends attributable to SONGS. SONGS had an insignificant impact on the environment as measured by this exposure pathway in 2020.

Table 32 - Marine Species Concentration

		INDICATOR		CONTROL	
Radionuclide	**Period [a]**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**
Fish Sample 1 Flesh [d]					
Co-58	PreOp	0.016 - 0.030	0.023	< LLD	< LLD
	2020 [b]	< LLD	< LLD	< LLD	< LLD
Co-60	PreOp	0.005 - 0.044	0.017	< LLD	< LLD
	2020	< LLD	< LLD	< LLD	< LLD
Ag-110m	PreOp	< LLD - 0.004	< LLD	< LLD	< LLD
	2020	< LLD	< LLD	< LLD	< LLD
Cs-137	PreOp	0.004 - 0.018	0.007	0.005 - 0.012	0.007
	2020	< LLD	< LLD	<LLD	< LLD
All other SONGS radionuclides	PreOp	< LLD	< LLD	< LLD	< LLD
	2020	< LLD	< LLD	< LLD	< LLD
Fish Sample 2 Flesh [d]					
Co-58	PreOp	0.009-0.011	0.010	< LLD	< LLD
	2020	< LLD	< LLD	< LLD	< LLD
Co-60	PreOp	0.004-0.045	0.017	< LLD	< LLD
	2020	< LLD	< LLD	< LLD	< LLD
Ag-110m	PreOp	0.002-0.009	0.006	< LLD	< LLD
	2020	< LLD	< LLD	< LLD	< LLD
Cs-137	PreOp	0.003-0.015	0.008	0.004-0.014	0.009
	2020	< LLD	<LLD	< LLD	< LLD
All other SONGS radionuclides	PreOp	< LLD	< LLD	< LLD	< LLD
	2020	< LLD	< LLD	< LLD	< LLD

		INDICATOR		CONTROL	
Radionuclide	**Period [a]**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**	**Range (pCi/g, wet)**	**Average (pCi/g, wet)**
Mussel Flesh (Bay or California) [d]					
Mn-54	PreOp 2020	0.009 - 0.025 < LLD	0.017 < LLD	< LLD < LLD	< LLD < LLD
Co-58	PreOp 2020	0.008 - 0.080 < LLD	0.028 < LLD	-- < LLD	-- < LLD
Co-60	PreOp 2020	0.005 - 0.400 < LLD	0.077 < LLD	< LLD < LLD	< LLD < LLD
Cs-137	PreOp 2020	0.003 - 0.006 < LLD	0.004 < LLD	< LLD < LLD	< LLD < LLD
Ru-103	PreOp 2020	< LLD - 0.045 < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD
All other SONGS Radionuclides	PreOp 2020 [c]	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD
Spiny Lobster Flesh (Bay or California) [d]					
Co-58	PreOp 2020	0.007 - 0.270 < LLD	0.086 < LLD	< LLD < LLD	< LLD < LLD
Co-60	PreOp 2020	0.014 - 0.210 < LLD	0.060 < LLD	< LLD < LLD	< LLD < LLD
Cs-137	PreOp 2020	0.005 - 0.011 < LLD	0.008 < LLD	0.040 - 0.015 < LLD	0.008 < LLD
All other SONGS radionuclides	PreOp 2020 [c]	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD

NOTES:

a Preoperational period is January 1979 – July 1982.

b LLD for the 2020 data are listed in Appendix B

c During 2020, all station related radionuclides from all sample locations were < LLD

d Samples collected in 2020 include crustacea, mollusks, and two adult species of fish at each location and collection evolution.

Local Crops

In the preoperational period of January 1979 through July 1982, Sr-90 was detected in the control samples of kale, parsley, and squash. Naturally occurring K-40 was detected in cucumber, kale, and tomato samples from the indicator and control locations. Ce-144 and Zr-95 were detected in one sample of parsley at the control location at concentrations of 0.12 and 0.09 pCi/g, wet weight respectively.

During 2020, only natural radionuclides were identified in local crops, at both the indicator and control locations. SONGS had no impact on the environment as measured by this exposure pathway in 2020.

Soil

A comparison of operational and preoperational data does not reveal any accumulation pattern of SONGS related isotopes in soil (refer to Table 33). The intermittent detection of Cs-137 in both indicator and control locations is due to residual fallout from atmospheric nuclear weapons testing. SONGS had no impact on the environment as measured by this exposure pathway in 2020.

Table 33 - Soil Concentration

Radionuclide	Period	Indicator		Control	
		Range (pCi/g)	Average (pCi/g)	Range (pCi/g)	Average (pCi/g)
Sr-90	PreOp 2020	0.02 - 0.08 N/A	0.044 N/A	< LLD - 0.03 N/A	< LLD N/A
Cs-137	PreOp 2020	0.02 - 0.20 <LLD	0.096 <LLD	< LLD - 0.06 <LLD	< 0.10 <LLD
All other SONGS radionuclides	PreOp 2020	< LLD < LLD	< LLD < LLD	< LLD < LLD	< LLD < LLD

Kelp

Kelp is normally collected semiannually from three indicator locations and from a control location situated at Salt Creek. The samples are analyzed by gamma-spectral analysis for naturally occurring and SONGS related radionuclides.

To assess the impact of SONGS on kelp, pre-operational data were compared to 2020 REMP data in Table 34. Radionuclides detected during the pre-operational period for SONGS include Mn-54, Co-60, Zr-95, I-131, and Cs-137.

Although I-131 activity has been detected in kelp since 1977, there is no evidence that the concentrations of I-131 are a result of operations at SONGS. The presence of I-131 in kelp is due to the sewer release of medical administrations of radioisotopes, since it has been detected consistently in control as well as indicator locations. Since 1988, the concentration of I-131, when detected, has typically been highest at the control locations. There is correlation between indicator and control sample locations over an extended period of time.

During the 2020 REMP only one kelp sample, the October Salt Creek control location, was available. The kelp canopy was missing from all other locations in 2020. No SONGS related radionuclides were detected. Since there is no longer a viable production mechanism for I-131 at SONGS, the detection of I-131 in kelp is due to factors external to SONGS. SONGS had no impact on the environment as measured by this exposure pathway in 2020.

Table 34 - Kelp Concentration

		Indicator		Control	
Radionuclide	Period	Range (pCi/g)	Average (pCi/g)	Range (pCi/g)	Average (pCi/g)
Mn-54	PreOp 2020	< LLD - 0.005 N/A	< LLD N/A	< LLD < LLD	< LLD < LLD
Co-60	PreOp 2020	0.006 - 0.009 N/A	0.008 N/A	< LLD < LLD	< LLD < LLD
Zr(Nb)-95	PreOp 2020	0.014 - 0.090 N/A	0.046 N/A	0.018 - 0.053 < LLD	0.036 < LLD
I-131	PreOp 2020	0.006 - 0.024 N/A	0.013 N/A	0.008 - 0.030 < LLD	0.014 < LLD
Cs-137	PreOp 2020	0.004 - 0.071 N/A	0.027 N/A	< LLD < LLD	< LLD < LLD
All other SONGS radionuclides	PreOp 2020	< LLD N/A	< LLD N/A	< LLD < LLD	< LLD < LLD

APPENDIX E. DEVIATIONS FROM ODCM SAMPLING REQUIREMENTS IN 2020

DEVIATIONS FROM ODCM SAMPLING REQUIREMENTS

Deviations from the ODCM sampling requirements are identified below in accordance with section 5.0 of the ODCM. During 2020, the ODCM specified *a priori* LLD was achieved for all REMP samples. Deviations from the ODCM were associated with external factors not within the control of REMP personnel such as limited availability of marine samples at the locations specified in the ODCM, external power outages, and other unavoidable deviations. The 2020 ODCM deviations had no meaningful impact on the REMP data and does not compromise the validity of the reported conclusions.

Direct Radiation

Thermoluminescent Dosimeters (TLDs)

1. TLD 78 was off station for the second, third, and fourth quarter 2020 due to construction activities.
2. TLDs 55 and 56 were off station during the fourth quarter of 2020 due to vandalism.

Air Sampling

At SONGS, the ODCM requires a total of four Indicator stations and one Control station. Downtime for each air sampler in 2020 was due to weekly sample collection, quarterly calibrator flow comparison checks, scheduled air sampler motor assembly / calibrator change-outs, and preventative air sampler motor assembly change-outs which was conducted if a motor assembly was observed to show signs of degraded performance (excessive bearing noise, vane erosion, flow decline, etc.). During 2020, there were no avoidable deviations from the ODCM.

Routine unavoidable air sampler down time (per sampler) includes the following:

Weekly sample collection events:	0.5 minutes (approx.) x 52 = 26 minutes
Quarterly calibrator comparison check:	5 minutes (approx.) x 4 = 20 minutes
Other air sampler maintenance:	10 minutes (approx.)

Other down times in excess of one hour are addressed below for each ODCM required air sampler.

1) Air Sampler #12 (Former SONGS Evaporation Pond) had 2 hours of down time during the collection period ending 02-11-2020 attributed to an external power outage.
2) Air Sampler #9 (State Beach Park) was out of service for an estimated 75 hours due to a motor failure during the collection period ending 3-24-2020.
3) Air Sampler #9 (State Beach Park) was out of service for 72.1 hours due to an external power outage during the collection period ending 5-5-2020. The power outage continued into the next collection period ending 5-12-2020 causing an additional 33.6 hours of down time during the collection period ending 5-12-2020.
4) Air Sampler #16 (San Luis Rey Substation (control)) was out of service for 12.2 hours during the collection period ending 6-23-2020 due to an external power outage.

5) Air Sampler #9 (State Beach Park) was out of service for 5.5 hours due to an external power outage during the collection period ending 8-4-2020.
6) Air Sampler #12 (Former SONGS Evaporation Pond) was out of service for 5.8 hours due to an external power outage during the collection period ending 8-4-2020.
7) Air Sampler #13 (Camp Pendleton East) was out of service for 11.4 hours on during the collection period ending 9-1-2020 due to an external power outage.
8) Air Sampler #16 (San Luis Rey Substation (control)) was out of service for 1.9 hours during the collection period ending 10-6-2020 due to an external power outage.

Ocean Water Sampling

No deviations were observed.

Drinking Water

No deviations were observed.

Shoreline Sediments

No deviations were observed.

Ocean Bottom Sediments

No deviations were observed.

Marine Species (Flesh)

No deviations were observed.

Local Crops

No deviations were observed.

Soil

No deviations were observed.

Kelp

Kelp samples are not required by Section 5.1 of the ODCM. Normally, four kelp beds are collected twice a year for a total of eight kelp samples. Only one sample was available during 2020. The Kelp canopy was absent at all locations for the rest of the year. For the radionuclide of interest in kelp (I-131), there is no credible source from the decommissioning activities at SONGS. This did not constitute a deviation from the ODCM.

APPENDIX F. ERRATA TO PREVIOUS AREORs

The 2019 AREOR reported nine (9) as the total number of local crop samples collected during 2019 on page 38 of the report. The actual number of local crop samples collected was eight (8) as reported on page 25 of the 2019 AREOR.

The total number of indicator ocean bottom sediment samples collected every six months at SONGS was reported to be three (3) on page 31 of the 2019 AREOR. The actual number of indicator ocean bottom sediment samples was four (4).

The dose measured at TLD 59 was incorrectly reported to be attributable to the operation of the ISFSI in the 2019 AREOR. A review of the local conditions at TLD 59 indicate that the measured dose is attributable to a local variation in the baseline signal. The average baseline for the SONGS area was estimated to be 15.8 mrem per standard quarter based on the measured baselines at locations near SONGS. However, the baseline is not uniform throughout the SONGS footprint. The baseline at each specific location within the EAB could only have been precisely measured before SONGS was constructed. The technology for TLDs did not exist at that time.

On page 51 of the 2019 AREOR, the note below Figure 11 reported the maximum 2019 average airborne particulate gross beta result as 0.036 pCi/m^3. This value was stated to be the maximum monthly average but should have stated that it was the maximum annual average.

These errors do not change the conclusion of the 2019 AREOR.

APPENDIX G. CDPH CO-LOCATED TLDs

DATA FROM THE CDPH TLDs CO-LOCATED WITH SONGS REMP TLDs DURING 2020

CDPH maintains a TLD program in the environs of SONGS. Per CDPH request, the 2020 exposure results from the CDPH dosimeters are reported in the table below. The Location Numbers refer to the current SONGS Decommissioning*Solutions* (SDS) alphanumeric location identifier and the current CDPH location number. The first quarter TLDs were left on-station until the end of the second quarter due to the limitations imposed as a result of the COVID epidemic. The dose was divided equally between the first and second quarter 2020.

Table 35 - 2020 State of California Data from the CDPH TLD program (mrem/standard quarter)

Location Numbers	Location Name	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
SDS-1, CDPH #2	City of San Clemente	20.5	20.5	25	34
SDS-22, CDPH #4	Former US Coast Guard Station – San Mateo Point	M	M	25	30
SDS-34, CDPH #5	San Onofre Elementary School	21	21	21	30
SDS-10, CDPH #6	Bluff (Adjacent to PIC #1) (San Onofre Surfing Beach)	21.5	21.5	25	30
SDS-16, CDPH #7	East Southeast Site Boundary	17.5	17.5	20	28
SDS-2, CDPH #8	Camp San Mateo	21.5	21.5	23	34
SDS-3, CDPH #9	Camp San Onofre	20.5	20.5	24	28
SDS-6, CDPH #10	Old El Camino Real (Old Highway 101) (ESE)	16	16	17	20
SDS-50, CDPH #13	Oceanside Fire Station	20.5	20.5	20	30

M=CDPH data is not available from CDPH #4 for the 1st and 2nd quarters 2020 since this TLD was not on station when the TLDs were collected in July 2020.

The CDPH TLD program does not conform to the same environmental dosimeter standard Reg. Guide 4.13 (ANSI N13.37-2014) used to generate direct radiation data for the SONGS REMP TLD program. CDPH lab reports results in different units of measurement and is therefore not technically equivalent to the SONGS TLD data set. The different methodologies and the different units of measurement make it unsuitable to directly compare individual REMP data to the corresponding individual CDPH TLD data. However, the CDPH results are consistent with conclusion that beyond the EAB there is no detectable direct radiation that is attributable to SONGS.

APPENDIX H. ISFSI TLD DATA

Summary

Per 10 CFR 72.126, SONGS implemented an area monitoring TLD program in the vicinity of the ISFSI.

An evaluation of the entire REMP TLD database yielded an estimated background exposure rate of approximately 15.8 mrem/std. quarter (91 days). However, some local variability within the SONGS EAB is known to exist and cannot be precisely know at every location within the SONGS. This value would need to have been measured before SONGS was constructed and TLD technology did not exist at that time. Therefore, a comparison of pre-operational data to the 2020 data needs to be considered in conjunction with a comparison of ISFSI TLD data and the estimated baseline background exposure rate within the EAB.

Environmental exposure rates are variable and small changes in TLD location can measurably change the data. SONGS REMP TLD data show an environmental seasonal variability that is not related to any activities at SONGS. The ISFSI TLD data gathered to date follow a similar seasonal variability.

The measured exposure rate for the ISFSI TLDs close to the ISFSI is consistent with the exposure rate expected from known radiological work activities. The elevated exposure rate from TLDs 301, 302, 303, 304, and 326 in 2020 is primarily due to the movement and storage of used fuel at the ISFSI during the year.

Publicly accessible REMP TLDs include SCE-55, SCE-56 and SCE-57. In 2020, ISFSI TLDs SCE-55 (San Onofre State Beach U1West), SCE-56 (located next to SCE-55), and SCE-59 (SONGS Meteorological Tower), recorded measurable annual facility doses. The occupancy adjusted dose to a member of the general public is less than one (1) mrem per year. This was reported in the 2020 Annual Radioactive Effluent Release Report.

Starting in the fourth quarter 2010, neutron dosimeters were placed in ISFSI TLD canisters 311, 324, 325, and 326. Beginning in the fourth quarter of 2016, neutron TLDs were co-located with locations SCE-339 through SCE-343. The neutron TLDs were added to obtain neutron information prior to the off load of spent fuel from Units 2 and 3.

The 2020 neutron TLDs identified measurable levels of neutron radiation from movement of spent fuel to dry storage. A dose equivalent conversion factor for the TLD neutron signal based on a similar ISFSI facility at another site was adopted to estimate the neutron dose rate at SONGS. It is being applied to the SONGS TLD results only to provide an estimate of the neutron dose equivalent being measured. The neutron dose has been included in the quarterly results for these locations in Table 36. The results from all locations at the fence around the ISFSI pad show that the dose to a member of the public, when adjusted for occupancy, would be less than one (1) mrem per year.

Table 36 - 2020 ISFSI TLD Data

TLD (SCE-##)	Location [a]	Qtr. Baseline (mrem)	2020 Quarterly Results (mrem) [f]				Baseline Adjusted Quarterly Results (mrem)				Annual Dose (mrem)	Annual Facility Dose (mrem)	Annual Public Dose [b] (mrem)
			1	*2*	*3*	*4*	*1*	*2*	*3*	*4*			
301		15.8	20.4	19.2	18.3	19.7	ND	ND	ND	ND	77.7	14.6	-
302		15.8	27.0	24.3	24.2	23.3	11.3	8.5	8.4	7.5	98.7	35.7	-
303		15.8	24.1	23.3	22.7	22.6	8.4	7.6	6.9	6.9	92.8	29.7	-
304		15.8	22.5	21.7	20.3	20.0	6.7	5.9	ND	ND	84.5	21.4	-
307		15.8	20.6	20.4	18.5	20.1	ND	ND	ND	ND	79.6	16.5	-
308		15.8	19.2	17.7	18.1	20.2	ND	ND	ND	ND	75.2	12.2	-
309		15.8	19.9	19.9	19.4	20.2	ND	ND	ND	ND	79.3	16.2	-
310		15.8	20.8	20.5	20.3	20.8	5.0	ND	ND	5.0	82.3	19.3	-
311	ISFSI-01 [c]	15.8	19.9	20.6	20.6	19.8	ND	ND	ND	ND	81.0	18.0	-
312		15.8	16.2	15.9	15.9	15.7	ND	ND	ND	ND	63.8	ND	-
314		15.8	20.9	20.0	20.4	20.2	5.2	ND	ND	ND	81.5	18.4	-
315		15.8	21.3	19.2	18.6	18.8	5.5	ND	ND	ND	77.9	14.9	-
316		15.8	16.6	15.9	15.8	16.8	ND	ND	ND	ND	65.2	ND	-
317		15.8	19.4	16.7	16.2	17.8	ND	ND	ND	ND	70.0	ND	-
318[e]		15.8	18.6	19.3	18.8	19.2	ND	ND	ND	ND	75.9	12.8	-
319[e]		15.8	18.6	19.1	18.3	20.1	ND	ND	ND	ND	76.1	13.0	-
320[e]		15.8	19.2	18.4	18.3	19.1	ND	ND	ND	ND	74.9	11.9	-
321[e]		15.8	19.2	19.5	18.7	19.9	ND	ND	ND	ND	77.4	14.3	-
322	Discontinued	15.8	--	--	--	--	-	-	-	-	-	-	-
323	Discontinued	15.8	--	--	--	--	-	-	-	-	-	-	-
324	Discontinued	15.8	--	--	--	--	-	-	-	-	-	-	-
325	Discontinued	15.8	--	--	--	--	-	-	-	-	-	-	-
326	ISFSI-02 [c]	15.8	21.4	22.5	22.3	24.5	5.6	6.7	6.5	8.8	90.7	27.7	-
327	Discontinued	15.8	--	--	--	--	-	-	-	-	-	-	-
328	Discontinued	15.8	--	--	--	--	-	-	-	-	-	-	-
339	ISFSI-08 [c]	15.8	26.5	26.4	24.2	24.4	10.7	10.6	8.5	8.7	101.5	38.4	-
340	ISFSI-09 [c]	15.8	23.5	23.1	21.6	22.5	7.7	7.3	5.8	6.7	90.6	27.6	-
341	ISFSI-10 [c]	15.8	23.9	23.7	24.0	24.3	8.2	7.9	8.2	8.5	95.9	32.9	-
342	ISFSI-11 [c]	15.8	26.6	26.4	27.5	27.3	10.9	10.6	11.7	11.5	107.8	44.7	-

TLD (SCE-##)	Location [a]	Qtr. Baseline (mrem)	2020 Quarterly Results (mrem) [f]				Baseline Adjusted Quarterly Results (mrem)				Annual Dose (mrem)	Annual Facility Dose (mrem)	Annual Public Dose [b] (mrem)
			1	*2*	*3*	*4*	*1*	*2*	*3*	*4*			
343	ISFSI-12 [c]	15.8	**22.2**	**20.8**	**23.7**	**23.6**	**6.4**	**5.0**	**7.9**	**7.8**	**90.2**	**27.2**	-
344		15.8	**21.9**	**20.3**	**20.0**	**21.2**	**6.1**	**ND**	**ND**	**5.4**	**83.4**	**20.4**	-
55 [d e]	San Onofre State Beach (U1 West) ISFSI-07 [c]	15.8	**21.0**	**22.5**	**21.7**	--	**5.2**	**6.8**	**5.9**	-	**86.9**	**N/A**	**< 1**
56 [d]	San Onofre State Beach (U1 West)	15.8	**19.2**	**18.5**	**18.7**	--	**ND**	**ND**	**ND**	-	**75.2**	**N/A**	< 1
57 [d]	San Onofre State Beach (Unit 2)	15.8	**18.3**	**17.2**	**17.6**	**17.7**	**ND**	**ND**	**ND**	**ND**	**70.8**	**ND**	< 1
59	SONGS Meteorological Tower	15.8	**20.1**	**20.0**	**19.4**	**19.9**	**ND**	**ND**	**ND**	**ND**	**79.5**	**16.4**	-

Notes:

a ISFSI TLDs (SCE-301 through SCE-344) are placed around the ISFSI pad, and not in locations accessible to the general public. TLD 59 is in an area that is not accessible to the general public. A public dose to these locations is not applicable.

b Public dose is not applicable for those TLDs that are not accessible to the general public.

c Station has a collocated neutron dosimeter package. The neutron dose is estimated using a neutron signal conversion factor measured at a similar ISFSI installation (HPSTID 08-015).

d These TLDs are publicly accessible. The public dose is based on an estimated occupancy of 300 hours per year.

e For TLD 55 the estimated neutron dose contributed to the total measured dose in 2020.

f For locations with a co-located neutron dosimetry package the estimated neutron dose (if any) is included in the reported dose.

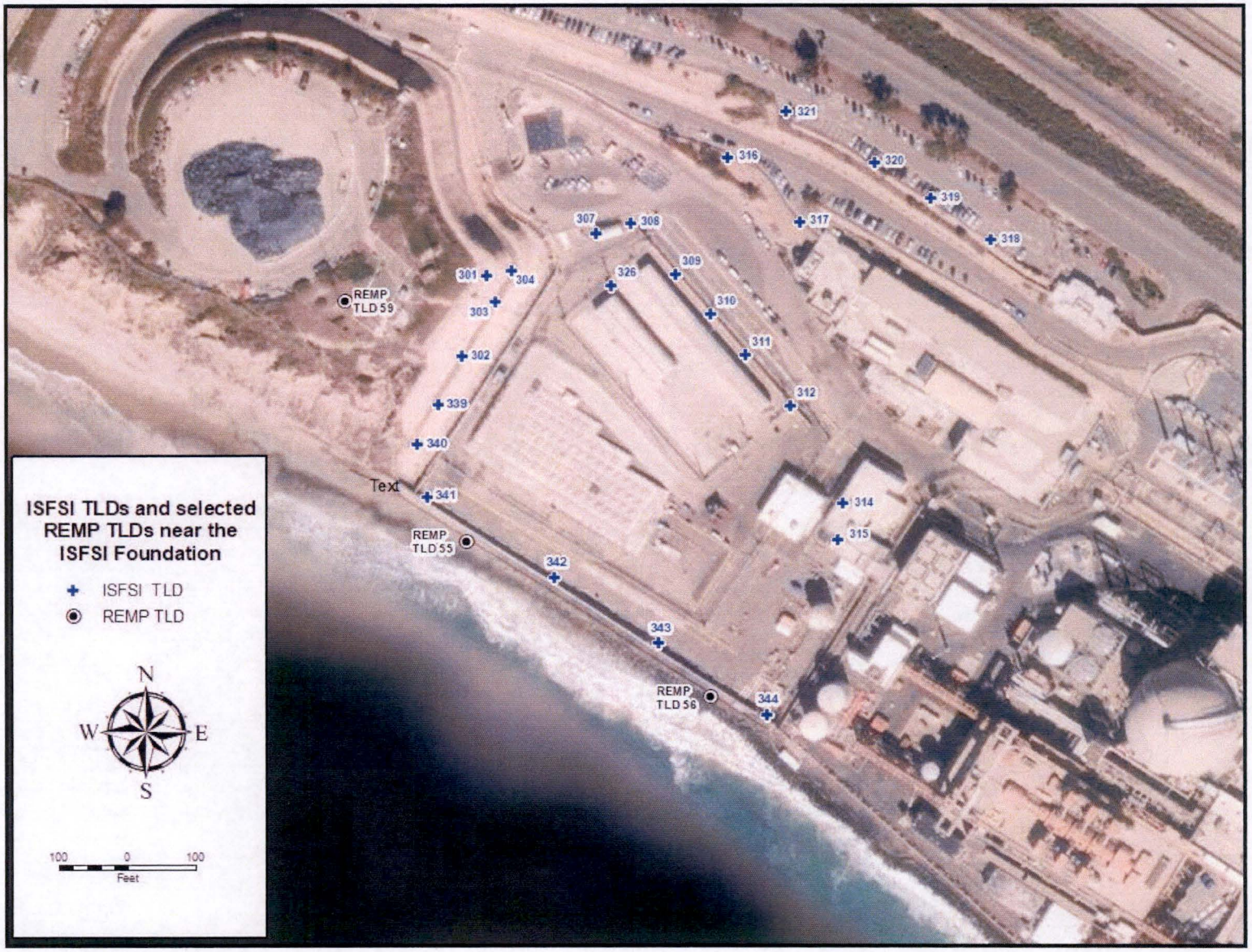

Figure 10 - SONGS ISFSI and Selected REMP TLD Locations

APPENDIX I. OFFSITE GROUND WATER SAMPLING

Offsite Drinking Water

All investigations have shown that there are no drinking water pathways at SONGS.

Figure 11 below illustrates groundwater well locations along with the flow of the groundwater. SONGS had no impact on drinking water wells in the vicinity of SONGS.

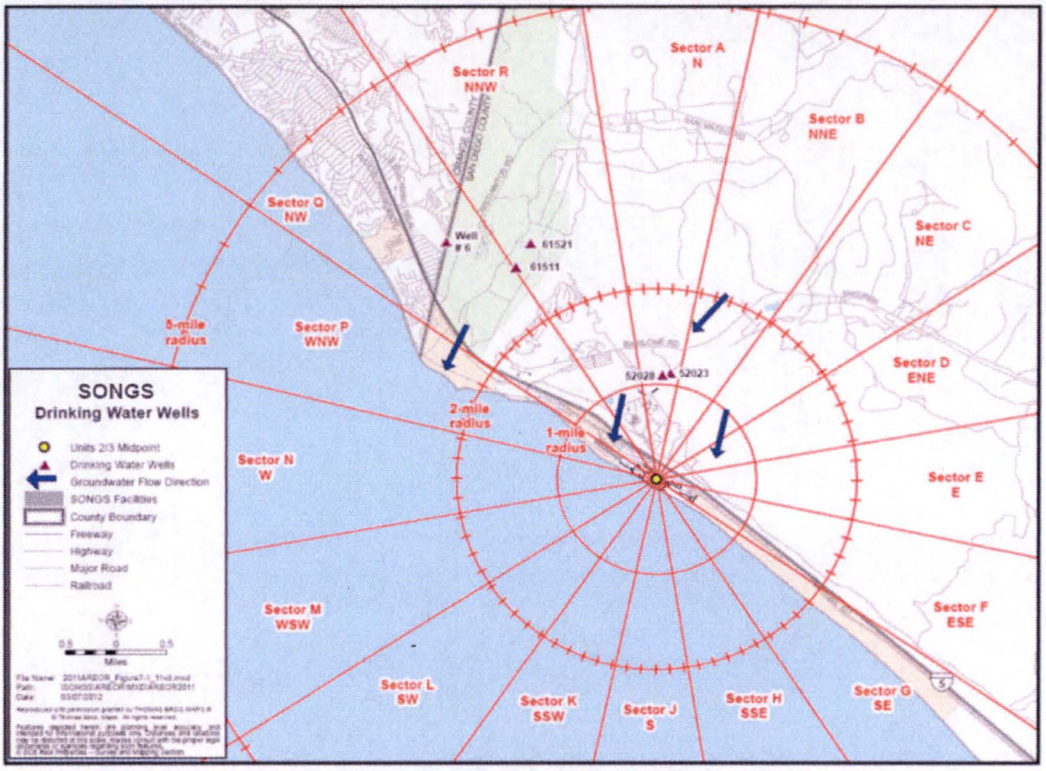

Figure 11 - Closest Drinking Water Wells

Glossary

a posteriori After the fact

a priori Before the fact

ALARA As Low As is Reasonably Achievable means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Cosmogenic nuclides Radionuclides (or isotopes) created when a high-energy cosmic ray interacts with the nucleus of an atom. These isotopes are produced within Earth materials such as rocks or soil, in Earth's atmosphere, and in extraterrestrial items such as meteorites. Radioactive isotopes beryllium-7 and beryllium-10 fall into this series of three light elements (lithium, beryllium, boron) formed mostly by cosmic ray spallation nucleosynthesis, both of these nuclides have half-lives too short for them to have been formed before the formation of the Solar System, and thus they cannot be primordial nuclides. Since the cosmic ray spallation route is the only possible source of beryllium-7 and beryllium-10 occurrence naturally in the environment, they are therefore cosmogenic.

Below is a list of radioisotopes formed by the action of cosmic rays in the atmosphere; the list also contains the production mode of the isotope.

Isotope	Mode of formation	Isotope	Mode of formation
^{3}H (tritium)	^{14}N (n, $^{12}C)^{3}H$	^{32}P	Spallation (Ar)
^{7}Be	Spallation (N and O)	^{34m}Cl	Spallation (Ar)
^{10}Be	Spallation (N and O)	^{35}S	Spallation (Ar)
^{11}C	Spallation (N and O)	^{36}Cl	^{35}Cl (n, γ)^{36}Cl
^{14}C	^{14}N (n, p) ^{14}C	^{37}Ar	^{37}Cl (p, n)^{37}Ar
^{18}F	^{18}O (p, n)^{18}F and Spallation (Ar)	^{38}Cl	Spallation (Ar)
^{22}Na	Spallation (Ar)	^{39}Ar	^{38}Ar (n, γ)^{39}Ar
^{24}Na	Spallation (Ar)	^{39}Cl	^{40}Ar (n, np)^{39}Cl & spallation (Ar)
^{28}Mg	Spallation (Ar)	^{41}Ar	^{40}Ar (n, γ)^{41}Ar
^{31}Si	Spallation (Ar)	^{81}Kr	^{80}Kr (n, γ) ^{81}Kr
^{32}Si	Spallation (Ar)		

Decay Series	There are three naturally occurring decay series of heavy elements that transform into a series of various radioactive elements by releasing energy in the form of particles, (such as alpha or beta), and/or gamma rays to end in a stable form of non-radioactive Lead. All three decay series start with extremely long lived radioactive, heavy elements that can be measured in geologic time units. They are Uranium-238 with an approximate half-life of 4.5 billion years, Uranium -235 with a half-life of about 700 million years, and Thorium- 232 with a half-life of 14 billion years. All three series contain some more well-known radioactive species, Radium and Radon.
Distinguishable from background	Detectable concentration of a radionuclide that is statistically different from the background concentration of that radionuclide at that location.
Dose	The amount of radiation that is absorbed by a person's body. In the radiation field the term dose is sometimes used interchangeably with dose equivalent.
Exclusion Area Boundary (EAB)	The boundary used for routine effluent calculations required by 10 CFR 20 at San Onofre Units 2 and 3; formed by two semi-circles with radii of 1967.5 ft. from the containment centers with a tangent connecting the landward and the seaward arcs.
Half-life	A measure of how fast half the mass of a radioactive element will transform itself into another element. Each radioactive element has its own unique rate of transformation. Consequently, if a radioactive element, such as Iodine-131 has a half-life of 8 days, then in 8 days half of the original amount of Iodine-131 will be gone; in another 8 days half of that half will be left and so on.
Gamma Spectroscopy	A scientific method used to analyze gamma rays emanating from radioactive elements. The analytical system determines the gamma ray energy which acts as a "fingerprint" for specific radioactive materials. For example, Potassium-40 (K-40) has a very, distinctive gamma energy at 1460 keV. This uniqueness allows the instrument to positively identify the K-40 1460 energy as its own unique fingerprint. A keV is an abbreviation for kilo electron volt, which is a measure of energy at the atomic level. A kilo is a scientific prefix for the multiplier 1,000.
Gross Beta	A screening technique employed to measure the total number of beta particles emanating from a radioactive sample, without isotopic identification. At SONGS samples with an elevated gross beta are analyzed by gamma spectroscopy to identify the specific radionuclides causing the elevated gross beta signal. A beta particle is a negatively charged particle a mass equal to that of an orbiting electron.
Liquid Scintillation	The analytical technique by which tritium activity is measured in water. A sample is placed in a glass vial containing scintillation cocktail. The mixture is sealed and homogenized. When the tritium decays it emits a very low energy beta particle. The beta interacts with the scintillating medium and produces a light pulse that is counted by the instrument.
Millirem (mrem)	One thousandth (1/1000) of a rem.

milliRoentgen (mR)	One thousandth (1/1000) of a Roentgen
pCi/kg	An acronym for a pico-curie per kilogram, which is a concentration unit that defines how much radioactivity is present in a unit mass, such as a kilogram. A "pico" is a scientific prefix for an exponential term that is equivalent to one trillionth (1/1,000,000,000,000).
pCi/l	An acronym for a pico-curie per liter, which is a concentration unit that defines how much radioactivity is present in a unit volume, such as a liter.
Rem	An acronym for roentgen equivalent man. It is a conventional unit of dose equivalent that is based on how much of the radiation energy is absorbed by the body multiplied by a quality factor, which is a measure of the relative hazard of energy transfer by different particles, (alpha, beta, neutrons, protons, etc.), gamma rays or x-rays. In comparison the average natural background radiation dose equivalent to the United States population is estimated to be 292 millirems per year, or 0.8 millirem per day, with 68 % of that dose coming from radon. A millirem is one thousandth, (1/1000), of a rem.
Roentgen	A special unit of exposure named after the discoverer of X-Rays, Wilhelm Roentgen. It is a measure of how much ionization is produced in the air when it is bombarded with X-Rays or Gamma Rays. Ionization is described as the removal of an orbital electron from an atom.
Skyshine	Radiation from a radioactive source that bounces off air molecules in the sky, much like a cue ball does off the banking of a billiard table, and is scattered/redirected back down to the earth.
Thermolumines cent Dosimeters (TLD)	Very small plastic-like phosphors or crystals that are placed in a small plastic cage and mounted on trees, posts, etc. to absorb any radiation that impinges on the material. Special readers are then used to heat the plastic to release the energy that was stored when the radiation was absorbed by the plastic. The energy released is in the form of light and that light is counted by the TLD reader. The intensity of the light emitted from the crystals is directly proportional to the amount of radiation that the TLD phosphor was exposed to.
Tritium (Hydrogen-3 or H-3)	H-3 is the naturally occurring radioactive form of Hydrogen. All radioactive elements are represented as a combination of their chemical symbol and their mass number. Therefore, Tritium, which is a heavy form of the Hydrogen molecule with one proton and two neutrons in the nucleus of its atom, is abbreviated and represented by its chemical symbol, H-3, for Hydrogen and 3 for the number of particles in its nucleus, or mass number. Similarly, other radioactive elements, such as Potassium-40, can be represented and abbreviated as K-40, and so on.