PILGRIM NUCLEAR POWER STATION

Facility Operating License DPR-35

Annual Radiological Environmental Operating Report

January 1 through December 31, 2020

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ANNUAL RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT

JANUARY 01 THROUGH DECEMBER 31, 2020

Prepared by: [signature] 5/5/21
L. Hageman — Date
Chemistry Supervisor

Reviewed by: [signature] 05/05/2021
M. Thornhill — Date
Peer Review: Radiation Protection CHP

Reviewed by: [signature] 5.6.21
M. Lawson — Date
Chemistry/ Radiation Protection Manager

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INTRODUCTION

This report summarizes the results of the Comprehensive Decommissioning International (CDI) Nuclear Radiological Environmental Monitoring Program (REMP) conducted in the vicinity of Pilgrim Nuclear Power Station (PNPS) during the period from January 1 to December 31, 2020. This document has been prepared in accordance with the requirements of PNPS Technical Specifications section 5.6.2.

The REMP has been established to monitor the radiation and radioactivity released to the environment as a result of previous Pilgrim Station's operation. This program, initiated in August 1968, includes the collection, analysis, and evaluation of radiological data in order to assess the impact of Pilgrim Station on the environment and on the general public.

SAMPLING AND ANALYSIS

The environmental sampling media collected in the vicinity of PNPS and at distant locations include air particulate filters, vegetation, seawater, sediment, shellfish, American lobster, and fishes. Some sample media such as soil, forage, irish moss, and cranberries were removed from the discussion of this report as they are no longer a pathway and therefore removed from the ODCM and sampling program. Soil sampling had been previously removed in 2003 in favor of extensive TLD monitoring.

During 2020, there were 527 samples collected from the atmospheric, aquatic, and terrestrial environments. In addition, 290 exposure measurements were obtained using environmental thermoluminescent dosimeters (TLDs).

A small number of inadvertent issues were encountered during 2020 in the collection of environmental samples in accordance with the PNPS Offsite Dose Calculation Manual (ODCM). Equipment failures and power outages resulted in a small number of instances in which lower than normal volumes were collected at the airborne sampling stations. 433 of 440 air particulate were collected and analyzed as required. Charcoal cartridge collection was discontinued in the beginning of December 2019 when Iodines had decayed away following the permant shutdown of PNPS on May 31, 2019. A full description of any discrepancies encountered with the environmental monitoring program is presented in Appendix D of this report.

There were 543 analyses performed on the environmental media samples. Analyses were performed by Teledyne Brown Engineering Laboratory in Knoxville, TN. Samples were analyzed as required by the PNPS ODCM.

LAND USE CENSUS

The annual land use census in the vicinity of Pilgrim Station was conducted as required by the PNPS ODCM from June 25 to July 20, 2020. A total of 21 vegetable gardens having an area of more than 500 square feet were identified within five kilometers (three miles) of PNPS. Five were lost since 2019 and six were added. No new milk or meat animals were located during the census. Unfortunately, none of the garden locations identified were collected as part of the environmental monitoring program, mainly due to residents' COVID-19 concerns. Other samples of natural vegetation were collected in predicted high-deposition areas.

RADIOLOGICAL IMPACT TO THE ENVIRONMENT

During 2020, samples collected as part of the REMP at Pilgrim Station continued to contain detectable amounts of naturally-occurring radioactive materials. No samples indicated any detectable radioactivity attributable to Pilgrim Station operations. Offsite ambient radiation measurements using environmental TLDs beyond the site boundary ranged between 46 and 86 milliRoentgens per year. The range of ambient radiation levels observed with the TLDs is consistent with natural background radiation levels for Massachusetts.

RADIOLOGICAL IMPACT TO THE GENERAL PUBLIC

During 2020, radiation doses to the general public as a result of previous Pilgrim Station's operation continued to be well below the federal limits and much less than the collective dose due to other sources of man-made (e.g., X-rays, medical, fallout) and naturally-occurring (e.g., cosmic, radon) radiation.

The calculated total body dose to the maximally exposed member of the general public from radioactive effluents and ambient radiation resulting from PNPS operations for 2020 was approximately 0.14 mrem for the year. This conservative estimate is well below the EPA's annual dose limit to any member of the general public and is a fraction of a percent of the typical dose received from natural and man-made radiation.

CONCLUSIONS

The 2020 Radiological Environmental Monitoring Program for Pilgrim Station resulted in the collection and analysis of hundreds of environmental samples and measurements. The data obtained were used to determine the impact of Pilgrim Station's operation on the environment and on the general public.

An evaluation of direct radiation measurements, environmental sample analyses, and dose calculations showed that all applicable federal criteria were met. Furthermore, radiation levels and resulting doses were a small fraction of those that are normally present due to natural and man-made background radiation.

Based on this information, there is no significant radiological impact on the environment or on the general public due to Pilgrim Station's operations.

1.0 INTRODUCTION

The Radiological Environmental Monitoring Program for 2020 performed by Comprehensive Decommissioning International (CDI) for Pilgrim Nuclear Power Station (PNPS) is discussed in this report. This report, which is required to be published annually by Pilgrim Station's Technical Specifications section 5.6.2, summarizes the results of measurements of radiation and radioactivity in the environment in the vicinity of the Pilgrim Station and at distant locations during the period January 1 to December 31, 2020.

The Radiological Environmental Monitoring Program consists of taking radiation measurements and collecting samples from the environment, analyzing them for radioactivity content, and interpreting the results. With emphasis on the critical radiation exposure pathways to humans, samples from the aquatic, atmospheric, and terrestrial environments are collected. These samples include, but are not limited to: air, vegetation, seawater, sediment, shellfish, American lobster, and fish. Thermoluminescent dosimeters (TLDs) are placed in the environment to measure gamma radiation levels. The TLDs are processed and the environmental samples are analyzed to measure the very low levels of radiation and radioactivity present in the environment as a result of PNPS operation and other natural and man-made sources. These results are reviewed by PNPS's Chemistry staff and have been reported semiannually or annually to the Nuclear Regulatory Commission and others since 1972.

In order to more fully understand how a nuclear power plant impacts humans and the environment, background information on radiation and radioactivity, natural and man-made sources of radiation, radioactive effluent controls, and radiological impact on humans is provided. It is believed that this information will assist the reader in understanding the radiological impact on the environment and humans from the previous operation of Pilgrim Station.

1.1 Radiation and Radioactivity

All matter is made of atoms. An atom is the smallest part into which matter can be broken down and still maintain all its chemical properties. Nuclear radiation is energy, in the form of waves or particles that is given off by unstable, radioactive atoms.

Radioactive material exists naturally and has always been a part of our environment. The earth's crust, for example, contains radioactive uranium, radium, thorium, and potassium. Some radioactivity is a result of nuclear weapons testing. Examples of radioactive fallout that is normally present in environmental samples are cesium-137 and strontium-90. Some examples of radioactive materials released from a nuclear power plant are cesium-137, iodine-131, strontium-90, and cobalt-60.

Radiation is measured in units of millirem, much like temperature is measured in degrees. A millirem is a measure of the biological effect of the energy deposited in tissue. The natural and man-made radiation dose received in one year by the average American is approximately 620 mrem (References 2, 3, 4).

Radioactivity is measured in curies. A curie is that amount of radioactive material needed to produce 37,000,000,000 nuclear disintegrations per second. This is an extremely large amount of radioactivity in comparison to environmental radioactivity. That is why radioactivity in the environment is measured in picocuries. One picocurie is equal to one trillionth of a curie.

1.2 Sources of Radiation

As mentioned previously, naturally occurring radioactivity has always been a part of our environment. Table 1.2-1 shows the sources and doses of radiation from natural and man-made sources.

Table 1.2-1

Radiation Sources and Corresponding Doses [1]

NATURAL		MAN-MADE	
Source	Radiation Dose (millirem/year)	Source	Radiation Dose (millirem/year)
Internal, inhalation[2]	230	Medical[3]	300
External, space	30	Consumer[4]	12
Internal, ingestion	30	Industrial[5]	0.6
External, terrestrial	20	Occupational	0.6
		Weapons Fallout	< 1
		Nuclear Power Plants	< 1
Approximate Total	310	Approximate Total	315
Combined Annual Average Dose: Approximately 625 millirem/year			

(1) Information from NCRP Reports 160 and 94

(2) Primarily from airborne radon and its radioactive progeny

(3) Includes CT (150 millirem), nuclear medicine (74 mrem), interventional fluoroscopy (43 mrem) and conventional radiography and fluoroscopy (30 mrem)

(4) Primarily from cigarette smoking (4.6 mrem), commercial air travel (3.4 mrem), building materials (3.5 mrem), and mining and agriculture (0.8 mrem)

(5) Industrial, security, medical, educational, and research

Cosmic radiation from the sun and outer space penetrates the earth's atmosphere and continuously bombards us with rays and charged particles. Some of this cosmic radiation interacts with gases and particles in the atmosphere, making them radioactive in turn. These radioactive byproducts from cosmic ray bombardment are referred to as cosmogenic radionuclides. Isotopes such as beryllium-7 and carbon-14 are formed in this way. Exposure to cosmic and cosmogenic sources of radioactivity results in approximately 30 mrem of radiation dose per year.

Additionally, natural radioactivity is in our body and in the food we eat (approximately 30 millirem/yr), the ground we walk on (approximately 20 millirem/yr) and the air we breathe (approximately 230 millirem/yr). The majority of a person's annual dose results from exposure to radon and thoron in the air we breathe. These gases and their radioactive decay products arise from the decay of naturally occurring uranium, thorium and radium in the soil and building products such as brick, stone, and concrete. Radon and thoron levels vary greatly with location, primarily due to changes in the concentration of uranium and thorium in the soil. Residents at some locations in Colorado, New York, Pennsylvania, and New Jersey have a higher annual dose as a result of higher levels of radon/thoron gases in these areas. In total, these various sources of naturally-occurring radiation and radioactivity contribute to a total dose of approximately 310 mrem per year.

In addition to natural radiation, we are normally exposed to radiation from a number of man-made sources. The single largest doses from man-made sources result from therapeutic and diagnostic

applications of x-rays and radiopharmaceuticals. The annual dose to an individual in the U.S. from medical and dental exposure is approximately 300 mrem. Consumer activities, such as smoking, commercial air travel, and building materials contribute approximately 13 mrem/yr. Much smaller doses result from weapons fallout (less than 1 mrem/yr) and nuclear power plants. Typically, the average person in the United States receives approximately 314 mrem per year from man-made sources. The collective dose from naturally-occurring and man-made sources results in a total dose of approximately 620 mrem/yr to the average American.

1.3 Nuclear Reactor Operations

Pilgrim Station was an operating boiling water reactor whose nuclear steam supply system was provided by General Electric Co. The nuclear station is located on a 1600-acre site approximately eight kilometers (five miles) east-southeast of the downtown area of Plymouth, Massachusetts. Commercial operation began in December 1972. Pilgrim Station was operational until June of 2019 before the decision to permentantly shut down and decommission the station.

Nuclear-generated electricity was produced at Pilgrim Station by many of the same techniques used for conventional oil and coal-generated electricity. Both systems use heat to boil water to produce steam. The steam turns a turbine, which turns a generator, producing electricity. In both cases, the steam passes through a condenser where it changes back into water and recirculates back through the system. The cooling water source for Pilgrim Station is the Cape Cod Bay.

The key difference between Pilgrim's nuclear power and conventional power is the source of heat used to boil the water. Conventional plants burn fossil fuels in a boiler, while nuclear plants make use of uranium in a nuclear reactor.

Inside the reactor, a nuclear reaction called fission takes place. Particles, called neutrons, strike the nucleus of a uranium-235 atom, causing it to split into fragments called radioactive fission products. The splitting of the atoms releases both heat and more neutrons. The newly-released neutrons then collide with and split other uranium atoms, thus making more heat and releasing even more neutrons, and on and on until the uranium fuel is depleted or spent. This process is called a chain reaction.

The operation of a nuclear reactor results in the release of small amounts of radioactivity and low levels of radiation. The radioactivity originates from two major sources, radioactive fission products and radioactive activation products.

Radioactive fission products, as illustrated in Figure 1.3-1 (Reference 5), originate from the fissioning of the nuclear fuel. These fission products get into the reactor coolant from their release by minute amounts of uranium on the outside surfaces of the fuel cladding, by diffusion through the fuel pellets and cladding and, on occasion, through defects or failures in the fuel cladding. These fission products circulate along with the reactor coolant water and will deposit on the internal surfaces of pipes and equipment. The radioactive fission products on the pipes and equipment emit radiation. Examples of some fission products are krypton-85 (Kr-85), strontium-90 (Sr-90), xenon-133 (Xe-133), and cesium-137 (Cs-137).

Nuclear Fission

Fission is the splitting of the uranium-235 atom by a neutron to release heat and more neutrons, creating a chain reaction. Radiation and fission products are by-products of the process.

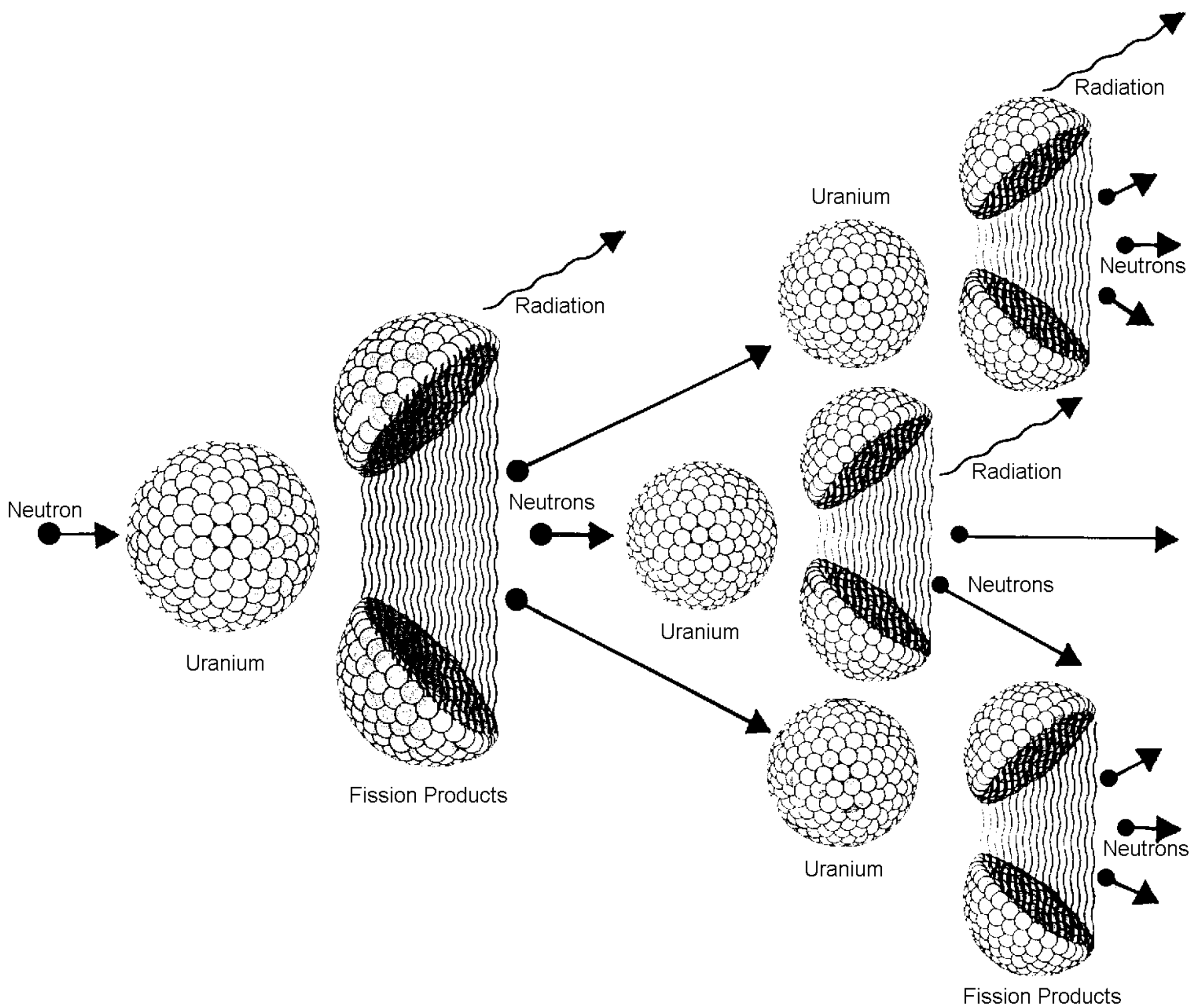


Figure 1.3-1
Radioactive Fission Product Formation

Radioactive activation products (see Figure 1.3-2), on the other hand, originate from two sources. The first is by neutron bombardment of the hydrogen, oxygen and other gas (helium, argon, nitrogen) molecules in the reactor cooling water. The second is a result of the fact that the internals of any piping system or component are subject to minute yet constant corrosion from the reactor cooling water. These minute metallic particles (for example: nickel, iron, cobalt, or magnesium) are transported through the reactor core into the fuel region, where neutrons may react with the nuclei of these particles, producing radioactive products. So, activation products are nothing more than ordinary naturally-occurring atoms that are made unstable or radioactive by neutron bombardment. These activation products circulate along with the reactor coolant water and will deposit on the internal surfaces of pipes and equipment. The radioactive activation products on the pipes and equipment emit radiation. Examples of some activation products are manganese-54 (Mn-54), iron-59 (Fe-59), cobalt-60 (Co-60), and zinc-65 (Zn-65).

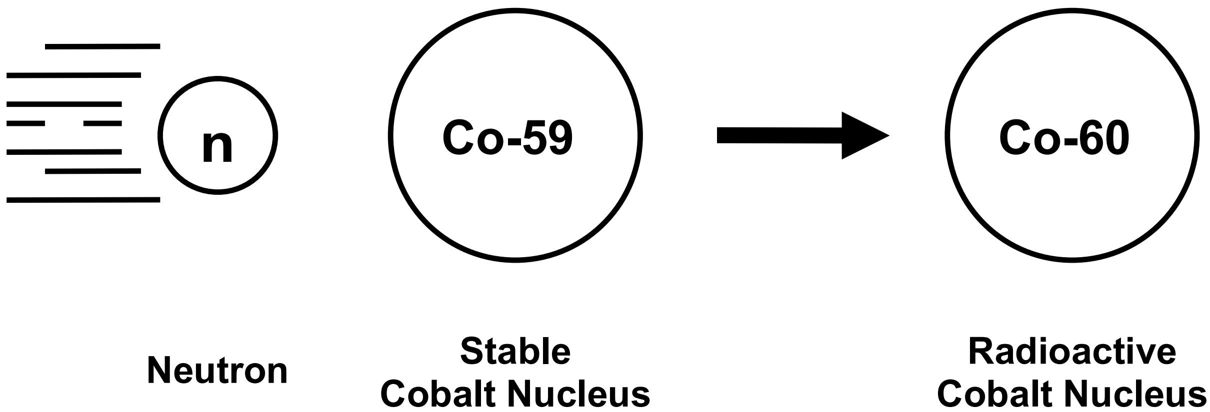


Figure 1.3-2
Radioactive Activation Product Formation

At Pilgrim Nuclear Power Station there are five independent protective barriers that confine these radioactive materials. These five barriers, which are shown in Figure 1.3-3 (Reference 5), are:

- fuel pellets;
- fuel cladding;
- reactor vessel and piping;
- primary containment (drywell and torus); and,
- secondary containment (reactor building).

SIMPLIFIED DIAGRAM OF A BOILING WATER REACTOR

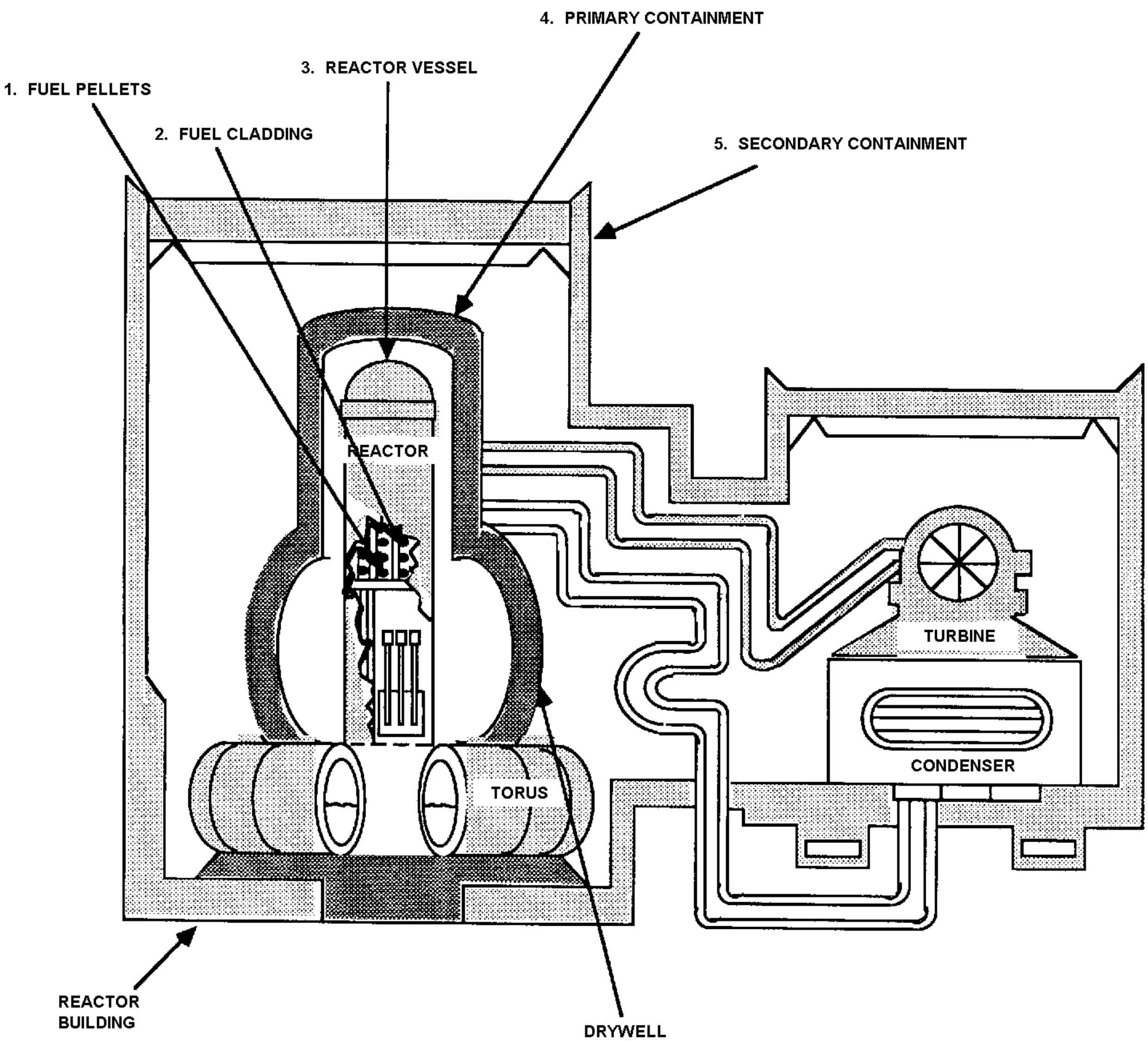


Figure 1.3-3
Barriers To Confine Radioactive Materials

The ceramic uranium fuel pellets provide the first barrier. Most of the radioactive fission products are either physically trapped or chemically bound between the uranium atoms, where they will remain. However, a few fission products that are volatile or gaseous may diffuse through the fuel pellets into small gaps between the pellets and the fuel cladding.

The second barrier, the fuel cladding, consists of zirconium alloy tubes that confine the fuel pellets. The small gaps between the fuel and the cladding contain the noble gases and volatile iodines that are types of radioactive fission products. This radioactivity can diffuse to a small extent through the fuel cladding into the reactor coolant water.

The third barrier consists of the reactor pressure vessel, steel piping and equipment that confine the reactor cooling water. The reactor pressure vessel, which holds the reactor fuel, is a 65-foot high by 19-foot diameter tank with steel walls approximately nine inches thick. This provides containment for radioactivity in the primary coolant and the reactor core. However, during the course of operations and maintenance, small amounts of radioactive fission and activation products can escape through valve leaks or upon breaching of the primary coolant system for maintenance.

The fourth barrier is the primary containment. This consists of the drywell and the torus. The drywell is a steel lined enclosure that is shaped like an inverted light bulb. An approximately five foot thick concrete wall encloses the drywell's steel pressure vessel. The torus is a donut-shaped pressure suppression chamber. The steel walls of the torus are nine feet in diameter with the donut itself having an outside diameter of approximately 130 feet. Small amounts of radioactivity may be released from primary containment during maintenance.

The fifth barrier is the secondary containment or reactor building. The reactor building is the concrete building that surrounds the primary containment. This barrier is an additional safety feature to contain radioactivity that may escape from the primary containment. This reactor building is equipped with a filtered ventilation system that is used when needed to reduce the radioactivity that escapes from the primary containment.

The five barriers confine most of the radioactive fission and activation products. However, small amounts of radioactivity do escape via mechanical failures and maintenance on valves, piping, and equipment associated with the reactor cooling water system. The small amounts of radioactive liquids and gases that do escape the various containment systems are further controlled by the liquid purification and ventilation filtration systems. Also, prior to a release to the environment, control systems exist to collect and purify the radioactive effluents in order to reduce releases to the environment to as low as is reasonably achievable. The control of radioactive effluents at Pilgrim Station will be discussed in more detail in the next section.

1.4 Radioactive Effluent Control

The small amounts of radioactive liquids and gases that might escape the five barriers are purified in the liquid and gaseous waste treatment systems, then monitored for radioactivity, and released only if the radioactivity levels are below the federal release limits.

Radioactivity released from the liquid effluent system to the environment is limited, controlled, and monitored by a variety of systems and procedures which include:

- reactor water cleanup system;
- liquid radwaste treatment system;
- sampling and analysis of the liquid radwaste tanks; and,
- liquid waste effluent discharge header radioactivity monitor.

The purpose of the reactor water cleanup system is to continuously purify the reactor cooling water by removing radioactive atoms and non-radioactive impurities that may become activated by neutron bombardment. A portion of the reactor coolant water is diverted from the primary coolant system and is directed through ion exchange resins where radioactive elements, dissolved and suspended in the water, are removed through chemical processes. The net effect is a substantial reduction of the radioactive material that is present in the primary coolant water and consequently the amount of radioactive material that might escape from the system.

Reactor cooling water that might escape the primary cooling system and other radioactive water sources are collected in floor and equipment drains. These drains direct this radioactive liquid waste to large holdup tanks. The liquid waste collected in the tanks is purified again using the liquid radwaste treatment system, which consists of a filter and ion exchange resins.

Processing of liquid radioactive waste results in large reductions of radioactive liquids discharged into Cape Cod Bay. Of all wastes processed through liquid radwaste treatment, 90 to 95 percent of all wastes are purified and the processed liquid is re-used in plant systems.

Prior to release, the radioactivity in the liquid radwaste tank is sampled and analyzed to determine if the level of radioactivity is below the release limits and to quantify the total amount of radioactive liquid effluent that would be released. If the levels are below the federal release limits, the tank is drained to the liquid effluent discharge header.

This liquid waste effluent discharge header is provided with a shielded radioactivity monitor. This detector is connected to a radiation level meter and a strip chart recorder in the Control Room. The radiation alarm is set so that the detector will alarm before radioactivity levels exceed the release limits. The liquid effluent discharge header has an isolation valve. If an alarm is received, the liquid effluent discharge valve will automatically close, thereby terminating the release to the Cape Cod Bay and preventing any liquid radioactivity from being released that may exceed the release limits. An audible alarm notifies the Control Room operator that this has occurred.

Some liquid waste sources which have a low potential for containing radioactivity, and/or may contain very low levels of contamination, may be discharged directly to the discharge canal without passing through the liquid radwaste discharge header. One such source of liquids is the neutralizing sump. However, prior to discharging such liquid wastes, the tank is thoroughly mixed and a representative sample is collected for analysis of radioactivity content prior to being discharged.

Another means for adjusting liquid effluent concentrations to below federal limits is by mixing plant cooling water from the condenser with the liquid effluents in the discharge canal. This larger volume of cooling water further dilutes the radioactivity levels far below the release limits.

The preceding discussion illustrates that many controls exist to reduce the radioactive liquid effluents released to the Cape Cod Bay to as far below the release limits as is reasonably achievable.

Radioactive releases from the radioactive gaseous effluent system to the environment are limited, controlled, and monitored by a variety of systems and procedures which include:

- reactor building ventilation system;
- reactor building vent effluent radioactivity monitor;
- sampling and analysis of reactor building vent effluents

The purpose of the reactor building ventilation system is to collect and exhaust reactor building air. Air collected from contaminated areas is filtered prior to combining it with air collected from other parts of the building. This combined airflow is then directed to the reactor building ventilation plenum that is located on the side of the reactor building. This plenum, which vents to the atmosphere, is equipped with a radiation detector. The radiation level meter and strip chart recorder for the reactor building vent effluent radioactivity monitor is located in the Control Room. To supplement the information continuously provided by the detector, air samples are taken periodically from the reactor building vent and are analyzed to quantify the total amount of tritium and radioactive gaseous and particulate effluents released.

Therefore, for both liquid and gaseous releases, radioactive effluent control systems exist to collect and purify the radioactive effluents in order to reduce releases to the environment to as low as is reasonably achievable. The effluents are always monitored, sampled and analyzed prior to release to make sure that radioactivity levels are below the release limits. If the release limits are being approached, isolation valves in some of the waste effluent lines will automatically shut to stop the release, or Control Room operators will implement procedures to ensure that federal regulatory limits are always met.

1.5 Radiological Impact on Humans

The final step in the effluent control process is the determination of the radiological dose impact to humans and comparison with the federal dose limits to the public. As mentioned previously, the purpose of continuous radiation monitoring and periodic sampling and analysis is to measure the quantities of radioactivity being released to determine compliance with the radioactivity release limits. This is the first stage for assessing releases to the environment.

Next, calculations of the dose impact to the general public from Pilgrim Station's radioactive effluents are performed. The purpose of these calculations is to periodically assess the doses to the general public resulting from radioactive effluents to ensure that these doses are being maintained as far below the federal dose limits as is reasonably achievable. This is the second stage for assessing releases to the environment.

The types and quantities of radioactive liquid and gaseous effluents released from Pilgrim Station during each given year are reported to the Nuclear Regulatory Commission annually. The 2020 Radioactive Effluents are provided in Appendix B and will be discussed in more detail in Section 3 of this report. These liquid and gaseous effluents were well below the federal release limits and were a small percentage of the PNPS ODCM effluent control limits.

These measurements of the physical and chemical nature of the effluents are used to determine how the radionuclides will interact with the environment and how they can result in radiation exposure to humans. The environmental interaction mechanisms depend upon factors such as the hydrological (water) and meteorological (atmospheric) characteristics in the area. Information on the water flow,

wind speed, wind direction, and atmospheric mixing characteristics are used to estimate how radioactivity will distribute and disperse in the ocean and the atmosphere.

The most important type of information that is used to evaluate the radiological impact on humans is data on the use of the environment. Information on fish and shellfish consumption, boating usage, beach usage, locations of cows and goats, locations of residences, locations of gardens, drinking water supplies, and other usage information are utilized to estimate the amount of radiation and radioactivity received by the general public.

The radiation exposure pathway to humans is the path radioactivity takes from its release point at Pilgrim Station to its effect on man. The movement of radioactivity through the environment and its transport to humans is portrayed in Figure 1.5-1.

EXAMPLES OF PILGRIM STATION'S RADIATION EXPOSURE PATHWAYS

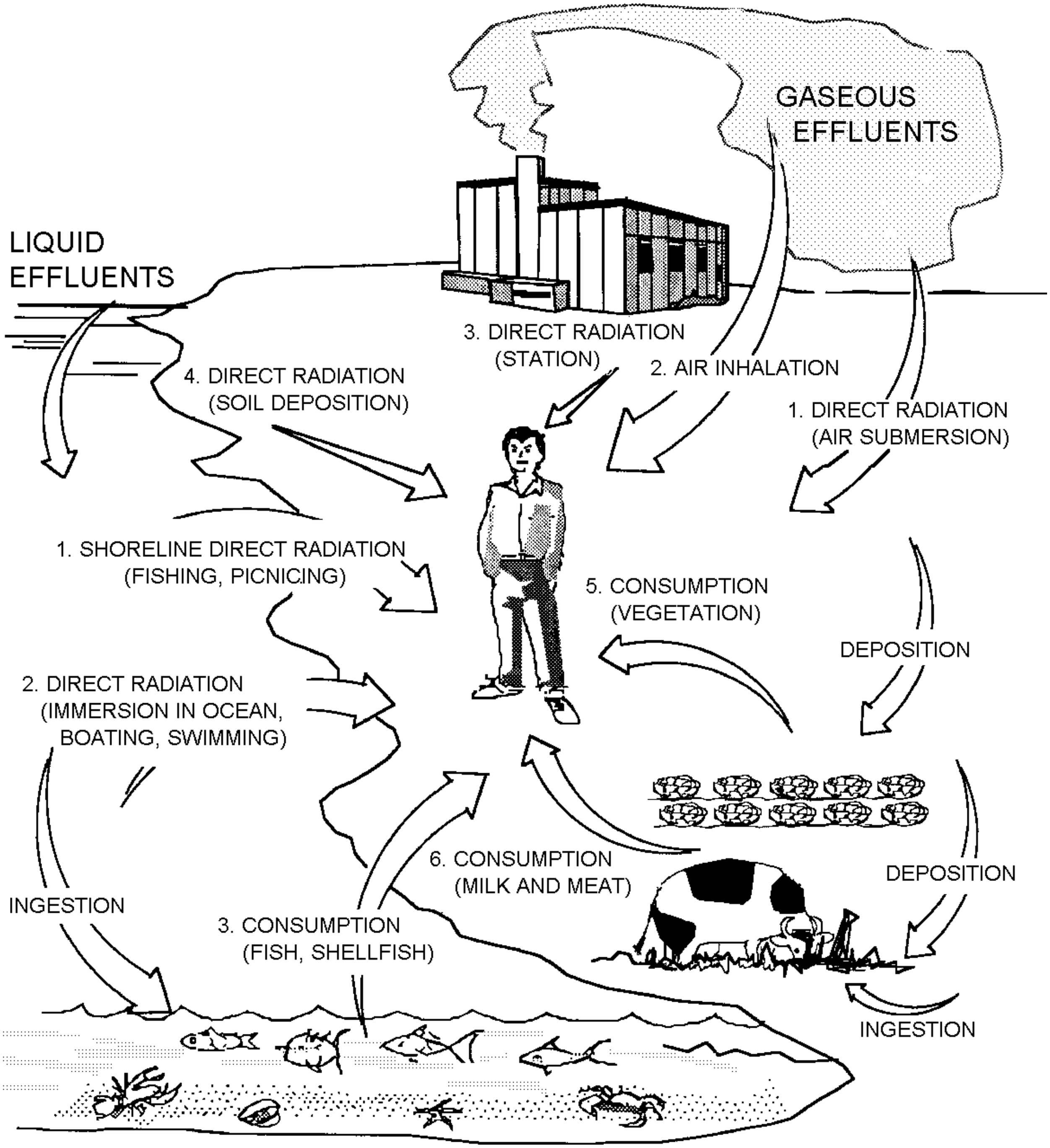


Figure 1.5-1
Radiation Exposure Pathways

There are three major ways in which liquid effluents affect humans:

- external radiation from liquid effluents that deposit and accumulate on the shoreline;
- external radiation from immersion in ocean water containing radioactive liquids; and,
- internal radiation from consumption of fish and shellfish containing radioactivity absorbed from the liquid effluents.

There are six major ways in which gaseous effluents affect humans:

- external radiation from an airborne plume of radioactivity;
- internal radiation from inhalation of airborne radioactivity;
- external radiation from deposition of radioactive effluents on soil;
- ambient (direct) radiation from contained sources at the power plant;
- internal radiation from consumption of vegetation containing radioactivity deposited on vegetation or absorbed from the soil due to ground deposition of radioactive effluents; and,
- internal radiation from consumption of milk and meat containing radioactivity deposited on forage that is eaten by cattle and other livestock.

In addition, ambient (direct) radiation emitted from contained sources of radioactivity at PNPS contributes to radiation exposure in the vicinity of the plant. Smaller amounts of ambient radiation result from low-level radioactive waste stored at the site prior to shipping and disposal.

To the extent possible, the radiological dose impact on humans is based on direct measurements of radiation and radioactivity in the environment. When PNPS-related activity is detected in samples that represent a plausible exposure pathway, the resulting dose from such exposure is assessed (see Appendix A). However, the operation of Pilgrim Nuclear Power Station resulted in releases of only small amounts of radioactivity, and, as a result of dilution in the atmosphere and ocean, even the most sensitive radioactivity measurement and analysis techniques cannot usually detect these tiny amounts of radioactivity above that which is naturally present in the environment. Therefore, radiation doses are calculated using radioactive effluent release data and computerized dose calculations that are based on very conservative NRC-recommended models that tend to result in over-estimates of resulting dose. These computerized dose calculations are performed by or for CDI personnel. These computer codes use the guidelines and methodology set forth by the NRC in Regulatory Guide 1.109 (Reference 6). The dose calculations are documented and described in detail in the Pilgrim Nuclear Power Station's Offsite Dose Calculation Manual (Reference 7), which has been reviewed by the NRC.

Monthly dose calculations are performed by PNPS personnel. It should be emphasized that because of the very conservative assumptions made in the computer code calculations, the maximum hypothetical dose to an individual is considerably higher than the dose that would actually be received by a real individual.

After dose calculations are performed, the results are compared to the federal dose limits for the public. The two federal agencies that are charged with the responsibility of protecting the public from radiation and radioactivity are the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA).

The NRC, in 10CFR 20.1301 (Reference 8) limits the levels of radiation to unrestricted areas resulting from the possession or use of radioactive materials such that they limit any individual to a dose of:

- less than or equal to 100 mrem per year to the total body.

In addition to this dose limit, the NRC has established design objectives for nuclear plant licensees. Conformance to these guidelines ensures that nuclear power reactor effluents are maintained as far below the legal limits as is reasonably achievable.

The NRC, in 10CFR 50 Appendix I (Reference 9) establishes design objectives for the dose to a member of the general public from radioactive material in liquid effluents released to unrestricted areas to be limited to:

- less than or equal to 3 mrem per year to the total body; and,
- less than or equal to 10 mrem per year to any organ.

The air dose due to release of noble gases in gaseous effluents is restricted to:

- less than or equal to 10 mrad per year for gamma radiation; and,
- less than or equal to 20 mrad per year for beta radiation.

The dose to a member of the general public from iodine-131, tritium, and all particulate radionuclides with half-lives greater than 8 days in gaseous effluents is limited to:

- less than or equal to 15 mrem per year to any organ.

The EPA, in 40CFR190.10 Subpart B (Reference 10), sets forth the environmental standards for the uranium fuel cycle. During normal operation, the annual dose to any member of the public from the entire uranium fuel cycle shall be limited to:

- less than or equal to 25 mrem per year to the total body;
- less than or equal to 75 mrem per year to the thyroid; and,
- less than or equal to 25 mrem per year to any other organ.

The summary of the 2020 radiological impact for Pilgrim Station and comparison with the EPA dose limits and guidelines, as well as a comparison with natural/man-made radiation levels, is presented in Section 3 of this report.

The third stage of assessing releases to the environment is the Radiological Environmental Monitoring Program (REMP). The description and results of the REMP at Pilgrim Nuclear Power Station during 2020 is discussed in Section 2 of this report.

2.0 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

2.1 Pre-Operational Monitoring Results

The Radiological Environmental Monitoring Program (REMP) at Pilgrim Nuclear Power Station was first initiated in August 1968, in the form of a pre-operational monitoring program prior to bringing the station on-line. The NRC's intent (Reference 11) with performing a pre-operational environmental monitoring program is to:

- measure background levels and their variations in the environment in the area surrounding the licensee's station; and,
- evaluate procedures, equipment, and techniques for monitoring radiation and radioactivity in the environment.

The pre-operational program (Reference 12) continued for approximately three and a half years, from August 1968 to June 1972. Examples of background radiation and radioactivity levels measured during this time period are as follows:

- Airborne Radioactivity Particulate Concentration (gross beta): 0.02 - 1.11 pCi/m^3;
- Ambient Radiation (TLDs): 4.2 - 22 micro-R/hr (37 - 190 mR/yr);
- Seawater Radioactivity Concentrations (gross beta): 12 - 31 pCi/liter;
- Fish Radioactivity Concentrations (gross beta): 2,200 - 11,300 pCi/kg;
- Milk Radioactive Cesium-137 Concentrations: 9.3 - 32 pCi/liter;
- Milk Radioactive Strontium-90 Concentrations: 4.7 - 17.6 pCi/liter;
- Cranberries Radioactive Cesium-137 Concentrations: 140 - 450 pCi/kg;
- Forage Radioactive Cesium-137 Concentrations: 150 - 290 pCi/kg.

This information from the pre-operational phase is used as a basis for evaluating changes in radiation and radioactivity levels in the vicinity of the plant following plant operation. In April 1972, just prior to initial reactor startup (June 12, 1972), Boston Edison Company implemented a comprehensive operational environmental monitoring program at Pilgrim Nuclear Power Station. This program (Reference 13) provides information on radioactivity and radiation levels in the environment for the purpose of:

- demonstrating that doses to the general public and levels of radioactivity in the environment are within established limits and legal requirements;
- monitoring the transfer and long-term buildup of specific radionuclides in the environment to revise the monitoring program and environmental models in response to changing conditions;
- checking the condition of the station's operation, the adequacy of operation in relation to the adequacy of containment, and the effectiveness of effluent treatment so as to provide a mechanism of determining unusual or unforeseen conditions and, where appropriate, to trigger special environmental monitoring studies;
- assessing the dose equivalent to the general public and the behavior of radioactivity released during the unlikely event of an accidental release; and,

- determining whether or not the radiological impact on the environment and humans is significant.

The Nuclear Regulatory Commission requires that Pilgrim Station provide monitoring of the plant environs for radioactivity that will be released as a result of normal operations and from postulated accidents. The NRC has established guidelines (Reference 14) that specify an acceptable monitoring program. The PNPS Radiological Environmental Monitoring Program was designed to meet and exceed these guidelines. Guidance contained in the NRC's Radiological Assessment Branch Technical Position on Environmental Monitoring (Reference 15) has been used to improve the program. In addition, the program has incorporated the provisions of an agreement made with the Massachusetts Wildlife Federation (Reference 16). The program was supplemented by including improved analysis of shellfish and sediment at substantially higher sensitivity levels to verify the adequacy of effluent controls at Pilgrim Station.

2.2 Environmental Monitoring Locations

Sampling locations have been established by considering meteorology, population distribution, hydrology, and land use characteristics of the Plymouth area. The sampling locations are divided into two classes, indicator and control. Indicator locations are those that are expected to show effects from PNPS operations, if any exist. These locations were primarily selected on the basis of where the highest predicted environmental concentrations would occur. While the indicator locations are typically within a few kilometers of the plant, the control stations are generally located so as to be outside the influence of Pilgrim Station. They provide a basis on which to evaluate fluctuations at indicator locations relative to natural background radiation and natural radioactivity and fallout from prior nuclear weapons tests.

The environmental sampling media collected in the vicinity of Pilgrim Station during 2020 included air particulate filters, vegetation, seawater, sediment, shellfish, American lobster, and fishes. The sampling medium, station description, station number, distance, and direction for indicator and control samples are listed in Table 2.2-1. These sampling locations are also displayed on the maps shown in Figures 2.2-1 through 2.2-6.

The radiation monitoring locations for the environmental TLDs are shown in Figures 2.2-1 through 2.2-4. The frequency of collection and types of radioactivity analysis are described in Pilgrim Station's ODCM, Sections 3/4.5.

The land-based (terrestrial) samples, seawater, and monitoring devices are collected by station personnel. The aquatic samples are collected by Normandeau Associates, Inc. The radioactivity analysis of samples are performed by the Teledyne Brown Engineering Laboratory, and the environmental dosimeters are analyzed by Stanford Dosimetry.

The frequency, types, minimum number of samples, and maximum lower limits of detection (LLD) for the analytical measurements, are specified in the PNPS ODCM. During 2003, a revision was made to the PNPS ODCM to standardize it to the model program described in NUREG-1302 (Reference 14) and the Branch Technical Position of 1979 (Reference 15). In accordance with this standardization, a number of changes occurred regarding the types and frequencies of sample collections.

In regard to terrestrial REMP sampling, routine collection and analysis of soil samples was discontinued in lieu of the extensive network of environmental TLDs around PNPS, and the weekly collection of air samples at air sample locations. Such TLD monitoring and air sampling would provide an early indication of any potential deposition of radioactivity, and follow-up soil sampling could be performed on an as-needed basis. Also, with the loss of the indicator milk sample at the Plymouth County Farm and the lack of a sufficient substitute location that could provide suitable volumes for analysis, it was deemed unnecessary to continue to collect and analyze control samples of milk. NRC guidance (Reference 14) contains provisions for collection of vegetation in lieu of milk sampling. Such samples have historically been collected near Pilgrim Station as part of the routine REMP program. With the permanent shut

down of the plant and the decay of Iodine the need for vegetation samples is also no longer necessary. Samples were collected during the 2020 year, but have since been removed from the REMP program.

In the area of marine sampling, a number of the specialized sampling and analysis requirements implemented as part of the Agreement with the Massachusetts Wildlife Federation (Reference 16) for licensing of a second reactor at PNPS were dropped. When the ODCM was revised in 1999 in accordance with NRC Generic Letter 89-01, the sampling program description was relocated to the ODCM. Steps were taken in 2003 to standardize the PNPS ODCM to the NUREG-1302 model, the specialized marine sampling requirements were changed to those of the model program. These changes include the following:

- A sample of the surface layer of sediment is collected, as opposed to specialized depth-incremental sampling to 30 cm and subdividing cores into 2 cm increments.
- Standard LLD levels of approximately 150 to 180 pCi/kg were established for sediment, as opposed to the specialized LLDs of 50 pCi/kg.
- Specialized analysis of sediment for plutonium isotopes was removed.
- Sampling of Irish moss, shellfish, and fish was rescheduled to a semiannual period, as opposed to a specialized quarterly sampling interval.
- Analysis of only the edible portions of shellfish (mussels and clams), as opposed to specialized additional analysis of the shell portions.
- Standard LLD levels of 130 to 260 pCi/kg were established for edible portions of shellfish, as opposed to specialized LLDs of 5 pCi/kg.

Upon receipt of the analysis results from the analytical laboratories, the PNPS staff reviews the results. If the radioactivity concentrations are above the reporting levels, the NRC must be notified within 30 days. For radioactivity that is detected that is attributable to Pilgrim Station's operation, calculations are performed to determine the cumulative dose contribution for the current year. Most importantly, if radioactivity levels in the environment become elevated as a result of the station's operation, an investigation is performed and corrective actions are recommended to reduce the amount of radioactivity to as far below the legal limits as is reasonably achievable.

The radiological environmental sampling locations are reviewed annually, and modified if necessary. A garden and milk animal census is performed every year to identify changes in the use of the environment in the vicinity of the station to permit modification of the monitoring and sampling locations. The results of the 2020 Garden and Milk Animal Census are reported in Appendix C.

The accuracy of the data obtained through Pilgrim Station’s Radiological Environmental Monitoring Program is ensured through a comprehensive Quality Assurance (QA) programs. PNPS's QA program has been established to ensure confidence in the measurements and results of the radiological monitoring program through:

- Regular surveillances of the sampling and monitoring program;
- An annual audit of the analytical laboratory by the sponsor companies;
- Participation in cross-check programs;
- Use of blind duplicates for comparing separate analyses of the same sample; and,
- Spiked sample analyses by the analytical laboratory.

QA audits and inspections of the Radiological Environmental Monitoring Program are performed by the NRC, American Nuclear Insurers, and by the PNPS Quality Assurance Department.

The Teledyne Brown Engineering Laboratory conducts extensive quality assurance and quality control programs. The 2020 results of these programs are summarized in Appendix E. These results indicate

that the analyses and measurements performed during 2020 exhibited acceptable precision and accuracy.

2.3 Interpretation of Radioactivity Analyses Results

The following pages summarize the analytical results of the environmental samples collected during 2020. Data for each environmental medium are included in a separate section. A table that summarizes the year's data for each type of medium follows a discussion of the sampling program and results. The unit of measurement for each medium is listed at the top of each table. The left hand column contains the radionuclides being reported, total number of analyses of that radionuclide, and the number of measurements that exceed ten times the yearly average for the control station(s). The latter are classified as "non-routine" measurements. The next column lists the Lower Limit of Detection (LLD) for those radionuclides that have detection capability requirements specified in the PNPS ODCM.

Those sampling stations within the range of influence of Pilgrim Station and which could conceivably be affected by its operation are called "indicator" stations. Distant stations, which are beyond plant influence, are called "control" stations. Ambient radiation monitoring stations are broken down into four separate zones to aid in data analysis.

For each sampling medium, each radionuclide is presented with a set of statistical parameters. This set of statistical parameters includes separate analyses for (1) the indicator stations, (2) the station having the highest annual mean concentration, and (3) the control stations. For each of these three groups of data, the following values are calculated:

- The mean value of detectable concentrations, including only those values above LLD;
- The standard deviation of the detectable measurements;
- The lowest and highest concentrations; and,
- The number of measurements with results greater than the Minimum Detectable Activity (activity which is three times greater than the standard deviation), out of the total number of measurements.

Each single radioactivity measurement datum is based on a single measurement and is reported as a concentration plus or minus one standard deviation. The quoted uncertainty represents only the random uncertainty associated with the measurement of the radioactive decay process (counting statistics), and not the propagation of all possible uncertainties in the sampling and analysis process. A sample or measurement is considered to contain detectable radioactivity if the measured value (e.g., concentration) exceeds three times its associated standard deviation. For example, a vegetation sample with a cesium-137 concentration of 85 ± 21 pCi/kilogram would be considered "positive" (detectable Cs-137), whereas another sample with a concentration of 60 ± 32 pCi/kilogram would be considered "negative", indicating no detectable cesium-137. The latter sample may actually contain cesium-137, but the levels counted during its analysis were not significantly different than the background levels.

The analytical laboratory that analyzes the various REMP samples employs a background subtraction correction for each analysis. A blank sample that is known not to contain any plant-related activity is analyzed for radioactivity, and the count rate for that analysis is used as the background correction. That background correction is then subtracted from the results for the analyses in that given set of samples. For example, if the blank/background sample produces 50 counts, and a given sample being analyzes produces 47 counts, then the net count for that sample is reported as -3 counts. That negative value of -3 counts is used to calculate the concentration of radioactivity for that particular analysis. Such a sample result is technically more valid than reporting a qualitative value such as "<LLD" (Lower limit of Detection) or "NDA" (No Detectable Activity)".

As an example of how to interpret data presented in the results tables, refer to the first entry on the table for air particulate filters (page 41). Gross beta (GR-B) analyses were performed on 569 routine samples. None of the samples exceeded ten times the average concentration at the control location. The lower limit of detection (LLD) required by the ODCM is 0.01 pCi/m^3.

For samples collected from the ten indicator stations, 516 out of 516 samples indicated detectable gross beta activity at the three-sigma (standard deviation) level. The mean concentration of gross beta activity in these 516 indicator station samples was 0.015 $\pm$ 0.0039 (1.5E-2 $\pm$ 3.9E-3) pCi/m^3. Individual values ranged from 0.0056 to 0.027 (5.6E-3 – 2.7E-2) pCi/m^3

The monitoring station which yielded the highest mean concentration was the control location ER (East Rocky Hill Road), which yielded a mean concentration of 0.016 $\pm$ 0.004 pCi/m^3, based on 52 detectable indications out of 52 samples observations. Individual values ranged from 0.0071 to 0.025 pCi/m^3.

At the control location, 52 out of 52 samples yielded detectable gross beta activity, for an average concentration of 0.048 $\pm$ 0.0037 pCi/m^3. Individual samples at the East Weymouth control location ranged from 0.0076 to 0.023 pCi/m^3.

Analyses for cesium-137 (Cs-137) were performed 44 times (quarterly composites for 11 stations * 4 quarters). No samples exceeded ten times the mean control station concentration. The required LLD value Cs-137 in the PNPS ODCM is 0.06 pCi/m^3.

At the indicator stations, all 40 of the Cs-137 measurements were below the detection level. The same was true for the four measurements made on samples collected from the control location.

Analyses for Beryllium-7 (Be-7) are used to indicate representative sampling for air samplers in environmental applications.

2.4 Ambient Radiation Measurements

The primary technique for measuring ambient radiation exposure in the vicinity of Pilgrim Station involves posting environmental thermoluminescent dosimeters (TLDs) at given monitoring locations and retrieving the TLDs after a specified time period. The TLDs are then taken to a laboratory and processed to determine the total amount of radiation exposure received over the period. Although TLDs can be used to monitor radiation exposure for short time periods, environmental TLDs are typically posted for periods of one to three months. Such TLD monitoring yields average exposure rate measurements over a relatively long time period. The PNPS environmental TLD monitoring program is based on a quarterly (three month) posting period, and a total of 54 locations are monitored using this technique. The number of TLD were reduced in April 2020 after the permanent shut down of the Pilgrim station. In addition, 4 of the 54 TLDs are currently located onsite, within the PNPS protected/restricted area, where the general public does not have access.

Out of the 275 TLDs (113 locations in 1st Qrt 2020 + 54 locations * 3 quarters) posted in the envionment during 2020, 275 were retrieved and processed. The results for environmental TLDs located offsite, beyond the PNPS protected/restricted area fence, are presented in Table 2.4-1. Results from onsite TLDs posted within the restricted area are presented in Table 2.4-2. In addition to TLD results for individual locations, results from offsite TLDs were grouped according to geographic zone to determine average exposure rates as a function of distance. These results are summarized in Table 2.4-3. All of the listed exposure values represent continuous occupancy (2190 hr/qtr or 8760 hr/yr).

Annual exposure rates measured at locations beyond the PNPS protected area boundary ranged from 46 to 123 mR/yr. The average exposure rate at control locations greater than 15 km from Pilgrim Station (i.e., Zone 4) was 69.7 ± 8.9 mR/yr. When the 3-sigma confidence interval is calculated based on these control measurements, 99% of all measurements of background ambient exposure would be expected to be between 35 and 85 mR/yr. The results for all TLDs within 15 km (excluding those Zone 1 TLDs

posted within the site boundary) ranged from 46 to 86 mR/yr, which compares favorably with the preoperational results of 37 - 190 mR/yr.

Inspection of onsite TLD results listed in Table 2.4-2 indicates that all of those TLDs located within the PNPS protected/restricted area yield exposure measurements higher than the average natural background. Such results are expected due to the close proximity of these locations to the movement of station spent fuel into dry casks.

A small number of offsite TLD locations in close proximity to the protected/restricted area indicated ambient radiation exposure above expected background levels. All of these locations are on Pilgrim Station controlled property, and experience exposure increases due to proximity to the onsite fuel storage pad (e.g., locations OA, TC, and P01) and/or transit and storage of radwaste onsite (e.g., locations BLE and BLW). Due to heightened security measures following September 11 2001, members for the general public do not have access to such locations within the owner-controlled area.

It should be noted that several of the TLDs used to calculate the Zone 1 averages presented in Table 2.4-3 are located on Pilgrim Station property. If the Zone 1 value is corrected for the near-site TLDs (those less than 0.6 km from the Reactor Building), the Zone 1 mean falls from a value of 72.0 ± 20.1 mR/yr to 64.8 ± 9.4 mR/yr. Additionally, exposure rates measured at areas beyond the site's control did not indicate any increase in ambient exposure from Pilgrim Station operation. For example, the annual exposure rate calculated from the TLD adjacent to the nearest offsite residence 0.80 kilometers (0.5 miles) southeast of the PNPS Reactor Building was 56.7 ± 2.8 mR/yr, which compares not too far off with the average control location exposure of 69.7 ± 8.9 mR/yr.

In conclusion, measurements of ambient radiation exposure around Pilgrim Station do not indicate any significant increase in exposure levels. Although some increases in ambient radiation exposure level were apparent on site property very close to Pilgrim Station, there were no measurable increases at areas beyond the site's control.

2.5 Air Particulate Filter Radioactivity Analyses

Airborne particulate radioactivity is sampled by drawing a stream of air through a glass fiber filter that has a very high efficiency for collecting airborne particulates. These samplers are operated continuously, and the resulting filters are collected weekly for analysis. Weekly filter samples are analyzed for gross beta radioactivity, and the filters are then composited on a quarterly basis for each location for gamma spectroscopy analysis. PNPS uses this technique to monitor locations in the Plymouth area, along with the control location in East Weymouth. At the start of 2020 11 locations were monitored. Four of the locations were no longer needed due to the plant condition and were discontinued with the change to the ODCM in May 2020.

Out of 440 filters (7 locations * 52 weeks and 4 locations *19 weeks), 433 samples were collected and analyzed during 2020. There were a few instances where power was lost or pumps failed during the course of the sampling period at some of the air sampling stations, resulting in lower than normal sample volumes. Although these filters were analyzed, the LLDs were not met and these analyses were not included with the other results. Two air sample stations proved to have larger issues. Plymouth Center was once the town offices, it had been closed and sold to a private school. During the beginning (mid-March) of the COVID-19 pandemic the school closed and there was no access to retieve the filter from the air sample station. Due to comtinually changing resources and site conditions at the end of 2020, East Breakwater went though a series of power supply removal issues effecting the last 4 collection weeks. All of these discrepancies are noted in Appendix D.

The results of the analyses performed on these 426 filter samples are summarized in Table 2.5-1. Trend plots for the gross beta radioactivity levels at the near station, property line, and offsite airborne monitoring locations are shown in Figures 2.5-1, 2.5-2 and 2.5-3, respectively. Gross beta radioactivity

was detected in 433 of the filter samples collected, including 52 of the 52 control location samples. This gross beta activity arises from naturally-occurring radionuclides such as radon decay daughter products. Naturally-occurring beryllium-7 was detected in 40 out of 40 of the quarterly composites analyzed with gamma spectroscopy. No airborne radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2020, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.6 Milk Radioactivity Analyses

As included in a provision in standard ODCM guidance in NUREG-1302 (Reference 13), sampling and analysis of vegetation from the offsite locations calculated to have the highest D/Q deposition factor can be performed in lieu of milk sampling. Such vegetation sampling has been routinely performed at Pilgrim Station as part of the radiological environmental monitoring program, and the results of this sampling are presented in Section 2.7.

2.7 Vegetable/Vegetation Radioactivity Analyses

Samples of vegetables and naturally-growing vegetation have historically been collected from the Plymouth County Farm and from the control locations in Bridgewater and Sandwich. Results of the land-use census are discussed in Appendix C. In addition to these garden samples, naturally-growing vegetation is collected from locations yielding the highest D/Q deposition factors. All of the various samples of vegetables/vegetation are collected annually and analyzed by gamma spectroscopy.

Thirteen samples of vegetables/vegetation were collected and analyzed as required during 2020. Results of the gamma analyses of these samples are summarized in Table 2.9-1. Naturally-occurring beryllium-7 and potassium-40 were identified in several of the samples collected. Cesium-137 was detected in one of the samples of vegetation collected as had been the case in prior years. Such Cs-137 is the result weapons-testing fallout (75 to 145 pCi/kg as projected from the pre-operational sampling program). It should be noted that natural vegetation samples collected in the 1990s often showed detectable Cs-137 from nuclear weapons tests up into the range of 300 to 400 pCi/kg, whereas soil samples often indicated concentrations in excess of 2000 pCi/kg. Cs-137 has a 30-year half-life, and measureable concentrations still remain in soil and vegetation as a result of atmospheric nuclear weapons testing performed during the 1950s through 1970s. No radioactivity attributable to Pilgrim Station was detected in any of the vegetable/vegetation samples collected during 2020, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.8 Surface Water Radioactivity Analyses

Samples of surface water are routinely collected from the discharge canal and from the control location at Powder Point Bridge in Duxbury. Grab samples are collected weekly from thePowder Point Bridge location. Samples of surface water are composited every four weeks and analyzed by gamma spectroscopy and low-level iodine analysis. These monthly composites are further composited on a quarterly basis and tritium analysis is performed on these quarterly samples.

A total of 32 samples of surface water were collected and analyzed as required during 2020. Bartlett Pond was removed from the ODCM in the fourth Quarter 2019. Results of the analyses of water samples are summarized in Table 2.12-1. Naturally-occurring potassium-40 was detected in several of the samples, especially those composed primarily of seawater. No radioactivity attributable to Pilgrim Station was detected in any of the surface water samples collected during 2020.

In response to the Nuclear Energy Institute Groundwater Protection Initiative, Pilgrim Station installed a number of groundwater monitoring wells within the protected area in late 2007. Because all of these wells are onsite, they are not included in the offsite radiological monitoring program, and are not presented in this report. Details regarding Pilgrim Station's groundwater monitoring effort can be found in the Annual Radioactive Effluent Release Report.

2.9 Sediment Radioactivity Analyses

Samples of sediment are routinely collected from the outfall area of the discharge canal and from three other locations in the Plymouth area (Manomet Point, Plymouth Harbor and Plymouth Beach), and from control locations in Duxbury and Marshfield. Samples are collected twice per year and are analyzed by gamma spectroscopy.

Eleven of twelve required samples of sediment were collected during 2020. Gamma analyses were performed on these samples. Results of the gamma analyses of sediment samples are summarized in Table 2.13-1. Naturally-occurring potassium-40 and actinium/thorium-228 were detected in all of the samples. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2020, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.10 Shellfish Radioactivity Analyses

Samples of blue mussels and soft-shell clams are collected from the discharge canal outfall and one other location in the Plymouth area (Plymouth Harbor), and from control locations in Duxbury and Marshfield. All samples are collected on a semiannual basis, and edible portions processed in the laboratory for gamma spectroscopy analysis.

Nine of the ten required samples of shellfish meat scheduled for collection during 2020 were obtained and analyzed. Results of the gamma analyses of these samples are summarized in Table 2.15-1. Naturally-occurring potassium-40 was detected in nine of the nine the samples. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2020, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.11 Lobster Radioactivity Analyses

Samples of lobsters are routinely collected from the outfall area of the discharge canal and from control locations in Cape Cod Bay and Vineyard Sound. Samples are collected monthly from the discharge canal outfall from June through September and once annually from the control locations. All lobster samples are normally analyzed by gamma spectroscopy.

Five samples of lobsters were collected as required during 2020. Results of the gamma analyses of these samples are summarized in Table 2.16-1. Naturally-occurring potassium-40 was detected in five of the five of the samples. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2020, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

2.12 Fish Radioactivity Analyses

Samples of fish are routinely collected from the area at the outfall of the discharge canal and from the control locations in Cape Cod Bay and Buzzard's Bay. Fish species are grouped into four major categories according to their biological requirements and mode of life. These major categories and the representative species are as follows:

- Group I – Bottom-Oriented: Winter Flounder, Yellowtail Flounder
- Group II - Near-Bottom Distribution: Tautog, Cunner, Pollock, Atlantic Cod, Hake
- Group III - Anadromous: Alewife, Smelt, Striped Bass
- Group IV - Coastal Migratory: Bluefish, Herring, Menhaden, Mackerel

Group I fishes are sampled on a semiannual basis from the outfall area of the discharge canal, and on an annual basis from a control location. Group II, III, and IV fishes are sampled annually from the discharge canal outfall and control location. All samples of fish are analyzed by gamma spectroscopy.

Eight samples of fish were collected during 2020. The seasonal sample of Group III fish (alewife, smelt, striped bass) from the Discharge Outfall becomes increasingly more difficult. Many fish species gravitated to the warmer waters. With the shutdown of the station the discharge flow and heat was reduced. These discrepancies are discussed in Appendix D. Results of the gamma analyses of fish samples collected are summarized in Table 2.17-1. The only radionuclide detected in any of the fish samples was naturally-occurring potassium-40. No radioactivity attributable to Pilgrim Station was detected in any of the fish samples collected during 2020, and results of any detectable naturally-occurring radioactivity were similar to those observed in the preoperational monitoring program.

Table 2.2-1

Routine Radiological Environmental Sampling Locations
Pilgrim Nuclear Power Station, Plymouth, MA

Description	Code	Distance	Direction
Air Particulate Filters			
Medical Building	WS	0.2 km	SSE
East Rocky Hill Road	ER	0.9 km	SE
West Rocky Hill Road	WR	0.8 km	WNW
Property Line	PL	0.5 km	NNW
Pedestrian Bridge	PB	0.2 km	N
Overlook Area	OA	0.1 km	W
East Breakwater	EB	0.5 km	ESE
Cleft Rock	CR	1.3 km	SSW
Plymouth Center	PC	6.7 km	W
Manomet Substation	MS	3.6 km	SSE
East Weymouth (Control)	EW	40 km	NW
Vegetation/Vegetables			
Plymouth County Farm	CF	5.6 km	W
Hanson Farm (Control)	HN	35 km	W

Table 2.2-1 (continued)

Routine Radiological Environmental Sampling Locations
Pilgrim Nuclear Power Station, Plymouth, MA

Description	Code	Distance	Direction
Surface Water			
Discharge Canal	DIS	0.2 km	N
Powder Point (Control)	PP	13 km	NNW
Sediment			
Discharge Canal Outfall	DIS	0.8 km	NE
Plymouth Harbor	Ply-H	4.1 km	W
Duxbury Bay (Control)	Dux-Bay	14 km	NNW
Plymouth Beach	PLB	4.0 km	WNW
Manomet Point	MP	3.3 km	ESE
Green Harbor (Control)	GH	16 km	NNW
Shellfish			
Discharge Canal Outfall	DIS	0.7 km	NNE
Plymouth Harbor	Ply-H	4.1 km	W
Duxbury Bay (Control)	Dux-Bay	13 km	NNW
Manomet Point	MP	4.0 km	ESE
Green Harbor (Control)	GH	16 km	NNW
Lobster			
Discharge Canal Outfall	DIS	0.5 km	N
Plymouth Harbor	Ply-H	6.4 km	WNW
Duxbury Bay (Control)	Dux-Bay	11 km	NNW
Fishes			
Discharge Canal Outfall	DIS	0.5 km	N
Vineyard Sound (Control)	MV	64 km	SSW
Buzzard’s Bay (Control)	BB	40 km	SSW
Cape Cod Bay (Control)	CC-Bay	24 km	ESE

Table 2.4-1

Offsite Environmental TLD Results

TLD Station	TLD Location*	Quarterly Exposure - mR/quarter (Value ± Std.Dev.)				2020 Annual** Exposure mR/year
ID Description	Distance/Direction	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	
Zone 1 TLDs: 0-3 km	0-3 km	17.8 ± 3.0	17.6 ± 2.9	17.6 ± 4.9	19.0 ± 7.8	72.0 ± 20.0
BLW BOAT LAUNCH WEST	0.11 km E	28.4 ± 1.2	25.8 ± 1.0	28.6 ± 1.1	38.6 ± 2.1	121.4 ± 22.7
OA OVERLOOK AREA	0.15 km W	19.3 ± 1.3	23.5 ± 1.3	36.9 ± 1.7	34.4 ± 2.8	114.2 ± 34.2
TC HEALTH CLUB	0.15 km WSW	15.4 ± 0.9	15.9 ± 0.8	17.0 ± 0.6	16.9 ± 0.8	65.3 ± 3.4
BLE BOAT LAUNCH EAST	0.16 km ESE	23.5 ± 1.7	23.6 ± 1.0	24.4 ± 1.1	51.0 ± 2.4	122.5 ± 54.4
ISF-3 ISFSI-3	0.21 km W	18.7 ± 1.1	17.8 ± 0.9	21.1 ± 0.9	22.4 ± 1.2	80.1 ± 8.8
P01 SHOREFRONT SECURITY	0.22 km NNW	16.3 ± 0.8	16.1 ± 0.7	17.8 ± 1.0	17.0 ± 1.3	67.1 ± 3.7
WS MEDICAL BUILDING	0.23 km SSE	17.5 ± 1.1	17.5 ± 0.7	18.0 ± 0.8	18.0 ± 0.9	71.0 ± 2.1
ISF-2 ISFSI-2	0.28 km W	16.4 ± 1.1	M ± M	17.2 ± 0.7	16.6 ± 0.8	66.9 ± 2.7
ISF-1 ISFSI-1	0.35 km SW	19.4 ± 1.4	18.4 ± 0.8	19.0 ± 0.8	18.5 ± 0.8	75.4 ± 2.7
PA SHOREFRONT PARKING	0.35 km NNW	18.0 ± 1.0	18.1 ± 0.7	17.7 ± 0.9	17.0 ± 0.8	70.9 ± 2.7
A STATION A	0.37 km WSW	16.5 ± 0.9	15.7 ± 0.9	14.8 ± 0.7	15.8 ± 0.7	62.9 ± 3.2
EB EAST BREAKWATER	0.44 km ESE	18.8 ± 1.2	19.0 ± 0.9	19.2 ± 0.9	17.2 ± 1.0	74.2 ± 4.1
B STATION B	0.44 km S	21.8 ± 1.2	20.8 ± 0.9	20.1 ± 1.2	20.3 ± 0.8	83.0 ± 3.7
PMT PNPS MET TOWER	0.44 km WNW	19.6 ± 1.2	19.0 ± 0.8	17.2 ± 0.8	17.7 ± 1.1	73.5 ± 4.8
L STATION L	0.50 km ESE	17.8 ± 0.8	17.9 ± 0.6	17.6 ± 0.7	17.1 ± 0.8	70.4 ± 2.1
G STATION G	0.53 km W	14.9 ± 0.9	14.4 ± 0.6	14.9 ± 0.6	13.6 ± 0.7	57.8 ± 3.0
PL PROPERTY LINE	0.54 km NW	16.8 ± 1.1	16.2 ± 0.7	16.7 ± 0.6	15.3 ± 0.8	64.9 ± 3.3
HB HALL'S BOG	0.63 km SE	17.7 ± 1.1	18.0 ± 0.6	18.3 ± 0.6	16.7 ± 0.7	70.7 ± 3.2
GH GREENWOOD HOUSE	0.65 km ESE	16.6 ± 0.8	17.7 ± 0.6	16.8 ± 0.6	15.9 ± 0.9	66.9 ± 3.4
WR W ROCKY HILL ROAD	0.83 km WNW	21.9 ± 1.1	20.9 ± 1.0	22.4 ± 1.0	21.1 ± 1.2	86.2 ± 3.5
ER E ROCKY HILL ROAD	0.89 km SE	14.9 ± 0.9	13.7 ± 0.5	14.4 ± 0.6	13.6 ± 0.7	56.6 ± 2.8
CR CLEFT ROCK	1.27 km SSW	18.5 ± 0.9	18.3 ± 0.8	17.5 ± 1.0	17.1 ± 0.8	71.4 ± 3.2
BD BAYSHORE/GATE RD	1.34 km WNW	18.3 ± 0.9	18.3 ± 0.8	16.3 ± 0.8	17.5 ± 0.9	70.5 ± 4.2
EM EMERSON ROAD	1.53 km SSE	16.3 ± 0.9	16.6 ± 0.8	14.8 ± 0.6	17.7 ± 0.9	65.4 ± 5.0
EP EMERSON/PRISCILLA	1.55 km SE	15.8 ± 1.1	15.5 ± 0.6	13.9 ± 0.6	M ± M	60.3 ± 4.4
BS BAYSHORE	1.76 km W	18.9 ± 0.8	18.8 ± 0.9	16.9 ± 0.7	17.6 ± 0.8	72.2 ± 4.2
JG JOHN GAULEY	1.99 km W	18.1 ± 1.2	17.8 ± 0.7	15.8 ± 0.6	17.0 ± 0.8	68.5 ± 4.4
J STATION J	2.04 km SSE	16.7 ± 0.8	16.2 ± 0.7	14.3 ± 0.8	15.1 ± 0.8	62.2 ± 4.5
RC PLYMOUTH YMCA	2.09 km WSW	16.7 ± 0.9	16.0 ± 0.7	13.7 ± 1.0	14.6 ± 0.8	60.9 ± 5.6
TT TAYLOR/THOMAS	2.26 km SE	16.1 ± 0.9	16.5 ± 0.7	14.8 ± 0.9	17.0 ± 1.3	64.3 ± 4.3
YV YANKEE VILLAGE	2.28 km WSW	18.0 ± 0.9	17.4 ± 1.0	15.4 ± 0.7	16.3 ± 0.7	67.1 ± 4.9
GN GOODWIN PROPERTY	2.38 km SW	13.6 ± 0.8	12.8 ± 0.6	11.2 ± 0.5	11.7 ± 0.7	49.2 ± 4.4
RW RIGHT OF WAY	2.83 km S	12.1 ± 0.7	12.4 ± 0.6	11.3 ± 0.5	14.4 ± 1.0	50.2 ± 5.4
TP TAYLOR/PEARL	2.98 km SE	14.7 ± 1.1	15.3 ± 0.7	13.1 ± 0.6	15.9 ± 0.7	59.1 ± 5.1

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.
** Annual value is based on arithmetic mean of the observed quarterly values multiplied by four quarters/year.
*** TLDs missing will be noted with M.

Table 2.4-1 (continued)

Offsite Environmental TLD Results

TLD Station ID Description	TLD Location* Distance/Direction	Quarterly Exposure - mR/quarter (Value ± Std.Dev.) Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	2020 Annual** Exposure mR/year
Zone 2 TLDs: 3-8 km	3-8 km	15.0 ± 2.1	15.3 ± 2.0	14.4 ± 2.4	15.7 ± 1.6	60.4 ± 8.1
ME MANOMET ELEM	3.29 km SE	15.8 ± 0.7	16.4 ± 1.1	15.3 ± 0.6	17.6 ± 1.1	65.1 ± 4.3
MS MANOMET SUBSTATION	3.60 km SSE	18.0 ± 0.9	17.6 ± 0.9	17.2 ± 0.8	15.9 ± 0.9	68.7 ± 4.1
PT PINES ESTATE	4.44 km SSW	14.0 ± 0.7	13.2 ± 0.7	12.7 ± 0.7	14.6 ± 0.8	54.6 ± 3.6
RM RUSSELL MILLS RD	4.85 km WSW	14.6 ± 0.8	13.9 ± 0.6	13.6 ± 0.5	15.7 ± 0.8	57.9 ± 4.0
MB MANOMET BEACH	5.43 km SSE	15.3 ± 0.7	15.2 ± 0.7	13.1 ± 0.5	15.5 ± 1.0	59.2 ± 4.7
BR BEAVERDAM ROAD	5.52 km S	14.8 ± 0.9	14.9 ± 0.9	14.2 ± 0.6	15.8 ± 0.9	59.7 ± 3.2
PC PLYMOUTH CENTER	6.69 km W	11.4 ± 0.5	M ± M	M ± M	M ± M	45.8 ± 0.0
LD LONG POND/DREW RD	6.97 km WSW	13.9 ± 0.8	13.2 ± 0.6	11.9 ± 0.8	12.5 ± 0.6	51.5 ± 3.8
HR HYANNIS ROAD	7.33 km SSE	14.3 ± 0.8	M ± M	12.9 ± 0.5	15.7 ± 0.7	57.2 ± 0.0
MH MEMORIAL HALL	7.58 km WNW	19.2 ± 0.9	18.8 ± 1.1	19.7 ± 0.6	18.4 ± 0.8	76.0 ± 2.9
CP COLLEGE POND	7.59 km SW	13.7 ± 0.7	14.5 ± 0.6	13.1 ± 0.5	15.5 ± 0.8	56.8 ± 4.4
Zone 3 TLDs: 8-15 km	8-15 km	15.1 ± 2.4	15.8 ± 1.9	14.3 ± 1.9	16.4 ± 1.4	61.6 ± 7.5
DW DEEP WATER POND	8.59 km W	15.9 ± 0.9	16.7 ± 0.7	16.1 ± 0.6	18.1 ± 0.8	66.8 ± 4.2
LP LONG POND ROAD	8.88 km SSW	12.8 ± 0.7	13.6 ± 0.6	12.2 ± 0.7	15.1 ± 1.1	53.8 ± 5.2
NP NORTH PLYMOUTH	9.38 km WNW	17.9 ± 1.1	17.9 ± 0.7	15.6 ± 0.6	16.7 ± 0.8	68.2 ± 4.7
SH SACRED HEART	12.92 km W	13.5 ± 0.7	14.9 ± 0.7	13.4 ± 0.7	15.7 ± 0.8	57.5 ± 4.7
Zone 4 TLDs: >15 km	>15 km	17.5 ± 2.2	18.5 ± 1.6	17.6 ± 0.5	18.3 ± 2.8	71.9 ± 6.1
DMF DIV MARINE FISH	20.97 km SSE	18.9 ± 0.9	19.6 ± 0.8	17.5 ± 0.6	20.3 ± 1.0	76.3 ± 5.0
EW E WEYMOUTH SUBST	39.69 km NW	16.0 ± 0.8	17.5 ± 1.0	17.7 ± 0.8	16.4 ± 0.8	67.6 ± 3.7

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.

** Annual value is based on arithmetic mean of the observed quarterly values multiplied by four quarters/year.

*** TLDs missing will be noted with M. Plymouth Center TLD could not be accessed for most of 2020 due to COVID-19 building closures.

Table 2.4-2

Onsite Environmental TLD Results

TLD Station ID Description	TLD Location* Distance/Direction	Quarterly Exposure - mR/quarter (Value ± Std.Dev.) Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	2020 Annual** Exposure mR/year
Onsite TLDs						
P04 FENCE-R SCREENHOUSE	66 m N	36.0 ± 1.5	39.0 ± 1.3	M ± M	M ± M	149.9 ± 9.3
P25 EXEC.BUILDING LAWN	76 m WNW	22.6 ± 1.0	34.5 ± 1.2	M ± M	M ± M	114.2 ± 33.7
P05 FENCE-WATER TANK	81 m NNE	19.7 ± 1.2	20.7 ± 1.1	M ± M	M ± M	80.8 ± 4.3
P06 FENCE-OIL STORAGE	85 m NE	24.6 ± 1.1	25.1 ± 1.0	M ± M	M ± M	99.3 ± 3.4
P08 COMPRESSED GAS STOR	92 m E	27.1 ± 1.2	23.1 ± 0.7	M ± M	M ± M	100.4 ± 11.8
P03 FENCE-L SCREENHOUSE	100 m NW	20.0 ± 1.1	24.2 ± 0.8	M ± M	M ± M	88.4 ± 12.2
P17 FENCE-EXEC.BUILDING	107 m W	117.9 ± 4.4	414.0 ± 10.9	837.5 ± 34.2	799.5 ± 47.7	2168.8 ± 1367.2
P07 FENCE-INTAKE BAY	121 m ENE	22.9 ± 1.2	23.3 ± 0.9	M ± M	M ± M	92.3 ± 3.3
P26 FENCE-WAREHOUSE	134 m ESE	23.2 ± 1.2	23.4 ± 0.8	M ± M	M ± M	93.2 ± 2.9
P02 FENCE-SHOREFRONT	135 m NW	19.2 ± 0.7	19.8 ± 0.8	M ± M	M ± M	78.0 ± 2.9
P09 FENCE-W BOAT RAMP	136 m E	21.7 ± 1.0	21.9 ± 0.9	M ± M	M ± M	87.1 ± 2.6
P16 FENCE-W SWITCHYARD	172 m SW	19.1 ± 1.2	20.7 ± 0.7	M ± M	M ± M	79.7 ± 5.3
P11 FENCE-TCF GATE	183 m ESE	29.6 ± 1.2	29.4 ± 1.4	36.0 ± 1.2	91.0 ± 4.4	186.0 ± 119.5
P27 FENCE-TCF/BOAT RAMP	185 m ESE	22.4 ± 1.1	22.8 ± 0.8	22.5 ± 1.0	37.7 ± 1.9	105.4 ± 30.4
P12 FENCE-ACCESS GATE	202 m SE	17.0 ± 0.9	17.8 ± 0.7	M ± M	M ± M	69.6 ± 3.1
P15 FENCE-E SWITCHYARD	220 m S	22.9 ± 1.1	27.4 ± 1.5	M ± M	M ± M	100.7 ± 13.4
P10 FENCE-TCF/INTAKE BAY	223 m E	24.1 ± 1.3	24.0 ± 0.9	24.4 ± 1.2	41.1 ± 2.7	113.7 ± 34.0
P13 FENCE-MEDICAL BLDG.	224 m SSE	17.6 ± 0.9	18.5 ± 0.8	M ± M	M ± M	72.0 ± 3.5
P14 FENCE-BUTLER BLDG	228 m S	15.5 ± 0.9	17.6 ± 0.6	M ± M	M ± M	66.3 ± 6.5

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.
** Annual value is based on arithmetic mean of the observed quarterly values multiplied by four quarters/year.
*** TLDs missing or removed from the ODCM mid year will be noted with M. P17 shows higher than typical readings due to the movement of dry cask storage canisters near TLD location.

Table 2.4-3

Average TLD Exposures By Distance Zone During 2020

Exposure Period	Average Exposure ± Standard Deviation: mR/period Zone 1* 0-3 km	Zone 2 3-8 km	Zone 3 8-15 km	Zone 4 >15 km
Jan-Mar	17.8 ± 3.0	15.0 ± 2.1	15.1 ± 2.4	17.5 ± 2.2
Apr-Jun	17.6 ± 2.9	15.3 ± 2.0	15.8 ± 1.9	18.5 ± 1.6
Jul-Sep	17.6 ± 4.9	14.4 ± 2.4	14.3 ± 1.9	17.6 ± 0.5
Oct-Dec	19.0 ± 7.8	15.7 ± 1.6	16.4 ± 1.4	18.3 ± 2.8
Jan-Dec	72.0 ± 20.0	60.4 ± 8.1	61.6 ± 7.5	71.9 ± 6.1

* Zone 1 extends from the PNPS restricted/protected area boundary outward to 3 kilometers (2 miles), and includes several TLDs located within the site boundary.

** When corrected for TLDs located within the site boundary, the Zone 1 annual average is calculated to be 62.1 ± 8.5 mR/yr.

Table 2.5-1
Air Particulate Filter Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2020)

MEDIUM: Air Particulates (AP) UNITS: pCi/cubic meter

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
Gross Beta	433 0	0.01	1.6E-2 ± 6.8E-3 6.7E-3 - 9.7E-2 381 / 381	PB: 1.7E-2 ± 1.2E-2 6.9E-3 - 9.7E-2 52 / 52	1.6E-2 ± 4.9E-3 8.6E-3 - 3.7E-2 52 / 52
Be-7	44 0		7.1E+1 ± 5.9E+1 -3.4E+0 - 1.4E+2 40 / 40	MS: 1.3E+2 ± 7.4E+0 1.3E+2 - 1.4E+2 4 / 4	1.2E+2 ± 3.3E+1 8.0E+1 - 1.6E+2 4 / 4
Cs-134	44 0	0.05	1.0E+1 ± 6.4E+1 -2.0E+2 - 2.7E+2 0 / 40	WR: 6.2E+1 ± 9.6E+1 1.5E-1 - 2.0E+2 0 / 4	-5.5E-1 ± 9.4E-1 -1.6E+0 - 5.6E-1 0 / 4
Cs-137	44 0	0.06	2.1E-1 ± 1.6E+0 -2.4E+0 - 8.3E+0 0 / 40	WR: 1.1E+0 ± 4.9E+0 -2.4E+0 - 8.3E+0 0 / 4	-3.9E-1 ± 4.8E-1 -8.9E-1 - 6.8E-2 0 / 4

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.7-1
Vegetable/Vegetation Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2020)

MEDIUM: Vegetation (TF) UNITS: pCi/kg wet

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
Be-7	13 0		1.9E+3 ± 5.0E+2 1.1E+3 - 2.5E+3 6 / 6	2.7E+3 ± 1.5E+2 2.7E+3 - 2.7E+3 1 / 1	3.7E+2 ± 1.0E+3 -1.6E+2 - 2.7E+3 2 / 7
K-40	13 0		3.2E+3 ± 6.4E+2 2.6E+3 - 4.4E+3 6 / 6	4.4E+3 ± 2.6E+2 4.4E+3 - 4.4E+3 1 / 1	2.4E+3 ± 9.1E+2 1.0E+3 - 3.5E+3 7 / 7
I-131	13 0	60	-2.0E+0 ± 1.7E+1 -2.2E+1 - 2.5E+1 0 / 6	2.5E+1 ± 7.4E+0 2.5E+1 - 2.5E+1 0 / 1	-9.6E+0 ± 1.6E+1 -2.9E+1 - 1.6E+1 0 / 7
Cs-134	13 0	60	5.2E+0 ± 1.3E+1 -7.7E+0 - 2.1E+1 0 / 6	2.1E+1 ± 6.5E+0 2.1E+1 - 2.1E+1 0 / 1	-1.1E+0 ± 1.0E+1 -1.8E+1 - 7.7E+0 0 / 7
Cs-137	13 0	80	2.7E+1 ± 4.8E+1 -4.9E+0 - 1.2E+2 1 / 6	1.2E+2 ± 1.2E+1 1.2E+2 - 1.2E+2 1 / 1	-2.7E+0 ± 1.0E+1 -1.2E+1 - 1.8E+1 0 / 7
AcTh-228	13 0		NDA NDA 0 / 0	NDA NDA 0 / 0	NDA NDA 0 / 0

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.8-1
Surface Water Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2020)

MEDIUM: Surface Water (WS) UNITS: pCi/L

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
H-3	8 0	3000	4.9E+1 ± 1.3E+2 -7.5E+1 - 2.1E+2 0 / 8	PwtPt: 4.9E+1 ± 1.3E+2 -7.5E+1 - 2.1E+2 0 / 4	-3.8E+0 ± 8.1E+1 -7.1E+1 - 1.1E+2 0 / 4
K-40	24 0		2.8E+2 ± 3.4E+1 2.1E+2 - 3.3E+2 12 / 12	PwdPt: 2.9E+2 ± 2.4E+1 2.4E+2 - 3.3E+2 12 / 12	2.9E+2 ± 2.4E+1 2.4E+2 - 3.3E+2 12 / 12
Mn-54	24 0	15	-3.7E-1 ± 7.6E-1 -1.7E+0 - 8.7E-1 0 / 12	PwdPt: -3.8E-2 ± 8.1E-1 -1.1E+0 - 1.5E+0 0 / 12	-3.8E-2 ± 8.1E-1 -1.1E+0 - 1.5E+0 0 / 12
Fe-59	24 0	30	3.8E-1 ± 3.3E+0 -7.7E+0 - 5.4E+0 0 / 12	Dis: 3.8E-1 ± 3.3E+0 -7.7E+0 - 5.4E+0 0 / 12	3.1E-1 ± 1.8E+0 -2.5E+0 - 2.8E+0 0 / 12
Co-58	24 0	15	-2.8E-1 ± 1.0E+0 -2.3E+0 - 1.2E+0 0 / 12	PwdPt: 2.0E-1 ± 1.1E+0 -1.1E+0 - 2.9E+0 0 / 12	2.0E-1 ± 1.1E+0 -1.1E+0 - 2.9E+0 0 / 12
Co-60	24 0	15	3.3E-1 ± 1.1E+0 -2.0E+0 - 1.8E+0 0 / 12	PwdPt: 5.2E-1 ± 9.1E-1 -7.3E-1 - 2.3E+0 0 / 12	5.2E-1 ± 9.1E-1 -7.3E-1 - 2.3E+0 0 / 12
Zn-65	24 0	30	-5.0E+0 ± 3.0E+0 -1.1E+1 - -1.5E+0 0 / 12	PwdPt: -2.7E+0 ± 3.7E+0 -8.9E+0 - 6.3E+0 0 / 12	-2.7E+0 ± 3.7E+0 -8.9E+0 - 6.3E+0 0 / 12
Zr-95	24 0	30	-2.0E-1 ± 1.8E+0 -3.0E+0 - 2.5E+0 0 / 12	PwdPt: 3.6E-1 ± 2.8E+0 -4.1E+0 - 7.4E+0 0 / 12	3.6E-1 ± 2.8E+0 -4.1E+0 - 7.4E+0 0 / 12
Nb-95	24 0	15	7.4E-1 ± 1.4E+0 -1.3E+0 - 3.9E+0 0 / 12	Dis: 7.4E-1 ± 1.4E+0 -1.3E+0 - 3.9E+0 0 / 12	5.5E-1 ± 9.2E-1 -6.9E-1 - 2.5E+0 0 / 12
I-131	24 0	15	1.0E+0 ± 2.1E+0 -2.3E+0 - 5.2E+0 0 / 12	Dis: 1.0E+0 ± 2.1E+0 -2.3E+0 - 5.2E+0 0 / 12	-5.0E-1 ± 3.1E+0 -5.1E+0 - 3.2E+0 0 / 12
Cs-134	24 0	15	4.3E-1 ± 1.1E+0 -1.1E+0 - 3.1E+0 0 / 12	Dis: 4.3E-1 ± 1.1E+0 -1.1E+0 - 3.1E+0 0 / 12	-2.3E-1 ± 1.1E+0 -1.6E+0 - 1.7E+0 0 / 12
Cs-137	24 0	18	-8.2E-2 ± 7.1E-1 -1.5E+0 - 9.6E-1 0 / 12	PwdPt: 2.7E-1 ± 1.4E+0 -1.5E+0 - 3.9E+0 0 / 12	2.7E-1 ± 1.4E+0 -1.5E+0 - 3.9E+0 0/ 12
Ba-140	24 0	60	1.0E+0 ± 8.3E+0 -1.3E+1 - 1.4E+1 0 / 12	PwdPt: 4.9E+0 ± 8.3E+0 -9.0E+0 - 1.6E+1 0 / 12	4.9E+0 ± 8.3E+0 -9.0E+0 - 1.6E+1 0 / 12
La-140	24 0	15	-1.2E-1 ± 2.3E+0 -4.6E+0 - 4.7E+0 0 / 12	Dis: -1.2E-1 ± 2.3E+0 -4.6E+0 - 4.7E+0 0 / 12	-9.3E-1 ± 1.8E+0 -3.5E+0 - 3.3E+0 0 / 12

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.9-1
Sediment Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2020)

MEDIUM: Sediment (SE) UNITS: pCi/kg dry

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
K-40	11 0		9.8E+3 ± 9.9E+2 8.5E+3 - 1.1E+4 8 / 8	DuxBay:1.6E+4 ± 7.9E+2 1.6E+4 - 1.6E+4 1 / 1	1.3E+4 ± 2.4E+3 1.1E+4 - 1.6E+4 3 / 3
Cs-134	11 0	150	1.7E+1 ± 1.8E+1 -7.8E+0 - 4.1E+1 0/ 8	GrnHrb: 4.6E+1 ± 3.2E+1 2.5E+1 - 6.8E+1 0 / 2	4.2E+1 ± 2.6E+1 2.5E+1 - 6.8E+1 0 / 3
Cs-137	11 0	180	5.4E+0 ± 1.8E+1 -2.4E+1 - 3.2E+1 0 / 8	DuxBay: 6.3E+1 ± 2.3E+1 6.3E+1 - 6.3E+1 0 / 1	2.0E+1 ± 3.9E+1 -4.3E+0 - 6.3E+1 0 / 3
AcTh-228	11 0		3.2E+2 ± 2.3E+2 1.1E+2 - 8.0E+2 8 / 8	Dis: 5.0E+2 ± 4.2E+2 2.0E+2 - 8.0E+2 2 / 2	4.1E+2 ± 7.7E+1 3.6E+2 - 4.9E+2 3 / 3

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.10-1
Shellfish Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2020)

MEDIUM: Shellfish (SF) UNITS: pCi/kg wet

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
K-40	9 0		1.5E+3 ± 1.8E+2 1.3E+3 - 1.6E+3 6 / 6	DuxBay: 1.9E+3 ± 7.4E+2 1.4E+3 - 2.4E+3 2 / 2	1.6E+3 ± 6.7E+2 1.1E+3 - 2.4E+3 3 / 3
Mn-54	9 0	130	1.2E+1 ± 1.6E+1 -2.7E+0 - 3.6E+1 0 / 6	GrnHrb: 3.8E+1 ± 1.2E+1 3.8E+1 - 3.8E+1 0 / 1	2.0E+1 ± 2.2E+1 -2.3E+0 - 3.8E+1 0 / 3
Fe-59	9 0	260	8.6E+0 ± 2.1E+1 -1.2E+1 - 4.2E+1 0 / 6	GrnHrb: 1.8E+1 ± 2.4E+1 1.8E+1 - 1.8E+1 0 / 1	4.2E+0 ± 1.9E+1 -1.1E+1 - 1.8E+1 0 / 3
Co-58	9 0	130	-1.1E+1 ± 1.0E+1 -2.1E+1 - -4.7E-2 0 / 6	GrnHrb: 1.4E+1 ± 1.1E+1 1.4E+1 - 1.4E+1 0 / 1	8.7E+0 ± 2.2E+1 -1.5E+1 - 2.7E+1 0 / 3
Co-60	9 0	130	1.9E+0 ± 2.2E+1 -3.5E+1 - 2.4E+1 0 / 6	DuxBay: 1.3E+1 ± 2.8E+1 -5.6E+0 - 3.2E+1 0 / 2	1.1E+1 ± 2.1E+1 -5.6E+0 - 3.2E+1 0 / 3
Zn-65	9 0	260	-3.6E+1 ± 4.6E+1 -1.0E+2 - 1.4E+0 0 / 6	GrnHrb: 8.8E+0 ± 2.8E+1 8.8E+0 - 8.8E+0 0 / 1	-3.0E+1 ± 4.2E+1 -6.6E+1 - 8.8E+0 0 / 3
Cs-134	9 0	130	-1.9E+0 ± 2.3E+1 -3.6E+1 - 2.9E+1 0 / 6	GrnHrb: 1.6E+1 ± 1.2E+1 1.6E+1 - 1.6E+1 0 / 1	5.5E+0 ± 3.5E+1 -3.3E+1 - 3.3E+1 0 / 3
Cs-137	9 0	150	6.4E+0 ± 2.0E+1 -2.1E+1 - 3.0E+1 0 / 6	PlyHrb: 7.4E+0 ± 1.5E+1 -6.2E+0 - 2.6E+1 0 / 4	1.1E+0 ± 1.1E+1 -3.8E+0 - 1.1E+1 0 / 3

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.11-1
Lobster Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2020)

MEDIUM: American Lobster (HA) UNITS: pCi/kg wet

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
K-40	5 0		2.5E+3 ± 5.1E+2 1.9E+3 - 3.0E+3 4 / 4	Dis: 2.5E+3 ± 5.1E+2 1.9E+3 - 3.0E+3 4 / 4	2.0E+3 ± 2.5E+2 2.0E+3 - 2.0E+3 1 / 1
Mn-54	5 0	130	-9.3E+0 ± 1.8E+1 -2.8E+1 - 1.4E+1 0 / 4	CCBay: 6.4E+0 ± 1.2E+1 6.4E+0 - 6.4E+0 0 / 1	6.4E+0 ± 1.2E+1 6.4E+0 - 6.4E+0 0 / 1
Fe-59	5 0	260	-2.0E+1 ± 3.0E+1 -5.0E+1 - 1.5E+1 0 / 4	CcBay:1.3E+1 ± 2.0E+1 1.3E+1 - 1.3E+1 0 / 1	1.3E+1 ± 2.0E+1 1.3E+1 - 1.3E+1 0 / 1
Co-58	5 0	130	1.5E+1 ± 1.7E+1 5.0E-1 - 3.8E+1 0 / 4	Dis: 1.5E+1 ± 1.7E+1 5.0E-1 - 3.8E+1 0 / 4	-3.8E+0 ± 1.1E+1 -3.8E+0 - -3.8E+0 0 / 1
Co-60	5 0	130	1.0E+1 ± 1.8E+1 -6.7E+0 - 3.2E+1 0 / 4	Dis: 1.0E+1 ± 1.8E+1 -6.7E+0 - 3.2E+1 0 / 4	-2.8E+1 ± 1.4E+1 -2.8E+1 - -2.8E+1 0 / 1
Zn-65	5 0	260	-5.1E+1 ± 3.7E+1 -1.0E+2 - -2.8E+1 0 / 4	Dis: -5.1E+1 ± 3.7E+1 -1.0E+2 - -2.8E+1 0 / 4	-7.0E+1 ± 2.4E+1 -7.0E+1 - -7.0E+1 0 / 1
Cs-134	5 0	130	8.3E-1 ± 2.1E+1 -2.6E+1 - 2.0E+1 0 / 4	CCBay: 2.4E+0 ± 1.1E+1 2.4E+0 - 2.4E+0 0 / 1	2.4E+0 ± 1.1E+1 2.4E+0 - 2.4E+0 0 / 1
Cs-137	5 0	150	-8.4E+0 ± 1.9E+1 -3.3E+1 - 1.0E+1 0 / 4	CCBay: 3.2E+1 ± 1.1E+1 3.2E+1 - 3.2E+1 0 / 1	3.2E+1 ± 1.1E+1 3.2E+1 - 3.2E+1 0 / 1

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Table 2.12-1
Fish Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2020)

MEDIUM: Fish (FH)   UNITS: pCi/kg wet

Radionuclide	No. Analyses Non-routine*	Required LLD	Indicator Stations Mean ± Std.Dev. Range Fraction>LLD	Station with Highest Mean Station: Mean ± Std.Dev. Range Fraction>LLD	Control Stations Mean ± Std.Dev. Range Fraction>LLD
K-40	8 0		3.0E+3 ± 6.1E+2 2.5E+3 - 3.5E+3 4 / 4	CCBay: 3.5E+3 ± 8.8E+2 2.9E+3 - 4.1E+3 2 / 2	3.5E+3 ± 5.9E+2 2.9E+3 - 4.1E+3 4 / 4
Mn-54	8 0	130	-4.8E+0 ± 1.5E+1 -2.4E+1 - 5.5E+0 0 / 4	CCBay: -2.9E+0 ± 2.0E+1 -1.6E+1 - 1.0E+1 0 / 2	-4.8E+0 ± 1.4E+1 -1.6E+1 - 1.0E+1 0 / 4
Fe-59	8 0	260	-2.9E+1 ± 2.2E+1 -3.9E+1 - -2.6E+0 0 / 4	BuzBay: 2.5E+1 ± 7.6E+1 -2.7E+1 - 7.7E+1 0 / 2	2.5E+0 ± 5.3E+1 -3.6E+1 - 7.7E+1 0 / 4
Co-58	8 0	130	-8.0E+0 ± 2.4E+1 -4.1E+1 - 8.2E+0 0 / 4	BuzBay: 2.3E+0 ± 1.3E+1 -4.7E+0 - 9.2E+0 0 / 2	-1.6E+0 ± 1.2E+1 -1.5E+1 - 9.2E+0 0 / 4
Co-60	8 0	130	-5.9E+0 ± 8.1E+0 -9.7E+0 - -3.1E-1 0 / 4	CCBay: 1.6E+1 ± 1.1E+1 1.0E+1 - 2.2E+1 0 / 2	4.4E+0 ± 1.7E+1 -1.6E+1 - 2.2E+1 0 / 4
Zn-65	8 0	260	-6.0E+1 ± 4.0E+1 -1.1E+2 - -1.8E+1 0 / 4	Buzbay: 2.4E+1 ± 4.7E+1 -6.1E+0 - 5.4E+1 0 / 2	1.6E+0 ± 3.8E+1 -2.8E+1 - 5.4E+1 0 / 4
Cs-134	8 0	130	-9.8E+0 ± 2.8E+1 -2.8E+1 - 3.0E+1 0 / 4	Buzbay: 1.4E+1 ± 2.2E+1 6.1E-1 - 2.8E+1 0 / 2	7.7E+0 ± 1.9E+1 -1.3E+1 - 2.8E+1 0 / 4
Cs-137	8 0	150	-2.7E+0 ± 1.7E+1 -1.4E+1 - 2.0E+1 0 / 4	Dis: -2.7E+0 ± 1.7E+1 -1.4E+1 - 2.0E+1 0 / 4	-3.4E+0 ± 1.6E+1 -1.9E+1 - 1.3E+1 0 / 4

* Non-Routine refers to those radionuclides that exceeded the Reporting Levels in ODCM Table 3.5-4.

Figure 2.2-1

Environmental TLD Locations Within the PNPS Protected Area

TLD Station		Location*
Description	Code	Distance/Direction
<u>TLDs Within Protected Area</u>		
FENCE-R SCREENHOUSE	P04	66 m N
EXEC.BUILDING LAWN	P25	76 m WNW
FENCE-WATER TANK	P05	81 m NNE
FENCE-OIL STORAGE	P06	85 m NE
COMPRESSED GAS STOR	P08	92 m E
FENCE-L SCREENHOUSE	P03	100 m NW
FENCE-EXEC.BUILDING	P17	107 m W
FENCE-INTAKE BAY	P07	121 m SSE
FENCE-WAREHOUSE	P26	134 m ESE
FENCE-SHOREFRONT	P02	135 m NW
FENCE-W BOAT RAMP	P09	136 m E
FENCE-W SWITCHYARD	P16	172 m SW
FENCE-TCF GATE	P11	183 m ESE
FENCE-TCF/BOAT RAMP	P27	185 m ESE
FENCE-ACCESS GATE	P12	202 m SE
FENCE-E SWITCHYARD	P15	220 m S
FENCE-TCF/INTAKE BAY	P10	223 m E
FENCE-MEDICAL BLDG.	P13	224 m SSE
FENCE-BUTLER BLDG	P14	228 m S

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.

Figure 2.2-1 (continued)
Environmental TLD Locations Within the PNPS Protected Area

Figure 2.2-2

TLD and Air Sampling Locations: Within 1 Kilometer

TLD Station		Location*	Air Sampling Station		Location*
Description	Code	Distance/Direction	Description	Code	Distance/Direction
Zone 1 TLDs: 0-3 km					
BOAT LAUNCH WEST	BLW	0.11 km E	OVERLOOK AREA	OA	0.15 km W
OVERLOOK AREA	OA	0.15 km W	PEDESTRIAN BRIDGE	PB	0.21 km N
HEALTH CLUB	TC	0.15 km WSW	MEDICAL BUILDING	WS	0.23 km SSE
BOAT LAUNCH EAST	BLE	0.16 km ESE	EAST BREAKWATER	EB	0.44 km ESE
ISFSI DOSE #3	ISF-3	0.21 km W	PROPERTY LINE	PL	0.54 km NNW
SHOREFRONT SECURITY	P01	0.22 km NNW	W ROCKY HILL ROAD	WR	0.83 km WNW
MEDICAL BUILDING	WS	0.23 km SSE	E ROCKY HILL ROAD	ER	0.89 km SE
ISFSI DOSE #2	ISF-2	0.29 km W			
ISFSI DOSE #1	ISF-1	0.35 km SW			
SHOREFRONT PARKING	PA	0.35 km NNW			
STATION A	A	0.37 km WSW			
STATION B	B	0.44 km S			
EAST BREAKWATER	EB	0.44 km ESE			
PNPS MET TOWER	PMT	0.44 km WNW			
STATION L	L	0.50 km ESE			
STATION G	G	0.53 km W			
PROPERTY LINE	PL	0.54 km NNW			
HALL'S BOG	HB	0.63 km SE			
GREENWOOD HOUSE	GH	0.65 km ESE			
W ROCKY HILL ROAD	WR	0.83 km WNW			
E ROCKY HILL ROAD	ER	0.89 km SE			

Figure 2.2-2 (continued)

TLD and Air Sampling Locations: Within 1 Kilometer

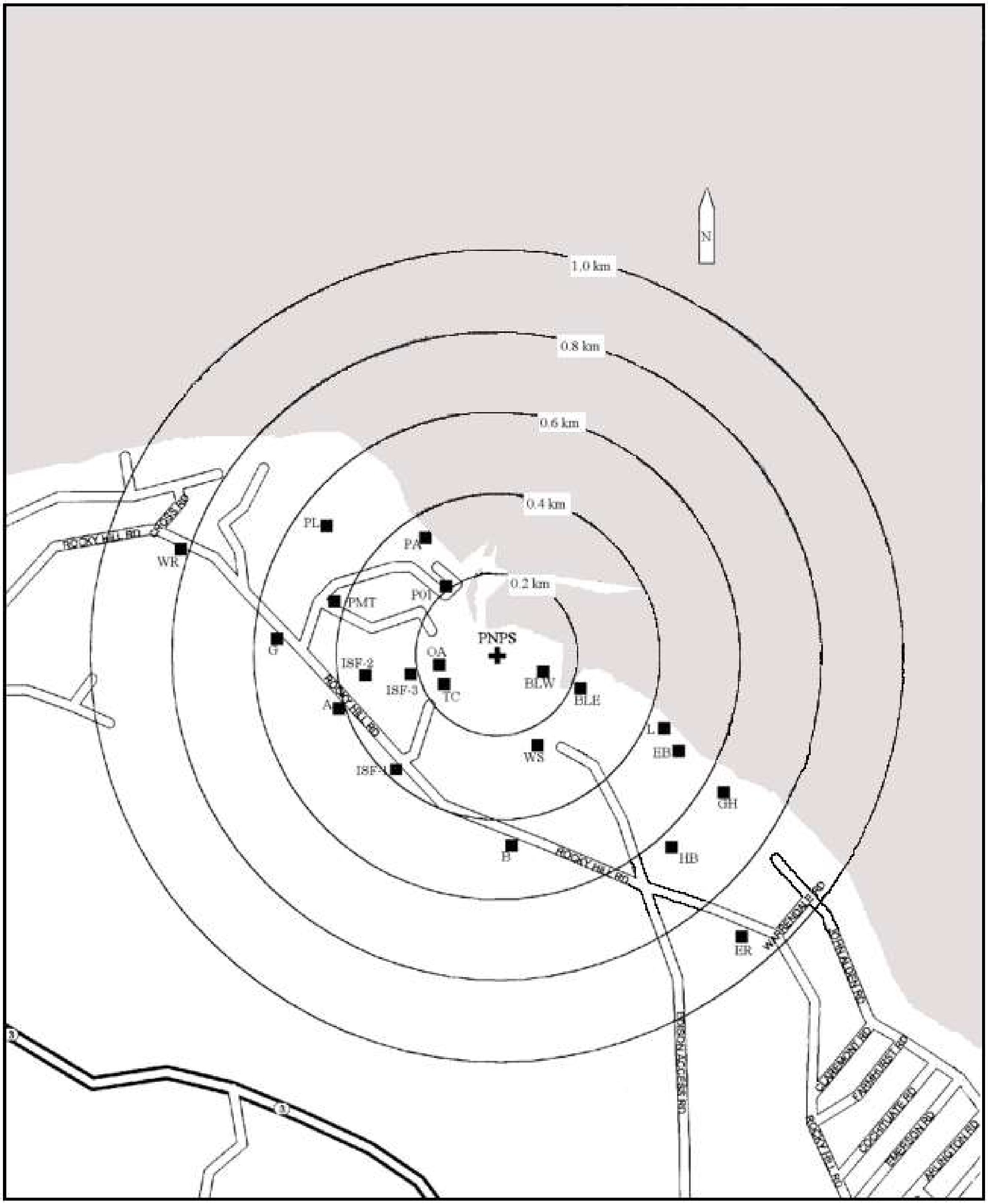


Figure 2.2-3

TLD and Air Sampling Locations: 1 to 5 Kilometers

TLD Station		Location*	Air Sampling Station		Location*
Description	Code	Distance/Direction	Description	Code	Distance/Direction
Zone 1 TLDs: 0-3 km					
CLEFT ROCK	CR	1.27 km SSW	CLEFT ROCK	CR	1.27 km SSW
BAYSHORE/GATE RD	BD	1.34 km WNW	MANOMET SUBSTATION	MS	3.60 km SSE
EMERSON ROAD	EM	1.53 km SSE			
EMERSON/PRISCILLA	EP	1.55 km SE			
BAYSHORE	BS	1.76 km W			
JOHN GAULEY	JG	1.99 km W			
STATION J	J	2.04 km SSE			
PLYMOUTH YMCA	RC	2.09 km WSW			
TAYLOR/THOMAS	TT	2.26 km SE			
YANKEE VILLAGE	YV	2.28 km WSW			
GOODWIN PROPERTY	GN	2.38 km SW			
RIGHT OF WAY	RW	2.83 km S			
TAYLOR/PEARL	TP	2.98 km SE			
Zone 2 TLDs: 3-8 km					
MANOMET ELEM	ME	3.29 km SE			
MANOMET SUBSTATION	MS	3.60 km SSE			
PINES ESTATE	PT	4.44 km SSW			
RUSSELL MILLS RD	RM	4.85 km WSW			

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.

Figure 2.2-3 (continued)

TLD and Air Sampling Locations: 1 to 5 Kilometers

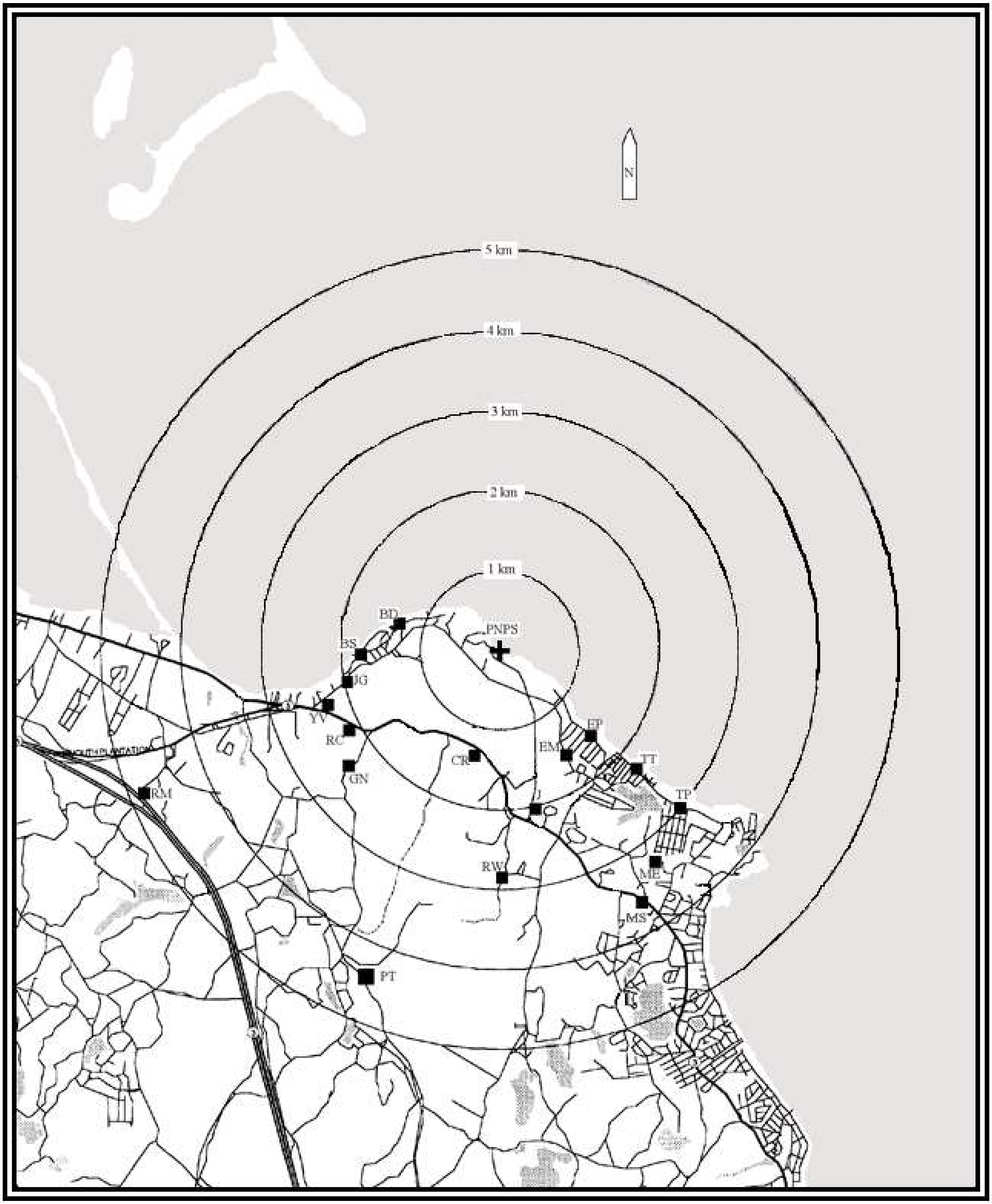


Figure 2.2-4

TLD and Air Sampling Locations: 5 to 25 Kilometers

TLD Station		Location*	Air Sampling Station		Location*
Description	Code	Distance/Direction	Description	Code	Distance/Direction
Zone 2 TLDs: 3-8 km					
MANOMET BEACH	MB	5.43 km SSE	PLYMOUTH CENTER	PC	6.69 km W
BEAVER DAM ROAD	BR	5.52 km S			
PLYMOUTH CENTER	PC	6.69 km W			
LONG POND/DREW RD	LD	6.97 km WSW			
HYANNIS ROAD	HR	7.33 km SSE			
MEMORIAL HALL	MH	7.58 km WNW			
COLLEGE POND	CP	7.59 km SW			
Zone 3 TLDs: 8-15 km					
DEEP WATER POND	DW	8.59 km W			
LONG POND ROAD	LP	8.88 km SSW			
NORTH PLYMOUTH	NP	9.38 km WNW			
SACRED HEART	SH	12.92 km W			
Zone 4 TLDs: >15 km					
DIV MARINE FISH	DMF	20.97 km SSE			

* Distance and direction are measured from centerline of Reactor Building to the monitoring location.

Figure 2.2-4 (continued)

TLD and Air Sampling Locations: 5 to 25 Kilometers

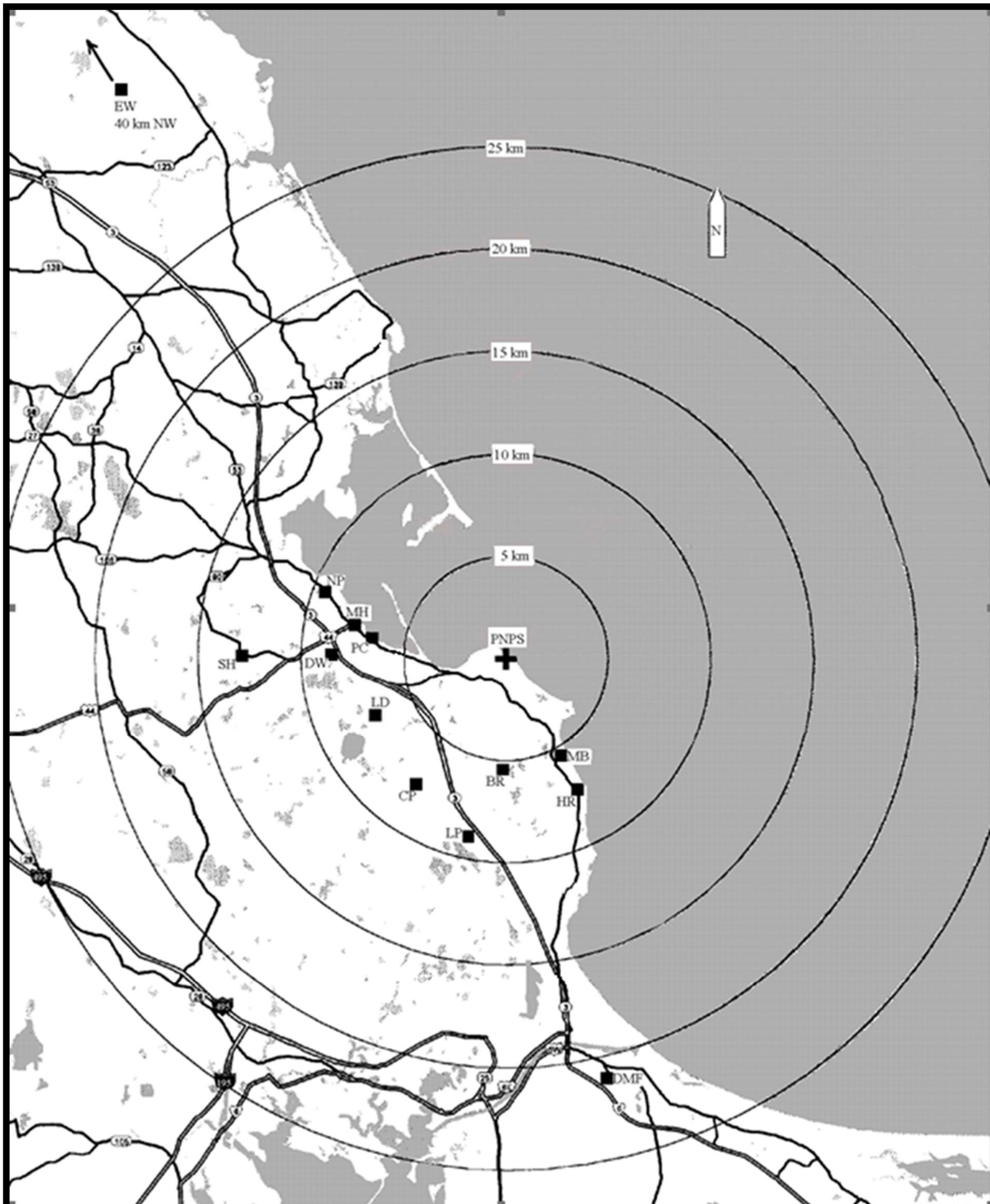


Figure 2.2-5

Terrestrial and Aquatic Sampling Locations

Description	Code	Distance/Direction*	Description	Code	Distance/Direction*
			SURFACE WATER		
VEGETABLES/VEGETATION			Discharge Canal	DIS	0.2 km N
Plymouth County Farm	CF	5.6 km W	Powder Point Control	PP	13 km NNW
Hanson Farm Control	HN	34 km W			
			SEDIMENT		
			Discharge Canal Outfall	DIS	0.8 km NE
			Plymouth Beach	PLB	4.0 km W
			Manomet Point	MP	3.3 km ESE
			Plymouth Harbor	PLY-H	4.1 km W
			Green Harbor Control	GH	16 km NNW
			SHELLFISH		
			Discharge Canal Outfall	DIS	0.7 km NNE
			Plymouth Harbor	PLY-H	4.1 km W
			Manomet Point	MP	4.0 km ESE
			Duxbury Bay Control	DUX-BAY	13 km NNW
			Green Harbor Control	GH	16 km NNW
			LOBSTER		
			Discharge Canal Outfall	DIS	0.5 km N
			Duxbury Bay Control	DUX-BAY	11 km NNW
			FISHES		
			Discharge Canal Outfall	DIS	0.5 km N
			Cape Cod Bay Control	CC-BAY	24 km ESE
			Buzzards Bay Control	BB	40 km SSW
			Vineyard Sound Control	MV	64 km SSW

* Distance and direction are measured from the centerline of the reactor to the sampling/monitoring location.

Figure 2.2-5 (continued)

Terrestrial and Aquatic Sampling Locations

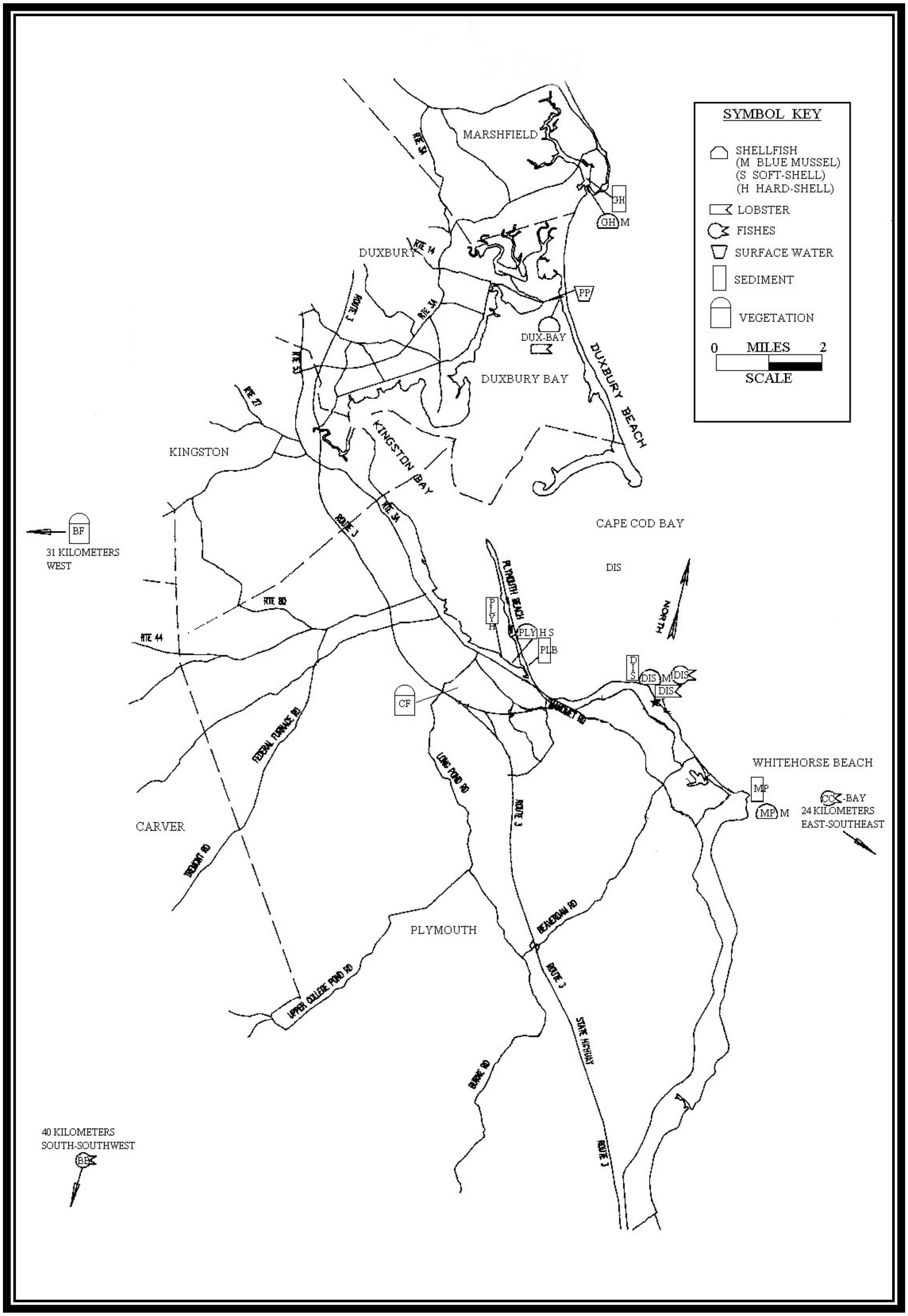


Figure 2.2-6

Environmental Sampling And Measurement Control Locations

Description	Code	Distance/Direction*	Description	Code	Distance/Direction*
TLD			SURFACE WATER		
Div. Marine Fisheries	DMF	21 km SSE	Powder Point Control	PP	13 km NNW
East Weymouth Substation	EW	40 km NW			
			SEDIMENT		
AIR SAMPLER			Green Harbor Control	GH	16 km NNW
East Weymouth Substation	EW	40 km NW			
			SHELLFISH		
VEGETABLES/VEGETATION			Duxbury Bay Control	DUX-BAY	13 km NNW
Bridgewater Control	BF	31 km W	Green Harbor Control	GH	16 km NNW
			LOBSTER		
			Duxbury Bay Control	DUX-BAY	11 km NNW
			FISHES		
			Cape Cod Bay Control	CC-BAY	24 km ESE
			Buzzards Bay Control	BB	40 km SSW
			Vineyard Sound Control	MV	64 km SSW

* Distance and direction are measured from the centerline of the reactor to the sampling/monitoring location.

Figure 2.2-6 (continued)

Environmental Sampling And Measurement Control Locations

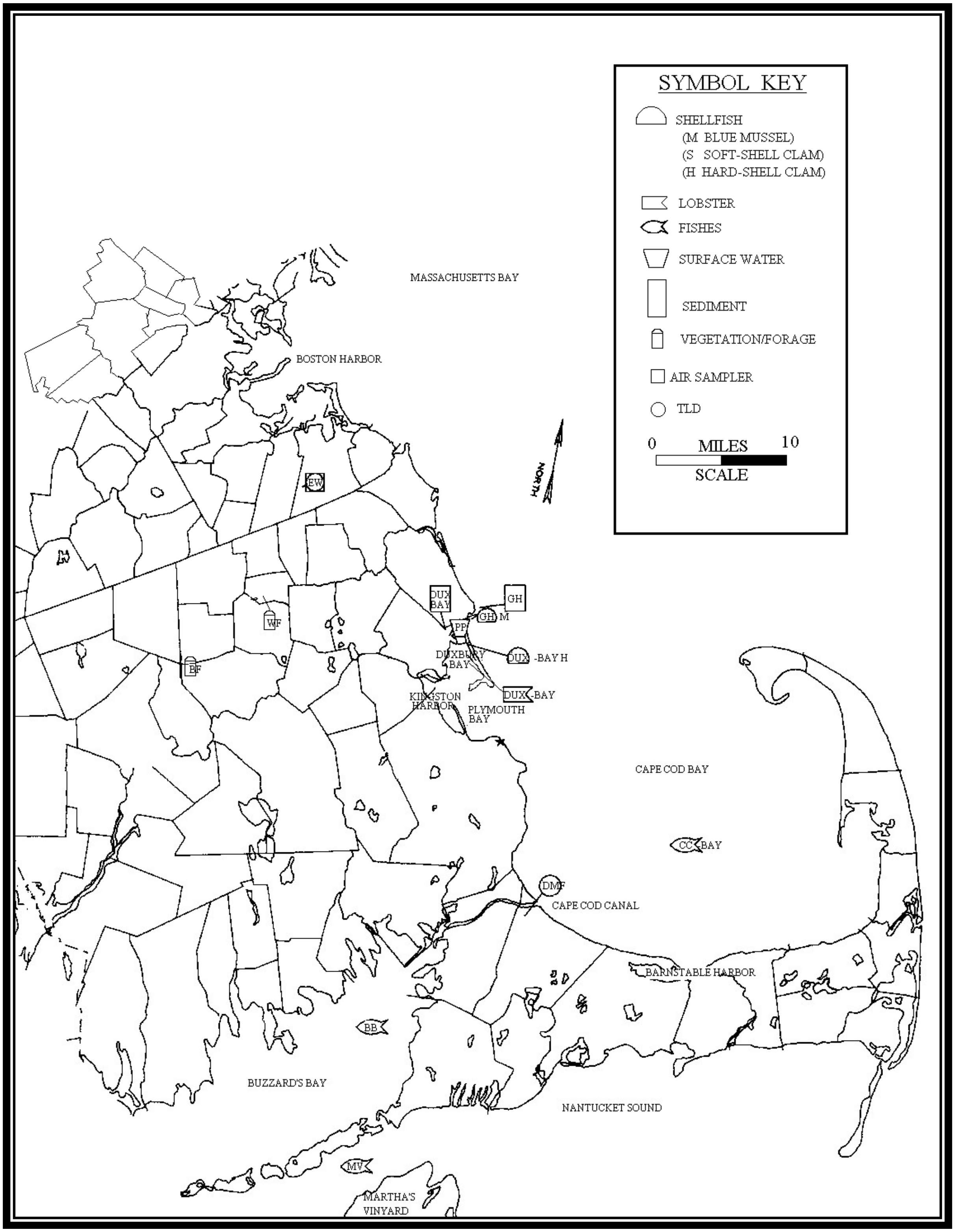


Figure 2.5-1
Airborne Gross-Beta Radioactivity Levels: Near Station Monitors

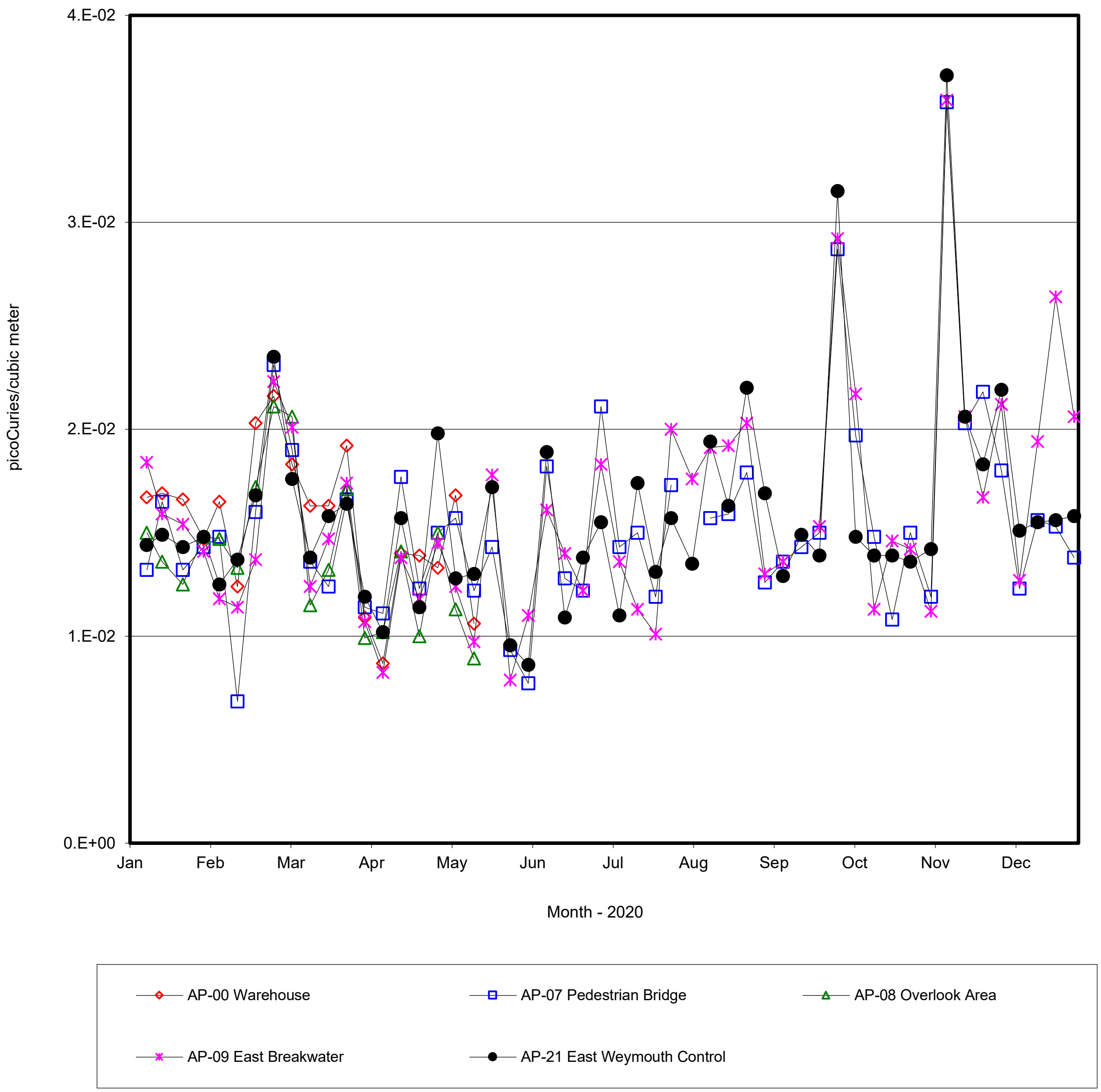


Figure 2.5-2
Airborne Gross-Beta Radioactivity Levels: Property Line Monitors

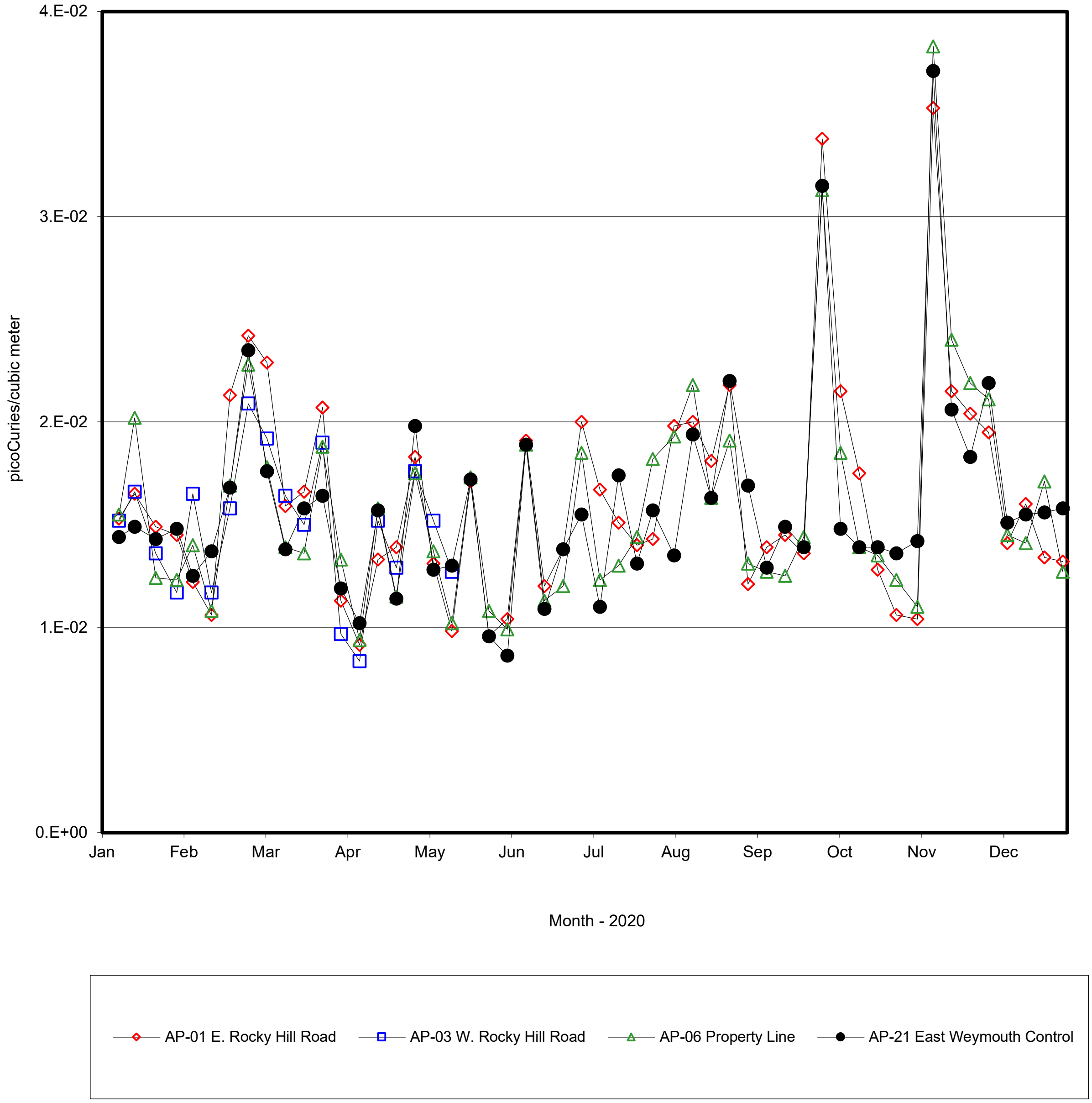
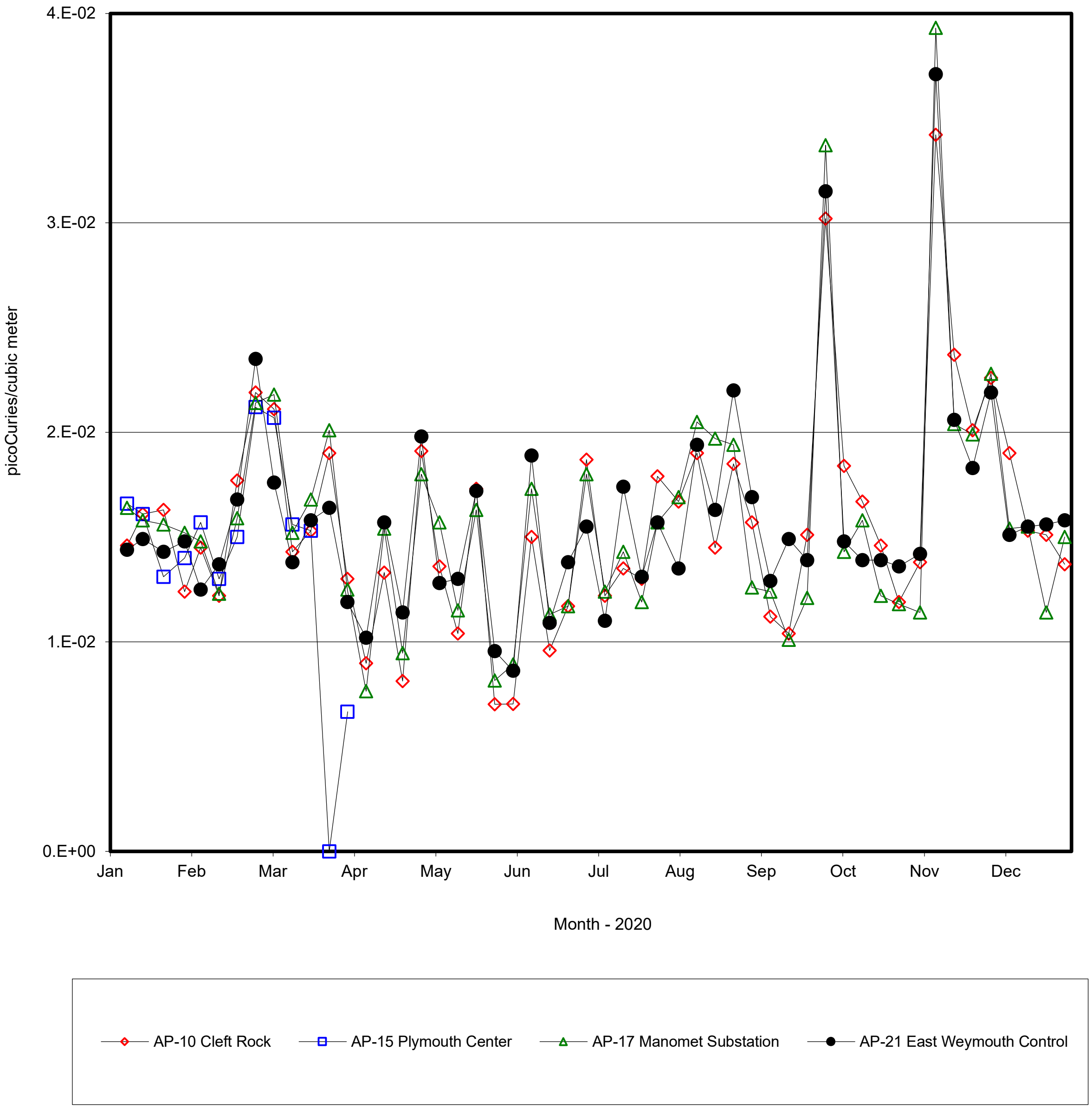


Figure 2.5-3
Airborne Gross-Beta Radioactivity Levels: Offsite Monitors



* Plymouth Center collection was discontinued after building was closed due to COVID-19 restrictions blocking access to the air sampler. Dip in sample results reflects sampling difficulties.

3.0 SUMMARY OF RADIOLOGICAL IMPACT ON HUMANS

The radiological impact to humans from the Pilgrim Station's radioactive liquid and gaseous releases has been estimated using two methods:

- calculations based on measurements of plant effluents; and
- calculations based on measurements of environmental samples.

The first method utilizes data from the radioactive effluents (measured at the point of release) together with conservative models that calculate the dispersion and transport of radioactivity through the environment to humans (Reference 7). The second method is based on actual measurements of radioactivity in the environmental samples and on dose conversion factors recommended by the Nuclear Regulatory Commission. The measured types and quantities of radioactive liquid and gaseous effluents released from Pilgrim Station during 2020 were reported to the Nuclear Regulatory Commission, copies of which are provided in Appendix B. The measured levels of radioactivity in the environmental samples that required dose calculations are listed in Appendix A.

The maximum individual dose from liquid effluents was calculated using the following radiation exposure pathways:

- shoreline external radiation during fishing and recreation at the Pilgrim Station Shorefront;
- external radiation from the ocean during boating and swimming; and
- ingestion of fish and shellfish.

For gaseous effluents, the maximum individual dose was calculated using the following radiation exposure pathways:

- external radiation from cloud shine and submersion in gaseous effluents;
- inhalation of airborne radioactivity;
- external radiation from soil deposition;
- consumption of vegetables; and
- consumption of milk and meat.

The results from the dose calculations based on PNPS operations are presented in Table 3.0-1. The dose assessment data presented were taken from the "Radioactive Effluent Release Report" for the period of January 1 through December 31, 2020 (Reference 17).

Table 3.0-1

Radiation Doses from 2020 Pilgrim Station Operations

	Maximum Individual Dose From Exposure Pathway - mrem/yr			
Receptor	Gaseous Effluents*	Liquid Effluents	Ambient Radiation**	Total
Total Body	0.00022	N/A	0.14	0.14
Thyroid	0.00015	N/A	0.14	0.14
Max. Organ	0.00022	N/A	0.14	0.14

* Gaseous effluent exposure pathway includes combined dose from particulates and tritium in addition to noble gases, calculated at the nearest residence or receptor location yielding the highest projected dose from all exposure pathways.

** Ambient radiation dose for the hypothetical maximum-exposed individual at a location beyond the PNPS owner-controlled area yielding highest ambient radiation exposure value as measured with TLDs.

Two federal agencies establish dose limits to protect the public from radiation and radioactivity. The Nuclear Regulatory Commission (NRC) specifies a whole body dose limit of 100 mrem/yr to be received by the maximum exposed member of the general public. This limit is set forth in Section 1301, Part 20, Title 10, of the U.S. Code of Federal Regulations (10CFR20). By comparison, the Environmental Protection Agency (EPA) limits the annual whole body dose to 25 mrem/yr, which is specified in Section 10, Part 190, Title 40, of the Code of Federal Regulations (40CFR190).

Another useful "gauge" of radiation exposure is provided by the amount of dose a typical individual receives each year from natural and man-made sources of radiation. Such radiation doses are summarized in Table 1.2-1. The typical American receives approximately 620 mrem/yr from such sources.

As can be seen from the doses resulting from Pilgrim Station Operations during 2020, all values are well within the federal limits specified by the NRC and EPA. In addition, the calculated doses from PNPS operation represent only a fraction of a percent of doses from natural and man-made radiation.

In conclusion, the radiological impact of Pilgrim Station operations, whether based on actual environmental measurements or calculations made from effluent releases, would yield doses well within any federal dose limits set by the NRC or EPA. Such doses represent only a small percentage of the typical annual dose received from natural and man-made sources of radiation.

4.0 REFERENCES

1) United States of America, Code of Federal Regulations, Title 10, Part 50, Appendix A Criteria 64.

2) Donald T. Oakley, "Natural Radiation Exposure in the United States." U. S. Environmental Protection Agency, ORP/SID 72-1, June 1972.

3) National Council on Radiation Protection and Measurements, Report No. 93, "Ionizing Radiation Exposures of the Population of the United States," September 1987.

4) United States Nuclear Regulatory Commission, Regulatory Guide 8.29, "Instructions Concerning Risks from Occupational Radiation Exposure," Revision 0, July 1981.

5) Boston Edison Company, "Pilgrim Station" Public Information Brochure 100M, WNTHP, September 1989.

6) United States Nuclear Regulatory Commission, Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Revision 1, October 1977.

7) Pilgrim Nuclear Power Station Offsite Dose Calculation Manual, Revision 13, November 2019.

8) United States of America, Code of Federal Regulations, Title 10, Part 20.1301.

9) United States of America, Code of Federal Regulations, Title 10, Part 50, Appendix I.

10) United States of America, Code of Federal Regulations, Title 40, Part 190.

11) United States Nuclear Regulatory Commission, Regulatory Guide 4.1, "Program for Monitoring Radioactivity in the Environs of Nuclear Power Plants," Revision 1, April 1975.

12) ICN/Tracerlab, "Pilgrim Nuclear Power Station Pre-operational Environmental Radiation Survey Program, Quarterly Reports," August 1968 to June 1972.

13) International Commission of Radiological Protection, Publication No. 43, "Principles of Monitoring for the Radiation Protection of the Population," May 1984.

14) United States Nuclear Regulatory Commission, NUREG-1302, "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling Water Reactors," April 1991.

15) United States Nuclear Regulatory Commission, Branch Technical Position, "An Acceptable Radiological Environmental Monitoring Program," Revision 1, November 1979.

16) Settlement Agreement Between Massachusetts Wildlife Federation and Boston Edison Company Relating to Offsite Radiological Monitoring - June 9, 1977.

17) Pilgrim Nuclear Power Station, “Annual Radioactive Effluent Release Report”, May 2020.

APPENDIX A

SPECIAL STUDIES

There were no environmental samples collected during 2020 that contained plant-related radioactivity. Therefore, no special studies were required to estimate dose from plant-related radioactivity.

APPENDIX B

Effluent Release Information

Table B.1
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Supplemental Information
January-December 2020

FACILITY: PILGRIM NUCLEAR POWER STATION **LICENSE: DPR-35**

1. REGULATORY LIMITS	
a. Fission and activation gases:	500 mrem/yr total body and 3000 mrem/yr for skin at site boundary
b,c. particulates with half-life: >8 days, tritium	1500 mrem/yr to any organ at site boundary
d. Liquid effluents:	0.06 mrem/month for whole body and 0.2 mrem/month for any organ (without radwaste treatment)
2. EFFLUENT CONCENTRATION LIMITS	
a. Fission and activation gases:	10CFR20 Appendix B Table II
b. Iodines:	10CFR20 Appendix B Table II
c. Particulates with half-life > 8 days:	10CFR20 Appendix B Table II
d. Liquid effluents:	2E-04 μCi/mL for entrained noble gases; 10CFR20 Appendix B Table II values for all other radionuclides
3. AVERAGE ENERGY	Not Applicable
4. MEASUREMENTS AND APPROXIMATIONS OF TOTAL RADIOACTIVITY	
a. Fission and activation gases:	High purity germanium gamma spectroscopy for all gamma emitters; radiochemistry analysis for H-3, Fe-55 (liquid effluents), Sr-89, and Sr-90
b. Iodines:	
c. Particulates:	
d. Liquid effluents:	

5. BATCH RELEASES	Jan-Mar 2020	Apr-Jun 2020	Jul-Sep 2020	Oct-Dec 2020	Jan-Dec 2020
a. Liquid Effluents					
1. Total number of releases:	N/A	N/A	N/A	N/A	N/A
2. Total time period (minutes):	N/A	N/A	N/A	N/A	N/A
3. Maximum time period (minutes):	N/A	N/A	N/A	N/A	N/A
4. Average time period (minutes):	N/A	N/A	N/A	N/A	N/A
5. Minimum time period (minutes):	N/A	N/A	N/A	N/A	N/A
6. Average stream flow during periods of release of effluents into a flowing stream (Liters/min):	N/A	N/A	N/A	N/A	N/A
b. Gaseous Effluents	None	None	None	None	None
6. ABNORMAL RELEASES					
a. Liquid Effluents	None	None	None	None	None
b. Gaseous Effluents	None	None	None	None	None

Table B.2-A
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents - Summation of All Releases
January-December 2020

RELEASE PERIOD	Jan-Mar 2020	Apr-Jun 2020	Jul-Sep 2020	Oct-Dec 2020	Jan-Dec 2020	Est. Total Error
A. FISSION AND ACTIVATION GASES						
Total Release: Ci	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	±22%
Average Release Rate: μCi/sec	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Percent of Effluent Control Limit*	*	*	*	*	*	
B. IODINE-131						
Total Iodine-131 Release: Ci	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	±20%
Average Release Rate: μCi/sec	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Percent of Effluent Control Limit*	*	*	*	*	*	
C. PARTICULATES WITH HALF-LIVES > 8 DAYS						
Total Release: Ci	0.00E+00	0.00E+00	0.00E+00	1.87E-06	1.87E-06	±21%
Average Release Rate: μCi/sec	0.00E+00	0.00E+00	0.00E+00	2.37E-07	5.93E-08	
Percent of Effluent Control Limit*	*	*	*	*	*	
Gross Alpha Radioactivity: Ci	NDA	NDA	NDA	NDA	NDA	
D. TRITIUM						
Total Release: Ci	2.55E+00	1.84E+00	1.09E+00	2.21E+00	7.69E+00	±20%
Average Release Rate: μCi/sec	3.24E-01	2.33E-01	1.38E-01	2.81E-01	2.44E-01	
Percent of Effluent Control Limit*	*	*	*	*	*	
E. CARBON-14						
Total Release: Ci	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Average Release Rate: μCi/sec	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Percent of Effluent Control Limit*	*	*	*	*	*	

Notes for Table B.2-A:

* Percent of Effluent Control Limit values based on dose assessments are provided in Section 6 of this report.

1. NDA stands for No Detectable Activity.
2. LLD for airborne gross alpha activity listed as NDA is 1E-11 μCi/cc.
3. N/A stands for not applicable.

Table B.2-B
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents – Elevated Release
January-December 2020

There was no elevated release during 2020. The elevated release through the PNPS Main Stack was secured in 2019 and is no longer a pathway.

Table B.2-C
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents – Ground-Level Release
January-December 2020

CONTINUOUS MODE RELEASES FROM GROUND-LEVEL RELEASE POINT					
Nuclide Released	Jan-Mar 2020	Apr-Jun 2020	Jul-Sep 2020	Oct-Dec 2020	Jan-Dec 2020
1. FISSION AND ACTIVATION GASES: Ci					
Ar-41	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-87	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-131m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total for Period	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2. IODINES: Ci					
I-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total for Period	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3. PARTICULATES WITH HALF-LIVES > 8 DAYS: Ci					
Cr-51	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn-54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-60	0.00E+00	0.00E+00	0.00E+00	1.87E-6	1.87E-6
Zn-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba/La-140	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total for Period	0.00E+00	0.00E+00	0.00E+00	1.87E06	1.87E-6
4. TRITIUM: Ci					
H-3	2.55E+00	1.84E+00	1.09E+00	2.21E+00	7.69E+00
5. CARBON-14: Ci					
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Notes for Table B.2-B:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for airborne radionuclides listed as NDA are as follows:
   Fission Gases: 1E-04 μCi/cc
   Iodines: 1E-12 μCi/cc
   Particulates: 1E-11 μCi/cc

Table B.2-C (continued)
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Gaseous Effluents – Ground-Level Release
January-December 2020

BATCH MODE RELEASES FROM GROUND-LEVEL RELEASE POINT					
Nuclide Released	Jan-Mar 2020	Apr-Jun 2020	Jul-Sep 2020	Oct-Dec 2020	Jan-Dec 2020
1. FISSION AND ACTIVATION GASES: Ci					
Ar-41	N/A	N/A	N/A	N/A	N/A
Kr-85	N/A	N/A	N/A	N/A	N/A
Kr-85m	N/A	N/A	N/A	N/A	N/A
Kr-87	N/A	N/A	N/A	N/A	N/A
Kr-88	N/A	N/A	N/A	N/A	N/A
Xe-131m	N/A	N/A	N/A	N/A	N/A
Xe-133	N/A	N/A	N/A	N/A	N/A
Xe-133m	N/A	N/A	N/A	N/A	N/A
Xe-135	N/A	N/A	N/A	N/A	N/A
Xe-135m	N/A	N/A	N/A	N/A	N/A
Xe-137	N/A	N/A	N/A	N/A	N/A
Xe-138	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
2. IODINES: Ci					
I-131	N/A	N/A	N/A	N/A	N/A
I-133	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
3. PARTICULATES WITH HALF-LIVES > 8 DAYS: Ci					
Cr-51	N/A	N/A	N/A	N/A	N/A
Mn-54	N/A	N/A	N/A	N/A	N/A
Fe-59	N/A	N/A	N/A	N/A	N/A
Co-58	N/A	N/A	N/A	N/A	N/A
Co-60	N/A	N/A	N/A	N/A	N/A
Zn-65	N/A	N/A	N/A	N/A	N/A
Sr-89	N/A	N/A	N/A	N/A	N/A
Sr-90	N/A	N/A	N/A	N/A	N/A
Ru-103	N/A	N/A	N/A	N/A	N/A
Cs-134	N/A	N/A	N/A	N/A	N/A
Cs-137	N/A	N/A	N/A	N/A	N/A
Ba/La-140	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
4. TRITIUM: Ci					
H-3	N/A	N/A	N/A	N/A	N/A
5. CARBON-14: Ci					
C-14	N/A	N/A	N/A	N/A	N/A

Notes for Table B.2-B:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for airborne radionuclides listed as NDA are as follows:
   - Fission Gases: 1E-04 μCi/cc
   - Iodines: 1E-12 μCi/cc
   - Particulates: 1E-11 μCi/cc

Table B.3-A
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Liquid Effluents - Summation of All Releases
January-December 2020

RELEASE PERIOD	Jan-Mar 2020	Apr-Jun 2020	Jul-Sep 2020	Oct-Dec 2020	Jan-Dec 2020	Est. Total Error
A. FISSION AND ACTIVATION PRODUCTS						
Total Release (not including tritium, gases, alpha): Ci	N/A	N/A	N/A	N/A	N/A	
Average Diluted Concentration During Period: µCi/mL	N/A	N/A	N/A	N/A	N/A	±12%
Percent of Effluent Concentration Limit*	N/A	N/A	N/A	N/A	N/A	
B. TRITIUM						
Total Release: Ci	N/A	N/A	N/A	N/A	N/A	
Average Diluted Concentration During Period: µCi/mL	N/A	N/A	N/A	N/A	N/A	±9.4%
Percent of Effluent Concentration Limit*	N/A	N/A	N/A	N/A	N/A	
C. DISSOLVED AND ENTRAINED GASES						
Total Release: Ci	N/A	N/A	N/A	N/A	N/A	
Average Diluted Concentration During Period: µCi/mL	N/A	N/A	N/A	N/A	N/A	±16%
Percent of Effluent Concentration Limit*	N/A	N/A	N/A	N/A	N/A	
D. GROSS ALPHA RADIOACTIVITY						
Total Release: Ci	N/A	N/A	N/A	N/A	N/A	±34%
E. VOLUME OF WASTE RELEASED PRIOR TO DILUTION						
Waste Volume: Liters	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	±5.7%
F. VOLUME OF DILUTION WATER USED DURING PERIOD						
Dilution Volume: Liters	1.32E+09	1.34E+09	1.35E+09	1.35E+09	5.37E+09	±10%

Notes for Table B.3-A:

* Additional percent of Effluent Control Limit values based on dose assessments are provided in Section 6 of this report.

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLD for dissolved and entrained gases listed as NDA is 1E-05 µCi/mL.
4. LLD for liquid gross alpha activity listed as NDA is 1E-07 µCi/mL.

Table B.3-B
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Liquid Effluents
January-December 2020

CONTINUOUS MODE RELEASES					
Nuclide Released	Jan-Mar 2020	Apr-Jun 2020	Jul-Sep 2020	Oct-Dec 2020	Jan-Dec 2020
1. FISSION AND ACTIVATION PRODUCTS: Ci					
Cr-51	N/A	N/A	N/A	N/A	N/A
Mn-54	N/A	N/A	N/A	N/A	N/A
Fe-55	N/A	N/A	N/A	N/A	N/A
Fe-59	N/A	N/A	N/A	N/A	N/A
Co-58	N/A	N/A	N/A	N/A	N/A
Co-60	N/A	N/A	N/A	N/A	N/A
Zn-65	N/A	N/A	N/A	N/A	N/A
Zn-69m	N/A	N/A	N/A	N/A	N/A
Sr-89	N/A	N/A	N/A	N/A	N/A
Sr-90	N/A	N/A	N/A	N/A	N/A
Zr/Nb-95	N/A	N/A	N/A	N/A	N/A
Mo/Tc-99	N/A	N/A	N/A	N/A	N/A
Ag-110m	N/A	N/A	N/A	N/A	N/A
Sb-124	N/A	N/A	N/A	N/A	N/A
I-131	N/A	N/A	N/A	N/A	N/A
I-133	N/A	N/A	N/A	N/A	N/A
Cs-134	N/A	N/A	N/A	N/A	N/A
Cs-137	N/A	N/A	N/A	N/A	N/A
Ba/La-140	N/A	N/A	N/A	N/A	N/A
Ce-141	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
2. DISSOLVED AND ENTRAINED GASES: Ci					
Xe-133	N/A	N/A	N/A	N/A	N/A
Xe-135	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A

Notes for Table B.3-B:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for liquid radionuclides listed as NDA are as follows:
   - Strontium: 5E-08 µCi/mL
   - Iodines: 1E-06 µCi/mL
   - Noble Gases: 1E-05 µCi/mL
   - All Others: 5E-07 µCi/mL

Table B.3-B (continued)
Pilgrim Nuclear Power Station
Annual Radioactive Effluent Release Report
Liquid Effluents
January-December 2020

BATCH MODE RELEASES					
Nuclide Released	Jan-Mar 2020	Apr-Jun 2020	Jul-Sep 2020	Oct-Dec 2020	Jan-Dec 2020
1. FISSION AND ACTIVATION PRODUCTS: Ci					
Na-24	N/A	N/A	N/A	N/A	N/A
Cr-51	N/A	N/A	N/A	N/A	N/A
Mn-54	N/A	N/A	N/A	N/A	N/A
Fe-55	N/A	N/A	N/A	N/A	N/A
Fe-59	N/A	N/A	N/A	N/A	N/A
Co-58	N/A	N/A	N/A	N/A	N/A
Co-60	N/A	N/A	N/A	N/A	N/A
Zn-65	N/A	N/A	N/A	N/A	N/A
Zn-69m	N/A	N/A	N/A	N/A	N/A
Sr-89	N/A	N/A	N/A	N/A	N/A
Sr-90	N/A	N/A	N/A	N/A	N/A
Zr/Nb-95	N/A	N/A	N/A	N/A	N/A
Mo/Tc-99	N/A	N/A	N/A	N/A	N/A
Ag-110m	N/A	N/A	N/A	N/A	N/A
Sb-124	N/A	N/A	N/A	N/A	N/A
I-131	N/A	N/A	N/A	N/A	N/A
I-133	N/A	N/A	N/A	N/A	N/A
Cs-134	N/A	N/A	N/A	N/A	N/A
Cs-137	N/A	N/A	N/A	N/A	N/A
Ba/La-140	N/A	N/A	N/A	N/A	N/A
Ce-141	N/A	N/A	N/A	N/A	N/A
Ce-144	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A
2. DISSOLVED AND ENTRAINED GASES: Ci					
Xe-133	N/A	N/A	N/A	N/A	N/A
Xe-135	N/A	N/A	N/A	N/A	N/A
Total for period	N/A	N/A	N/A	N/A	N/A

Notes for Table B.3-B:

1. N/A stands for not applicable.
2. NDA stands for No Detectable Activity.
3. LLDs for liquid radionuclides listed as NDA are as follows:
   - Strontium: 5E-08 μCi/mL
   - Iodines: 1E-06 μCi/mL
   - Noble Gases: 1E-05 μCi/mL
   - All Others: 5E-07 μCi/mL

APPENDIX C

LAND USE CENSUS RESULTS

The annual land use census for gardens and milk and meat animals in the vicinity of Pilgrim Station was performed on June 25th to July 20th, 2020. The census was conducted by driving along each improved road/street in the Plymouth area within 5 kilometers (3 miles) of Pilgrim Station to survey for visible gardens with an area of greater than 500 square feet. In compass sectors where no gardens were identified within 5 km, the survey was extended to 8 km (5 mi). A total of 21 gardens were identified in the vicinity of Pilgrim Station. In addition, the Town of Plymouth Animal Inspector was contacted for information regarding milk and meat animals.

Atmospheric deposition (D/Q) values at the locations of the identified gardens were compared to those for the existing sampling program locations. These comparisons enabled PNPS personnel to ascertain the best locations for monitoring for releases of airborne radionuclides. Samples of naturally-growing vegetation were collected at the site boundary in the ESE and SE sectors to monitor for atmospheric deposition in the vicinity of the nearest resident in the SE sector.

In addition to these special sampling locations identified and sampled in conjunction with the 2020 land use census, samples were also collected from control locations in Bridgewater (31 km W) and Sandwich (21 km SSE).

Samples of naturally-growing vegetation were also collected in the vicinity of the site boundary locations yielding the highest deposition (D/Q) factors for each of the two release points. These locations, and their distance and direction relative to the PNPS Reactor Building, are as follows:

Highest Reactor Building Vent D/Q:	0.6 km SE
2nd highest D/Q, both release points:	1.1 km S

No new milk or meat animals were identified during the land use census. In addition, the Town of Plymouth Animal Inspector stated that their office is not aware of any animals at locations other than the Plimoth Plantation. Although milk sampling is not performed at Plimoth Plantation, effluent dose calculations are performed for this location assuming the presence of a milk ingestion pathway, as part of the Annual Radioactive Effluent Release Report (Reference 17).

APPENDIX D

ENVIRONMENTAL MONITORING PROGRAM DISCREPANCIES

There were a number of instances during 2020 in which inadvertent issues were encountered in the collection of environmental samples. All of these issues were minor in nature and did not have an adverse effect on the results or integrity of the monitoring program. The PNPS TLD placement still far exceeds that prescribed by NUREG-1302. Details of these various problems are given below.

Within the air sampling program, there were a few instances in which continuous sampling was interrupted at the seven airborne sampling locations during 2020. Most of these interruptions were due to short-term power losses and were sporadic and of limited duration (less than 24 hours out of the weekly sampling period). Such events did not have any significant impact on the scope and purpose of the sampling program, and lower limits of detection (LLDs) were met for both airborne particulates on 433 filters collected. In the fourth quarter of 2019, following the permanent shutdown of the station, the use of charcoal cartridges was discontinued as iodine had decayed away.

Out of 440 filters (7 locations * 52 weeks and 4 locations *19 weeks), 433 samples were collected and analyzed during 2020. In accordance with ODCM Table 3.5-1, offsite REMP air particulate filters are to be collected at a weekly interval. Weekly is defined as once every seven days with a one-day grace period before and after the scheduled date. occasionally samples are collected with a longer than seven day interval due to access (especially in the winter) or someother issue. It must be emphasized that the station continued to sample during the duration and no monitoring time was lost.

The configuration of air samplers that had been in use at Pilgrim Station since the early 1980s, was replaced between June and August of 2012. Both the pumps and dry gas meters were replaced, and operating experience since changing over to the new configuration has been favorable. Although the occurrence of pump failures and gas meter problems have been largely eliminated, the new configuration is still subject to trips of the ground fault interrupt circuit (GFCI). Such problems can be encountered at air samplers located at the East Breakwater and Pedestrian Bridge. Both of these locations are immediately adjacent to the shoreline and are subject to significant wind-blown salt water, and are prone to tripping of the GFCI. The following table contains a listing of problems encountered with air sampling stations during 2020, many of which resulted in loss of more than 24 hours during the sampling period. All problems were rectified by a ground fault reset or minor maintenance.

Location	Sampling Period	Sampling Hours Lost	Problem Description/Resolution
PB	7/27-8/4	190	Ground Fault Circuit Interrupt (GFCI) tripped LLDs not Met due to low volume (IR-1915)
CR	4/7-4/14 11/24-12-1	18 198	Volume enough to meet LLDs Ground Fault Circuit Interrupt (GFCI) tripped LLDs not Met due to low volume (IR-2397)
WR	4/21-4/28	168	Loss of power to sample station
EB	9/8-9/15 12/2-12/8 12/15-12-29	146 168 336	Ground Fault Circuit Interrupt (GFCI) tripped sample volume insufficient to meet LLDs Power supply removed. Temp supply installed (IR-2512)
PC	3/17-3/31	No hours lost	2 week sample. No access to sample location

Despite the lower-than-normal sampling volumes in the various instances involving power interruptions and equipment failures, required LLDs were met on 433 of the 440 particulate filters during 2020. When viewed collectively during the entire year of 2020, the following sampling recoveries were achieved in the airborne sampling program. Note the stations with <35% recovery is due to the removal of sample location from the ODCM mid year.

Location	Recovery	Location	Recovery	Location	Recovery
WS	99.9%	PB	97.7%	PC	23.3%
ER	99.9%	OA	32.7%	MS	99.9%
WR	34.6%	EB	92.2%	EW	99.9%
PL	99.9%	CR	97.4%		

An alternate location had to be found for sampling control vegetable samples in the Bridgewater area. In past years, samples had been collected at the Bridgewater County Farm, associated with the Bridgewater Correctional Facility. Due to loss of state funding for garden projects during 2006, no garden was grown. An alternate location was found at the Hanson Farm in Bridgewater, located in the same compass sector, and at approximately the same distance as the Bridgewater County Farm. Additional samples of naturally-occurring vegetation were collected from a distant control location in Sandwich. As expected for control samples, vegetables and vegetation collected at these locations only contained naturally-occurring radioactivity (Be-7 and K-40).No radionuclides attributed to PNPS operations were detected in any of the edible crop samples collected during 2020.

Naturally-growing leafy vegetation (grass, leaves from trees and bushes, etc.) was collected near some gardens identified during the annual land use census. Due to the unavailability of crops grown in several of these gardens, these substitute samples were collected as near as practicable to the gardens of interest. No radionuclides attributed to PNPS operations were detected in any of the samples. Additional details regarding the land use census can be found in Appendix C of this report.

Group III fishes, consisting of alewife, smelt, or striped bass are normally collected once each year in the summer from the vicinity of the Discharge Canal Outfall. Since the shut down of Pilgrim station the warm water plume of the discharge, which drew in fish species like the Striped Bass, has dissipated and is no longer present. Fish species once in such abundance to bring in harbor seals and sharks behind them are no longer found in the plant area. Repeated and concerted efforts were made to collect these species, but failed to produce all required samples.

In summary, the various problems encountered in collecting and analyzing environmental samples during 2020 were relatively minor when viewed in the context of the entire monitoring program. These discrepancies were promptly corrected when issue was identified, where possible. None of the discrepancies resulted in an adverse impact on the overall monitoring program.

APPENDIX E

Environmental Dosimetry Company
Annual 2020 Quality Assurance Status Report

ENVIRONMENTAL DOSIMETRY COMPANY

ANNUAL QUALITY ASSURANCE STATUS REPORT

January - December 2020

Prepared By: ______________ Date: 3/22/21

Approved By: ______________ Date: 3/22/21

Environmental Dosimetry Company
10 Ashton Lane
Sterling, MA 01564

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EXECUTIVE SUMMARY

Routine quality control (QC) testing was performed for dosimeters issued by the Environmental Dosimetry Company (EDC) .

During this annual period100% (72/72) of the 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 (Table 1). In addition, 100% (12/12) of the dosimeter sets evaluated against the internal tolerance limits met EDC acceptance criteria (Table 2) and 100% (6/6) of independent testing passed the performance criteria (Table 3). Trending graphs, which evaluate performance statistic for high-energy photon irradiations and co-located stations are given in Appendix A.

One internal assessment and one external audit were performed in 2020.There was one deficiency issued in the external audit.

I. INTRODUCTION

The TLD systems at the Environmental Dosimetry Company (EDC) are calibrated and operated to ensure consistent and accurate evaluation of TLDs. The quality of the dosimetric results reported to EDC clients is ensured by in-house performance testing and independent performance testing by EDC clients, and both internal and client directed program assessments.

The purpose of the dosimetry quality assurance program is to provide performance documentation of the routine processing of EDC dosimeters. Performance testing provides a statistical measure of the bias and precision of dosimetry processing against a reliable standard, which in turn points out any trends or performance changes. Two programs are used:

A. QC Program

Dosimetry quality control tests are performed on EDC Panasonic 814 Environmental dosimeters. These tests include: (1) the in-house testing program coordinated by the EDC QA Officer and (2) independent test perform by EDC clients. In-house test are performed using six pairs of 814 dosimeters, a pair is reported as an individual result and six pairs are reported as the mean result.Results of these tests are described in this report.

Excluded from this report are instrumentation checks. Although instrumentation checks represent an important aspect of the quality assurance program, they are not included as process checks in this report. Instrumentation checks represent between 5-10% of the TLDs processed.

B. QA Program

An internal assessment of dosimetry activities is conducted annually by the Quality Assurance Officer (Reference 1). The purpose of the assessment is to review procedures, results, materials or components to identify opportunities to improve or enhance processes and/or services.

II. PERFORMANCE EVALUATION CRITERIA

A. Acceptance Criteria for Internal Evaluations

1. Bias

For each dosimeter tested, the measure of bias is the percent deviation of the reported result relative to the delivered exposure. The percent deviation relative to the delivered exposure is calculated as follows:

$$\frac{\left(H_i' - H_i\right)}{H_i}100$$

where:

H_i' = the corresponding reported exposure for the ith dosimeter (i.e., the reported exposure)

H_i = the exposure delivered to the ith irradiated dosimeter (i.e., the delivered exposure)

2. Mean Bias

For each group of test dosimeters, the mean bias is the average percent deviation of the reported result relative to the delivered exposure. The mean percent deviation relative to the delivered exposure is calculated as follows:

$$\sum\left(\frac{(H_i' - H_i)}{H_i}\right)100\left(\frac{1}{n}\right)$$

where:

H_i' = the corresponding reported exposure for the ith dosimeter (i.e., the reported exposure)

H_i = the exposure delivered to the ith irradiated test dosimeter (i.e., the delivered exposure)

n = the number of dosimeters in the test group

3. Precision

For a group of test dosimeters irradiated to a given exposure, the measure of precision is the percent deviation of individual results relative to the mean reported exposure. At least two values are required for the determination of precision. The measure of precision for the ith dosimeter is:

$$\left(\frac{(H_i' - \bar{H})}{\bar{H}}\right)100$$

where:

H_i' = the reported exposure for the ith dosimeter (i.e., the reported exposure)

$\bar{H}$ = the mean reported exposure; i.e., $\bar{H} = \sum H_i'\left(\frac{1}{n}\right)$

n = the number of dosimeters in the test group

4. EDC Internal Tolerance Limits

All evaluation criteria are taken from the “EDC Quality System Manual,” (Reference 2). These criteria are only applied to individual test dosimeters irradiated with high-energy photons (Cs-137) and are as follows for Panasonic Environmental dosimeters: ± 15% for bias and ± 12.8% for precision.

B. QC Investigation Criteria and Result Reporting

EDC Quality System Manual (Reference 2) specifies when an investigation is required due to a QC analysis that has failed the EDC bias criteria. The criteria are as follows:

1. No investigation is necessary when an individual QC result falls outside the QC performance criteria for accuracy.

2. Investigations are initiated when the mean of a QC processing batch is outside the performance criterion for bias.

C. Reporting of Environmental Dosimetry Results to EDC Customers

1. All results are to be reported in a timely fashion.

2. If the QA Officer determines that an investigation is required for a process, the results shall be issued as normal. If the QC results prompting the investigation have a mean bias from the known of greater than ±20%, the results shall be issued with a note indicating that they may be updated in the future, pending resolution of a QA issue.

3. Environmental dosimetry results do not require updating if the investigation has shown that the mean bias between the original results and the corrected results, based on applicable correction factors from the investigation, does not exceed ±20%.

III. DATA SUMMARY FOR ISSUANCE PERIOD JANUARY-DECEMBER 2020

A. General Discussion

Results of performance tests conducted are summarized and discussed in the following sections. Summaries of the performance tests for the reporting period are given in Tables 1 through 3 and Figures 1 through 4.

Table 1 provides a summary of individual dosimeter results evaluated against the EDC internal acceptance criteria for high-energy photons only. During this period100% (72/72) of the individual dosimeters, evaluated against these criteria, met the tolerance limits for accuracy and 100% (72/72) met the criterion for precision. A graphical interpretation is provided in Figures 1 and 2.

Table 2 provides the bias and standard deviation results for each group (N=6) of dosimeters evaluated against the internal tolerance criteria. Overall,100% (12/12) of the dosimeter sets, evaluated against the internal tolerance performance criteria, met these criteria. A graphical interpretation is provided in Figure 3.

Table 3 presents the independent blind spike results for dosimeters processed during this annual period. All results passed the performance acceptance criterion. Figure 4 is a graphical interpretation of Seabrook Station blind co-located station results.

B. Result Trending

One of the main benefits of performing quality control tests on a routine basis is to identify trends or performance changes. The results of the Panasonic environmental dosimeter performance tests are presented in Appendix A. The results are evaluated against each of the performance criteria listed in Section II, namely: individual dosimeter accuracy, individual dosimeter precision, and mean bias.

All of the results presented in Appendix A are plotted sequentially by processing date.

IV. STATUS OF EDC CONDITION REPORTS (CR)

During this annual period, one EDC Condition Report was issued. CR 1-2020 was issued to document the deficiency from the DTE Energy Audit 20-003.

V. STATUS OF AUDITS/ASSESSMENTS

1. Internal

   EDC Internal Quality Assurance Assessment was conducted during the fourth quarter 2020. There were no findings identified.

2. External

   DTE Energy Audit 20-003 was conducted on July 28-30, 2020. There was one deficiency identified.

VI. PROCEDURES AND MANUALS REVISED DURING JANUARY - DECEMBER 2020

Manual 1 was revised on September 28, 2020.

Several procedures were reissued with no changes as part of the 5 year review cycle.

VII. CONCLUSION AND RECOMMENDATIONS

The quality control evaluations continue to indicate the dosimetry processing programs at the EDC satisfy the criteria specified in the Quality System Manual. The EDC demonstrated the ability to meet all applicable acceptance criteria.

VIII. REFERENCES

1. EDC Quality Control and Audit Assessment Schedule, 2020.

2. EDC Manual 1, Quality System Manual, Rev. 4, September 28, 2020.

TABLE 1

PERCENTAGE OF INDIVIDUAL DOSIMETERS THAT PASSED EDC INTERNAL CRITERIA JANUARY – DECEMBER 2020[(1), (2)]

Dosimeter Type	Number Tested	% Passed Bias Criteria	% Passed Precision Criteria
Panasonic Environmental	72	100	100

[(1)]This table summarizes results of tests conducted by EDC.
[(2)]Environmental dosimeter results are free in air.

TABLE 2

MEAN DOSIMETER ANALYSES (N=6) JANUARY – DECEMBER 2020[(1), (2)]

Process Date	Exposure Level	Mean Bias %	Standard Deviation %	Tolerance Limit +/- 15%
4/28/2020	37	1.8	1.2	Pass
5/02/2020	94	2.9	1.4	Pass
5/20/2020	56	-0.5	1.4	Pass
7/28/2020	72	4.1	0.6	Pass
8/07/2020	111	4.0	1.3	Pass
9/24/2020	25	-4.6	1.2	Pass
10/24/2020	35	5.2	1.6	Pass
10/28/2020	60	1.6	0.7	Pass
11/18/2020	91	0.5	1.6	Pass
01/21/2021	31	3.8	1.7	Pass
02/09/2021	83	0.3	0.8	Pass
02/16/2021	46	5.3	1,5	Pass

[(1)]This table summarizes results of tests conducted by EDC for TLDs issued in 2020.
[(2)]Environmental dosimeter results are free in air.

TABLE 3
SUMMARY OF INDEPENDENT DOSIMETER TESTING JANUARY – DECEMBER 2020[(1), (2)]

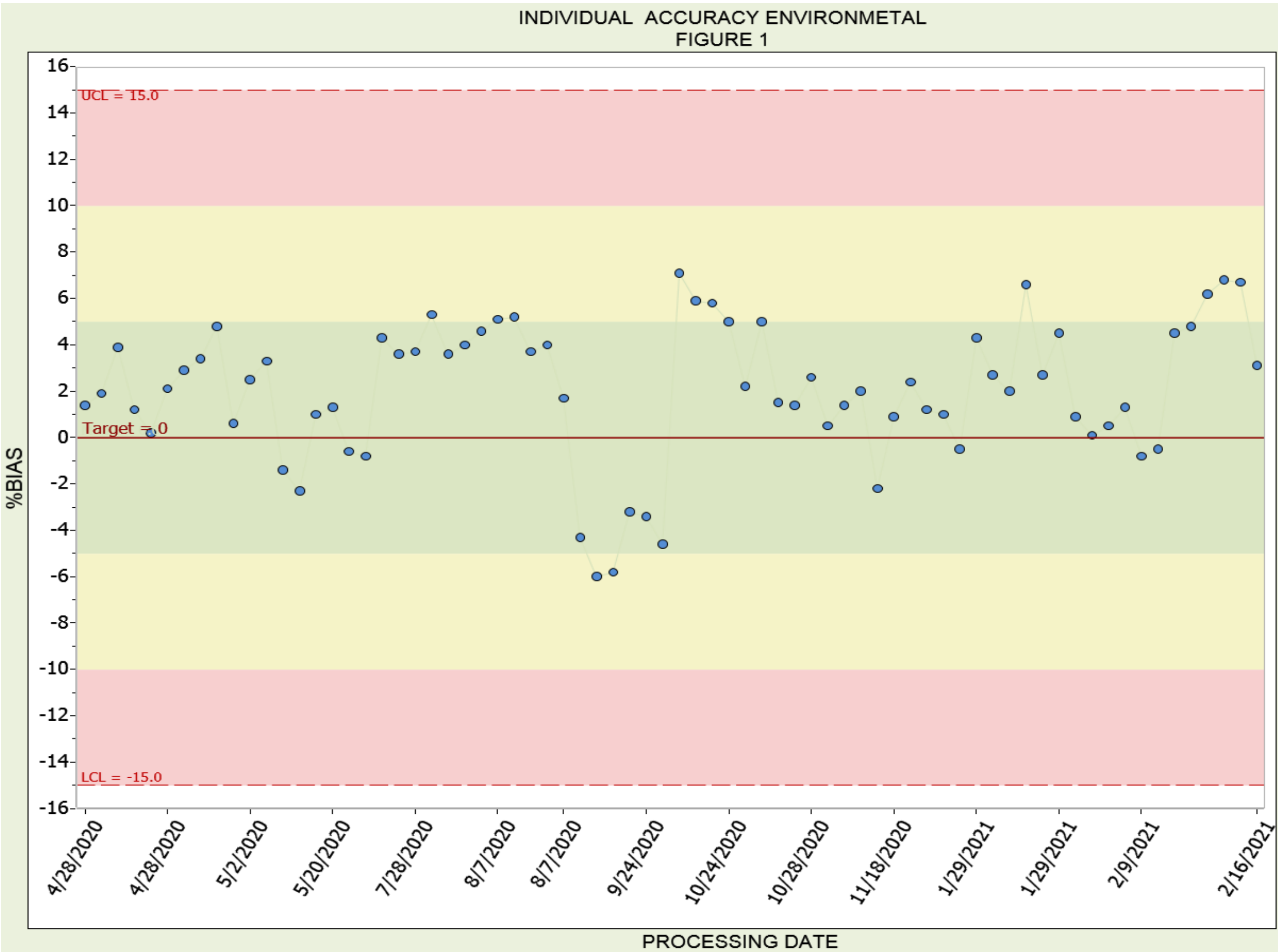
Issuance Period	Client	Mean Bias %	Standard Deviation %	Pass / Fail
1st Qtr. 2020	Millstone	-3.8	3.0	Pass
2nd Qtr.2020	Seabrook	0.5	1.4	Pass
2nd Qtr.2020	Millstone	-3.0	1.6	Pass
3rd Qtr. 2020	Millstone	0.4	2.6	Pass
4th Qtr.2020	PSEG(PNNL)	-3.2	0.9	Pass
4th Qtr.2020	Seabrook	6.9	1.9	Pass
4th Qtr.2020	SONGS	-8.4	1.3	Pass
4th Qtr.2020	Millstone	3.0	1.9	Pass

[(1)]Performance criteria are +/- 15%.
[(2)]Blind spike irradiations using Cs-137

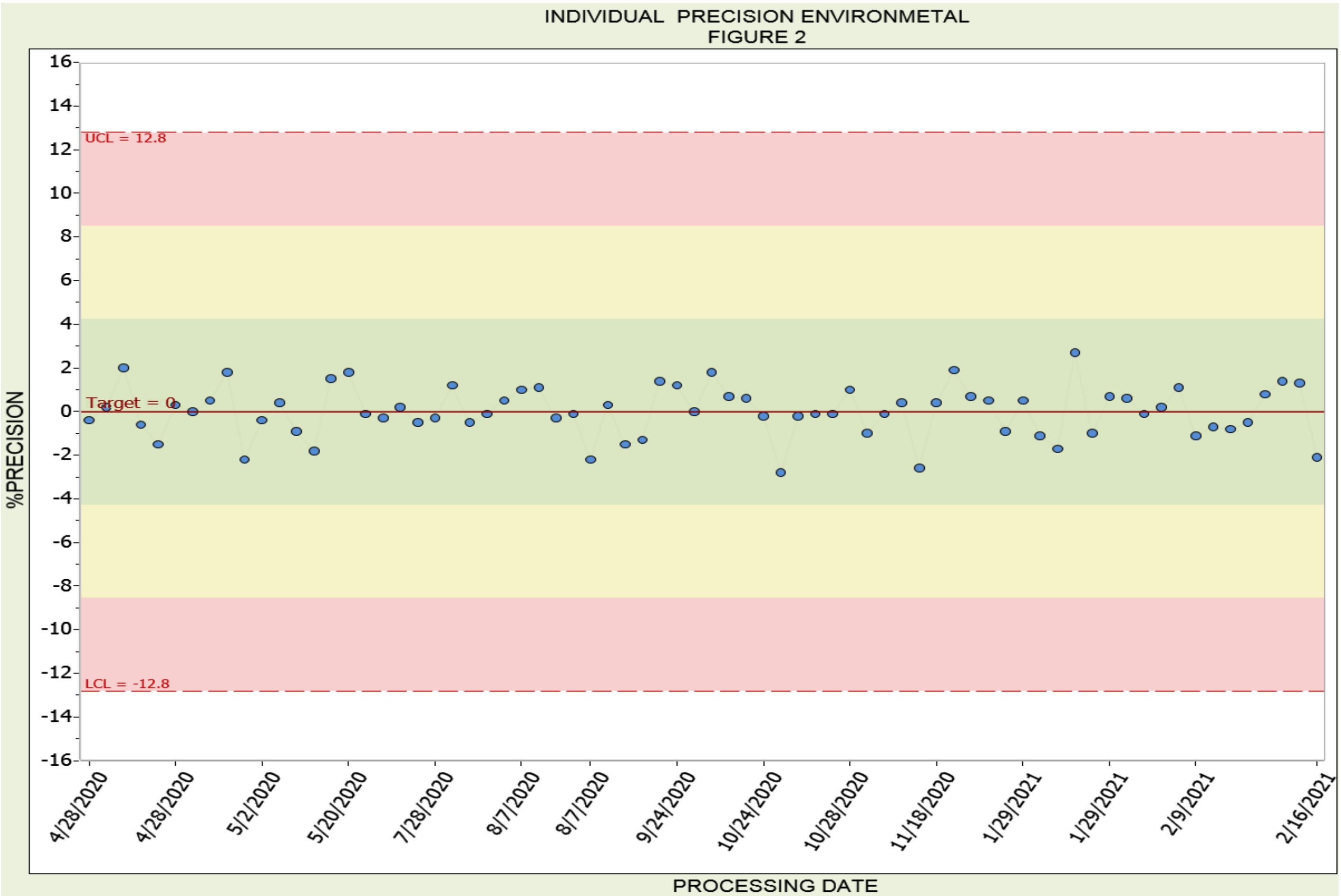
APPENDIX A

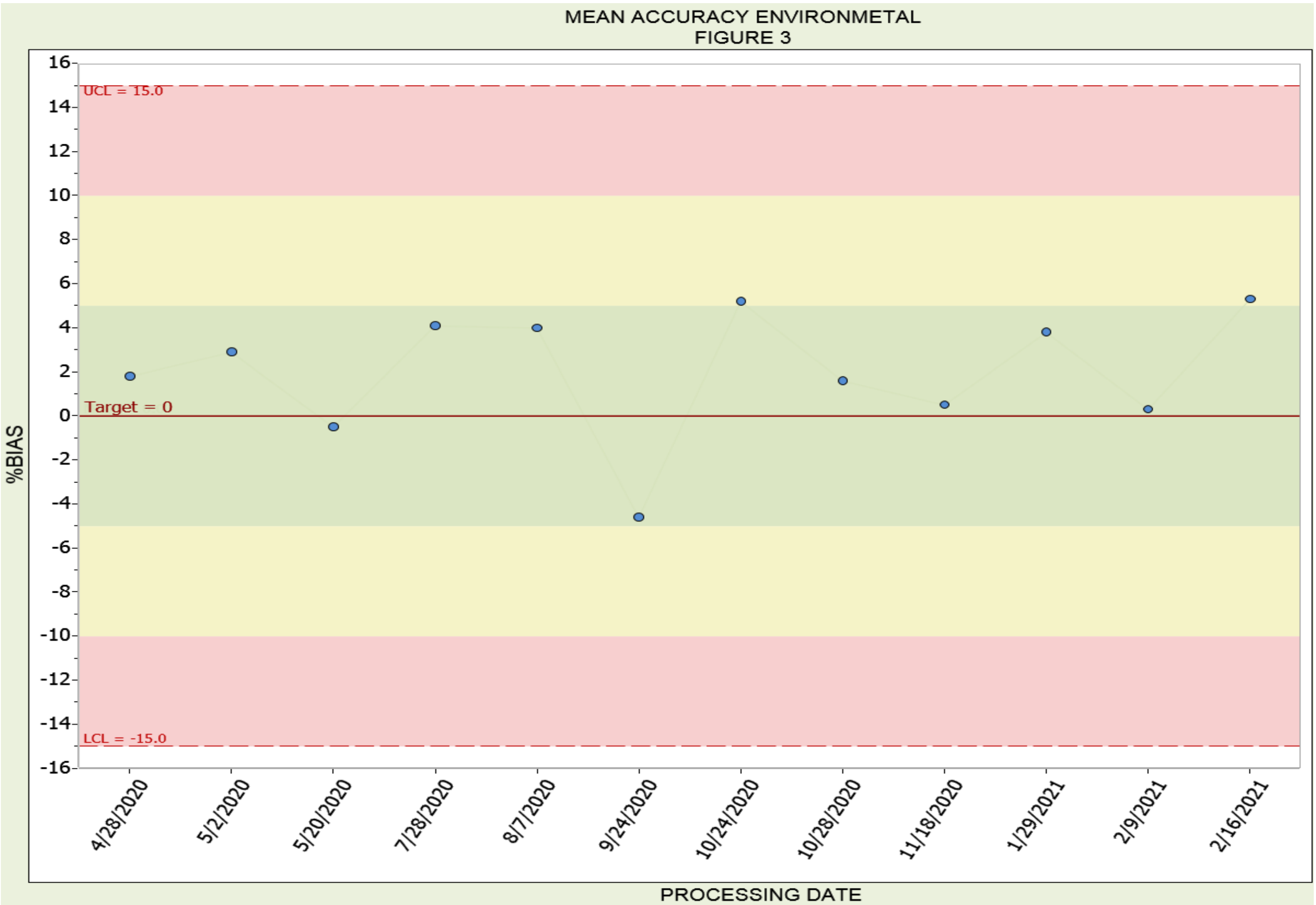
DOSIMETRY QUALITY CONTROL TRENDING GRAPHS

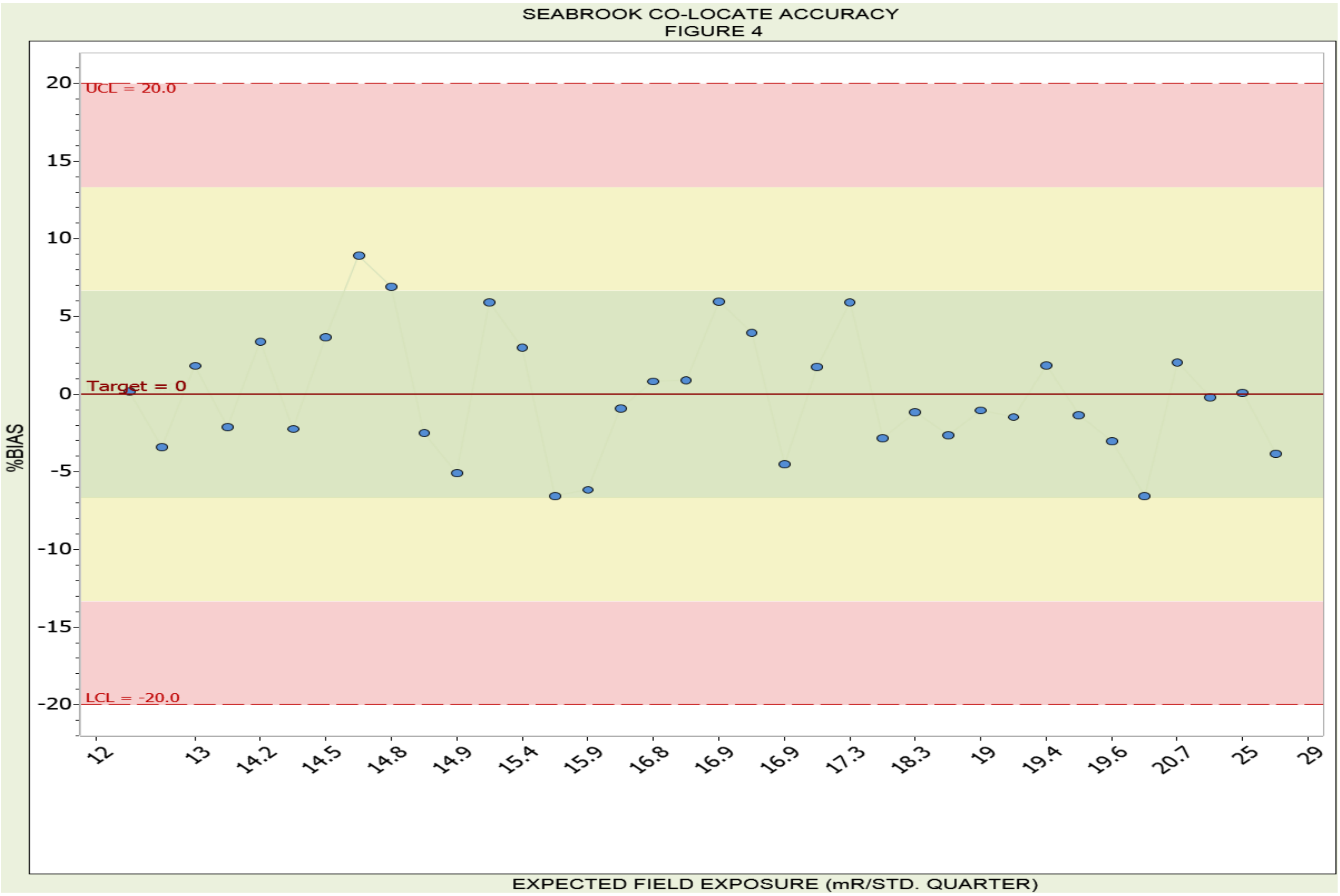
ISSUE PERIOD JANAURY - DECEMBER 2020



INDIVIDUAL ACCURACY ENVIRONMETAL
FIGURE 1
UCL = 15.0
Target = 0
LCL = -15.0
%BIAS
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
4/28/2020
4/28/2020
5/2/2020
5/20/2020
7/28/2020
8/7/2020
8/7/2020
9/24/2020
10/24/2020
10/28/2020
11/18/2020
1/29/2021
1/29/2021
2/9/2021
2/16/2021
PROCESSING DATE


INDIVIDUAL PRECISION ENVIRONMETAL
FIGURE 2
UCL = 12.8
Target = 0
LCL = -12.8
%PRECISION
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
4/28/2020
4/28/2020
5/2/2020
5/20/2020
7/28/2020
8/7/2020
8/7/2020
9/24/2020
10/24/2020
10/28/2020
11/18/2020
1/29/2021
1/29/2021
2/9/2021
2/16/2021
PROCESSING DATE


MEAN ACCURACY ENVIRONMETAL
FIGURE 3
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
UCL = 15.0
Target = 0
LCL = -15.0
%BIAS
4/28/2020
5/2/2020
5/20/2020
7/28/2020
8/7/2020
9/24/2020
10/24/2020
10/28/2020
11/18/2020
1/29/2021
2/9/2021
2/16/2021
PROCESSING DATE


SEABROOK CO-LOCATE ACCURACY
FIGURE 4
UCL = 20.0
Target = 0
LCL = -20.0
%BIAS
20
15
10
5
0
-5
-10
-15
-20
12
13
14.2
14.5
14.8
14.9
15.4
15.9
16.8
16.9
16.9
17.3
18.3
19
19.4
19.6
20.7
25
29
EXPECTED FIELD EXPOSURE (mR/STD. QUARTER)

APPENDIX F

Teledyne Brown Engineering Environmental Services
Annual 2020 Quality Assurance Report

A.1 Analytics Environmental Radioactivity Cross Check Program
Teledyne Brown Engineering Environmental Services

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Value	Known Value (a)	Ratio of TBE to Known Result	Evaluation (b)
September 2020	E13247	Milk	Sr-89	pCi/L	62.8	95.4	0.66	N(1)
			Sr-90	pCi/L	12.0	12.8	0.94	A
	E13248	Milk	Ce-141	pCi/L	156	150	1.04	A
			Co-58	pCi/L	172	180	0.96	A
			Co-60	pCi/L	369	379	0.97	A
			Cr-51	pCi/L	372	372	1.00	A
			Cs-134	pCi/L	171	200	0.85	A
			Cs-137	pCi/L	241	250	0.96	A
			Fe-59	pCi/L	217	200	1.08	A
			I-131	pCi/L	84.6	95.0	0.89	A
			Mn-54	pCi/L	175	180	0.97	A
			Zn-65	pCi/L	252	270	0.93	A
	E13249	Charcoal	I-131	pCi	70.2	75.8	0.93	A
	E13250	AP	Ce-141	pCi	101	101	1.00	A
			Co-58	pCi	111	120	0.92	A
			Co-60	pCi	249	254	0.98	A
			Cr-51	pCi	287	249	1.15	A
			Cs-134	pCi	114	134	0.85	A
			Cs-137	pCi	159	168	0.95	A
			Fe-59	pCi	127	134	0.95	A
			Mn-54	pCi	114	121	0.94	A
			Zn-65	pCi	168	181	0.93	A
	E13251	Soil	Ce-141	pCi/g	0.241	0.191	1.26	W
			Co-58	pCi/g	0.211	0.228	0.93	A
			Co-60	pCi/g	0.466	0.481	0.97	A
			Cr-51	pCi/g	0.450	0.472	0.95	A
			Cs-134	pCi/g	0.273	0.254	1.07	A
			Cs-137	pCi/g	0.370	0.390	0.95	A
			Fe-59	pCi/g	0.233	0.254	0.92	A
			Mn-54	pCi/g	0.217	0.229	0.95	A
			Zn-65	pCi/g	0.368	0.343	1.07	A
	E13252	AP	Sr-89	pCi	79.9	100.0	0.80	A
			Sr-90	pCi	12.1	13.4	0.90	A

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

(b) Analytics evaluation based on TBE internal QC limits:
A = Acceptable - reported result falls within ratio limits of 0.80-1.20
W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30
N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

(1) See ***NCR 20-19***

A.1 Analytics Environmental Radioactivity Cross Check Program
Teledyne Brown Engineering Environmental Services

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Value	Known Value [(a)]	Ratio of TBE to Known Result	Evaluation [(b)]
December 2020	E13254	Milk	Sr-89	pCi/L	82.2	89.7	0.92	A
			Sr-90	pCi/L	12.4	13.0	0.96	A
	E13255	Milk	Ce-141	pCi/L	91.1	100	0.91	A
			Co-58	pCi/L	77.5	84.3	0.92	A
			Co-60	pCi/L	147	152	0.97	A
			Cr-51	pCi/L	259	253	1.02	A
			Cs-134	pCi/L	97.1	108	0.90	A
			Cs-137	pCi/L	117	127	0.92	A
			Fe-59	pCi/L	114	112	1.02	A
			I-131	pCi/L	84.3	91.9	0.92	A
			Mn-54	pCi/L	137	143	0.96	A
			Zn-65	pCi/L	175	190	0.92	A
	E13256	Charcoal	I-131	pCi	70.2	78.2	0.90	A
	E13257A	AP	Ce-141	pCi	67.4	74.6	0.90	A
			Co-58	pCi	57.9	62.9	0.92	A
			Co-60	pCi	108	113	0.95	A
			Cr-51	pCi	162	189	0.86	A
			Cs-134	pCi	68.1	80.4	0.85	A
			Cs-137	pCi	82.4	95.0	0.87	A
			Fe-59	pCi	80.5	83.7	0.96	A
			Mn-54	pCi	102	107	0.95	A
			Zn-65	pCi	115	142	0.81	A
	E13258	Soil	Ce-141	pCi/g	0.167	0.170	0.98	A
			Co-58	pCi/g	0.125	0.143	0.87	A
			Co-60	pCi/g	0.245	0.257	0.95	A
			Cr-51	pCi/g	0.393	0.429	0.92	A
			Cs-134	pCi/g	0.147	0.183	0.80	A
			Cs-137	pCi/g	0.260	0.288	0.90	A
			Fe-59	pCi/g	0.199	0.190	1.05	A
			Mn-54	pCi/g	0.229	0.243	0.94	A
			Zn-65	pCi/g	0.320	0.322	0.99	A
	E13259	AP	Sr-89	pCi	85.0	78.6	1.08	A
			Sr-90	pCi	13.1	11.4	1.15	A

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

(b) Analytics evaluation based on TBE internal QC limits:
A = Acceptable - reported result falls within ratio limits of 0.80-1.20
W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30
N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

A.2 DOE's Mixed Analyte Performance Evaluation Program (MAPEP)
Teledyne Brown Engineering Environmental Services

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Value	Known Value (a)	Acceptance Range	Evaluation (b)
February 2020	20-GrF42	AP	Gross Alpha	Bq/sample	0.676	1.24	0.37 - 2.11	A
			Gross Beta	Bq/sample	2.03	2.00	1.00 - 3.00	A
	20-MaS42	Soil	Ni-63	Bq/kg	0.01		*(1)*	A
			Sr-90	Bq/kg	348	340	238 - 442	A
	20-MaW42	Water	Ni-63	Bq/L	11.6	11.1	7.8 - 14.4	A
			Pu-238	Bq/L	0.926	0.94	0.66 - 1.22	A
			Pu-239/240	Bq/L	0.712	0.737	0.516 - 0.958	A
	20-RdF42	AP	U-234/233	Bq/sample	0.0416	0.075	0.053 - 0.098	N(3)
			U-238	Bq/sample	0.0388	0.078	0.055 - 0.101	N(3)
	20-RdV42	Vegetation	Cs-134	Bq/sample	3.23	3.82	2.67 - 4.97	A
			Cs-137	Bq/sample	2.64	2.77	1.94 - 3.60	A
			Co-57	Bq/sample	0.0281		*(1)*	A
			Co-60	Bq/sample	2.62	2.79	1.95 - 3.63	A
			Mn-54	Bq/sample	4.3	4.58	3.21 - 5.95	A
			Sr-90	Bq/sample	0.396	0.492	0.344 - 0.640	A
			Zn-65	Bq/sample	3.93	3.79	2.65 - 4.93	A
August 2020	20-GrF43	AP	Gross Alpha	Bq/sample	0.267	0.528	0.158 - 0.989	A
			Gross Beta	Bq/sample	0.939	0.915	0.458 - 1.373	A
	20-MaS43	Soil	Ni-63	Bq/kg	438	980	686 - 1274	N(4)
			Tc-99	Bq/kg	1.11		*(1)*	A
	20-MaW43	Water	Ni-63	Bq/L	0.175		*(1)*	A
			Tc-99	Bq/L	8.8	9.4	6.6 - 12.2	A
	20-RdV43	Vegetation	Cs-134	Bq/sample	3.635	4.94	3.46 - 6.42	W
			Cs-137	Bq/sample	0.0341		*(1)*	A
			Co-57	Bq/sample	5.855	6.67	4.67 - 8.67	W
			Co-60	Bq/sample	3.122	4.13	2.89 - 5.37	W
			Mn-54	Bq/sample	4.524	5.84	4.09 - 7.59	A
			Sr-90	Bq/sample	1.01	1.39	0.97 - 1.81	W
			Zn-65	Bq/sample	4.706	6.38	4.47 - 8.29	W

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

(b) DOE/MAPEP evaluation:

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

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

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

(1) False positive test

(2) Sensitivity evaluation

(3) See ***NCR 20-13***

(4) See ***NCR 20-20***

A.3 ERA Environmental Radioactivity Cross Check Program
Teledyne Brown Engineering Environmental Services

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Value	Known Value [(a)]	Acceptance Limits	Evaluation [(b)]
March 2020	MRAD-32	Water	Am-241	pCi/L	52.5	45.3	31.1 - 57.9	A
			Fe-55	pCi/L	155	152	89.3 - 221	A
			Pu-238	pCi/L	34.0	36.4	21.9 - 47.2	A
			Pu-239	pCi/L	30.9	33.6	20.8 - 41.4	A
April 2020	RAD-121	Water	Ba-133	pCi/L	41.8	41.8	34.0- 46.7	A
			Cs-134	pCi/L	42.9	46.3	37.1 - 50.9	A
			Cs-137	pCi/L	226	234	211 - 259	A
			Co-60	pCi/L	52.4	50.3	45.3 - 57.9	A
			Zn-65	pCi/L	83.3	86.8	78.1 - 104	A
			GR-A	pCi/L	20.1	23.6	11.9 - 31.6	A
			GR-B	pCi/L	45.6	60.5	41.7 - 67.2	A
			U-Nat	pCi/L	18.45	18.6	14.9 - 20.9	A
			H-3	pCi/L	14200	14100	12300 - 15500	A
			Sr-89	pCi/L	58.0	60.1	48.3 - 67.9	A
			Sr-90	pCi/L	34.1	44.7	33.0 - 51.2	A
			I-131	pCi/L	27.4	28.9	24.1 - 33.8	A
September 2020	MRAD-33	Soil	Sr-90	pCi/Kg	4360	4980	1550 - 7760	A
		AP	Fe-55	pCi/Filter	189	407	149 - 649	A
			U-234	pCi/Filter	17.9	18.3	13.6 - 21.4	A
			U-238	pCi/Filter	19.1	18.1	13.7 - 21.6	A
		Water	Am-241	pCi/L	160	176	121 - 225	A
			Fe-55	pCi/L	299	298	175 - 433	A
			Pu-238	pCi/L	200	191	115 - 247	A
			Pu-239	pCi/L	105	100	61.9 - 123	A
October 2020	RAD-123	Water	Ba-133	pCi/L	37.1	37.0	29.8 - 41.6	A
			Cs-134	pCi/L	50.6	52.7	42.5 - 58.0	A
			Cs-137	pCi/L	131	131	118 - 146	A
			Co-60	pCi/L	62.9	60.5	54.4 - 69.1	A
			Zn-65	pCi/L	167	162	146 - 191	A
			GR-A	pCi/L	40.0	26.2	13.3 - 34.7	N[(1)]
			GR-B	pCi/L	47.5	69.1	48.0 - 76.0	N[(1)]
			U-Nat	pCi/L	17.2	20.3	16.3 - 22.7	A
			H-3	pCi/L	23800	23200	20,300 - 25,500	A
			Sr-89	pCi/L	41.1	43.3	33.4 - 50.5	A
			Sr-90	pCi/L	28.5	30.2	22.0 - 35.0	A
			I-131	pCi/L	22.9	28.2	23.5 - 33.1	N[(2)]
November 2020	QR111920K	Water	GR-A	pCi/L	50.7	52.4	27.3 - 65.6	A
			GR-B	pCi/L	24.9	24.3	15.0 - 32.3	A

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

(b) ERA evaluation:
A = Acceptable - Reported value falls within the Acceptance Limits
N = Not Acceptable - Reported value falls outside of the Acceptance Limits

(1) See ***NCR 20-18***

(2) See ***NCR 20-17***

Summary of Results – Inter-laboratory Comparison Program (ICP)

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

A. Analytics Evaluation Criteria

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

B. ERA Evaluation Criteria

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

C. DOE Evaluation Criteria

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

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

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

For the TBE laboratory, 126 out of 133 analyses performed met the specified acceptance criteria. Seven analyses did not meet the specified acceptance criteria for the following reasons and were addressed through the TBE Corrective Action Program. A summary is found below:

1. The MAPEP February 2020 AP U-233/234 and U-238 results were evaluated as *Not Acceptable*. The reported value for U-233/234 was 0.0416 ± 0.0102 Bq/sample and the known result was 0.075 Bq/sample (acceptance range 0.053 - 0.098). The reported value for U-238 was 0.0388 ± 0.00991 Bq/sample and the

known result was 0.078 Bq/sample (acceptance range 0.055 - 0.101). This sample was run as the workgroup duplicate and had RPD's of 10.4% (U-234) and 11.7% (U-238). After the known results were obtained, the sample was relogged. The filter was completely digested with tracer added originally; the R1 results were almost identical. It was concluded that the recorded tracer amount was actually double, causing the results to be skewed. Lab worksheets have been modified to verify actual tracer amount vs. LIMS data. TBE changed vendors for this cross-check to ERA MRAD during the 2nd half of 2020. Results were acceptable at 97.8% for U-234 and 106% for U-238. (NCR 20-13)

2. The Analytics September 2020 milk Sr-89 result was evaluated as *Not Acceptable*. The reported value was 62.8 pCi/L and the known result was 95.4 (66%). All QC data was reviewed and there were no anomalies. This was the first failure for milk Sr-89 since 2013 and there have only been 3 upper/lower boundary warnings since that time. It is believed that there may have been some loss during the sample prep (ashing). The December 2020 result was at 92% of the known. (NCR 20-19)

3. The ERA October 2020 water I-131 result was evaluated as *Not Acceptable*. The reported value was 22.9 pCi/L and the known result was 28.2 (acceptance range 23.5 - 33.1). The reported result was 81% of the known, which passes TBE QC criteria. This was the first failure for water I-131. (NCR 20-17)

4. The ERA October 2020 water Gross Alpha and Gross Beta results were evaluated as *Not Acceptable*. The reported/acceptable values and ranges are as follows:

	Reported	Known	Range
Gross Alpha	40.0	26.2	13.3 - 34.7
Gross Beta	47.5	69.1	48.0 - 76.0

All QC data was reviewed with no anomalies and a cause for failure could not be determined. This was the first failure for water Gross Beta. A Quick Response follow-up cross-check was analyzed as soon as possible with acceptable results at 96.8% for Gross Alpha and 102% for Gross Beta. (NCR 20-18)

5. The MAPEP August 2020 soil Ni-63 result was evaluated as *Not Acceptable*. The reported value was 438 ± 21.1 Bq/kg and the known result was 980 Bq/kg (acceptance range 686 - 1274). It is believed that some Ni-63 loss may have occurred during the sample prep. This investigation is still on-going at this time. (NCR 20-20)

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