PILGRIM NUCLEAR POWER STATION

Facility Operating License DPR-35

Annual Radiological Environmental Operating Report

January 1 through December 31, 2021

HOLTEC
DECOMMISSIONING
INTERNATIONAL

PILGRIM NUCLEAR POWER STATION
Facility Operating License DPR-35

ANNUAL RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT

JANUARY 01 THROUGH DECEMBER 31, 2021

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Pilgrim Nuclear Power Station
Annual Radiological Environmental Operating Report
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INTRODUCTION

This report summarizes the results of the Holtec (HDI) 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, 2021. This document has been prepared in accordance with the requirements of PNPS Facility Licensing Basis.

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, seawater, sediment, shellfish, American lobster, and fishes. Some sample media such as soil, forage, Irish moss, vegetation 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 2021, there were 409 samples collected from the atmospheric, aquatic, and terrestrial environments. In addition, 185 exposure measurements were obtained using environmental thermoluminescent dosimeters (TLDs).

A small number of inadvertent issues were encountered during 2021 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. 335 of 342 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 permanent 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.

Analyses on environmental samples 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 is no longer conducted. All crop-based foods no longer exist within a 5 mile radius of the plant. Cranberries and Irish Moss crops were removed from the ODCM in revision 14. The collection of broad leaf vegetation was to account for deposition of iodine on a type of cattle feed in lieu of sampling for milk. There are no milk farms withing 5 miles. The need to account for changes in new or old gardens diminished once the plant shutdown and not only was no new iodine created, but that which had been created all decayed after 10 half lives for I-131 had passed (1 calendar quarter).

Broadleaf vegetation may still be consumed by humans, and it will be projected and accounted for in dose modeling for all nuclides remaining that are released off site, but the only radionuclide detected in REMP samples while the plant was operating was Cs-137 from fall out (recently – Chernobyl and Fukushima) which is deposited on and absorbed through the roots of plants and trees and has a 30-year half-life. The current dose model for gaseous release dose calculations utilizes a garden at the site boundary in the predominant downwind direction. As this is the most conservative scenario, no land use census will produce an alternate garden with higher off-site dose potential.

The wind rose maps for Pilgrim RBV mixed mode releases and ground releases show the predominant wind direction from the SSW in both frequency and wind speed. This means the predominant wind direction is from the land out to sea from the WNW to the SSW with SSW the most frequent compass point wind comes from toward the station. Essentially, gaseous effluents from the plant, however minor in quantity compared to when operating, are blown out to sea.

RADIOLOGICAL IMPACT TO THE ENVIRONMENT

During 2021, 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 (1 mR=0.933 mrem) 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 2021, 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 2021 was approximately 0.30 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 2021 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 decommissioning operations.

1.0 INTRODUCTION

The Radiological Environmental Monitoring Program for 2021 performed by Comprehensive Decommissioning International (CDI), now Holtec Decommissioning International (HDI), owned by Holtec for Pilgrim Nuclear Power Station (PNPS) is discussed in this report. This report, which is required to be published annually by Pilgrim Station's Facility Licensing Basis, 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, 2021.

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, 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 plants are cesium-137, iodine-131, strontium-90, and cobalt-60. Iodine is no longer an active Pilgrim station isotope as the station no longer produces iodine and that which was previously produced has decayed away.

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 May 31, 2019 before the decision to permanently 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.

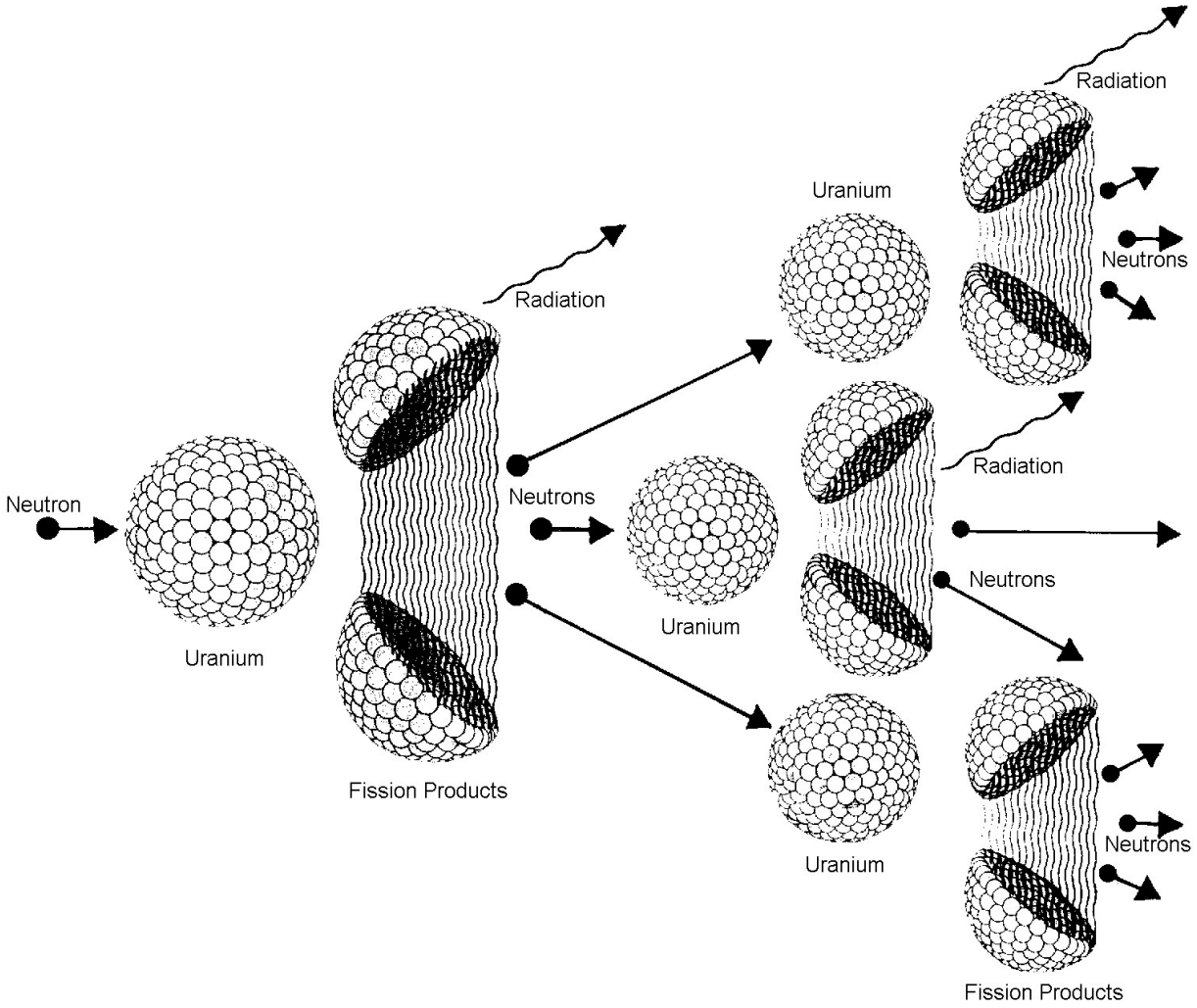


Figure 1.3-1
Radioactive Fission Product Formation

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).

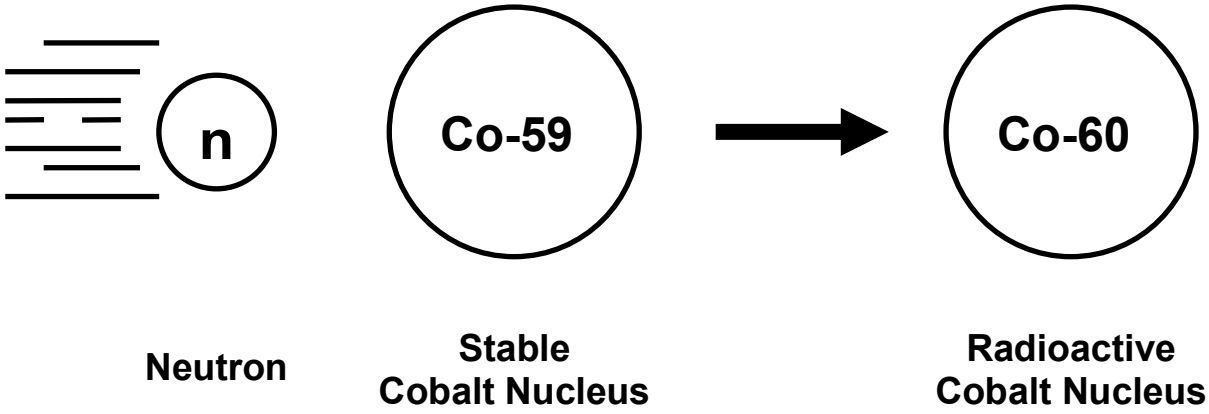


Figure 1.3-2
Radioactive Activation Product Formation

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

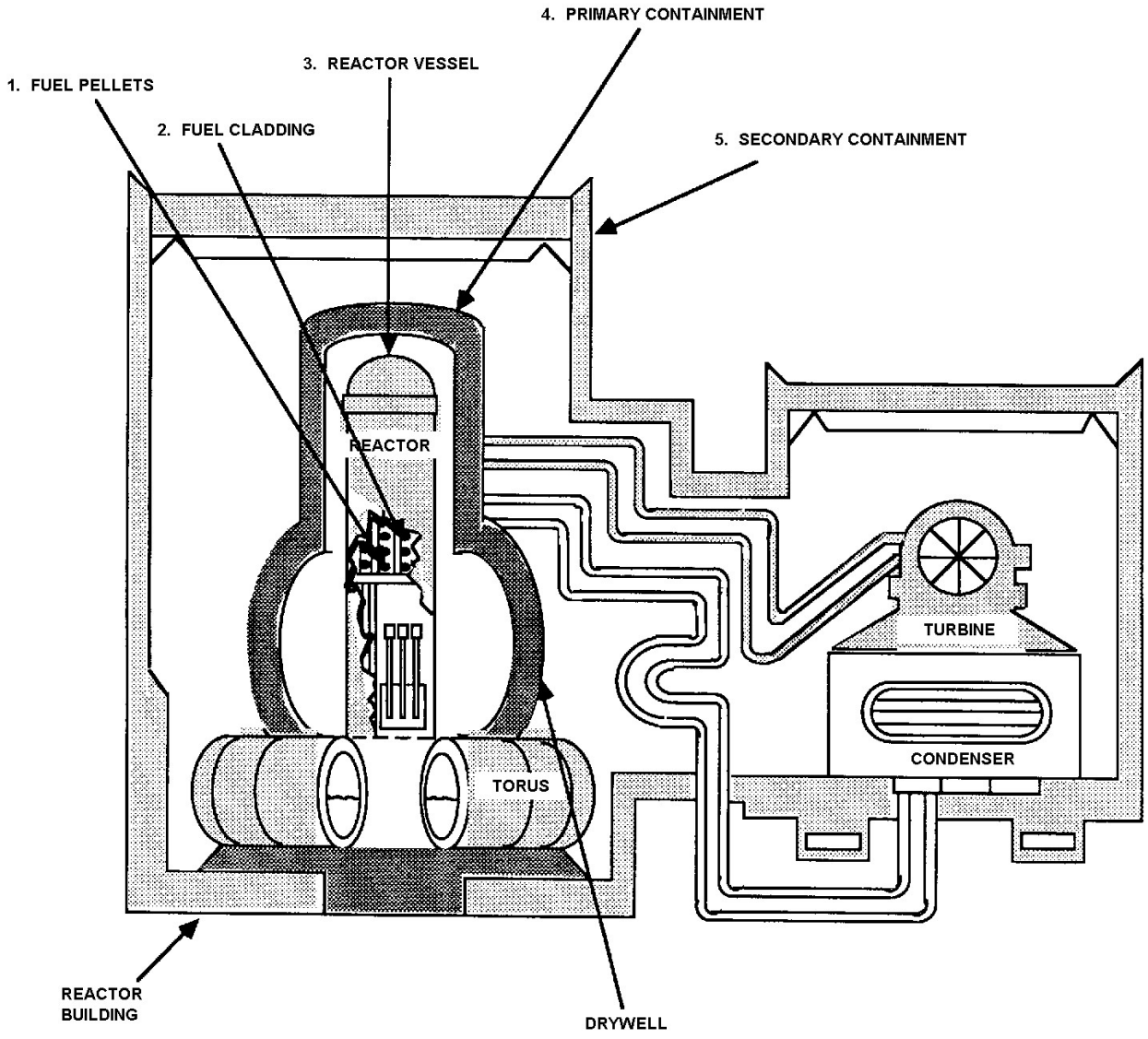


Figure 1.3-3
Barriers To Confine Radioactive Materials

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 or spent fuel pool water.

The third barrier consists of the reactor vessel, steel piping and equipment that confine the reactor water. The reactor vessel, which once held 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 water once used as primary coolant. However, during the course of decommissioning 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 last barrier is the reactor building. This reactor building is equipped with a controlled filtered ventilation system that is used to keep the building as at a negative pressure.

These barriers confine most of the remaining 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/fuel pool systems. 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. Prior to a release to the environment, control systems collect and purify the radioactive effluents in order to reduce releases to the environment to as low as is reasonably achievable (ALARA). 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 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 as permitted.

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

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

Water used previously for reactor or spent fuel cooling 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.

More recently the option has been added to the ODCM (rev. 15) to be able to utilize the torus as a “tank” (as it no longer serves its original purpose to aid in reactor level/ pressure control) to hold larger amounts of radwaste and process through means other than the established radwaste treatment system (ie. Demineralizers previously used with in the condensate system) for purification prior to release.

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 (salt service water) 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 air flow is then directed to the reactor building ventilation plenum that is located on the side of the reactor building. A sample stream of the plenum flows through a sampling rack equipped with a paticulate filter. Air samples are taken on a weekly frequency from the reactor building vent and are analyzed to quantify the total amount of tritium and radioactive particulate effluents released. This plenum, which vents to the atmosphere, was previously equipped with a gaseous radiation detector. The gaseous radiation monitor was removed from the ODCM in revision 15. All Noble gases have decayed away, save Kr-85 which is trapped inside gaps in the fuel bundles. Kr-85 is a beta emitter with one gamma released for every 250 decays. The detector installed in the RBV plenum would not detect it, the point is moot, as of December 2021 all Spent fuel has been transferred to sealed dry storage casks on the Independent Spent Fuel Storage Installation (ISFSI) II pad.

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 (ALARA). The effluents are always monitored, sampled and analyzed prior to release to make sure that radioactivity levels are below 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 in the Annual Radiological Effluent Release Report (ARERR) 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

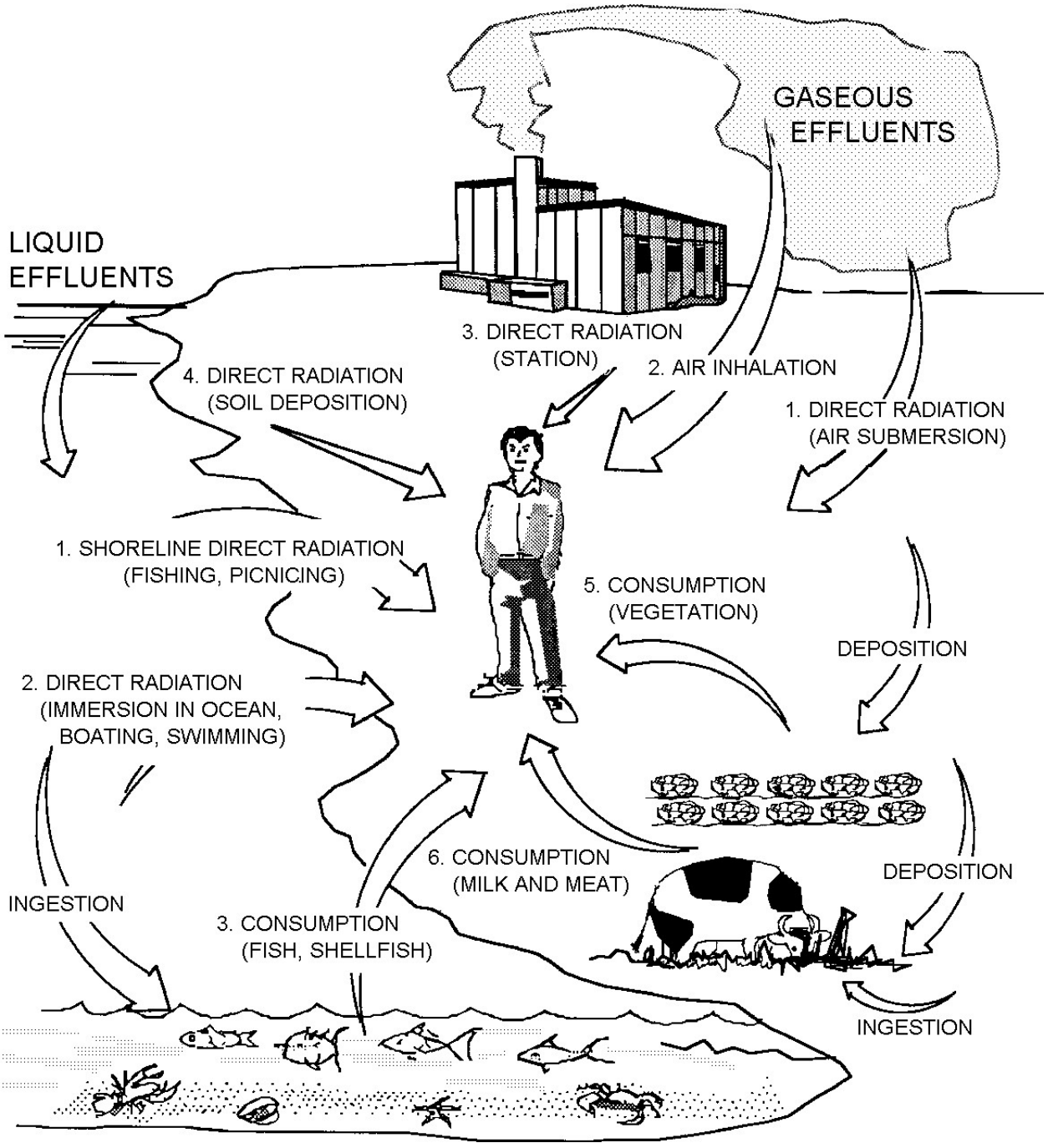


Figure 1.5-1
Radiation Exposure Pathways

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 station 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.

- Note: There are no noble gas release at Pilgrim due to gases having decayed away

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.

- Note: There are no iodine release at Pilgrim due to no more produces and that which has been produced by the plant operation having decayed away

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.

- Note: There is no longer a “fuel cycle, as normal operations ceased on May 31, 2019.

The summary of the 2021 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 2021 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 2021 included air particulate filters, 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. Sample collection requirements 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 operations, 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.
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 Audits.

The Teledyne Brown Engineering Laboratory conducts extensive quality assurance and quality control programs. The 2021 results of these programs are summarized in Appendix E. These results indicate that the analyses and measurements performed during 2021 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 2021. 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 operations 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 based on distance.

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 $\pm$ 21 pCi/kilogram would be considered "positive" (detectable Cs-137), whereas another sample with a concentration of 60 $\pm$ 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 seven indicator stations, 288 out of 288 samples indicated detectable gross beta activity at the three-sigma (standard deviation) level. The mean concentration of gross beta activity in these 288 indicator station samples was 0.017 $\pm$ 0.0054 (1.7E-2 $\pm$ 5.4E-3) pCi/m^3. Individual values ranged from 0.0072 to 0.049 (7.2E-3 – 4.9E-2) pCi/m^3

The monitoring station which yielded the highest mean concentration was the sample location ER (East Rocky Hill Road), which yielded a mean concentration of 0.018 $\pm$ 0.006 pCi/m^3, based on 53 detectable indications out of 53 samples observations. Individual values ranged from 0.0075 to 0.045 pCi/m^3.

At the control location, 53 out of 53 samples yielded detectable gross beta activity, for an average concentration of 0.017 $\pm$ 0.0043 pCi/m^3. Individual samples at the East Weymouth control location ranged from 0.0088 to 0.025 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 44 locations are monitored using this technique. The number of TLD were reduced in April 2020 after the permanent shut down of the Pilgrim station, then again in 2021 to collapse the outer ring to 3km from the plant. Only the 2 control locations Division of Marine Fisheries (DMF) and East Weymouth (EW) and the indicator station Manomet Elementary (ME) remain outside of the 3km distance. In addition, 4 of the 44 TLDs are currently located onsite, within the PNPS protected/restricted area, as well as 12 out of 44 are currently located outside the protected area but inside the site boundary and area used for business purposes only where the general public does not have access.

Though the “business area only” or “exclusion zone” could *physically* be accessed, jersey barriers, signage and security tours would drastically limit the stay of a person with out proper authorization to be within the areas.

Out of the 189 TLDs posted in the environment during 2021, 185 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 48 to 329 mR/yr. The average exposure rate at control locations greater than 15 km from Pilgrim Station (i.e., Zone 4) was 72.8 ± 4.0 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 60 and 84 mR/yr. The results for all TLDs within 15 km (excluding those Zone 1 TLDs posted within the site boundary) ranged from 48 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 as well as radwaste material for storage or shipment.

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 90.5 ± 70.6 mR/yr to 64.7 $\pm$ 8.9 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 58.2 $\pm$ 2.0 mR/yr, which compares not too far off with the average control location exposure of 67.6 ± 3.7 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 2021 seven locations were monitored. One location (Manomet Substation) was no longer needed due to the plant condition and was discontinued with the change to the ODCM in June 2021.

Out of 342 filters (6 locations * 53 weeks and 1 location * 24 weeks), 335 samples were collected and analyzed during 2021. 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. East Breakwater had three instances in the first quarter 2021 where the

activities on site were not communicated and the power was interrupted. All of these discrepancies are noted in Appendix D.

The results of the analyses performed on these 335 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 335 of the filter samples collected, including 53 of the 53 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 2021, 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, but due to plant condition the requirement for sampling no longer applies. Sample requirements and sample locations were removed in ODCM revision 15.

2.7 Vegetable/Vegetation Radioactivity Analyses

Vegetation sampling as well as the Land Use census was discontinued, removed from the ODCM in revision 15 as described in the milk section above. Crop based foodstuffs no longer exist within a 5 mile radius on the plant (previously cranberries and Irish Moss) and were previously removed from the ODCM. The use of broadleaf vegetation was to account for the deposition of iodine on a type of cattle feed in lieu of sampling for milk. As there are no milk farms within the influence of the plant and the need to account for changes in new or old gardens has diminished with the shutdown and fuel removal at the plant, the requirement was removed.

Broadleaf vegetation may still be consumed by humans, and it will be projected and accounted for in the dose modelling for all nuclides remaining that are released off site, but the only radionuclide detected in REMP samples while the plant was operating was Cs-137 from fall out (recently – Chernobyl and Fukashima) which is deposited on and absorbed thru the roots of plants and trees and has a 30-year half-life.

The current dose model for gaseous release dose calculations utilizes a garden at the site boundary in the predominant downwind direction. As this is the most conservative scenario, no land use census will produce an alternat garden with higher off-site dose potential.

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 the Powder Point Bridge location. Samples of surface water are composited every four weeks and analyzed by gamma spectroscopy. 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 2021. Bartlett Pond sample point 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 all monthly composite samples, especially those composed primarily of seawater. No radioactivity attributable to Pilgrim Station was detected in any of the surface water samples collected during 2021.

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 by marine sampling vendor (Normandeau) and are analyzed by gamma spectroscopy.

Twelve of twelve required samples of sediment were collected during 2021 plus two extra samples collected from Duxbury Bay. 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 2021, 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.

Ten of the ten required samples of shellfish meat scheduled for collection during 2021 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 ten of the ten the samples. No radioactivity attributable to Pilgrim Station was detected in any of the samples collected during 2021, 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. 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 2021. 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 2021, 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 2021. 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 2021, 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			
East Rocky Hill Road	ER	0.9 km	SE
Property Line	PL	0.5 km	NNW
Pedestrian Bridge	PB	0.2 km	N
East Breakwater	EB	0.5 km	ESE
Cleft Rock	CR	1.3 km	SSW
East Weymouth (Control)	EW	40 km	NW
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.)				2021 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	21.0 ± 14.4	21.9 ± 13.6	21.8 ± 13.1	25.8 ± 26.6	90.5 ± 70.6
BLW BOAT LAUNCH WEST	0.11 km E	54.1 ± 3.3	59.2 ± 2.8	51.5 ± 1.9	45.8 ± 1.9	210.6 ± 22.8
OA OVERLOOK AREA	0.15 km W	37.6 ± 2.4	38.6 ± 1.9	39.7 ± 2.4	32.9 ± 1.3	148.7 ± 12.7
TC HEALTH CLUB	0.15 km WSW	17.5 ± 1.1	17.8 ± 1.0	18.5 ± 0.6	18.1 ± 1.1	71.9 ± 2.5
BLE BOAT LAUNCH EAST	0.16 km ESE	89.7 ± 3.3	77.7 ± 5.1	79.4 ± 4.8	82.1 ± 4.9	328.9 ± 22.9
ISF-3 ISFSI-3	0.21 km W	23.3 ± 1.2	24.4 ± 1.1	34.2 ± 1.0	152.7 ± 4.8	234.6 ± 251.7
P01 SHOREFRONT SECURITY	0.22 km NNW	20.2 ± 1.3	21.1 ± 0.9	19.6 ± 0.7	17.9 ± 0.9	78.7 ± 5.9
WS MEDICAL BUILDING	0.23 km SSE	12.1 ± 0.5	Removed	Removed	Removed	12.1 ± 0.5
ISF-2 ISFSI-2	0.28 km W	18.2 ± 0.8	19.8 ± 0.6	21.9 ± 0.7	32.5 ± 1.4	92.3 ± 25.8
ISF-1 ISFSI-1	0.35 km SW	18.6 ± 1.0	20.6 ± 0.7	20.5 ± 0.8	19.8 ± 1.1	79.5 ± 4.0
PA SHOREFRONT PARKING	0.35 km NNW	18.5 ± 0.6	18.2 ± 0.8	18.8 ± 0.5	18.2 ± 1.0	73.6 ± 1.9
A STATION A	0.37 km WSW	15.6 ± 0.7	15.8 ± 0.7	15.3 ± 0.5	16.4 ± 1.0	63.1 ± 2.4
EB EAST BREAKWATER	0.44 km ESE	21.8 ± 1.1	22.6 ± 0.8	23.0 ± 0.9	24.4 ± 1.4	91.7 ± 5.0
B STATION B	0.44 km S	21.4 ± 0.9	22.0 ± 1.1	22.0 ± 0.7	21.7 ± 1.5	87.1 ± 2.4
PMT PNPS MET TOWER	0.44 km WNW	17.6 ± 0.6	M ± M	16.4 ± 0.7	19.2 ± 1.6	70.9 ± 6.2
L STATION L	0.50 km ESE	26.0 ± 1.6	29.3 ± 1.7	30.2 ± 1.6	29.8 ± 1.6	115.4 ± 8.3
G STATION G	0.53 km W	14.5 ± 0.7	14.9 ± 0.7	15.2 ± 0.4	15.7 ± 1.0	60.3 ± 2.4
PL PROPERTY LINE	0.54 km NW	16.4 ± 0.8	17.1 ± 0.7	17.5 ± 0.6	18.9 ± 1.0	69.9 ± 4.6
HB HALL'S BOG	0.63 km SE	18.8 ± 0.7	19.2 ± 0.6	19.4 ± 1.7	18.9 ± 1.1	76.3 ± 2.5
GH GREENWOOD HOUSE	0.65 km ESE	16.5 ± 0.8	16.9 ± 0.5	17.0 ± 0.6	16.7 ± 1.0	67.1 ± 1.7
WR W ROCKY HILL ROAD	0.83 km WNW	20.2 ± 1.3	21.0 ± 0.7	21.6 ± 0.5	22.8 ± 1.2	85.6 ± 4.9
ER E ROCKY HILL ROAD	0.89 km SE	14.3 ± 0.5	14.3 ± 0.6	15.1 ± 0.5	14.5 ± 1.0	58.2 ± 2.0
CR CLEFT ROCK	1.27 km SSW	19.3 ± 0.8	18.3 ± 0.6	18.5 ± 0.6	18.4 ± 1.0	74.4 ± 2.4
BD BAYSHORE/GATE RD	1.34 km WNW	16.9 ± 0.5	17.4 ± 0.9	17.5 ± 0.6	17.4 ± 0.9	69.2 ± 1.9
EM EMERSON ROAD	1.53 km SSE	16.0 ± 0.6	16.3 ± 0.6	16.4 ± 0.5	15.4 ± 1.0	64.0 ± 2.3
EP EMERSON/PRISCILLA	1.55 km SE	15.2 ± 0.5	15.6 ± 0.6	15.9 ± 0.5	15.8 ± 0.9	62.5 ± 1.7
BS BAYSHORE	1.76 km W	17.1 ± 1.0	17.9 ± 0.7	17.5 ± 0.7	M ± M	69.9 ± 2.5
JG JOHN GAULEY	1.99 km W	16.4 ± 0.9	16.1 ± 0.6	16.1 ± 0.7	18.1 ± 1.4	66.6 ± 4.2
J STATION J	2.04 km SSE	14.4 ± 0.5	M ± M	14.7 ± 0.7	14.2 ± 1.0	57.8 ± 2.0
RC PLYMOUTH YMCA	2.09 km WSW	14.9 ± 0.7	15.0 ± 0.9	14.9 ± 0.5	14.5 ± 0.9	59.2 ± 1.8
TT TAYLOR/THOMAS	2.26 km SE	15.1 ± 0.7	16.3 ± 0.6	15.9 ± 0.7	16.0 ± 1.3	63.2 ± 2.6
YV YANKEE VILLAGE	2.28 km WSW	16.2 ± 0.5	16.5 ± 0.6	16.5 ± 0.4	15.8 ± 0.9	65.0 ± 1.8
GN GOODWIN PROPERTY	2.38 km SW	11.8 ± 0.4	12.1 ± 0.4	12.2 ± 0.6	11.9 ± 0.9	48.0 ± 1.5
RW RIGHT OF WAY	2.83 km S	14.0 ± 1.2	13.3 ± 0.7	13.5 ± 0.5	13.1 ± 0.8	54.0 ± 2.3
TP TAYLOR/PEARL	2.98 km SE	14.9 ± 0.5	14.9 ± 0.6	14.8 ± 0.6	14.7 ± 0.9	59.3 ± 1.4

* 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		TLD Location*	Quarterly Exposure - mR/quarter (Value ± Std.Dev.)				2021 Annual** Exposure mR/year
ID	Description	Distance/Direction	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	
Zone 2 TLDs: 3-8 km		3-8 km	14.8 ± 2.2	15.4 ± 2.3	17.2 ± 0.5	16.6 ± 0.8	61.6 ± 8.5
ME	MANOMET ELEM	3.29 km SE	16.5 ± 0.7	17.5 ± 0.5	17.1 ± 0.8	16.3 ± 0.9	67.3 ± 2.7
MS	MANOMET SUBSTATION	3.60 km SSE	16.6 ± 0.5	17.0 ± 0.8	17.2 ± 0.8	16.9 ± 1.0	67.6 ± 1.9
PT	PINES ESTATE	4.44 km SSW	13.2 ± 0.7	13.7 ± 0.5	Removed	Removed	53.8 ± 2.1
RM	RUSSELL MILLS RD	4.85 km WSW	13.8 ± 0.4	14.2 ± 0.6	Removed	Removed	56.0 ± 1.8
MB	MANOMET BEACH	5.43 km SSE	14.0 ± 0.5	14.7 ± 0.6	Removed	Removed	57.3 ± 2.5
BR	BEAVERDAM ROAD	5.52 km S	14.9 ± 0.8	14.9 ± 0.5	Removed	Removed	59.6 ± 1.8
LD	LONG POND/DREW RD	6.97 km WSW	11.9 ± 0.5	12.3 ± 0.7	Removed	Removed	48.5 ± 2.1
HR	HYANNIS ROAD	7.33 km SSE	13.9 ± 0.8	14.6 ± 0.6	Removed	Removed	57.0 ± 0.0
MH	MEMORIAL HALL	7.58 km WNW	19.5 ± 0.9	20.4 ± 0.7	Removed	Removed	79.7 ± 3.3
CP	COLLEGE POND	7.59 km SW	13.6 ± 0.8	14.8 ± 0.7	Removed	Removed	56.8 ± 4.1
Zone 3 TLDs: 8-15 km		8-15 km	14.6 ± 2.1	15.3 ± 1.9	N/A	N/A	59.8 ± 7.6
DW	DEEP WATER POND	8.59 km W	16.2 ± 0.6	17.3 ± 0.6	Removed	Removed	67.1 ± 3.6
LP	LONG POND ROAD	8.88 km SSW	12.4 ± 0.7	13.4 ± 0.5	Removed	Removed	51.6 ± 3.3
NP	NORTH PLYMOUTH	9.38 km WNW	16.6 ± 0.5	16.5 ± 0.8	Removed	Removed	66.1 ± 1.9
SH	SACRED HEART	12.92 km W	13.3 ± 0.5	14.0 ± 0.6	Removed	Removed	54.6 ± 2.3
Zone 4 TLDs: >15 km		>15 km	17.8 ± 1.1	17.5 ± 0.6	18.2 ± 1.4	18.6 ± 1.5	72.4 ± 4.0
DMF	DIV MARINE FISH	20.97 km SSE	18.5 ± 0.7	M ± M	19.1 ± 0.6	19.5 ± 1.0	76.2 ± 2.7
EW	E WEYMOUTH SUBST	39.69 km NW	17.1 ± 0.7	17.5 ± 0.6	17.3 ± 0.7	17.6 ± 1.1	69.5 ± 1.8

* 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 2.4-2

Onsite Environmental TLD Results

TLD Station		TLD Location*	Quarterly Exposure - mR/quarter (Value ± Std.Dev.)				2021 Annual** Exposure mR/year
ID	Description	Distance/Direction	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	
Onsite TLDs							
P17	FENCE-EXEC.BUILDING	107 m W	798.8 ± 27.2	772.2 ± 21.7	712.2 ± 19.3	146.8 ± 7.7	2429.9 ± 1237.6
P11	FENCE-TCF GATE	183 m ESE	131.5 ± 4.7	115.0 ± 5.7	102.2 ± 3.0	110.0 ± 4.9	458.6 ± 50.5
P27	FENCE-TCF/BOAT RAMP	185 m ESE	68.4 ± 4.0	66.4 ± 6.6	66.0 ± 3.5	66.1 ± 5.8	266.9 ± 11.2
P10	FENCE-TCF/INTAKE BAY	223 m E	81.5 ± 6.3	79.2 ± 3.8	80.7 ± 7.6	87.8 ± 9.3	329.2 ± 20.7

* 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 are noted with M.
-P17 shows higher than typical readings due to the movement of dry cask storage canisters and radwaste storage near TLD location, though decreasing in 4th quarter due to casks moving from ISFSI I pad to ISFSI II pad location.

Table 2.4-3

Average TLD Exposures By Distance Zone During 2021

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	21.0 ± 14.4	14.8 ± 2.2	14.6 ± 2.1	17.8 ± 1.1
Apr-Jun	21.9 ± 13.6	15.4 ± 2.3	15.3 ± 1.9	17.5 (1)
Jul-Sep	21.8 ± 13.1	17.2 ± 0.5	Removed	18.2 ± 1.4
Oct-Dec	25.8 ± 26.6	16.6 ± 0.8	Removed	18.6 ± 1.5
Jan-Dec	90.5 ± 70.6	61.6 ± 8.5	59.8 ± 7.6	72.4 ± 4.0

* 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 64.7 ± 8.9 mR/yr.

(1) No Standard deviation due to single data point.

Table 2.5-1
Air Particulate Filter Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2021)

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	341 0	0.01	1.7E-2 ± 5.4E-3 7.2E-3 - 4.9E-2 288 / 288	ER: 1.8E-2 ± 6.3E-3 7.5E-3 - 4.9E-2 53 / 53	1.7E-2 ± 4.3E-3 8.8E-3 - 2.5E-2 53 / 53
Be-7	44 0		6.1E-2 ± 6.3E-2 -5.2E-4 - 1.6E-1 40 / 40	1.3E-1 ± 2.2E-2 1.1E-1 - 1.5E-1 4 / 4	1.1E-1 ± 2.3E-2 9.6E-2 - 1.5E-1 4 / 4
Cs-134	44 0	0.05	-3.3E-4 ± 3.9E-3 -1.4E-2 - 1.7E-2 0 / 40	1.8E-4 ± 9.5E-4 -1.2E-3 - 7.3E-4 0 / 4	-1.9E-4 ± 8.6E-4 -1.0E-3 - 6.0E-4 0 / 4
Cs-137	44 0	0.06	2.1E-5 ± 4.7E-4 -1.3E-3 - 9.0E-4 0 / 40	EB: 3.8E-4 ± 5.5E-4 -1.1E-4 - 9.0E-4 0 / 4	-7.0E-5 ± 2.2E-4 -1.9E-4 - 1.7E-4 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 2021)

As stated in summary sections earlier in this report, vegetation sampling has been discontinued.

Table 2.8-1
Surface Water Radioactivity Analyses

Radiological Environmental Program Summary
Pilgrim Nuclear Power Station, Plymouth, MA
(January - December 2021)

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	12 0	3000	-4.2E+1 ± 9.4E+1 -1.8E+2 - 2.2E+1 0 / 8	PwPt: 5.6E+1 ± 2.2E+2 -1.1E+2 - 2.7E+2 0 / 4	5.6E+1 ± 1.6E+2 -1.1E+2 - 2.7E+2 0 / 4
K-40	24 0		2.8E+2 ± 3.3E+1 2.4E+2 - 3.4E+2 12 / 12	PwPt: 3.0E+2 ± 5.3E+1 2.1E+2 - 3.7E+2 12 / 12	3.0E+2 ± 5.3E+1 2.1E+2 - 3.7E+2 12 / 12
Mn-54	24 0	15	-2.8E-1 ± 1.5E+0 -2.3E+0 - 2.9E+0 0 / 12	Dis: -2.8E-1 ± 1.5E+0 -2.3E+0 - 2.9E+0 0 / 12	-2.8E-1 ± 1.2E+0 -2.5E+0 - 1.5E+0 0 / 12
Fe-59	24 0	30	-2.2E+0 ± 4.1E+0 -1.0E+1 - 3.0E+0 0 / 12	PwPt: 1.6E+0 ± 3.6E+0 -4.0E+0 - 8.5E+0 0 / 12	1.6E+0 ± 3.6E+0 -4.0E+0 - 8.5E+0 0 / 12
Co-58	24 0	15	-5.8E-1 ± 1.8E+0 -4.5E+0 - 2.5E+0 0 / 12	PwPt: -5.1E-1 ± 1.8E+0 -3.6E+0 - 2.3E+0 0 / 12	-5.1E-1 ± 1.8E+0 -3.6E+0 - 2.3E+0 0 / 12
Co-60	24 0	15	1.6E-1 ± 2.0E+0 -3.5E+0 - 3.8E+0 0 / 12	PwPt: 5.8E-1 ± 1.7E+0 -1.8E+0 - 3.2E+0 0 / 12	5.8E-1 ± 1.7E+0 -1.8E+0 - 3.2E+0 0 / 12
Zn-65	24 0	30	-3.8E+0 ± 4.3E+0 -1.1E+1 - 1.4E+0 0 / 12	PwPt: -1.6E+0 ± 3.9E+0 -8.3E+0 - 3.7E+0 0 / 12	-1.6E+0 ± 3.9E+0 -8.3E+0 - 3.7E+0 0 / 12
Zr-95	24 0	30	-1.8E-1 ± 3.6E+0 -6.6E+0 - 7.5E+0 0 / 12	PwPt: 2.8E-1 ± 2.9E+0 -3.4E+0 - 6.3E+0 0 / 12	2.8E-1 ± 2.9E+0 -3.4E+0 - 6.3E+0 0 / 12
Nb-95	24 0	15	-6.8E-1 ± 1.6E+0 -3.1E+0 - 2.7E+0 0 / 12	PwPt: 4.8E-1 ± 2.7E+0 -3.6E+0 - 6.3E+0 0 / 12	4.8E-1 ± 2.7E+0 -3.6E+0 - 6.3E+0 0 / 12
Cs-134	24 0	15	3.1E-1 ± 1.7E+0 -2.2E+0 - 2.7E+0 0 / 12	Dis: 3.1E-1 ± 1.7E+0 -2.2E+0 - 2.7E+0 0 / 12	-1.9E-1 ± 2.0E+0 -3.8E+0 - 2.8E+0 0 / 12
Cs-137	24 0	18	-2.6E-1 ± 2.5E+0 -6.1E+0 - 3.2E+0 0 / 12	PwPt: 4.3E-1 ± 1.6E+0 -1.4E+0 - 4.1E+0 0 / 12	4.3E-1 ± 1.6E+0 -1.4E+0 - 4.1E+0 0/ 12
Ba-140	24 0	60	-2.6E+0 ± 1.0E+1 -2.3E+1 - 1.6E+1 0 / 12	PwPt:3.4E+0 ± 1.3E+1 -2.6E+1 - 1.9E+1 0 / 12	3.4E+0 ± 1.3E+1 -2.6E+1 - 1.9E+1 0 / 12
La-140	24 0	15	1.8E+0 ± 5.5E+0 -9.6E+0 - 1.2E+1 0 / 12	Dis:1.8E+0 ± 5.5E+0 -9.6E+0 - 1.2E+1 0 / 12	-9.8E-1 ± 4.5E+0 -9.8E+0 - 7.0E+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 2021)

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	14 0		9.2E+3 ± 1.3E+3 7.1E+3 - 1.2E+4 8 / 8	DuxBay: 1.5E+4 ± 5.3E+2 1.4E+4 - 1.5E+4 2 / 2	1.3E+4 ± 2.5E+3 1.0E+4 - 1.5E+4 4 / 4
Cs-134	14 0	150	1.5E+1 ± 2.2E+1 -4.9E+0 - 5.1E+1 0/ 8	GrnHrb: 4.0E+1 ± 3.8E+1 1.4E+1 - 6.6E+1 0 / 2	3.1E+1 ± 2.5E+1 1.4E+1 - 6.6E+1 0 / 4
Cs-137	14 0	180	-4.6E+0 ± 1.7E+1 -3.0E+1 - 2.9E+1 0 / 8	GrnHrb: 1.8E+1 ± 1.1E+1 1.3E+1 - 2.3E+1 0 / 2	1.0E+1 ± 1.4E+1 -7.1E+0 - 2.3E+1 0 / 4
AcTh-228	14 0		2.5E+2 ± 5.6E+1 2.0E+2 - 3.6E+2 7 / 7	DuxBay: 5.3E+2 ± 6.7E+1 4.9E+2 - 5.8E+2 2 / 2	4.3E+2 ± 1.3E+2 3.1E+2 - 5.8E+2 4 / 4

* 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 2021)

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	10 0		1.5E+3 ± 3.8E+2 1.0E+3 - 1.9E+3 6 / 6	GrnHrb: 1.8E+3 ± 2.2E+2 1.7E+3 - 1.8E+3 2 / 2	1.6E+3 ± 3.9E+2 1.1E+3 - 1.8E+3 4 / 4
Mn-54	10 0	130	-4.3E+0 ± 1.3E+1 -1.9E+1 - 1.2E+1 0 / 6	Duxbay: 3.3E+0 ± 8.9E+0 9.1E-1 - 5.7E+0 0 / 2	-8.7E+0 ± 1.6E+1 -2.8E+1 - 5.7E+0 0 / 4
Fe-59	10 0	260	-2.0E+1 ± 2.6E+1 -5.0E+1 - 1.1E+1 0 / 6	Duxbay: 1.4E+1 ± 5.1E+1 -2.0E+1 - 4.8E+1 0 / 2	1.2E+1 ± 3.2E+1 -2.0E+1 - 4.8E+1 0 / 4
Co-58	10 0	130	1.5E+1 ± 1.7E+1 1.9E+0 - 4.4E+1 0 / 6	PlyHrb: 2.0E+1 ± 2.0E+1 1.9E+0 - 4.4E+1 0 / 4	-7.4E+0 ± 1.9E+1 -2.3E+1 - 1.6E+1 0 / 4
Co-60	10 0	130	7.9E-1 ± 1.1E+1 -6.9E+0 - 1.9E+1 0 / 6	Dis: 7.1E+0 ± 1.8E+1 -4.7E+0 - 1.9E+1 0 / 2	-4.6E+0 ± 2.0E+1 -2.9E+1 - 1.7E+1 0 / 4
Zn-65	10 0	260	-4.3E+1 ± 3.2E+1 -7.4E+1 - 4.2E+0 0 / 6	GrnHrb: -4.8E+0 ± 5.8E+1 -4.2E+1 - 3.2E+1 0 / 2	-1.1E+1 ± 3.7E+1 -4.2E+1 - 3.2E+1 0 / 4
Cs-134	10 0	130	1.5E+1 ± 2.2E+1 -8.4E+0 - 4.0E+1 0 / 6	PlyHrb: 2.3E+1 ± 2.3E+1 -8.4E+0 - 4.0E+1 0/ 4	-1.4E+1 ± 2.1E+1 -4.3E+1 - 1.8E+0 0 / 4
Cs-137	10 0	150	-1.0E+1 ± 2.2E+1 -3.9E+1 - 1.3E+1 0 / 6	PlyHrb: -8.8E+0 ± 1.8E+1 -2.9E+1 - 1.3E+1 0 / 4	-2.2E+1 ± 1.5E+1 -3.7E+1 - -5.0E+0 0 / 4

* 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 2021)

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 ± 6.2E+2 1.7E+3 - 3.1E+3 4 / 4	Dis: 2.5E+3 ± 6.2E+2 1.7E+3 - 3.1E+3 4 / 4	1.8E+3 ± 3.4E+2 1.8E+3 - 1.8E+3 1 / 1
Mn-54	5 0	130	1.3E+1 ± 2.5E+1 -8.6E+0 - 4.1E+1 0 / 4	Dis: 1.3E+1 ± 2.5E+1 -8.6E+0 - 4.1E+1 0 / 1	8.1E+0 ± 1.2E+1 8.1E+0 - 8.1E+0 0 / 1
Fe-59	5 0	260	5.3E+1 ± 8.7E+1 -3.2E+1 - 1.7E+2 0 / 4	Dis: 5.3E+1 ± 8.7E+1 -3.2E+1 - 1.7E+2 0 / 1	2.8E+1 ± 2.6E+1 2.8E+1 - 2.8E+1 0 / 1
Co-58	5 0	130	3.3E+0 ± 4.4E+1 -3.2E+1 - 6.3E+1 0 / 4	CcBay: 2.6E+1 ± 1.1E+1 2.6E+1 - 2.6E+1 0 / 4	2.6E+1 ± 1.1E+1 2.6E+1 - 2.6E+1 0 / 1
Co-60	5 0	130	3.0E+0 ± 3.0E+1 -2.8E+1 - 3.2E+1 0 / 4	Dis: 3.0E+0 ± 3.0E+1 -2.8E+1 - 3.2E+1 0 / 4	-6.7E+0 ± 1.4E+1 -6.7E+0 - -6.7E+0 0 / 1
Zn-65	5 0	260	-7.1E+1 ± 2.7E+1 -9.1E+1 - -4.1E+1 0 / 4	Dis: -7.1E+1 ± 2.7E+1 -9.1E+1 - -4.1E+1 0 / 4	-1.1E+2 ± 3.0E+1 -1.1E+2 - -1.1E+2 0 / 1
Cs-134	5 0	130	1.5E+1 ± 1.4E+1 1.1E+0 - 2.8E+1 0 / 4	Dis: 1.5E+1 ± 1.4E+1 1.1E+0 - 2.8E+1 0 / 1	-1.1E+1 ± 1.4E+1 -1.1E+1 - -1.1E+1 0 / 1
Cs-137	5 0	150	-5.8E-1 ± 1.1E+1 -9.7E+0 - 9.7E+0 0 / 4	Dis: -5.8E-1 ± 1.1E+1 -9.7E+0 - 9.7E+0 0 / 4	-7.8E+0 ± 1.2E+1 -7.8E+0 - -7.8E+0 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 2021)

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		3.3E+3 ± 1.0E+3 1.7E+3 - 4.1E+3 5 / 5	BuzBay: 3.5E+3 ± 1.7E+3 2.2E+3 - 5.4E+3 3 / 3	3.5E+3 ± 1.7E+3 2.2E+3 - 5.4E+3 3 / 3
Mn-54	8 0	130	-2.2E+0 ± 3.9E+1 -6.4E+1 - 3.4E+1 0 / 5	BuzBay: -2.8E-1 ± 2.1E+1 -2.2E+1 - 1.3E+1 0 / 3	-2.8E-1 ± 2.1E+1 -2.2E+1 - 1.3E+1 0 / 3
Fe-59	8 0	260	4.4E+0 ± 2.7E+1 -1.8E+1 - 3.5E+1 0 / 5	Dis: 4.4E+0 ± 2.7E+1 -1.8E+1 - 3.5E+1 0 / 5	-4.0E+1 ± 3.7E+1 -7.7E+1 - -9.1E+0 0 / 3
Co-58	8 0	130	-3.6E+0 ± 3.6E+1 -4.0E+1 - 5.4E+1 0 / 5	Dis: -3.6E+0 ± 3.6E+1 -4.0E+1 - 5.4E+1 0/ 5	-3.7E+0 ± 1.4E+1 -1.8E+1 - 4.2E+0 0 / 3
Co-60	8 0	130	-7.9E+0 ± 2.9E+1 -3.2E+1 - 4.0E+1 0 / 5	Dis: -7.9E+0 ± 2.9E+1 -3.2E+1 - 4.0E+1 0 / 5	-2.4E+1 ± 1.1E+1 -3.3E+1 - -1.9E+1 0 / 3
Zn-65	8 0	260	-4.9E+1 ± 8.3E+1 -1.5E+2 - 5.4E+1 0 / 5	Dis: -4.9E+1 ± 8.3E+1 -1.5E+2 - 5.4E+1 0 / 5	-9.4E+1 ± 9.1E+1 -1.6E+2 - 7.0E+0 0 / 3
Cs-134	8 0	130	5.2E+0 ± 2.1E+1 -1.3E+1 - 2.8E+1 0 / 5	BuxBay: 1.4E+1 ± 1.5E+1 -6.9E-1 - 2.2E+1 0 / 3	1.4E+1 ± 1.5E+1 -6.9E-1 - 2.2E+1 0 / 3
Cs-137	8 0	150	1.9E+1 ± 2.6E+1 -9.8E+0 - 4.8E+1 0 / 5	Dis: 1.9E+1 ± 2.6E+1 -9.8E+0 - 4.8E+1 0 / 5	1.3E+1 ± 1.6E+1 -9.9E-1 - 2.7E+1 0 / 3

* 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
TLDs Within Protected Area		
FENCE-EXEC.BUILDING	P17	107 m W
FENCE-TCF GATE	P11	183 m ESE
FENCE-TCF/BOAT RAMP	P27	185 m ESE
FENCE-TCF/INTAKE BAY	P10	223 m E

* 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	PEDESTRIAN BRIDGE	PB	0.21 km N
OVERLOOK AREA	OA	0.15 km W	EAST BREAKWATER	EB	0.44 km ESE
HEALTH CLUB	TC	0.15 km WSW	PROPERTY LINE	PL	0.54 km NNW
BOAT LAUNCH EAST	BLE	0.16 km ESE	E ROCKY HILL ROAD	ER	0.89 km SE
ISFSI DOSE #3	ISF-3	0.21 km W			
SHOREFRONT SECURITY	P01	0.22 km NNW			
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			
ISFSI DOSE #4	ISF-4	0.35 km WSW			
ISFSI DOSE #5	ISF-5	0.37 km WSW			
STATION A	A	0.37 km WSW			
ISFSI DOSE #6	ISF-6	0.41 km WSW			
STATION B	B	0.44 km S			
EAST BREAKWATER	EB	0.44 km ESE			
PNPS MET TOWER	PMT	0.44 km WNW			
ISFSI DOSE #7	ISF-7	0.45 km W			
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

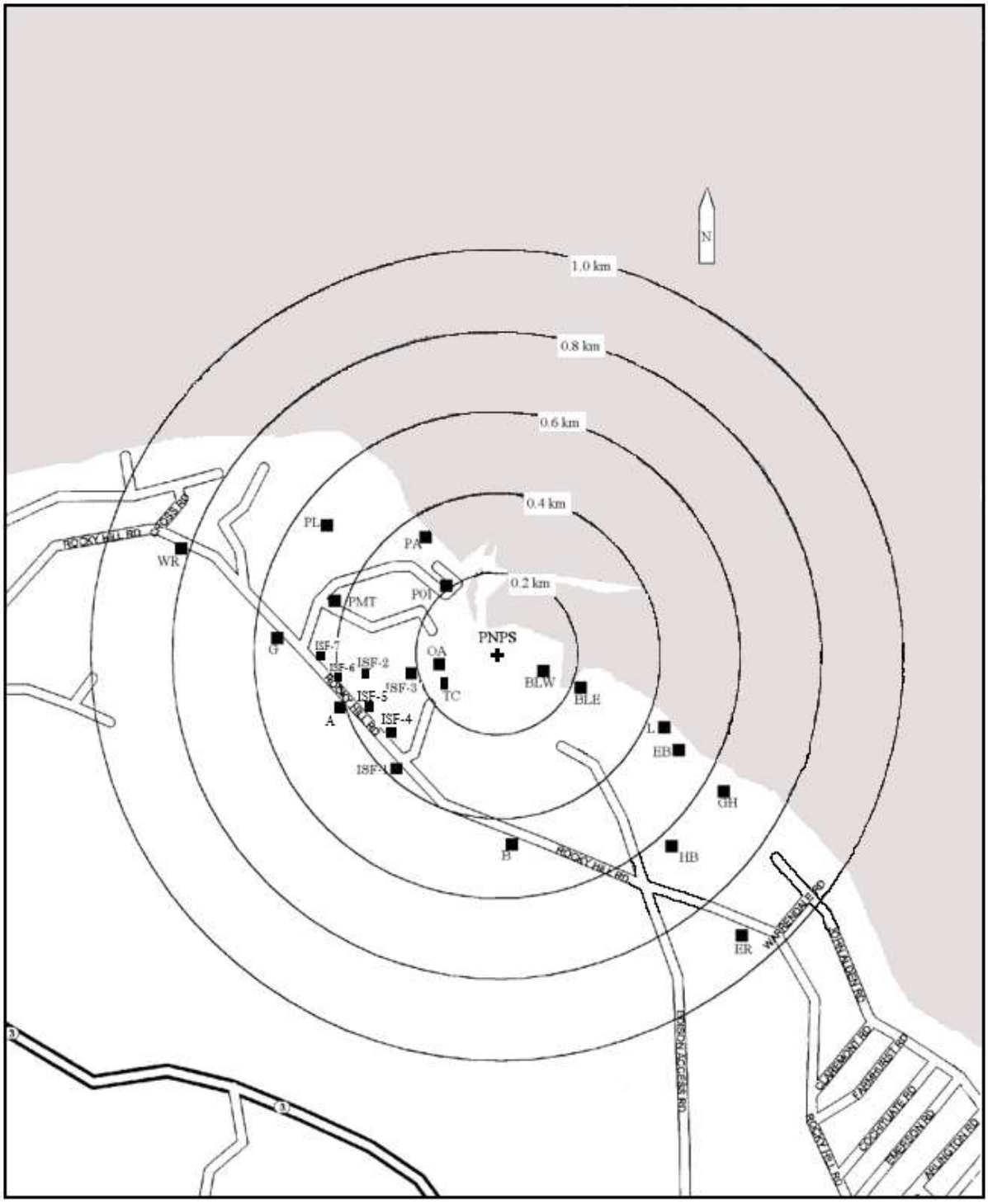


Figure 2.2-3

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			
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			

* 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

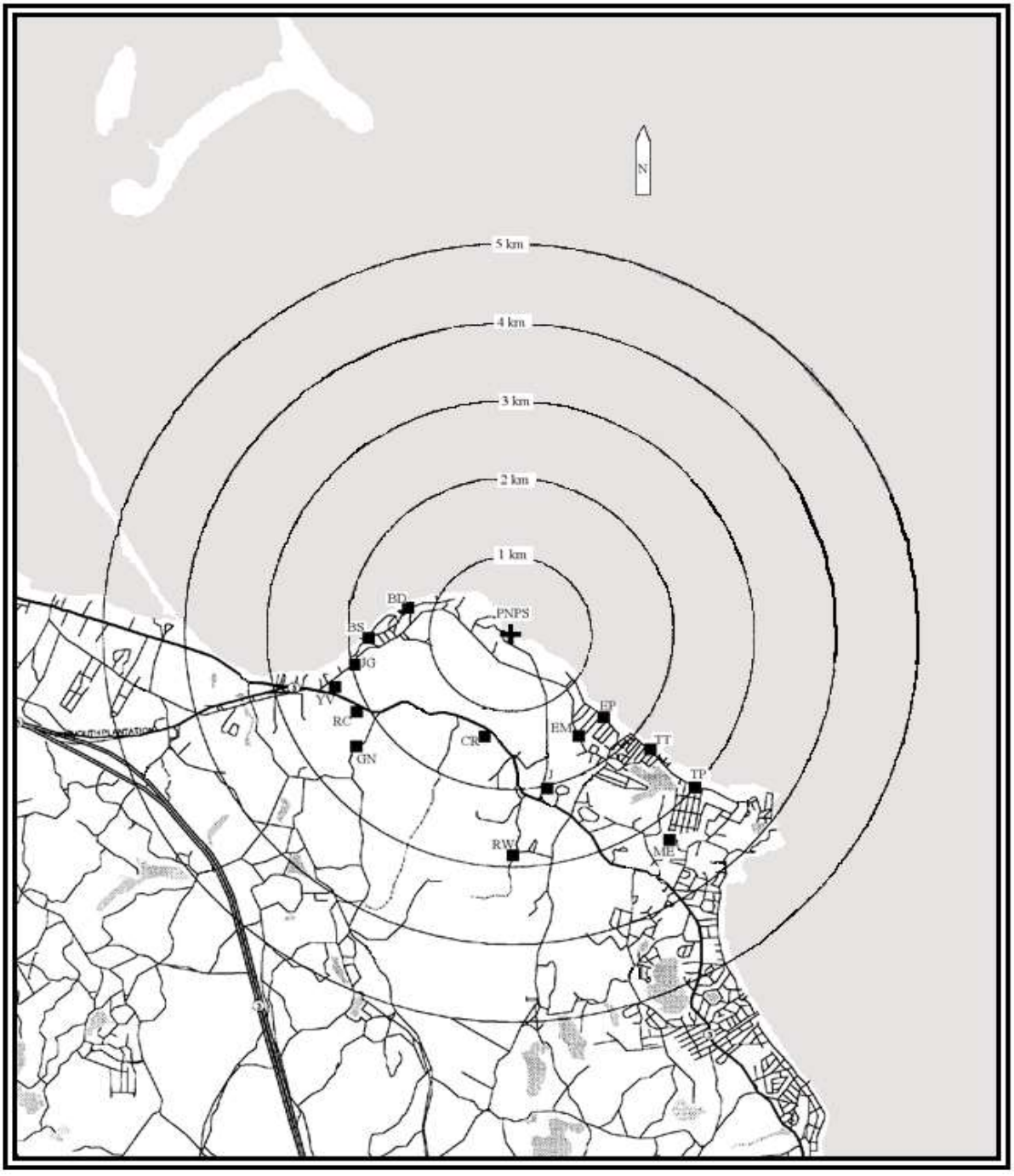


Figure 2.2-4

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 4 TLDs: >15 km			EAST WEYMOUTH SUBST	EW	39.69 km NW
DIV MARINE FISH	DMF	20.97 km SSE			
EAST WEYMOUTH SUBST	EW	39.69 km NW			

* 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

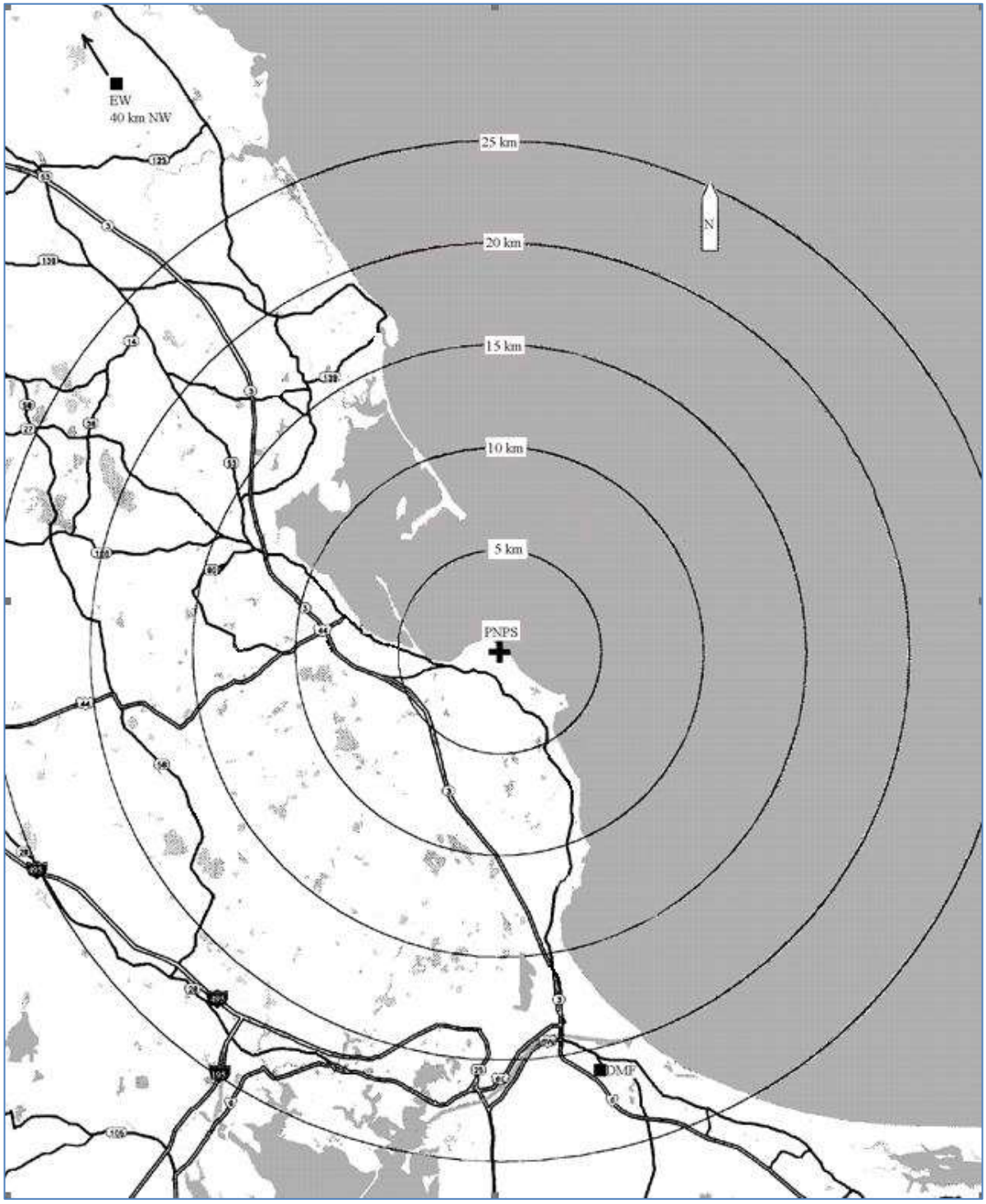


Figure 2.2-5

Marine/ Aquatic Sampling Locations

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
Manomet Point	MP	3.3 km ESE
Plymouth Beach	PLB	4.0 km WNW
Plymouth Harbor	PLY-H	4.1 km W
Green Harbor Control	GH	16 km NNW
MUSSELS		
Discharge Canal Outfall	DIS	0.7 km NNE
Plymouth Harbor	PLY-H	4.1 km W
Green Harbor Control	GH	16 km NNW
SOFT-SHELLED CLAMS		
Plymouth Harbor	PLY-H	4.1 km W
Duxbury Bay Control	DUX-BAY	13 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)

Marine/Aquatic Sampling Locations

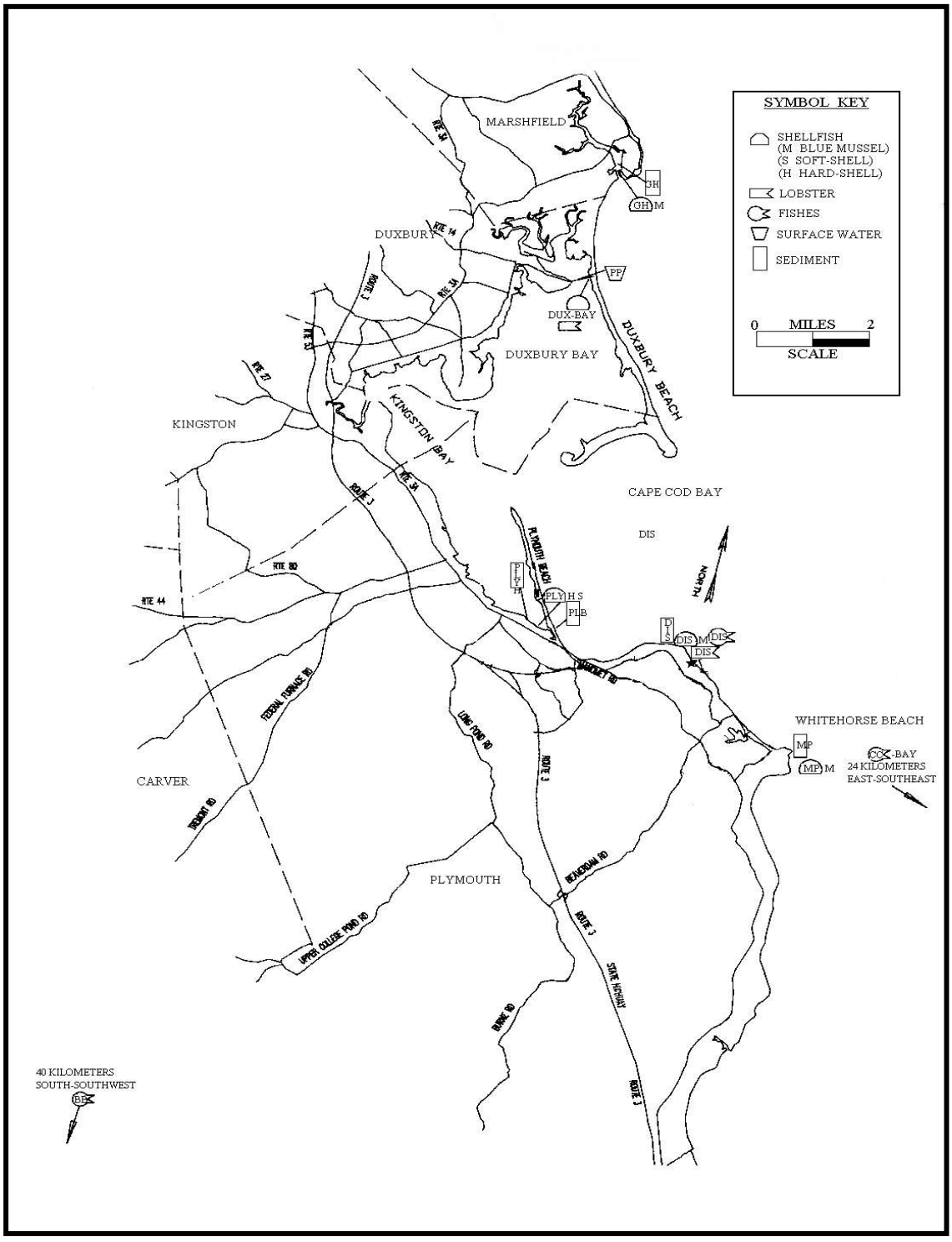


Figure 2.2-6

Environmental Sampling And Measurement Control Locations

Description	Code	Distance/Direction*
TLD (Controls)		
Div. Marine Fisheries	DMF	21 km SSE
East Weymouth Substation	EW	40 km NW
AIR SAMPLING (Control)		
East Weymouth Substation	EW	40 km NW

Description	Code	Distance/Direction*
SURFACE WATER		
Powder Point Control	PP	13 km NNW
SEDIMENT		
Green Harbor Control	GH	16 km NNW
MUSSELS		
Green Harbor Control	GH	16 km NNW
SOFT-SHELLED CLAMS		
Duxbury Bay Control	DUX-BAY	13 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

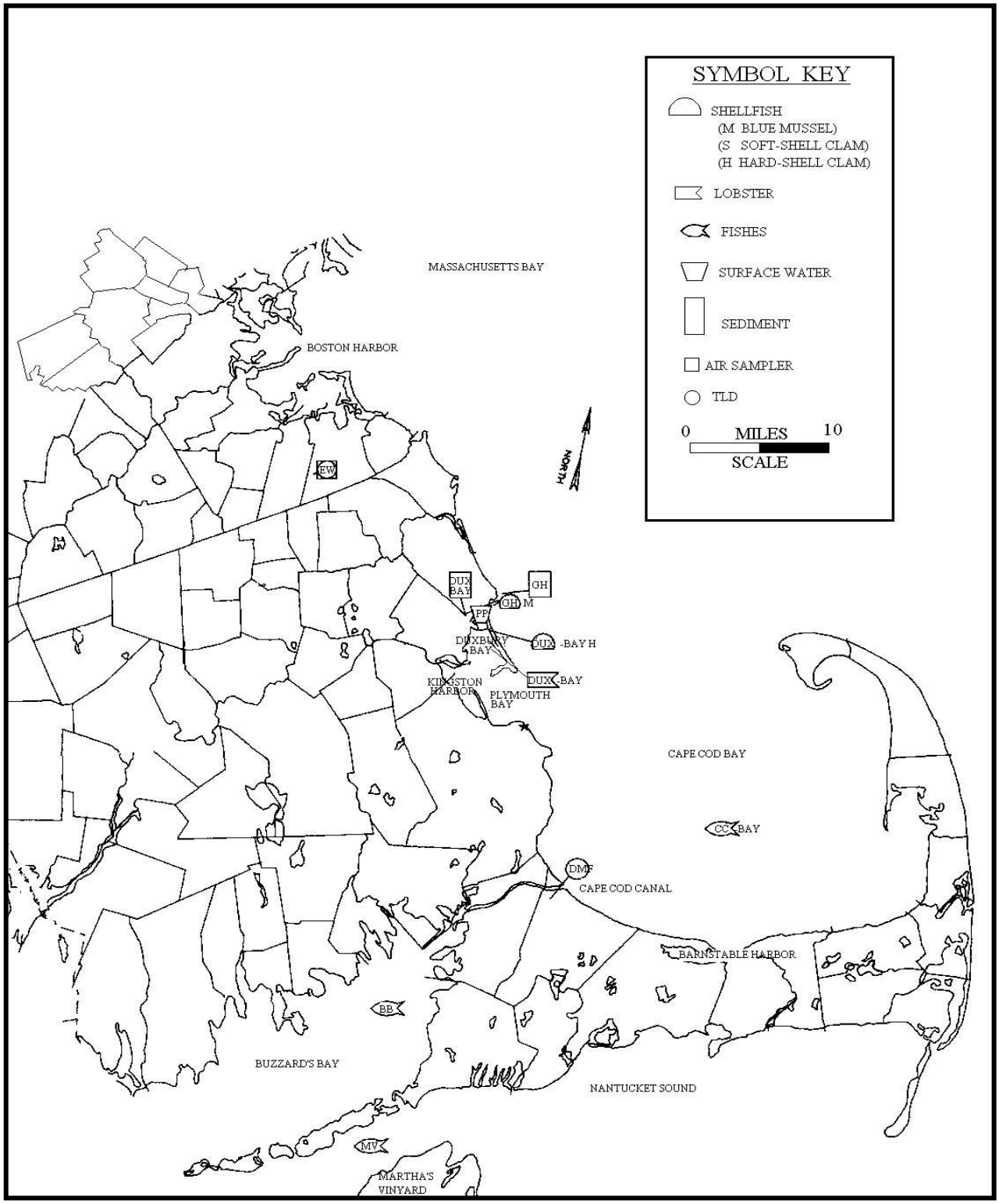


Figure 2.5-1
Airborne Gross-Beta Radioactivity Levels: Near Station Monitors

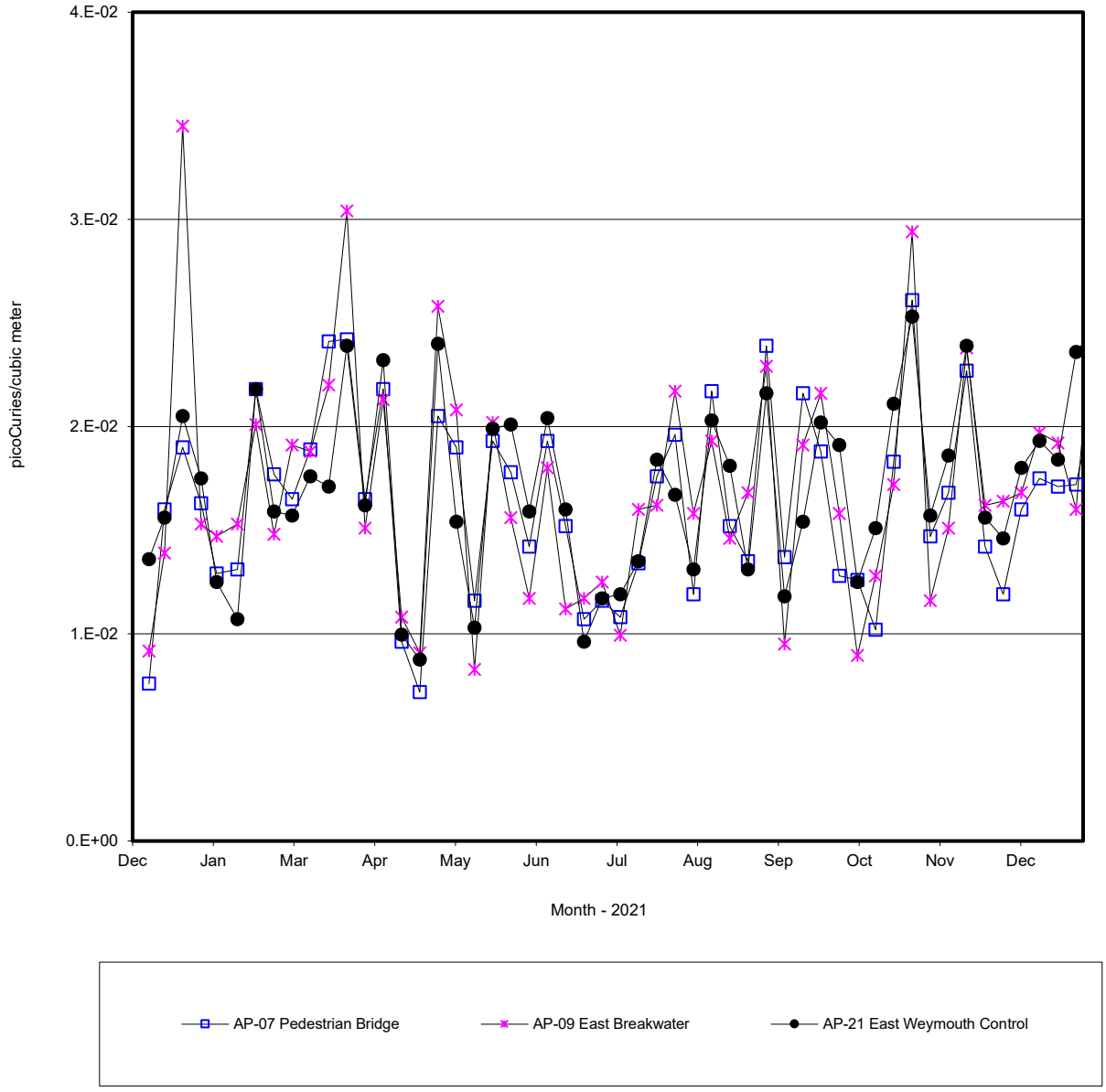


Figure 2.5-2
Airborne Gross-Beta Radioactivity Levels: Property Line Monitors

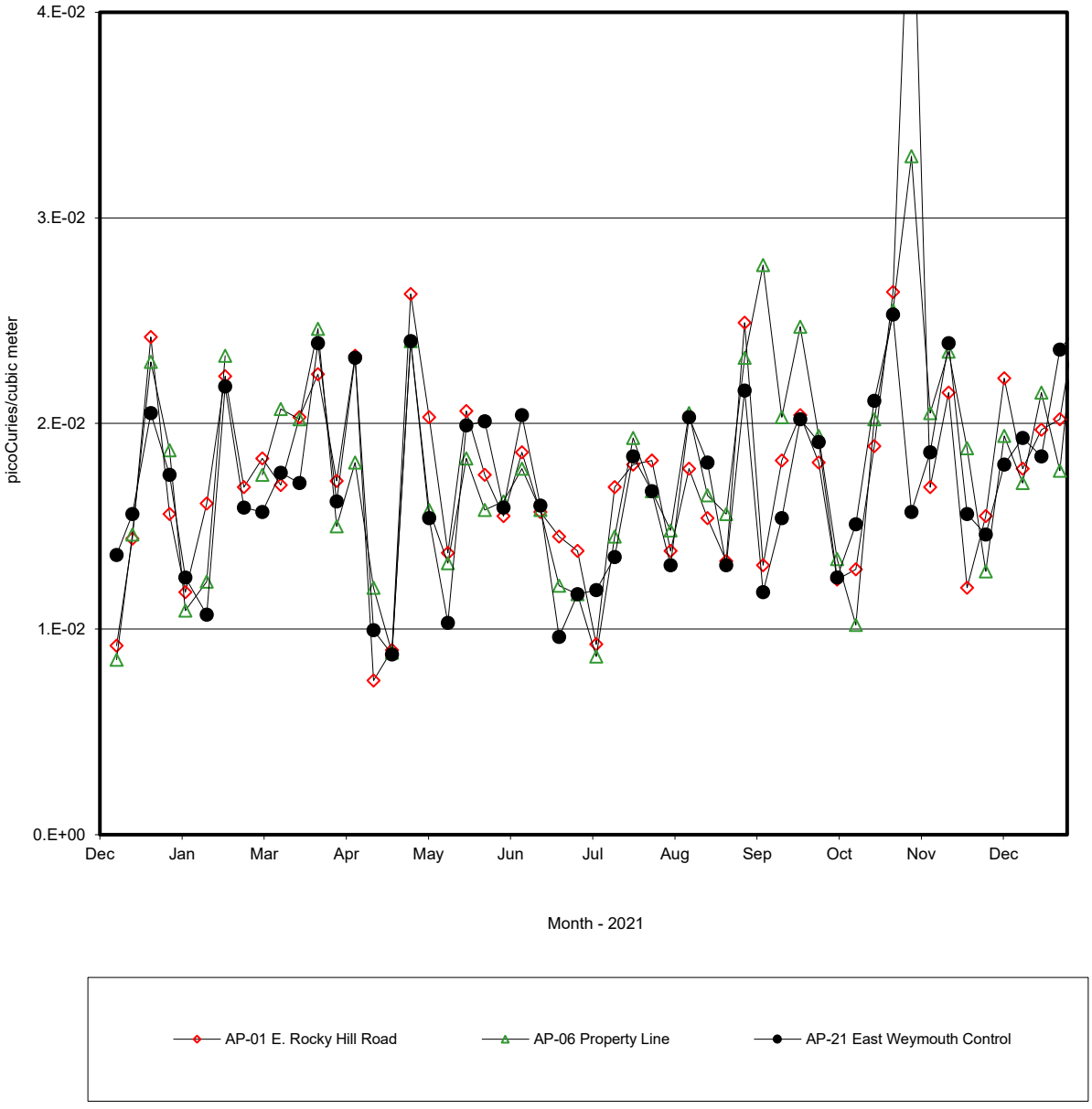
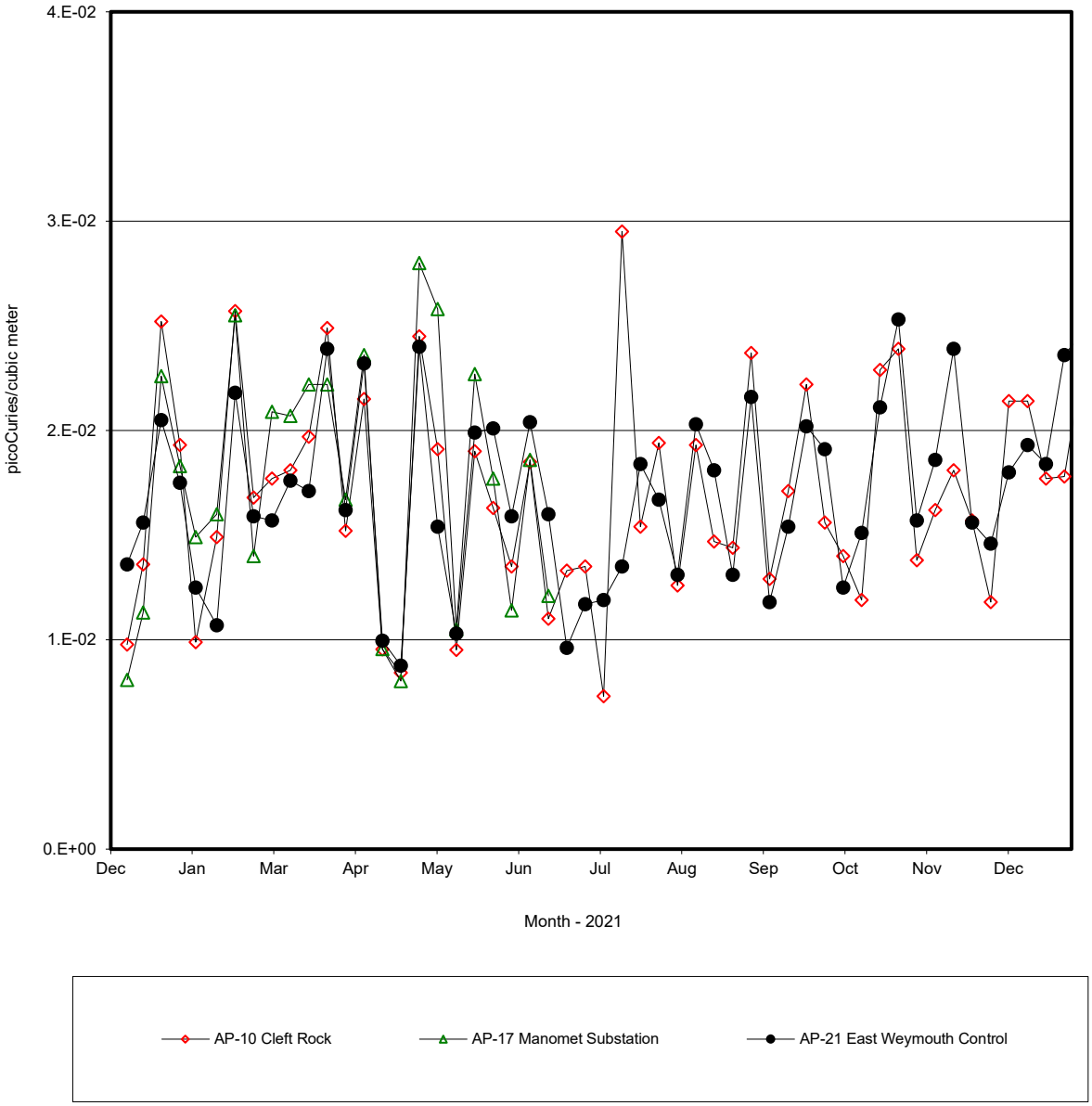


Figure 2.5-3
Airborne Gross-Beta Radioactivity Levels: Offsite Monitors



* Manomet substation collection was discontinued after the ODCM revision 15 collapsed the outer sampling ring to 3km.

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 2021 were reported to the Nuclear Regulatory Commission within the station's Annual Radiological Effluent Release Report (ARERR). The measured levels of radioactivity in the special studies environmental samples that required dose calculations are listed in Appendix A.

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

- shoreline external radiation during fishing and recreation at the Pilgrim Station Shorefront; Note: there is no actual access to the shorefront allowed to a MEMBER of the PUBLIC. Recreational areas were closed to unauthorized personnel after 9/11.
- 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. Note: There are no milk/ meat animals in the vicinity Pilgrim Station

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, 2021 (Reference 17).

Table 3.0-1

Radiation Doses from 2021 Pilgrim Station Operations

Receptor	Maximum Individual Dose From Exposure Pathway - mrem/yr			
	Gaseous Effluents*	Liquid Effluents	Ambient Radiation**	Total
Total Body	0.00023	N/A	0.30	0.30
Thyroid	0.00015	N/A	0.30	0.30
Max. Organ	0.00024	N/A	0.30	0.30

* Gaseous effluent exposure pathway includes combined dose from particulates and tritium, 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 decommissioning operations during 2021, 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 decommissioning 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 15, June 2021.

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 2021.

APPENDIX A

SPECIAL STUDIES

There were no environmental samples collected during 2021 that contained plant-related radioactivity. Therefore, no special studies were required to estimate dose from plant-related radioactivity.

APPENDIX B

LAND USE CENSUS RESULTS

The annual land use census requirement for gardens and milk and meat animals, as well as the broadleaf vegetation collection in the vicinity of Pilgrim Station was discontinued in 2021 with Revision 15 of the ODCM. As stated earlier in this report the broadleaf vegetation collection was in lieu of milk sampling as a type of cattle feed to account for iodine deposition. At the plant is permanently in a shutdown and decommissioned status no new iodine is produced and that which was produced has decayed away.

No new milk or meat animals were identified during the last 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 C

ENVIRONMENTAL MONITORING PROGRAM DISCREPANCIES

There were a number of instances during 2021 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 six airborne sampling locations during 2021. Most of these interruptions were due to short-term power losses due to weather related events . 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 335 filters collected. In the fourth quarter of 2019, following the permanent shutdown of the station, the use of charcoal cartridges at air sample locations was discontinued as iodine had decayed away.

Out of 342 filters 335 samples were collected and analyzed during 2021. 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. In 2021 the air sample station at the Pedestrian Bridge was modified to increase the capabilities of collecting a representative sample after observations during an NRC inspection of the REMP program. The following table contains a listing of problems encountered with air sampling stations during 2021, 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
EB	1/12-1/19/21	75	Ground Fault Circuit Interrupt (GFCI) tripped LLDs not Met due to low volume (IR-2600)
PL	2/16-3/2/21	No hours lost	2 week sample. No access to sample location (IR-2783
EB	3/16-3/23/21	162	Loss of power to sample station (cord was removed) (IR-2877)
CR	7/6-7/13/21	91	Ground Fault Circuit Interrupt (GFCI) tripped sample volume insufficient to meet LLDs
PC		No hours lost	2 week sample. No access to sample location
PL PB ER	10/26-11/3/21	130 31.8 149	Due to storm, three stations lost power. (IR 3942)

Despite the lower-than-normal sampling volumes in the various instances involving power interruptions and equipment failures, required LLDs were met on 335 of the 342 particulate filters during 2021. When viewed collectively during the entire year of 2021, the following sampling recoveries were achieved in the airborne sampling program. Note the Manomet station has 46% recovery is due to the removal of sample location from the ODCM mid year and some are over 100% as the calculation is based off 52 weeks and 2021 included 53 weeks of samples.

Location	Recovery	Location	Recovery
ER	100.1%	CR	100.8%
PL	100.3%	MS	46.1%
PB	101.5%	EW	101.8%
EB	99.8%		

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. Group I (autumn) and Group III (autumn) fish could not be collected.

In summary, the various problems encountered in collecting and analyzing environmental samples during 2021 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 D

Environmental Dosimetry Company
Annual 2021 Quality Assurance Status Report

ENVIRONMENTAL DOSIMETRY COMPANY

ANNUAL QUALITY ASSURANCE STATUS REPORT

January - December 2021

Prepared By: _____ Date: 3/16/22

Approved By: _____ Date: 3/16/22

Environmental Dosimetry Company
10 Ashton Lane
Sterling, MA 01564

TABLE OF CONTENTS

LIST OF TABLES

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 was performed in 2021.There were no findings.

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 i^{th} dosimeter (i.e., the reported exposure)

H_i = the exposure delivered to the i^{th} 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 i^{th} dosimeter (i.e., the reported exposure)

H_i = the exposure delivered to the i^{th} irradiated test dosimeter (i.e., the delivered exposure)

n = the number of dosimeters in the test group

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 i^{th} dosimeter is:

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

where:

H_i' = the reported exposure for the i^{th} 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

3. 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.

4. 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.

5. 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 2021

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)

No condition reports were issued during this annual period.

V. STATUS OF AUDITS/ASSESSMENTS

1. Internal

EDC Internal Quality Assurance Assessment was conducted during the fourth quarter 2021. There were no findings identified.

2. External

None.

VI. PROCEDURES AND MANUALS REVISED DURING JANUARY - DECEMBER 2021

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, 2021.

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 2021[(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 2021[(1), (2)]

Process Date	Exposure Level	Mean Bias %	Standard Deviation %	Tolerance Limit +/-15%
5/04/2021	33	0.6	0.9	Pass
5/06/2021	120	-0.2	1.4	Pass
5/26/2021	53	-3.8	1.6	Pass
7/27/2021	67	2.8	1.4	Pass
8/04/2021	91	-1.8	2.3	Pass
9/14/2021	47	-0.2	2.3	Pass
11/01/2021	28	3.7	0.6	Pass
11/03/2021	74	1.9	1.9	Pass
11/09/2021	103	1.1	1.1	Pass
01/26/2022	37	2.6	1.9	Pass
01/30/2022	85	-4.2	1.1	Pass
02/06/2022	58	2.9	1.2	Pass

[(1)]This table summarizes results of tests conducted by EDC for TLDs issued in 2021.
[(2)]Environmental dosimeter results are free in air.

TABLE 3
SUMMARY OF INDEPENDENT DOSIMETER TESTING JANUARY – DECEMBER 2021[(1), (2)]

Issuance Period	Client	Mean Bias %	Standard Deviation %	Pass / Fail
1st Qtr. 2021	SONGS	-3.8	1.4	Pass
1st Qtr. 2021	SONGS	-4.7	1.1	Pass
2nd Qtr.2021	Seabrook	3.1	1.0	Pass
3rd Qtr. 2021	Millstone	-4.7	1.4	Pass
4th Qtr.2021	PSEG(PNNL) 50mR	1.3	0.8	Pass
4th Qtr.2021	PSEG(PNNL) 100mR	1.8	0.8	Pass
4th Qtr.2021	PSEG(PNNL) 150mR	-0.6	0.5	Pass
4th Qtr.2021	PSEG(PNNL) 200mR	-2.6	2.0	Pass
4th Qtr.2021	Seabrook	2.6	1.4	Pass

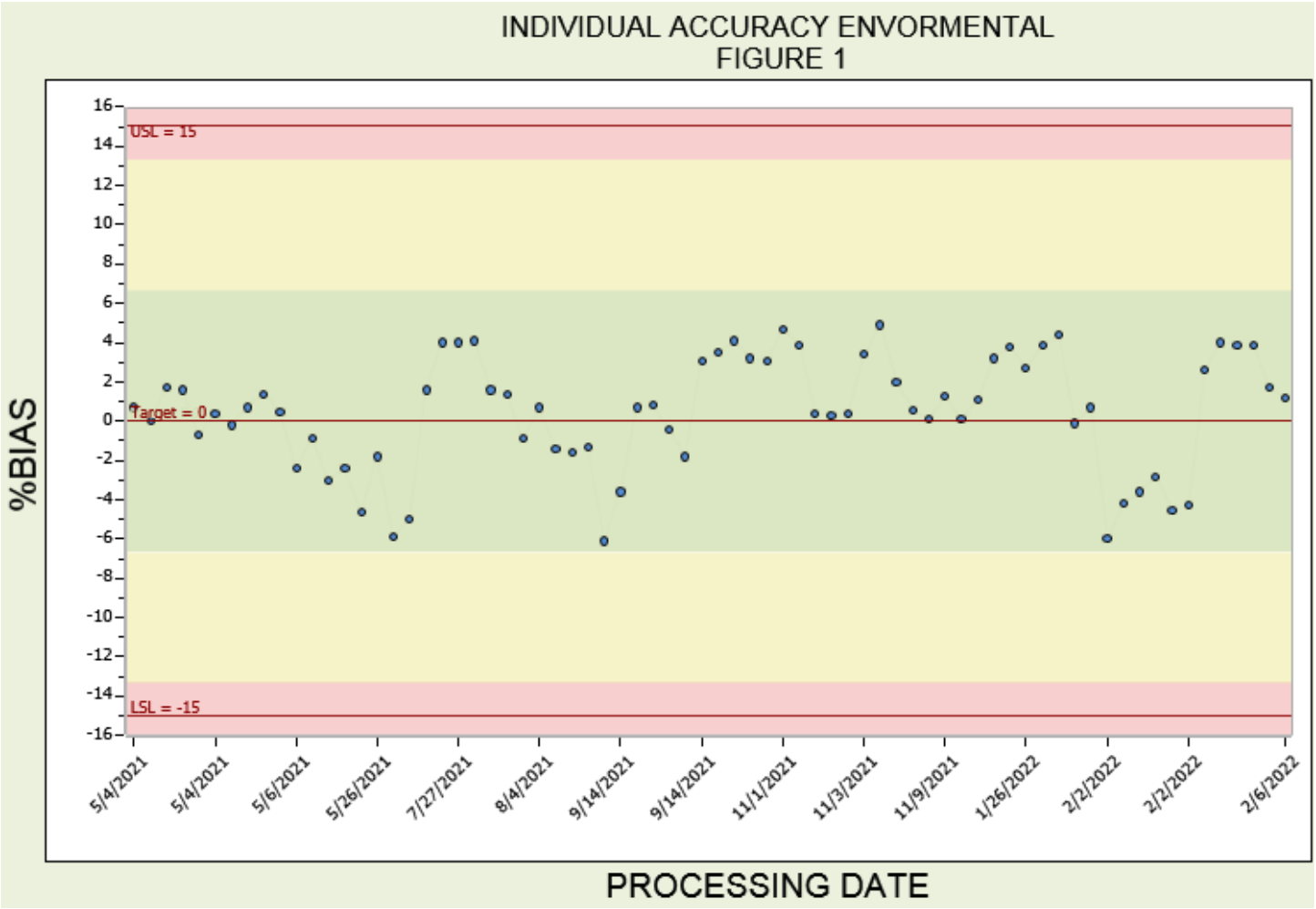
[(1)]Performance criteria are +/- 15%.
[(2)]Blind spikeirradiations using Cs-137

APPENDIX A

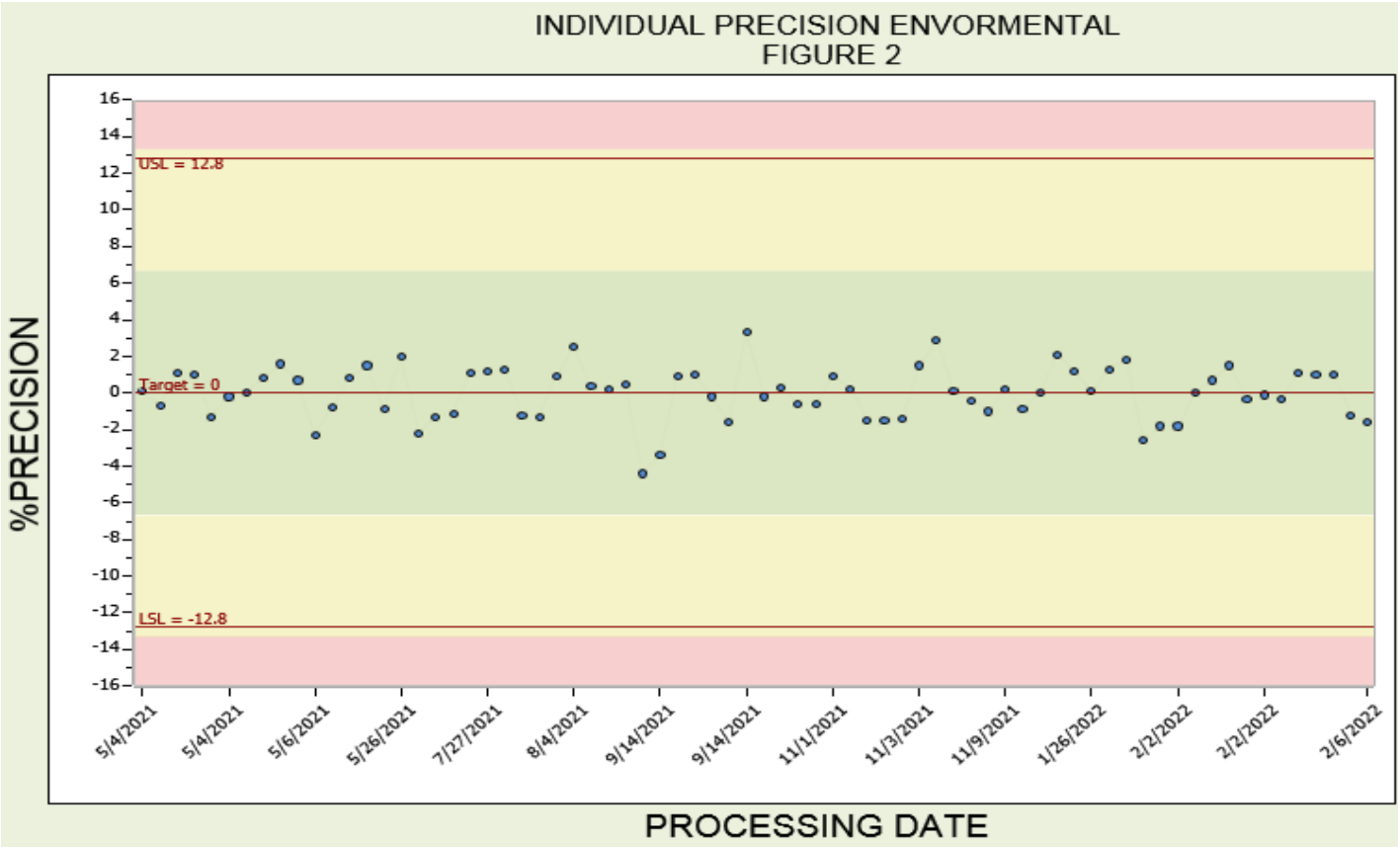
DOSIMETRY QUALITY CONTROL TRENDING GRAPHS

ISSUE PERIOD JANAURY - DECEMBER 2021

INDIVIDUAL ACCURACY ENVORMENTAL
FIGURE 1

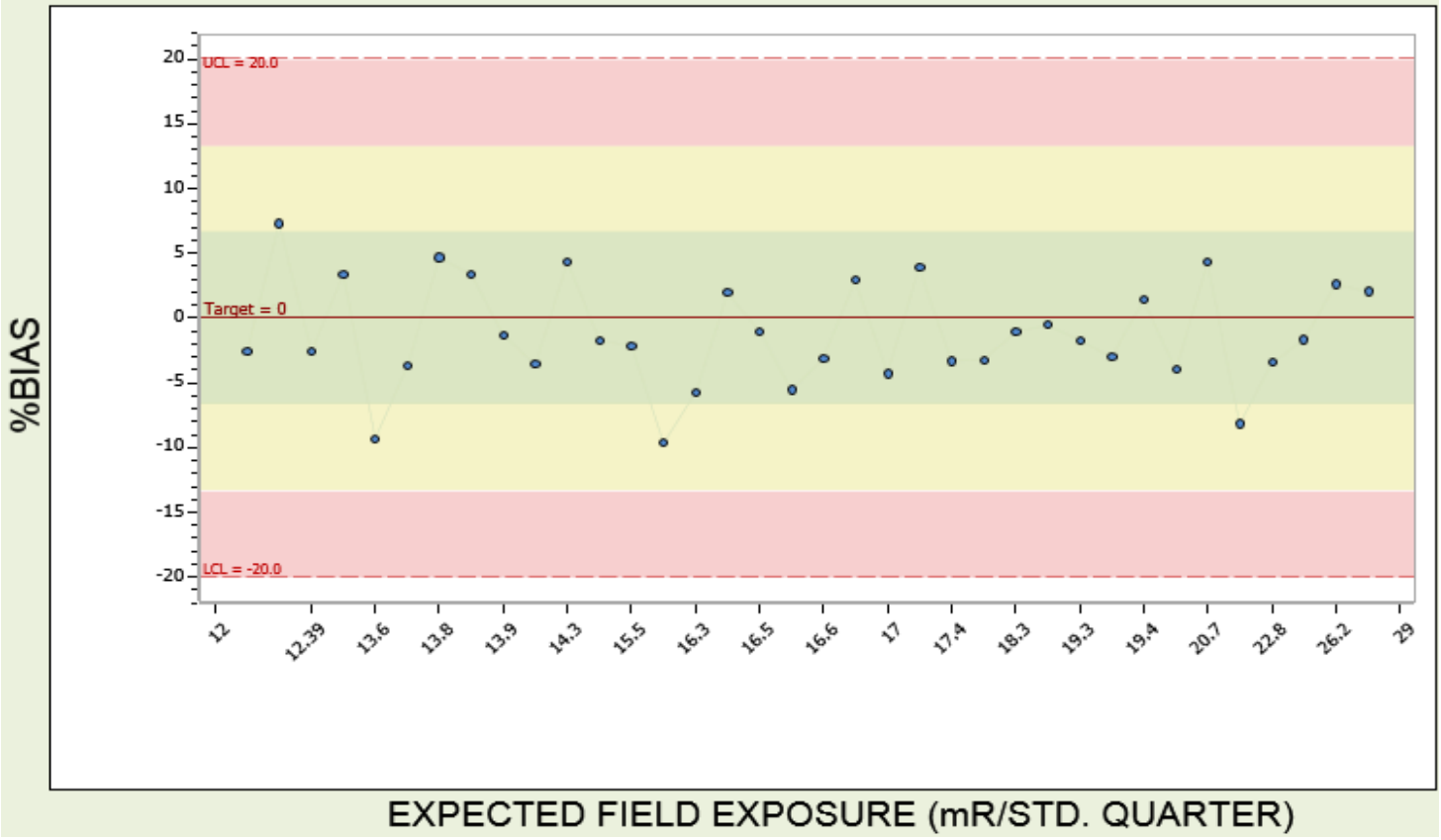


INDIVIDUAL PRECISION ENVORMENTAL
FIGURE 2



MEAN ACCURACY ENVORMENTAL
FIGURE 3

SEABROOK CO-LOCATE ACCURACY
FIGURE 4



APPENDIX E

Teledyne Brown Engineering Environmental Services
Annual 2021 Quality Assurance Report

TELEDYNE
BROWN ENGINEERING
A Teledyne Technologies Company

TELEDYNE BROWN ENGINEERING ENVIRONMENTAL SERVICES

Knoxville Laboratory

4th Quarter 2021 QUALITY ASSURANCE REPORT

January – December 2021

Teledyne Brown Engineering
2508 Quality Lane
Knoxville, TN 37931-3133

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4th Quarter 2021 Quality Assurance Report

Review and Signatures

Quality Assurance Manager:
Contractual Review

Sharon L Northcutt 02/04/22

Sharon L. Northcutt **Date**

Laboratory Operations Manager:
Technical Review

Keith O. Jeter 2/4/22

Keith O. Jeter **Date**

TABLE OF CONTENTS

I. INTRODUCTION

This report covers the Quality Assurance (QA) Program for the Analytical Services function of the Teledyne Brown Engineering Environmental Services (TBE-ES) laboratory for January through December 2021.

A. Operational Quality Control Scope

The TBE-ES Laboratory Quality Control (QC) Program is designed to monitor the quality of analytical processing associated with environmental, effluent (USNRC Regulatory Guide 4.15), bioassay, industrial process, and waste characterization (10CFR Part 61) samples.

Quality Control of radioanalyses involves an internal process control program and participation in external independent third party programs administered by Analytics, Environmental Resource Associates (ERA) and the Department of Energy (DOE) Mixed Analyte Performance Evaluation Program (MAPEP). *The MAPEP is designed to evaluate specific analytical capabilities that are of importance for DOE analytical services. These types of performance evaluation samples may contain both radiological and non-radiological "mixed" analytes and are reflective of real-world samples seen from DOE monitoring sites. Although TBE-ES is not currently under contract to analyze samples for DOE sites, the laboratory chooses to participate in PE program because it offers a variety of matrices and nuclides that are analyzed on a routine basis (water, soil, air filters, etc.).*

1. Interlaboratory

Results for third-party process checks prepared by Analytics, ERA and MAPEP are not reported during the first quarter of the year.

Inter-laboratory cross-check samples are received and reported as follows:

- Analytics cross-check samples are analyzed by TBE two times per year, typically in April and September.
- MAPEP provides samples semi-annually in March and September with required reporting dates in May and November, respectively, following sample receipt.
- ERA cross-check samples are analyzed by TBE semi-annually in April and October with required reporting dates in May and November, respectively, following sample receipt.

2. Intralaboratory

The internal QC program is designed to include QC functions such as instrumentation checks (to insure proper instrument response) and blank samples (to which no analyte radioactivity has been added) for contamination checks and instrumentation backgrounds. Process controls (or process checks) are actual samples analyzed in duplicate (duplicates) in order to evaluate the precision of laboratory measurements. Accuracy of analyses is measured by analyzing blank samples which have been spiked

with a known quantity of a radioisotope (spikes) that are of interest to laboratory clients. Some client samples are also spiked with a known activity of target analyte (matrix spikes) and aid in evaluating analytical method performance.

QC samples are intended to evaluate the entire radiochemical and radiometric process. Process control and qualification analyses samples seek to mimic the media type of those samples submitted for analysis by laboratory clients. The magnitude of the process control program combines both internal and external sources targeted at 10% of the routine sample analysis load. A summary of blanks, spikes and duplicates is found in Attachments B.1 and B.2.

3. Quality Assurance Program

To provide direction and consistency in administering the quality assurance program, TBE-ES has developed and follows a Quality Manual and a set of Standard Operating Procedures (SOP). The plan describes the scheduled frequency and scope of Quality Assurance and Quality Control (QA/QC) considered necessary for an adequate QA/QC program conducted throughout the year.

Internal audits are performed on an annual schedule, usually during the 4th quarter. External audits are performed by prospective and/or existing clients in accordance with contractual specifications. State audits are conducted to maintain client-specific certification requirements and for accreditation by the National Environmental Laboratory Accreditation Program (NELAP). The Nuclear Procurement Issues Corporation (NUPIC) evaluates suppliers of laboratory services to nuclear utilities. TBE-ES is audited every 33-36 months by NUPIC as a function of the utilities' Radiological Environmental Monitoring Program (REMP).

One audit was performed during the second quarter of 2021 by the Utah Department of Health (NELAP). Results are included in Attachment D.2.

B. Performance Characteristics

1. Interlaboratory Accuracy

TBE-ES has adopted a QC acceptance protocol based upon two external performance models. For the interlaboratory programs that have established performance criteria (e.g., established warning and failure limits), the laboratory uses those established criteria to evaluate QC sample results. For interlaboratory QC programs which report no pre-set acceptance (pass/fail) criteria (e.g. Analytics Cross Check Program), results are evaluated in accordance with TBE-ES internal acceptance criteria.

a) Analytics' Evaluation Criteria

Analytics' evaluation report provides a ratio of TBE's result and the Analytics known value. Since flag values are not assigned, TBE-ES

evaluates the reported ratios based on internal QC requirements, which are based on the DOE MAPEP criteria.

b) MAPEP Evaluation Criteria

MAPEP evaluation criteria found in the *Handbook for the Department of Energy's Mixed Analyte Performance Evaluation Program (MAPEP)*, MAPEP-HB-1 Rev. 2 (June 13, 2018), pp. 9-11 & 30-32 and online at https://www.id.energy.gov/resl/mapep/MAPEP-HB-1%20Rev%202.pdf contains the following information:

MAPEP's evaluation report provides a calculated relative bias for the lab's reported results, the acceptance range, and associated flag values. The relative bias places the laboratory result in one of three categories:

- Acceptable (flag = A) — Bias <= 20%
- Acceptable with Warning (flag = W) — 20% < Bias <=30%
- Not Acceptable (flag = N) — Bias > 30%

Radiological results must be reported with an associated uncertainty at one standard deviation. The uncertainty associated with a result is not currently used as part of the acceptance criteria, but an uncertainty evaluation is used to flag potential areas of concern. MAPEP assigns A (Acceptable), W (Acceptable with Warning) and N (Not Acceptable) uncertainty flags based upon the relative precision (RP) ratio:

$$RP = (\text{Reported Uncertainty} / \text{Reported Result}) \times 100$$

Uncertainty flags are currently for information only, but reported total uncertainties are used to evaluate performance in false positive/ negative tests and sensitivity evaluations.

The MAPEP program uses false-positive testing in each session to identify laboratory results that indicate the presence of a particular radionuclide when, in fact, the actual activity of the radionuclide is far below the detection limit of the measurement. Not Acceptable (N) performance, and hence a false positive result, is indicated when the range encompassing the result, plus or minus the total uncertainty at three standard deviations, does not include zero (i.e. 2.5 ± 0.2; range of 1.9 –3.1). Statistically, the probability that a result can exceed the absolute value of its total uncertainty at three standard deviations by chance alone is less than 1%. MAPEP uses a three standard deviation criterion for the false positive test to ensure confidence about issuing a false-positive performance evaluation. A result that is greater than three times the total uncertainty of the measurement represents a statistically- positive detection with over 99% confidence.

Sensitivity evaluations are routinely performed to complement the false-positive tests. In a sensitivity evaluation, the radionuclide is present at or near the detection limit, and the difference between the reported result and the MAPEP reference value is compared to the propagated combined total uncertainties. The results are evaluated at three standard deviations. If the observed difference is greater than three times the combined total uncertainty, the sensitivity evaluation in "Not Acceptable". The probability that such a difference

can occur by chance alone is less than 1%. If the participant did not report a statistically-positive result, a “Not Detected” is noted in the text field of the MAPEP performance report. A non-detect is potentially a false-negative result, dependent upon the laboratory’s detection limit for the radionuclide.

False-negative tests are also performed in combination with the sensitivity evaluations. In this scenario, the sensitivity of the reported measurement indicates that the known specific activity of the targeted radionuclide in the performance evaluation sample should have been detected, but was not, and a “Not Acceptable” performance evaluation is issued. The uncertainty of the MAPEP reference value and of the reported result at three standard deviations is used for the false-negative test.

The false-positive/negative and sensitivity evaluation tests are conducted in a manner that assists the participants with their measurement uncertainty estimates and helps ensure they are not under estimating or over inflating their total uncertainties. If the total uncertainty is over-inflated in order to pass a false-positive test, it will result in a “Not Detected” if the test is actually a sensitivity evaluation. The opposite is true for a false-positive test. False-negatives and failed sensitivity evaluations can also result from under-estimating the total uncertainty. An accurate estimate of measurement uncertainty is required for consistent performance at the acceptable level.

c) ERA Evaluation Criteria

The ERA evaluation report provides an acceptance range for control and warning limits with associated flag values. Acceptance limits for drinking/potable water are established per The NELAC Institute’s (TNI) guidance. The TNI Standard uses Fields of Proficiency Testing (FoPT) Tables to calculate upper and lower acceptance limits set at the Mean ± 2 standard deviations (SD). ERA’s acceptance limits for other matrices differ based on historical data from past studies.

d) NRC Verification Test Comparison Criteria

Some laboratory clients submit double-blind 10 CFR Part 50 performance evaluation samples. The lab processes these samples as routine client samples and sends the reports to the client, who then reports the result(s) to the sample’s originator. This may be via an outside vendor (i.e. Analytics) or prepared by the client. After the results are received by the client, NRC Resolution Criteria is used to determine acceptance of results using a calculated resolution number (known value / 1-sigma uncertainty) and a calculated ratio (lab result of unknown/known value). Clients may or may not share the result with the laboratory and are therefore usually not included with this report.

2. Intralaboratory Accuracy Acceptance Criteria

a) Process Controls

The measure of accuracy for a group of test measurements to a given spike level is found by calculating the recovery of the spike activity found versus the added spike activity. The percent recovery is calculated as follows:

$$\% \text{ Recovery} = (A_m / A_s)\ 100$$

Where: A_m = the activity measured

A_s = the spiked activity

Internal Process Control sample results use acceptance criteria of 70%-130% for spike recovery. Warning limits are set from 70%-79% and 121%-130%. Results evaluated as "Warning" are assessed for trends of low or high bias and are used to detect potential problems. The laboratory's internal acceptance criteria are based on MAPEP's defined performance levels of bias greater than 30%.

Matrix spikes (MS) may be used to document the bias of a method in a sample matrix. MS acceptance criteria is 60% - 140% recovery.

b) Other Measures

Backgrounds, which represent the ambient signal response recorded by measuring instruments, are independent of radioactivity contributed by the radionuclides being measured in the sample. If possible, equivalent media for preparing laboratory processing blanks will be used.

Acceptable method blank sample results have no three-sigma statistically-positive activity for the target parameters. If all sample results associated with the blank are greater than the MDC, then the blank MDC shall be less than the activity of the least active sample in the work order or it will be flagged with a qualifier in the client report with a case narrative.

Replicate/duplicate (DUP) and matrix spike duplicate (MSD) samples are produced by taking two aliquots from a single sample and assigning each aliquot a different Lab Sample Number. In cases of duplicate analyses where there are no "known" values, the analyses will be evaluated for precision only. All duplicates are carried through the complete sample preparation and analytical procedure. Precision is evaluated by calculating the Relative Percent Difference (RPD) between the two samples. Relative Percent Difference is calculated as the absolute difference between two values normalized to the average value, expressed as a percentage:

$$\% \text{ RPD} = (\text{abs}[\text{orig} - \text{dup}] / [\text{orig} + \text{dup}]/2) \times 100$$

Matrix spike duplicates are split samples spiked with identical concentrations of a target analyte and are used to evaluate precision and bias. The matrix spike duplicate recovery is expressed as a percentage:

% MSD = (abs[orig activity* – dup activity]/spike activity) x 100

**If the original activity is not detected then the activity is considered zero (0)*

For purposes of analytical reporting, each result specifies the radionuclide concentration and the *a posteriori* Minimum Detectable Concentration (MDC). TBE-ES calculates the *a posteriori* MDC using the sample's actual measurement parameters (i.e., sample volume, chemical recovery, instrument background, etc.) to demonstrate that the Nuclear Regulatory Commission's (NRC) *a priori* MDC has been met for each radionuclide/sample. By TBE-ES policy, the *a posteriori* MDC must be less than the required NRC *a priori* MDC.

3. Investigations and Nonconformance Reports

QC investigations are initiated when QC results fall outside of the QC criteria. Other investigations may arise from unanticipated situations which are not clearly defined in the procedures or bounded by pre-established performance criteria but have the potential of becoming QA-related issues. The QA investigation is the mechanism to quickly ascertain if there is "due cause" to issue a formal Non-Conformance Report (NCR).

An NCR is issued to formally document a QC investigation into the root cause of failure, the corrective action taken, and the action taken to prevent recurrence where applicable. Investigations may include review of procedures, interviews of personnel, review of laboratory and instrument logbooks, observation of analyst techniques and any other items identified as necessary to resolve the issue. For intercomparison performance evaluation samples, it is TBE's policy to issue an NCR for all unacceptable results.

II. ANALYTICAL SERVICES QUALITY CONTROL SYNOPSIS

A. Interlaboratory Cross-Check Program

During this reporting period, 27 nuclides associated with six media types (Air Filter, Charcoal [Air Iodine], Milk, Soil, Vegetation and Water) were analyzed. Samples were obtained from Analytics, the Department of Energy's (DOE) Mixed Analyte Performance Evaluation Program (MAPEP) and Environmental Resource Associates (ERA). Media types representative of client analyses performed during this reporting period were selected. The results are presented in Attachment A.

1. Analytics Environmental Cross Check Program

   Twelve nuclides were evaluated in air particulate, charcoal filter, milk and soil matrices during this reporting period. All analyses were within acceptable criteria.

2. DOE's MAPEP Quality Assessment Program

   Fourteen nuclides in water, air particulate (AP), soil, urine and vegetation samples were evaluated in January - December 2021. All of the environmental analyses performed were evaluated as within the acceptable/acceptable with warning criteria except for one AP Gross Alpha and two soil Ni-63. TBE also analyzed water and soil for Tc-99 for informational purposes (not on required list for REMP) and one soil sample was evaluated as unacceptable.

   NCR 21-02, NCR 21-03 and **NCR 21-13** were initiated to address the failures and Corrective Actions issued. All raw and associated QC data were reviewed and found to be within acceptable limits. (See Attachment C for NCR detail).

3. ERA Environmental Cross Check Program (RAD/MRAD)

   Eighteen nuclides were evaluated in water, soil, and air particulate samples during January - December 2021. All analyses performed were within acceptable criteria except for one water Fe-55, one Gross Beta and one H-3.

   NCR 21-01, **NCR 21-10**, **NCR 21-11** and **NCR 21-14** were initiated to address failures and Corrective Action was issued. All raw and associated QC data were reviewed and found to be within acceptable limits. (See Attachment C for NCR detail).

B. Intralaboratory Cross-Check Program

During this reporting period, 21 nuclides (and numerous gamma nuclides) in various matrices, including air particulate, charcoal, vegetation, fish, milk, soil/sediment and water were analyzed by means of the laboratory's internal process control program. A compilation of intralaboratory comparison data for this reporting period is summarized in Attachment B. *(Note: Only gamma nuclides that are typically seen in samples are included in the attachment – a complete list is available upon request).*

The TBE-ES laboratory's internal process control program evaluated 7,805 analyses during this period.

1. Blanks

   During this reporting period, all 1474/1475 blanks analyzed were less than the MDC. One workgroup blank for Ni-63 was above the MDC. The workrgoup included a blank, spike and two client samples whose activity was greater than 5x the blank. The blank activity was reported with a case narrative.

2. Spikes

   During this reporting period, 1435/1436 workgroup and matrix spikes analyzed were within the acceptance criteria. Samples in the single WG with a failing spike recovery were not reported but were completely re-prepped. The new workgroup QC was within acceptable range.

3. Duplicates

   All of the 4894 duplicate sets analyzed were within acceptance criteria.

C. Non-Conformance Reports (NCRs)

   A total of fourteen NCRs were initiated for this monitoring period and corrective action assigned.

D. Instrumentation

   TBE-ES uses the statistical principle method of evaluation for instrument quality control check data based on the mean, 2-sigma and 3-sigma set point model or uses pre-set tolerance limits. Each detector is checked prior to use for that day and the resulting data points are automatically compared to statistical baselines to determine the instrument's acceptability for counting. Control charts showing this data are available during audits or upon request. TBE-ES instrumentation includes:

   1. Gamma Spectroscopy

      Gamma detectors are routinely monitored for energy, full width at half maximum, efficiency, and background. TBE-ES gamma detectors operated without incident during this reporting period. Occasional second runs (as allowed by our QA program) were necessary to verify acceptable operation. Some amplifier fine gain adjustments and liquid nitrogen addition to the dewars were also necessary when data trends indicate an energy drift on the detector.

   2. Liquid Scintillation Counters (LSC):

      LSC instruments, used in tritium, carbon-14, nickel-63 and other low-energy beta-emitters, are monitored for background and efficiency. The reliability of

these instruments is exceptional with zero instances of background or efficiency values outside of control limits.

3. Alpha/Beta Gas Flow Proportional (GFP) Counters:

GFP detectors used for gross alpha/beta, strontium-89/90, iodine-131 (low level) and other nuclides are monitored for background and efficiency. These detectors operated without incident during this reporting period. Occasionally, second runs (primarily for alpha due to the sensitivity of source placement) were necessary to verify acceptable operation or because of low P-10 pressure. After gas change-out and purging, control check values return to control norms.

4. Alpha Spectroscopy:

Alpha detectors are routinely monitored for energy, full width at half maximum, efficiency, and background. TBE-ES alpha detectors operated without incident during this reporting period. Occasional second runs (as allowed by our QA program) were necessary to verify acceptable operation.

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ATTACHMENT A

Interlaboratory Quality Control Program Results

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A.1

Analytics Cross Check Program Results

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

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value [a]	Ratio of TBE to Analytics Result	Evaluation [b]
March 2021	E13466	Milk	Sr-89	pCi/L	84.6	87.1	0.97	A
			Sr-90	pCi/L	11.5	12.6	0.91	A
	E13467	Milk	Ce-141	pCi/L	111	125	0.89	A
			Co-58	pCi/L	123	128	0.96	A
			Co-60	pCi/L	140	154	0.91	A
			Cr-51	pCi/L	252	242	1.04	A
			Cs-134	pCi/L	130	151	0.86	A
			Cs-137	pCi/L	110	110	1.00	A
			Fe-59	pCi/L	105	109	0.96	A
			I-131	pCi/L	77.6	86.9	0.89	A
			Mn-54	pCi/L	111	112	0.99	A
			Zn-65	pCi/L	200	211	0.95	A
	E13468	Charcoal	I-131	pCi	83.5	88.5	0.94	A
	E13469	AP	Ce-141	pCi	103.0	103	1.00	A
			Co-58	pCi	93.3	105	0.89	A
			Co-60	pCi	136	126	1.08	A
			Cr-51	pCi	213	198	1.07	A
			Cs-134	pCi	123.0	124	0.99	A
			Cs-137	pCi	86.3	90.1	0.96	A
			Fe-59	pCi	81.3	89.6	0.91	A
			Mn-54	pCi	93.5	92.0	1.02	A
			Zn-65	pCi	166	173	0.96	A
	E13470	Soil	Ce-141	pCi/g	0.232	0.262	0.89	A
			Co-58	pCi/g	0.251	0.268	0.94	A
			Co-60	pCi/g	0.306	0.322	0.95	A
			Cr-51	pCi/g	0.517	0.506	1.02	A
			Cs-134	pCi/g	0.263	0.317	0.83	A
			Cs-137	pCi/g	0.278	0.301	0.92	A
			Fe-59	pCi/g	0.228	0.229	1.00	A
			Mn-54	pCi/g	0.221	0.235	0.94	A
			Zn-65	pCi/g	0.448	0.441	1.02	A
	E13471	AP	Sr-89	pCi	92.2	95.5	0.97	A
			Sr-90	pCi	11.7	13.9	0.84	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.1 Analytics Environmental Radioactivity Cross Check Program
Teledyne Brown Engineering Environmental Services

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value [(a)]	Ratio of TBE to Analytics Result	Evaluation [(b)]
September 2021	E13472	Milk	Sr-89	pCi/L	66.4	85.4	0.78	W
			Sr-90	pCi/L	11.9	14.0	0.85	A
	E13473	Milk	Ce-141	pCi/L	118	114	1.03	A
			Co-58	pCi/L	116	118	0.98	A
			Co-60	pCi/L	142	145	0.98	A
			Cr-51	pCi/L	244	236	1.03	A
			Cs-134	pCi/L	81	93.1	0.87	A
			Cs-137	pCi/L	105	112	0.94	A
			Fe-59	pCi/L	105	102	1.03	A
			I-131	pCi/L	65.1	85.6	0.76	W
			Mn-54	pCi/L	128	128	1.00	A
			Zn-65	pCi/L	158	153	1.03	A
	E13474	Charcoal	I-131	pCi	85.2	90.9	0.94	A
	E13475	AP	Ce-141	pCi	126	135	0.94	A
			Co-58	pCi	148	139	1.07	A
			Co-60	pCi	183	171	1.07	A
			Cr-51	pCi	322	278	1.16	A
			Cs-134	pCi	118	110	1.08	A
			Cs-137	pCi	147	132	1.12	A
			Fe-59	pCi	131	120	1.09	A
			Mn-54	pCi	161	151	1.06	A
			Zn-65	pCi	202	180	1.12	A
	E13476	Soil	Ce-141	pCi/g	0.215	0.219	0.98	A
			Co-58	pCi/g	0.208	0.226	0.92	A
			Co-60	pCi/g	0.277	0.277	1.00	A
			Cr-51	pCi/g	0.388	0.452	0.86	A
			Cs-134	pCi/g	0.157	0.178	0.88	A
			Cs-137	pCi/g	0.270	0.284	0.95	A
			Fe-59	pCi/g	0.218	0.195	1.12	A
			Mn-54	pCi/g	0.239	0.246	0.97	A
			Zn-65	pCi/g	0.312	0.293	1.06	A
	E13477	AP	Sr-89	pCi	85.6	68.3	1.25	W
			Sr-90	pCi	12.6	11.2	1.13	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

MAPEP Quality Assessment Program Results

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

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value [a]	Acceptance Range	Evaluation [b]
February 2021	21-GrF44	AP	Gross Alpha	Bq/sample	0.371	1.77	0.53 - 3.01	N(3)
			Gross Beta	Bq/sample	0.731	0.65	0.325 - 0.974	A
	21-MaS44	Soil	Ni-63	Bq/kg	310	689.0	482 - 896	N(4)
			Tc-99	Bq/kg	457	638	447 - 829	W
	21-MaSU44	Urine	Cs-134	Bq/L	2.34	2.73	1.91 - 3.55	A
			Cs-137	Bq/L	2.54	2.71	1.90 - 3.52	A
			Co-57	Bq/L	0.4100		*(1)*	A
			Co-60	Bq/L	2.24	2.44	1.71 - 3.17	A
			Mn-54	Bq/L	2.03	2.03	1.42 - 2.64	A
			K-40	Bq/L	52.8	54.0	38 - 70	A
			U-234	Bq/L	0.108	0.0877	0.0614 - 0.114	W
			U-238	Bq/L	0.101	0.091	0.064 - 0.118	A
			Zn-65	Bq/L	1.06	1.34	*(2)*	A
	21-MaW44	Water	Ni-63	Bq/L	6.7	8.2	5.7 - 10.7	A
			Tc-99	Bq/L	3.850	4.01	2.81 - 5.21	A
	21-RdV44	Vegetation	Cs-134	Bq/sample	3.13	3.60	2.5 - 4.7	A
			Cs-137	Bq/sample	4.64	4.69	3.28 - 6.10	A
			Co-57	Bq/sample	5.25	5.05	3.54 - 6.57	A
			Co-60	Bq/sample	2.86	2.99	2.09 - 3.89	A
			Mn-54	Bq/sample	5.02	5.25	3.68 - 6.83	A
			Sr-90	Bq/sample	0.631	0.673	0.471 - 0.875	A
			Zn-65	Bq/sample	-0.233		*(1)*	A
August 2021	21-GrF45	AP	Gross Alpha	Bq/sample	0.368	0.960	0.288 - 1.632	A
			Gross Beta	Bq/sample	0.595	0.553	0.277 - 0.830	A
	21-MaS45	Soil	Ni-63	Bq/kg	546	1280	896 - 1664	N(5)
			Tc-99	Bq/kg	453	777	544 - 1010	N(5)
	21-MaSU45	Urine	Cs-134	Bq/L	3.10	3.62	2.53 - 4.71	A
			Cs-137	Bq/L	0.083		*(1)*	A
			Co-57	Bq/L	0.844	0.87	0.606 - 1.125	A
			Co-60	Bq/L	0.0535		*(1)*	A
			Mn-54	Bq/L	0.459	0.417	*(2)*	A
			K-40	Bq/L	48.8	54.0	38 - 70	A
			U-234	Bq/L	0.133	0.116	0.081 - 0.151	A
			U-238	Bq/L	0.137	0.121	0.085 - 0.157	A
			Zn-65	Bq/L	0.339	0.420	*(2)*	A
	21-MaW45	Water	Ni-63	Bq/L	33.5	39.5	27.7 - 51.4	A
			Tc-99	Bq/L	3.5	3.7	2.60 - 4.82	A
	21-RdV45	Vegetation	Cs-134	Bq/sample	3.42	4.34	3.04 - 5.64	W
			Cs-137	Bq/sample	2.14	2.21	1.55 - 2.87	A
			Co-57	Bq/sample	4.08	4.66	3.26 - 6.06	A
			Co-60	Bq/sample	2.81	3.51	2.46 - 4.56	A
			Mn-54	Bq/sample	0.035		*(1)*	A
			Sr-90	Bq/sample	1.15	1.320	0.92 - 1.72	A
			Zn-65	Bq/sample	2.05	2.43	1.70 - 3.16	A

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

(b) DOE/MAPEP evaluation:
A = Acceptable - reported result falls within ratio limits of 0.80-1.20
W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30
N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

(1) False positive test
(2) Sensitivity evaluation
*(3) See **NCR 21-02***
*(4) See **NCR 21-03***
*(5) See **NCR 21-13***
(6) Tc-99 cross-checks done for TBE information only - not required

A.3

ERA Cross Check Program Results

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

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value [a]	Acceptance Limits	Evaluation [b]
March 2021	MRAD-34	Water	Am-241	pCi/L	175	157	108 - 201	A
			Fe-55	pCi/L	579	275	162 - 400	N(1)
			Pu-238	pCi/L	181	171	103 - 222	A
			Pu-239	pCi/L	153	142	87.9 - 175	A
		Soil	Sr-90	pCi/kg	6570	9190	2860 - 14,300	A
		AP	Fe-55	pCi/filter	107	121	44.2 - 193	A
			U-234	pCi/filter	25.99	25.5	18.9 - 29.9	A
			U-238	pCi/filter	24.7	25.3	19.1 - 30.2	A
April 2021	RAD-125	Water	Ba-133	pCi/L	92.3	90.5	76.2 - 99.6	A
			Cs-134	pCi/L	62.9	70.5	57.5 - 77.6	A
			Cs-137	pCi/L	161	168	151 - 187	A
			Co-60	pCi/L	22.5	20.9	17.7 - 25.8	A
			Zn-65	pCi/L	183	177.0	159 - 208	A
			GR-A	pCi/L	30.8	30.2	15.4 - 39.4	A
			GR-B	pCi/L	60.1	67.5	46.8 - 74.2	A
			U-Nat	pCi/L	36.45	36.9	30.0 - 40.8	A
			H-3	pCi/L	13,400	14,600	12,800 - 16,100	A
			Sr-89	pCi/L	64.5	63.5	51.4 - 71.5	A
			Sr-90	pCi/L	22.8	23.0	16.5 - 27.0	A
			I-131	pCi/L	28.2	26.7	22.2 - 31.4	A
September 2021	MRAD-35	Water	Am-241	pCi/L	68	63.7	43.7 - 81.5	A
			Fe-55	pCi/L	179	246	145 - 358	A
			Pu-238	pCi/L	102	114	68.5 - 148	A
			Pu-239	pCi/L	32	34.3	21.2 - 42.3	A
		Soil	Sr-90	pCi/kg	6160	6090	1,900 - 9,490	A
		AP	Fe-55	pCi/filter	493	548	200 - 874	A
			Pu-238	pCi/filter	28	28.5	21.5 - 35.0	A
			Pu-239	pCi/filter	21	21.6	16.1 - 26.1	A
			U-234	pCi/filter	7.95	7.76	5.75 - 9.09	A
			U-238	pCi/filter	8.0	7.69	5.81 - 9.17	A
October 2021	RAD-127	Water	Ba-133	pCi/L	82.8	87.5	73.6 - 96.2	A
			Cs-134	pCi/L	64.0	70.1	57.1 - 77.1	A
			Cs-137	pCi/L	145	156	140 - 174	A
			Co-60	pCi/L	83.2	85.9	77.3 - 96.8	A
			Zn-65	pCi/L	133	145	130 - 171	A
			GR-A	pCi/L	76.0	66.7	35.0 - 82.5	A
			GR-B	pCi/L	63.0	55.7	38.1 - 62.6	N(2)
			U-Nat	pCi/L	52.88	55.5	45.3 - 61.1	A
			H-3	pCi/L	13,800	17,200	15,000 - 18,900	N(3)
			Sr-89	pCi/L	54.9	61.0	49.1 - 68.9	A
			Sr-90	pCi/L	24.8	29.3	21.3 - 34.0	A
			I-131	pCi/L	27.4	26.4	21.9 - 31.1	A
December 2021	QR 120121Y	Water	GR-B	pCi/L	47.6	39.8	26.4 - 47.3	N(4)
			H-3	pCi/L	17,500	17,800	15,600 - 19,600	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 21-01***

*(2) See **NCR 21-10***

*(3) See **NCR 21-11***

*(4) See **NCR 21-14***

A.4

Formal Interlaboratory Quality Control Program Results

Eckert & Ziegler

Analytics

1380 Seaboard Industrial Blvd.
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ANAB ACCREDITED ISO/IEC 17043 PROFICIENCY TESTING PROVIDER

RESULTS OF ENVIRONMENTAL CROSS CHECK PROGRAM

TELEDYNE BROWN

ENGINEERING

1st QUARTER 2021

(Ref. Date 11 Mar 2021, Rev. 0)

17 May 2021

Levan Tkavadze , Nuclear Metrologist

Sample	Analysis	ENGINEERING Value, pCi/L	EZA Value, pCi/L	Ratio ENGINEERING: EZA
E13466 Milk	Sr-89	8.46E+01	8.71E+01	0.97
	Sr-90	1.15E+01	1.26E+01	0.91

Sample	Analysis	ENGINEERING Value, pCi/L	EZA Value, pCi/L	Ratio ENGINEERING: EZA
E13467 Milk	Ce-141	1.11E+02	1.25E+02	0.89
	Co-58	1.23E+02	1.28E+02	0.96
	Co-60	1.40E+02	1.54E+02	0.91
	Cr-51	2.52E+02	2.42E+02	1.04
	Cs-134	1.30E+02	1.51E+02	0.86
	Cs-137	1.10E+02	1.10E+02	1.00
	Fe-59	1.05E+02	1.09E+02	0.96
	I-131	7.76E+01	8.69E+01	0.89
	K-40	1.34E+03	Not Measured	---
	Mn-54	1.11E+02	1.12E+02	0.99
	Zn-65	2.00E+02	2.11E+02	0.95

Sample	Analysis	ENGINEERING Value, pCi	EZA Value, pCi	Ratio ENGINEERING: EZA
E13468 Cartridge	I-131	8.35E+01	8.85E+01	0.94

Sample	Analysis	ENGINEERING Value, pCi	EZA Value, pCi	Ratio ENGINEERING: EZA
E13471 Filter	Sr-89	9.22E+01	9.55E+01	0.97
	Sr-90	1.17E+01	1.39E+01	0.84

Sample	Analysis	ENGINEERING Value, pCi	EZA Value, pCi	Ratio ENGINEERING: EZA
E13469 Filter	Ce-141	1.03E+02	1.03E+02	1.00
	Co-58	9.33E+01	1.05E+02	0.89
	Co-60	1.36E+02	1.26E+02	1.08
	Cr-51	2.13E+02	1.98E+02	1.07
	Cs-134	1.23E+02	1.24E+02	0.99
	Cs-137	8.63E+01	9.01E+01	0.96
	Fe-59	8.13E+01	8.96E+01	0.91
	Mn-54	9.35E+01	9.20E+01	1.02
	Zn-65	1.66E+02	1.73E+02	0.96

Sample	Analysis	ENGINEERING Value, pCi/g	EZA Value, pCi/g	Ratio ENGINEERING: EZA
E13470 Soil	Ce-141	2.32E-01	2.62E-01	0.89
	Co-58	2.51E-01	2.68E-01	0.94
	Co-60	3.06E-01	3.22E-01	0.95
	Cr-51	5.17E-01	5.06E-01	1.02
	Cs-134	2.63E-01	3.17E-01	0.83
	Cs-137	2.78E-01	3.01E-01	0.92
	Fe-59	2.28E-01	2.29E-01	1.00
	K-40	9.86E-01	Not Measured	---
	Mn-54	2.21E-01	2.35E-01	0.94
	Zn-65	4.48E-01	4.41E-01	1.02

Eckert & Ziegler

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RESULTS OF ENVIRONMENTAL CROSS CHECK PROGRAM

TELEDYNE BROWN ENGINEERING

3rd QUARTER 2021

(Ref. Date 09 Sep 2021, Rev. 0)

L. Tk

29 Nov 2021

Levan Tkavadze , Nuclear Metrologist

Sample	Analysis	ENGINEERING Value, pCi/L	EZA Value, pCi/L	Ratio ENGINEERING: EZA
E13472 Milk	Sr-89	6.64E+01	8.54E+01	0.78
	Sr-90	1.19E+01	1.40E+01	0.85

Sample	Analysis	ENGINEERING Value, pCi/L	EZA Value, pCi/L	Ratio ENGINEERING: EZA
E13473 Milk	Ce-141	1.18E+02	1.14E+02	1.03
	Co-58	1.16E+02	1.18E+02	0.98
	Co-60	1.42E+02	1.45E+02	0.98
	Cr-51	2.44E+02	2.36E+02	1.03
	Cs-134	8.11E+01	9.31E+01	0.87
	Cs-137	1.05E+02	1.12E+02	0.94
	Fe-59	1.05E+02	1.02E+02	1.03
	I-131	6.51E+01	8.56E+01	0.76
	K-40	1.46E+03	Not Measured	---
	Mn-54	1.28E+02	1.28E+02	1.00
	Zn-65	1.58E+02	1.53E+02	1.03

Sample	Analysis	ENGINEERING Value, pCi	EZA Value, pCi	Ratio ENGINEERING: EZA
E13474 Cartridge	I-131	8.52E+01	9.09E+01	0.94

Sample	Analysis	ENGINEERING Value, pCi	EZA Value, pCi	Ratio ENGINEERING: EZA
E13475 Filter	Ce-141	1.26E+02	1.35E+02	0.94
	Co-58	1.48E+02	1.39E+02	1.07
	Co-60	1.83E+02	1.71E+02	1.07
	Cr-51	3.22E+02	2.78E+02	1.16
	Cs-134	1.18E+02	1.10E+02	1.08
	Cs-137	1.47E+02	1.32E+02	1.12
	Fe-59	1.31E+02	1.20E+02	1.09
	Mn-54	1.61E+02	1.51E+02	1.06
	Zn-65	2.02E+02	1.80E+02	1.12

Sample	Analysis	ENGINEERING Value, pCi/g	EZA Value, pCi/g	Ratio ENGINEERING: EZA
E13476 Soil	Ce-141	2.15E-01	2.19E-01	0.98
	Co-58	2.08E-01	2.26E-01	0.92
	Co-60	2.77E-01	2.77E-01	1.00
	Cr-51	3.88E-01	4.52E-01	0.86
	Cs-134	1.57E-01	1.78E-01	0.88
	Cs-137	2.70E-01	2.84E-01	0.95
	Fe-59	2.18E-01	1.95E-01	1.12
	K-40	9.31E-01	Not Measured	---
	Mn-54	2.39E-01	2.46E-01	0.97
	Zn-65	3.12E-01	2.93E-01	1.06

Sample	Analysis	ENGINEERING Value, pCi	EZA Value, pCi	Ratio ENGINEERING: EZA
E13477 Filter	Sr-89	8.56E+01	6.83E+01	1.25
	Sr-90	1.26E+01	1.12E+01	1.13

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP Series 44
(TELE01) Teledyne Brown Engineering - Environmental Services
2508 Quality Lane
Knoxville, TN 37931-6819

MAPEP-21-GrF44: Gross alpha/beta air filter

Radiological — Units: (Bq/sample)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Gross alpha	.371	1.77	N		-79.0	0.53 - 3.01	.0468	A
Gross beta	.731	0.649	A		12.6	0.325 - 0.974	.0536	A

Radiological Reference Date: February 1, 2021

MAPEP-21-MaS44: Radiological and inorganic combined soil standard

Inorganic — Units: (mg/kg)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Antimony	NR	78				55 - 101		
Arsenic	NR	45.8				32.1 - 59.5		
Barium	NR	223				156 - 290		
Beryllium	NR	60.6				42.4 - 78.8		
Cadmium	NR	7.05				4.94 - 9.17		
Chromium	NR	49.9				34.9 - 64.9		
Cobalt	NR	194				136 - 252		
Copper	NR	34.0				23.8 - 44.2		
Lead	NR	28.8				20.2 - 37.4		
Nickel	NR	148				104 - 192		
Selenium	NR	16.9				11.8 - 22.0		
Silver	NR	42.5				29.8 - 55.3		
Technetium-99	NR	0.00101				0.00071 - 0.00131		
Thallium	NR	11.0				7.7 - 14.3		
Uranium-235	NR	0.0469				0.0328 - 0.0610		
Uranium-238	NR	16.7				11.7 - 21.7		
Uranium-Total	NR	16.7				11.7 - 21.7		
Vanadium	NR	279				195 - 363		
Zinc	NR	370				259 - 481		

Radiological — Units: (Bq/kg)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	NR	88				62 - 114		
Cesium-134	NR					False Positive Test		
Cesium-137	NR	1550				1085 - 2015		
Cobalt-57	NR	920				644 - 1196		

Radiological								Units: (Bq/kg)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Cobalt-60	NR	1370				959 - 1781		
Iron-55	NR	910				637 - 1183		
Manganese-54	NR					False Positive Test		
Nickel-63	310	689	N		-55.0	482 - 896	32.1	A
Plutonium-238	NR	49.1				34.4 - 63.8		
Plutonium-239/240	NR					False Positive Test		
Potassium-40	NR	618				433 - 803		
Strontium-90	NR	272				190 - 354		
Technetium-99	457	638	W		-28.4	447 - 829	43.2	A
Uranium-234	NR	59				41 - 77		
Uranium-238	NR	208				146 - 270		
Zinc-65	NR	604				423 - 785		

Radiological Reference Date: February 1, 2021

MAPEP-21-MaSU44: Radiological urine standard

Radiological								Units: (Bq/L)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	NR	0.0748				0.0524 - 0.0972		
Cesium-134	2.34	2.73	A		-14.3	1.91 - 3.55	.123	A
Cesium-137	2.54	2.71	A		-6.3	1.90 - 3.52	.171	A
Cobalt-57	.041		A			False Positive Test	.0472	
Cobalt-60	2.24	2.44	A		-8.2	1.71 - 3.17	.124	A
Curium-244	NR					False Positive Test		
Hydrogen-3	NR					False Positive Test		
Iron-55	NR					False Positive Test		
Manganese-54	2.03	2.03	A		0.0	1.42 - 2.64	.177	A
Nickel-63	NR					False Positive Test		
Plutonium-238	NR	0.0468				0.0328 - 0.0608		
Plutonium-239/240	NR	0.0772				0.0540 - 0.1004		
Potassium-40	52.8	54	A		-2.2	38 - 70	2.37	A
Radium-226	NR					False Positive Test		
Strontium-90	NR	0.48				0.34 - 0.62		
Technetium-99	NR					False Positive Test		
Uranium-234	.108	0.0877	W		23.1	0.0614 - 0.1140	.0319	W
Uranium-238	.101	0.091	A		11.0	0.064 - 0.118	.0304	N
Zinc-65	1.06	1.34	A			Sensitivity Evaluation	.309	

Radiological Reference Date: February 1, 2021

MAPEP-21-MaW44: Radiological and inorganic combined water standard

Inorganic								Units: (mg/L)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Antimony	NR	8.63				6.04 - 11.22		
Arsenic	NR	2.06				1.44 - 2.68		
Barium	NR	7.58				5.31 - 9.85		

Inorganic

Units: (mg/L)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Beryllium	NR	3.15				2.21 - 4.10		
Cadmium	NR	0.748				0.524 - 0.972		
Chromium	NR	4.01				2.81 - 5.21		
Cobalt	NR	10.3				7.2 - 13.4		
Copper	NR	5.53				3.87 - 7.19		
Lead	NR	2.52				1.76 - 3.28		
Mercury	NR	0.106				0.074 - 0.138		
Nickel	NR	5.05				3.54 - 6.57		
Selenium	NR	0.676				0.473 - 0.879		
Technetium-99	NR	6.35E-6				4.45E-6 - 8.26E-6		
Thallium	NR	2.46				1.72 - 3.20		
Uranium-235	NR	0.000499				3.49E-4 - 6.49E-4		
Uranium-238	NR	0.069				0.048 - 0.090		
Uranium-Total	NR	0.070				0.049 - 0.091		
Vanadium	NR	17.4				12.2 - 22.6		
Zinc	NR	15.5				10.9 - 20.2		

Radiological

Units: (Bq/L)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	NR					False Positive Test		
Cesium-134	NR	11.5				8.1 - 15.0		
Cesium-137	NR	7.9				5.5 - 10.3		
Cobalt-57	NR	11.4				8.0 - 14.8		
Cobalt-60	NR					False Positive Test		
Hydrogen-3	NR					False Positive Test		
Iron-55	NR	26.9				18.8 - 35.0		
Manganese-54	NR	15.5				10.9 - 20.2		
Nickel-63	6.7	8.2	A		-18.3	5.7 - 10.7	.765	A
Plutonium-238	NR	0.577				0.404 - 0.750		
Plutonium-239/240	NR	0.649				0.454 - 0.844		
Potassium-40	NR					False Positive Test		
Radium-226	NR	0.632				0.442 - 0.822		
Strontium-90	NR	4.47				3.13 - 5.81		
Technetium-99	3.85	4.01	A		-4.0	2.81 - 5.21	1.32	N
Uranium-234	NR	0.85				0.60 - 1.11		
Uranium-238	NR	0.86				0.60 - 1.12		
Zinc-65	NR	10.5				7.4 - 13.7		

Radiological Reference Date: February 1, 2021

MAPEP-21-RdV44: Radiological vegetation

Inorganic

Units: (ug/sample)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Uranium-235	NR	0.0825				0.0578 - 0.1073		
Uranium-238	NR	11.5				8.1 - 15.0		

Inorganic

Units: (ug/sample)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Uranium-Total	NR	11.6				8.1 - 15.1		

Radiological

Units: (Bq/sample)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	NR	0.0586				0.0410 - 0.0762		
Cesium-134	3.13	3.6	A		-13.1	2.5 - 4.7	.166	A
Cesium-137	4.64	4.69	A		-1.1	3.28 - 6.10	.245	A
Cobalt-57	5.25	5.05	A		4.0	3.54 - 6.57	.171	A
Cobalt-60	2.86	2.99	A		-4.3	2.09 - 3.89	.178	A
Manganese-54	5.02	5.25	A		-4.4	3.68 - 6.83	.275	A
Plutonium-238	NR	0.0446				0.0312 - 0.0580		
Plutonium-239/240	NR	0.0921				0.0645 - 0.1197		
Strontium-90	.631	0.673	A		-6.2	0.471 - 0.875	.0232	A
Uranium-234	NR	0.138				0.097 - 0.179		
Uranium-238	NR	0.143				0.100 - 0.186		
Zinc-65	-.233		A			False Positive Test	.229	

Radiological Reference Date: February 1, 2021

MAPEP Mixed Analyte Performance Evaluation Program

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP Series 45

(TELE01) Teledyne Brown Engineering - Environmental Services
2508 Quality Lane
Knoxville, TN 37931-6819

MAPEP-21-GrF45: Gross alpha/beta air filter

Radiological — Units: (Bq/sample)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Gross alpha	.368	0.960	A		-61.7	0.288 - 1.632	.049	A
Gross beta	.595	0.553	A		7.6	0.277 - 0.830	.0487	A

Radiological Reference Date: August 1, 2021

MAPEP-21-MaS45: Radiological and inorganic combined soil standard

Inorganic — Units: (mg/kg)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Antimony	NR	29.9				20.9 - 38.9		
Arsenic	NR	20.2				14.1 - 26.3		
Barium	NR	144				101 - 187		
Beryllium	NR	20.8				14.6 - 27.0		
Cadmium	NR	16.4				11.5 - 21.3		
Chromium	NR	53.3				37.3 - 69.3		
Cobalt	NR	149				104 - 194		
Copper	NR	197				138 - 256		
Lead	NR	72.0				50.4 - 93.6		
Mercury	NR	0.215				0.151 - 0.280		
Nickel	NR	124				87 - 161		
Selenium	NR	13.1				9.2 - 17.0		
Silver	NR	59.9				41.9 - 77.9		
Technetium-99	NR	0.00123				0.00086 - 0.00160		
Thallium	NR	30.1				21.1 - 39.1		
Uranium-235	NR	0.0391				0.0274 - 0.0508		
Uranium-238	NR	13.5				9.5 - 17.6		
Uranium-Total	NR	13.6				9.5 - 17.7		
Vanadium	NR	201				141 - 261		
Zinc	NR	317				222 - 412		

Radiological — Units: (Bq/kg)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	NR	98				69 - 127		
Cesium-134	NR	1170				819 - 1521		
Cesium-137	NR	572				400 - 744		

Issued 12/16/2021

Printed 12/16/2021

Radiological									Units: (Bq/kg)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Cobalt-57	NR					False Positive Test		
Cobalt-60	NR	722				505 - 939		
Iron-55	NR	1020				714 - 1326		
Manganese-54	NR	410				287 - 533		
Nickel-63	546	1280	N		-57.3	896 - 1664	79.7	A
Plutonium-238	NR	59.8				41.9 - 77.7		
Plutonium-239/240	NR	71.3				49.9 - 92.7		
Potassium-40	NR	607				425 - 789		
Strontium-90	NR					False Positive Test		
Technetium-99	453	777	N		-41.7	544 - 1010	43.3	A
Uranium-234	NR	51.4				36.0 - 66.8		
Uranium-238	NR	168				118 - 218		
Zinc-65	NR	907				635 - 1179		

Radiological Reference Date: August 1, 2021

MAPEP-21-MaSU45: Radiological urine standard

Radiological									Units: (Bq/L)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	NR	0.0747				0.0523 - 0.0971		
Cesium-134	3.1	3.62	A		-14.4	2.53 - 4.71	.126	A
Cesium-137	.083		A			False Positive Test	.101	
Cobalt-57	.844	0.865	A		-2.4	0.606 - 1.125	.0975	A
Cobalt-60	.0535		A			False Positive Test	.0953	
Curium-244	NR					False Positive Test		
Hydrogen-3	NR					False Positive Test		
Manganese-54	.459	0.417	A			Sensitivity Evaluation	.109	
Plutonium-238	NR	0.0455				0.0319 - 0.0592		
Plutonium-239/240	NR	0.091				0.064 - 0.118		
Potassium-40	48.8	54	A		-9.6	38 - 70	3.45	A
Radium-226	NR					False Positive Test		
Strontium-90	NR	1.48				1.04 - 1.92		
Technetium-99	NR					False Positive Test		
Uranium-234	.133	0.116	A		14.7	0.081 - 0.151	.022	W
Uranium-238	.137	0.121	A		13.2	0.085 - 0.157	.0219	W
Zinc-65	.339	0.420	A	(17)		Sensitivity Evaluation	.28	

Radiological Reference Date: August 1, 2021

MAPEP-21-MaW45: Radiological and inorganic combined water standard

Inorganic									Units: (mg/L)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Antimony	NR	7.27				5.09 - 9.45		
Arsenic	NR	2.46				1.72 - 3.20		
Barium	NR	3.18				2.23 - 4.13		
Beryllium	NR	4.03				2.82 - 5.24		

Inorganic

Units: (mg/L)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Cadmium	NR	0.468				0.328 - 0.608		
Chromium	NR	2.48				1.74 - 3.22		
Cobalt	NR	6.04				4.23 - 7.85		
Copper	NR	8.29				5.80 - 10.78		
Lead	NR	3.00				2.10 - 3.90		
Mercury	NR	0.128				0.090 - 0.166		
Nickel	NR	0.00102				Sensitivity Evaluation		
Selenium	NR	0.411				0.288 - 0.534		
Technetium-99	NR	5.87E-6				4.11E-6 - 7.63E-6		
Thallium	NR	3.06				2.14 - 3.98		
Uranium-235	NR	7.0E-6				Sensitivity Evaluation		
Uranium-238	NR	9.9E-4				6.93E-4 - 1.29E-3		
Uranium-Total	NR	1.00E-3				0.00070 - 0.00130		
Vanadium	NR	10.1				7.1 - 13.1		
Zinc	NR	8.42				5.89 - 10.95		

Radiological

Units: (Bq/L)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	NR	0.426				0.298 - 0.554		
Cesium-134	NR	10.4				7.3 - 13.5		
Cesium-137	NR					False Positive Test		
Cobalt-57	NR	13.9				9.7 - 18.1		
Cobalt-60	NR	14.0				9.8 - 18.2		
Hydrogen-3	NR	250				175 - 325		
Iron-55	NR	49.8				34.9 - 64.7		
Manganese-54	NR	9.0				6.3 - 11.7		
Nickel-63	33.5	39.5	A		-15.2	27.7 - 51.4	3.62	A
Plutonium-238	NR	0.0096				Sensitivity Evaluation		
Plutonium-239/240	NR	0.528				0.370 - 0.686		
Potassium-40	NR					False Positive Test		
Radium-226	NR	0.226				0.158 - 0.294		
Strontium-90	NR	3.86				2.70 - 5.02		
Technetium-99	3.5	3.71	A		-5.7	2.60 - 4.82	1.32	N
Uranium-234	NR	0.0215				Sensitivity Evaluation		
Uranium-238	NR	0.0123				Sensitivity Evaluation		
Zinc-65	NR					False Positive Test		

Radiological Reference Date: August 1, 2021

MAPEP-21-RdV45: Radiological vegetation

Inorganic

Units: (ug/sample)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Uranium-235	NR	0.102				0.071 - 0.133		
Uranium-238	NR	14.2				9.9 - 18.5		
Uranium-Total	NR	14.3				10.0 - 18.6		

Inorganic

Units: (ug/sample)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag

Radiological

Units: (Bq/sample)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	NR	0.0747				0.0523 - 0.0971		
Cesium-134	3.42	4.34	W		-21.2	3.04 - 5.64	.153	A
Cesium-137	2.14	2.21	A		-3.2	1.55 - 2.87	.195	A
Cobalt-57	4.08	4.66	A		-12.4	3.26 - 6.06	.17	A
Cobalt-60	2.81	3.51	A		-19.9	2.46 - 4.56	.183	A
Manganese-54	.035		A			False Positive Test	.11	
Plutonium-238	NR	0.0655				0.0459 - 0.0852		
Plutonium-239/240	NR					False Positive Test		
Strontium-90	1.15	1.32	A		-12.9	0.92 - 1.72	.0412	A
Uranium-234	NR	0.183				0.128 - 0.238		
Uranium-238	NR	0.176				0.123 - 0.229		
Zinc-65	2.05	2.43	A		-15.6	1.70 - 3.16	.444	W

Radiological Reference Date: August 1, 2021

Notes:

(17) = NOT DETECTED - reported a statistically zero result

MRAD-34 Final Evaluation Report

A Waters Company

Sharon Northcutt
QA Manager
Teledyne Brown Engineering
2508 Quality Ln.
Knoxville, TN 37931
(865) 934-0374

EPA ID: TN11387
ERA Customer Number: T200801
Report Issued: 05/25/21
Study Dates: 03/22/21 - 05/21/21

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
MRAD Soil Radionuclides (cat# 802, lot# A034-608)												
2700	Actinium-228	pCi/kg		3170	2090 - 3990	Not Reported				3160	399	
2755	Americium-241	pCi/kg		1620	875 - 2290	Not Reported				1460	243	
2772	Bismuth-212	pCi/kg		3280	939 - 4890	Not Reported				3430	357	
2773	Bismuth-214	pCi/kg		1380	662 - 2050	Not Reported				1340	116	
2800	Cesium-134	pCi/kg		5920	4050 - 7080	Not Reported				5290	552	
2805	Cesium-137	pCi/kg		7570	5720 - 9570	Not Reported				7460	594	
2815	Cobalt-60	pCi/kg		5060	3980 - 6250	Not Reported				4920	390	
2902	Lead-212	pCi/kg		3350	2340 - 4240	Not Reported				3320	442	
2903	Lead-214	pCi/kg		1440	605 - 2260	Not Reported				1480	199	
2905	Manganese-54	pCi/kg		< 1000	0.00 - 1000	Not Reported						
2930	Plutonium-238	pCi/kg		1930	963 - 2930	Not Reported				1770	214	
2932	Plutonium-239	pCi/kg		1720	937 - 2480	Not Reported				1590	121	
2946	Potassium-40	pCi/kg		24700	17000 - 29500	Not Reported				25100	1930	
3005	Strontium-90	pCi/kg	6570	9190	2860 - 14300	Acceptable	HASL 300 Sr-03 28th ED 1997	5/18/2021	-1.38	8360	1300	Shannon Cooper
3028	Thorium-234	pCi/kg		4020	1520 - 6880	Not Reported				3910	1070	
3036	Uranium-234	pCi/kg		4060	1900 - 5320	Not Reported				3700	310	
3038	Uranium-238	pCi/kg		4020	2210 - 5400	Not Reported				3600	338	
3055	Uranium-Total	pCi/kg		8260	4580 - 10700	Not Reported				7290	722	
3055	Uranium-Total (mass)	µg/kg		12000	5420 - 16200	Not Reported				10000	477	
3070	Zinc-65	pCi/kg		7040	5620 - 9600	Not Reported				7120	735	

MRAD-34 Final Evaluation Report

A Waters Company

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EPA ID: TN11387
ERA Customer Number: T200801
Report Issued: 05/25/21
Study Dates: 03/22/21 - 05/21/21

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
MRAD Air Filter Radionuclides (cat# 800, lot# A034-606)												
2755	Americium-241	pCi/Filter		60.2	43.0 - 80.3	Not Reported				61.6	3.91	
2800	Cesium-134	pCi/Filter		1030	668 - 1260	Not Reported				940	114	
2805	Cesium-137	pCi/Filter		163	134 - 214	Not Reported				175	16.8	
2815	Cobalt-60	pCi/Filter		1220	1040 - 1550	Not Reported				1280	83.5	
2885	Iron-55	pCi/Filter	107	121	44.2 - 193	Acceptable	TBE Proprietary	4/29/2021	0.856	105	2.63	Shannon Cooper
2905	Manganese-54	pCi/Filter		< 50.0	0.00 - 50.0	Not Reported						
2930	Plutonium-238	pCi/Filter		35.4	26.7 - 43.5	Not Reported				36.6	0.961	
2932	Plutonium-239	pCi/Filter		20.5	15.3 - 24.7	Not Reported				21.2	0.911	
3005	Strontium-90	pCi/Filter		189	120 - 257	Not Reported				194	10.9	
3036	Uranium-234	pCi/Filter	25.99	25.5	18.9 - 29.9	Acceptable	ASTM D3972	4/14/2021	0.712	24.4	2.25	
3038	Uranium-238	pCi/Filter	24.7	25.3	19.1 - 30.2	Acceptable	ASTM D3972	4/14/2021	0.246	24.1	2.39	
3055	Uranium-Total	pCi/Filter		52.0	38.0 - 61.7	Not Reported				50.6	2.37	
3055	Uranium-Total (mass)	µg/Filter		75.9	60.9 - 88.9	Not Reported				72.4	1.57	
3070	Zinc-65	pCi/Filter		771	632 - 1180	Not Reported				875	94.2	

MRAD-34 Final Evaluation Report

A Waters Company

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EPA ID: TN11387
ERA Customer Number: T200801
Report Issued: 05/25/21
Study Dates: 03/22/21 - 05/21/21

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
MRAD Water Radionuclides (cat# 804, lot# A034-617)												
D2755	Americium-241	pCi/L	175	157	108 - 201	Acceptable	TBE Proprietary	4/8/2021	1.42	161	9.58	Shannon Cooper
2800	Cesium-134	pCi/L		1610	1220 - 1770	Not Reported				1500	93.5	
2805	Cesium-137	pCi/L		578	495 - 657	Not Reported				586	20.9	
2815	Cobalt-60	pCi/L		2180	1880 - 2500	Not Reported				2230	69.7	
2885	Iron-55	pCi/L	579	275	162 - 400	Not Acceptable	TBE Proprietary	4/28/2021	1.56	356	143	Shannon Cooper
2905	Manganese-54	pCi/L		< 100	0.00 - 100	Not Reported						
2930	Plutonium-238	pCi/L	181	171	103 - 222	Acceptable	ASTM D3865	4/12/2021	1.39	148	24.1	Shannon Cooper
2932	Plutonium-239	pCi/L	153	142	87.9 - 175	Acceptable	ASTM D3865	4/12/2021	1.41	124	20.9	Shannon Cooper
3005	Strontium-90	pCi/L		671	483 - 829	Not Reported				672	64.2	
3036	Uranium-234	pCi/L		160	122 - 183	Not Reported				149	9.81	
3038	Uranium-238	pCi/L		158	122 - 186	Not Reported				148	7.14	
3055	Uranium-Total	pCi/L		325	254 - 370	Not Reported				298	8.14	
3055	Uranium-Total (mass)	µg/L		474	384 - 538	Not Reported				449	13.0	
3070	Zinc-65	pCi/L		1720	1530 - 2170	Not Reported				1820	90.7	

RAD-125 Final Evaluation Report

ERA
A Waters Company

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(865) 934-0374

EPA ID: TN11387
ERA Customer Number: T200801
Report Issued: 05/24/21
Study Dates: 04/05/21 - 05/20/21

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
RAD Gamma EmitterS™ (cat# 808, lot# R125-758)												
2765	Barium-133	pCi/L	92.3	90.5	76.2 - 99.6	Acceptable	EPA 901.1 1980	4/8/2021	1.22	87.6	3.83	Shannon Cooper
2800	Cesium-134	pCi/L	62.9	70.5	57.5 - 77.6	Acceptable	EPA 901.1 1980	4/8/2021	-0.743	66.6	4.97	Shannon Cooper
2805	Cesium-137	pCi/L	161	168	151 - 187	Acceptable	EPA 901.1 1980	4/8/2021	-0.519	165	7.90	Shannon Cooper
2815	Cobalt-60	pCi/L	22.5	20.9	17.7 - 25.8	Acceptable	EPA 901.1 1980	4/8/2021	0.303	22.2	1.11	Shannon Cooper
3070	Zinc-65	pCi/L	183	177	159 - 208	Acceptable	EPA 901.1 1980	4/8/2021	-0.379	186	9.19	Shannon Cooper
RAD GroSS™ Alpha/Beta (cat# 809, lot# R125-759)												
2830	Gross Alpha	pCi/L	30.8	30.2	15.4 - 39.4	Acceptable	EPA 900.0 (GPC) 1 2018	4/29/2021	0.247	29.3	6.26	Susan Ogletree
2840	Gross Beta	pCi/L	60.1	67.5	46.8 - 74.2	Acceptable	EPA 900.0 (GPC) 1 2018	4/29/2021	-0.0817	60.6	6.47	Susan Ogletree
RAD NaturalS™ (cat# 811, lot# R125-751)												
2965	Radium-226	pCi/L		19.3	14.3 - 22.0	Not Reported				19.4	1.66	
2970	Radium-228	pCi/L		10.3	6.71 - 12.8	Not Reported				10.4	1.84	
3055	Uranium (Nat)	pCi/L	36.45	36.9	30.0 - 40.8	Acceptable	EPA 908.0 1980	4/21/2021	1.26	35.0	1.14	Shannon Cooper
3055	Uranium (Nat) mass	µg/L		53.8	43.7 - 59.5	Not Reported				52.4	0.424	
RAD TritiuM™ (cat# 812, lot# R125-752)												
3030	Tritium	pCi/L	13400	14600	12800 - 16100	Acceptable	EPA 906.0 1980	4/16/2021	-1.28	14400	787	Susan Ogletree
RAD Strontium-89/90 (cat# 807, lot# R125-757)												
2995	Strontium-89	pCi/L	64.5	63.5	51.4 - 71.5	Acceptable	EPA 905.0 1980	5/18/2021	0.338	61.6	8.49	Shannon Cooper
3005	Strontium-90	pCi/L	22.8	23.0	16.5 - 27.0	Acceptable	EPA 905.0 1980	5/18/2021	0.0853	22.5	3.49	Shannon Cooper
RAD Iodine-131 (cat# 810, lot# R125-750)												
2875	Iodine-131	pCi/L	28.2	26.7	22.2 - 31.4	Acceptable	EPA 901.1 1980	4/21/2021	0.175	27.9	1.80	Shannon Cooper

MRAD-35 Final Evaluation Report

A Waters Company

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EPA ID: TN11387
ERA Customer Number: T200801
Report Issued: 11/22/2021
Study Dates: 09/20/2021 - 11/19/2021

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
MRAD Air Filter Radionuclides (cat# 800, lot# A035-606)												
2755	Americium-241	pCi/Filter		27.7	19.8 - 36.9	Not Reported				28.8	2.50	
2800	Cesium-134	pCi/Filter		241	156 - 296	Not Reported				226	33.8	
2805	Cesium-137	pCi/Filter		187	154 - 245	Not Reported				200	22.3	
2815	Cobalt-60	pCi/Filter		310	264 - 394	Not Reported				334	26.7	
2885	Iron-55	pCi/Filter	493	548	200 - 874	Acceptable	TBE Proprietary	10/21/2021	0.649	463	45.9	Shannon Cooper
2905	Manganese-54	pCi/Filter		< 50.0	0.00 - 50.0	Not Reported						
2930	Plutonium-238	pCi/Filter	28	28.5	21.5 - 35.0	Acceptable	TBE Proprietary	10/19/2021	-0.319	28.4	1.30	Shannon Cooper
2932	Plutonium-239	pCi/Filter	21	21.6	16.1 - 26.1	Acceptable	TBE Proprietary	10/19/2021	-0.717	21.7	1.02	Shannon Cooper
3005	Strontium-90	pCi/Filter		19.2	12.1 - 26.1	Not Reported				17.5	0.927	
3036	Uranium-234	pCi/Filter	7.95	7.76	5.75 - 9.09	Acceptable	TBE Proprietary	10/21/2021	0.782	7.75	0.251	Shannon Cooper
3038	Uranium-238	pCi/Filter	8.03	7.69	5.81 - 9.17	Acceptable	TBE Proprietary	10/21/2021	1.14	7.70	0.294	Shannon Cooper
3055	Uranium-Total	pCi/Filter		15.8	11.5 - 18.7	Not Reported				15.9	0.650	
1184	Uranium (mass)	µg/Filter		23.1	18.5 - 27.1	Not Reported				23.4	1.11	
3070	Zinc-65	pCi/Filter		366	300 - 559	Not Reported				419	50.5	

MRAD-35 Final Evaluation Report

ERA
A Waters Company

Sharon Northcutt
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Teledyne Brown Engineering
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Knoxville, TN 37931
(865) 934-0374

EPA ID: TN11387
ERA Customer Number: T200801
Report Issued: 11/22/2021
Study Dates: 09/20/2021 - 11/19/2021

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
MRAD Soil Radionuclides (cat# 802, lot# A035-608)												
2700	Actinium-228	pCi/kg		3240	2140 - 4080	Not Reported				3210	369	
2755	Americium-241	pCi/kg		891	481 - 1260	Not Reported				872	205	
2772	Bismuth-212	pCi/kg		3350	959 - 4990	Not Reported				3160	991	
2773	Bismuth-214	pCi/kg		1370	658 - 2040	Not Reported				1420	220	
2800	Cesium-134	pCi/kg		2650	1810 - 3170	Not Reported				2520	281	
2805	Cesium-137	pCi/kg		3660	2770 - 4630	Not Reported				3710	275	
2815	Cobalt-60	pCi/kg		4730	3720 - 5840	Not Reported				4730	350	
2902	Lead-212	pCi/kg		3420	2390 - 4320	Not Reported				3360	455	
2903	Lead-214	pCi/kg		1490	626 - 2340	Not Reported				1470	167	
2905	Manganese-54	pCi/kg		< 1000	0.00 - 1000	Not Reported						
2930	Plutonium-238	pCi/kg		1250	623 - 1900	Not Reported				1170	166	
2932	Plutonium-239	pCi/kg		1450	790 - 2090	Not Reported				1350	216	
2946	Potassium-40	pCi/kg		24700	17000 - 29500	Not Reported				25000	2670	
3005	Strontium-90	pCi/kg	6160	6090	1900 - 9490	Acceptable	HASL 300 Sr-03 28th ED 1997	11/2/2021	0.234	5810	1500	Shannon Cooper
3028	Thorium-234	pCi/kg		2720	1030 - 4660	Not Reported				3040	780	
3036	Uranium-234	pCi/kg		2740	1280 - 3590	Not Reported				2610	383	
3038	Uranium-238	pCi/kg		2720	1490 - 3650	Not Reported				2690	571	
3055	Uranium-Total	pCi/kg		5580	3100 - 7210	Not Reported				5370	835	
1184	Uranium (mass)	µg/kg		8140	3670 - 11000	Not Reported				6910	1900	
3070	Zinc-65	pCi/kg		4860	3880 - 6630	Not Reported				5110	506	

MRAD-35 Final Evaluation Report

A Waters Company

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EPA ID: TN11387
ERA Customer Number: T200801
Report Issued: 11/22/2021
Study Dates: 09/20/2021 - 11/19/2021

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
MRAD Water Radionuclides (cat# 804, lot# A035-617)												
2755	Americium-241	pCi/L	68	63.7	43.7 - 81.5	Acceptable	TBE Proprietary	10/25/2021	0.848	60.9	8.40	Shannon Cooper
2800	Cesium-134	pCi/L		649	490 - 714	Not Reported				613	38.0	
2805	Cesium-137	pCi/L		2170	1860 - 2470	Not Reported				2160	79.0	
2815	Cobalt-60	pCi/L		964	831 - 1110	Not Reported				984	46.6	
2885	Iron-55	pCi/L	179	246	145 - 358	Acceptable	TBE Proprietary	10/20/2021	-1.28	213	26.3	Shannon Cooper
2905	Manganese-54	pCi/L		< 100	0.00 - 100	Not Reported						
2930	Plutonium-238	pCi/L	102	114	68.5 - 148	Acceptable		10/25/2021	-0.0784	103	13.9	Shannon Cooper
2932	Plutonium-239	pCi/L	32	34.3	21.2 - 42.3	Acceptable		10/25/2021	0.264	31.0	3.89	Shannon Cooper
3005	Strontium-90	pCi/L		936	674 - 1160	Not Reported				927	64.0	
3036	Uranium-234	pCi/L		40.8	31.1 - 46.7	Not Reported				39.0	1.59	
3038	Uranium-238	pCi/L		40.5	31.4 - 47.7	Not Reported				39.5	1.43	
3055	Uranium-Total	pCi/L		83.2	64.9 - 94.8	Not Reported				80.3	3.33	
1184	Uranium (mass)	µg/L		121	98.0 - 137	Not Reported				120	6.94	
3070	Zinc-65	pCi/L		394	351 - 497	Not Reported				412	38.1	

ERA
A Waters Company

Final Evaluation Report

Study: RAD-127

ERA Customer Number: T200801

Laboratory Name: Teledyne Brown Engineering

RAD Results

RAD-127 Final Evaluation Report

A Waters Company

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EPA ID: TN11387
ERA Customer Number: T200801
Report Issued: 11/26/2021
Study Dates: 10/08/2021 - 11/22/2021

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
RAD Gamma EmitterS™ (cat# 808, lot# R127-758)												
2765	Barium-133	pCi/L	82.8	87.5	73.6 - 96.2	Acceptable	EPA 901.1 1980	10/19/2021	-0.290	85.1	7.98	
2800	Cesium-134	pCi/L	64.0	70.1	57.1 - 77.1	Acceptable	EPA 901.1 1980	10/19/2021	-0.605	68.8	7.95	
2805	Cesium-137	pCi/L	145	156	140 - 174	Acceptable	EPA 901.1 1980	10/19/2021	-0.926	154	10.0	
2815	Cobalt-60	pCi/L	83.2	85.9	77.3 - 96.8	Acceptable	EPA 901.1 1980	10/19/2021	-0.386	85.5	6.09	
3070	Zinc-65	pCi/L	133	145	130 - 171	Acceptable	EPA 901.1 1980	10/19/2021	-1.21	150	14.4	
RAD GroSS™ Alpha/Beta (cat# 809, lot# R127-759)												
2830	Gross Alpha	pCi/L	76	66.7	35.0 - 82.5	Acceptable	EPA 900.0 (GPC) 1 2018	11/11/2021	1.35	60.1	11.7	
2840	Gross Beta	pCi/L	63.0	55.7	38.1 - 62.6	Not Acceptable	EPA 900.0 (GPC) 1 2018	11/4/2021	1.61	52.3	6.67	
RAD NaturalS™ (cat# 811, lot# R127-751)												
2965	Radium-226	pCi/L		16.8	12.5 - 19.2	Not Reported				16.8	2.27	
2970	Radium-228	pCi/L		11.1	7.28 - 13.7	Not Reported				11.1	2.33	
1055	Uranium (Nat)	pCi/L	52.88	55.5	45.3 - 61.1	Acceptable	EPA 908.0 1980	10/26/2021	0.236	52.3	2.31	
1184	Uranium (mass)	µg/L		81.0	66.1 - 89.2	Not Reported				76.5	2.47	
RAD TritiuM™ (cat# 812, lot# R127-752)												
3030	Tritium	pCi/L	13800	17200	15000 - 18900	Not Acceptable	EPA 906.0 1980	10/26/2021	-3.72	17200	921	
RAD Strontium-89/90 (cat# 807, lot# R127-757)												
2995	Strontium-89	pCi/L	54.9	61.0	49.1 - 68.9	Acceptable	EPA 905.0 1980	11/2/2021	-0.315	56.3	4.28	
3005	Strontium-90	pCi/L	24.8	29.3	21.3 - 34.0	Acceptable	EPA 905.0 1980	11/3/2021	-1.54	27.9	2.01	
RAD Iodine-131 (cat# 810, lot# R127-750)												
2875	Iodine-131	pCi/L	27.4	26.4	21.9 - 31.1	Acceptable	EPA 901.1 1980	10/28/2021	0.292	26.9	1.76	

120121Y Final Evaluation Report

A Waters Company

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EPA ID: TN11387
ERA Customer Number: T200801

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
RAD GroSS™ Alpha/Beta (cat# 759, lot# 120121Y) Study Dates: 12/01/2021 - 12/27/2021												
2830	Gross Alpha	pCi/L		63.3	33.2 - 78.5	Not Reported				54.8	13.2	
2840	Gross Beta	pCi/L	47.6	39.8	26.4 - 47.3	Not Acceptable	EPA 900.0 (GPC) 1 2018	12/16/2021	2.38	36.0	4.88	
RAD TritiuM™ (cat# 752, lot# 120121Y) Study Dates: 12/01/2021 - 12/27/2021												
3030	Tritium	pCi/L	17500	17800	15600 - 19600	Acceptable	EPA 906.0 1980	12/10/2021	-0.259	17700	818	

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A.5

Client Cross Check Samples

Eckert & Ziegler

Analytics

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Atlanta, Georgia 30318 U.S.A.

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Fax 404-352-2837

ANAB ACCREDITED ISO/IEC 17043 PROFICIENCY TESTING PROVIDER

RESULTS OF RADIOCHEMISTRY CROSS CHECK PROGRAM

CONFIDENTIAL

2nd QUARTER 2021

(Ref. Date 14 May 2021, Rev. 3)

L. Tk

04 Jan 2022

Levan Tkavadze , Nuclear Metrologist

Sample	Analysis	CONFIDENTIAL	EZA Value, uCi/ml	CONFIDENTIAL	Resolution	Comparison
A37532 Liquid	Sr-89	1.04E-02	9.91E-03	1.05	17	AGREEMENT
	Sr-90	9.64E-04	9.47E-04	1.02	12.5	AGREEMENT

Sample	Analysis	CONFIDENTIAL	EZA Value, uCi/ml	CONFIDENTIAL	Resolution	Comparison
A37533 Liquid	Fe-55	2.15E-03	2.00E-03	1.08	12.5	AGREEMENT

Eckert & Ziegler

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RESULTS OF RADIOCHEMISTRY CROSS CHECK PROGRAM

CONFIDENTIAL

2nd QUARTER 2021

(Ref. Date 14 May 2021, Rev. 0)

L. Tk

13 Jan 2022

Levan Tkavadze , Nuclear Metrologist

Sample	Analysis	CONFIDENTIAL	EZA Value, uCi/ml	CONFIDENTIAL	Resolution	Comparison
A37865 Liquid Report L91923	Sr-89	9.60E-03	9.91E-03	0.97	17	AGREEMENT
	Sr-90	1.05E-03	9.47E-04	1.11	12.5	AGREEMENT

Eckert & Ziegler
Analytics

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ANAB ACCREDITED ISO/IEC 17043 PROFICIENCY TESTING PROVIDER

RESULTS OF RADIOCHEMISTRY CROSS CHECK PROGRAM

CONFIDENTIAL CLIENT

3rd QUARTER 2021

(Ref. Date 13 Aug 2021, Rev. 2)

L. Tk

02 Nov 2021

Levan Tkavadze , Nuclear Metrologist

Sample	Analysis	[redacted] Value, uCi/ml	EZA Value, uCi/ml	Ratio [redacted] / EZA	Resolution	Comparison
A37497 Liquid	Sr-89	5.97E-03	7.05E-03	0.85	17	AGREEMENT
	Sr-90	8.36E-04	7.99E-04	1.05	12.5	AGREEMENT

Sample	Analysis	[redacted] Value, uCi/ml	EZA Value, uCi/ml	Ratio [redacted] / EZA	Resolution	Comparison
A37498 Liquid	Gross Alpha (Am-241)	4.38E-05	5.00E-05	0.88	12.5	AGREEMENT

Sample	Analysis	[redacted] Value, uCi/ml	EZA Value, uCi/ml	Ratio [redacted] / EZA	Resolution	Comparison
A37503 Liquid	Fe-55	1.09E-03	9.96E-04	1.09	12.5	AGREEMENT

Eckert & Ziegler

Analytics

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ANAB ACCREDITED ISO/IEC 17043 PROFICIENCY TESTING PROVIDER

RESULTS OF RADIOCHEMISTRY CROSS CHECK PROGRAM

CONFIDENTIAL

4th QUARTER 2021

(Ref. Date 05 Nov 2021, Rev. 0)

L. Tk

17 Dec 2021

Levan Tkavadze , Nuclear Metrologist

Sample	Analysis	CONFIDENTIAL	EZA Value uCi	CONFIDENTIAL	Resolution	Comparison
A38180 Filter	Sr-89	7.70E-04	7.19E-04	1.07	17	AGREEMENT
	Sr-90	6.05E-05	7.12E-05	0.85	12.5	AGREEMENT

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ATTACHMENT B

Intralaboratory Quality Control Program Results

ATTACHMENT B.1
TBE - ES QC Program
In-House Water Blanks and Spikes

Nuclide	# of Samples Analyzed	Blank Results	Spike Recovery % (Range*)	% of Samples Within 20% of Known Value
Am-241	38	All < MDC	73.8 - 108	97
C-14	64	All < MDC	71.4 - 128	76.6
Ce-144 (RAD)	21	All < MDC	NA	
Cs-137 (RAD)	16	All < MDC	87.3 - 109	56
Fe-55	107	All < MDC	70.4 - 125	79.4
Gross Alpha	136	All < MDC	70.1 - 106	75.0
Gross Beta	105	All < MDC	72.4 - 125	83.8
H-3	343	All < MDC	71.3 - 127	94.5
I-129/131	109	All < MDC	70.4 - 128	86.2
Ni-63[(1)]	120	All < MDC [(2)]	70.4 - 115	88.3
P-32	13	All < MDC	NA	
Pb-210	3	All < MDC	89.7 - 121	67
Pu-239/240	39	All < MDC	75.5 - 108	95
S-35 (RAD)	8	All < MDC	NA	
Sr-89	125	All < MDC	72.0 - 125	94
Sr-90	139	All < MDC	71.6 - 130	86.3
Tc-99	28	All < MDC	771.4 - 95.1	60.7
Th-230	13	All < MDC	84.5 - 99.3	100
U-238	48	All < MDC	86.3 - 112	100

[(1)] One spike failure: Not reported/not included with data/workgroup completely re-prepped
[(2)] One blank failure: Sample result > 5x blank activity (reported with case narrative)
**Internal Process Control results use TBE-ES acceptance criteria of 70 -130% recovery*

Matrix Spikes

Nuclide	Count Date	Sample Result	Spiked Result	Spike Value	%
Fe-55	02/02/21	< 120	501	488	103
Fe-55	05/03/21	< 47.9	417	424	98.3
Fe-55	08/04/21	< 75.9	1170	1610	72.7
Fe-55	11/03/21	<131	1611	1500	107
Gr-A CP	01/26/21	2.29	43.6	52.3	79.0
Gr-A CP	04/27/21	1.96	46.2	52.3	84.6
Gr-A CP	07/27/21	2.73	45.0	52.3	80.8
Gr-A CP	10/22/21	2.39	46.8	52.2	85.0
Gr-B	01/27/21	17.8	89.2	95.1	75.1
Gr-B	04/21/21	5.5	47.8	56.6	74.7
Gr-B	07/27/21	12.2	53.3	56.2	73.1
Gr-B	10/20/21	9.7	46.5	55.9	65.9
H-3 (Dist)	01/23/21	< 264	4830	4150	116
H-3 (Dist)	04/21/21	< 266	4950	4070	122
H-3 (Dist)	07/29/21	< 286	5120	4000	128
H-3 (Dist)	10/21/21	< 275	4140	3940	105
Ni-63	02/05/21	< 4.32	699	873	80.1
Ni-63	05/04/21	< 4.02	811	871	93.1
Ni-63	08/05/21	< 4.98	768	869	88.4
Ni-63	11/02/21	< 4.47	691	868	79.6
Pb-210	06/19/21	0.775	22.0	21.9	96.9
Pb-210	11/16/21	0.412	26.5	23.7	110
Pb-210	11/23/21	0.427	16.9	14.0	118
Sr-89	02/16/21	< 8.2	105	119	88.2
Sr-89	08/04/21	< 7.8	1200	1540	77.9
Sr-89	11/02/21	< 6.9	149	198	75.3
Sr-90	02/16/21	< 1.0	45.7	54.1	84.5
Sr-90	04/28/21	< 0.86	59.5	55.0	108
Sr-90	08/04/21	< 0.92	143.0	110	130
Sr-90	11/02/21	< 0.93	43.3	54.5	79.5

***Internal Process Control results use TBE-ES acceptance criteria of 60 -140% recovery*

ATTACHMENT B.2

TBE - ES QC Program In-House Duplicates*

Matrix	Nuclide	# of Dups Analyzed	# Samples Evaluated for RPD**	RPD Range	RPD Upper Limit
Air Particulates	Be-7 (Gamma)	48	6	1.3 - 12.9	30
	Gross Alpha	64	19	0.5 - 29.6	30
	Gross Beta	516	242	0.0 - 29.8	30
	Sr-89	72	5	2.2 - 19.9	30
	Sr-90	75	0		30
	Th-228	15	0		30
	U-234	1	1	7.1	30
	U-238	1	1	4.8	30
Charcoal	I-131 (Gamma)	427	2	5.3 - 6.1	50
Feed/Food/Grass/Veg	Be-7 (Gamma)	34	3	5.7 - 35.4	50
	K-40 (Gamma)	35	34	0.3 - 41.9	50
Fish/Shellfish [1]	Be-7 (Gamma)	7	0		50
	K-40 (Gamma)	7	3	1.1 - 22.6	50
Milk	K-40 (Gamma)	155	155	0.0 - 25.3	30
Sediment/Soil/Solid	C-14 (RAD)	18	4	16.8 - 34.3	50
	H-3 (RAD) [2]	7	0		50
	K-40	15	9	0.5 - 40.8	50
	Pb-210	3	1	10.6	50
Water/Liquid	Am-241	6	2	12.4 - 23.0	30
	Fe-55	10	0		30
	Gross Alpha	25	2	7.2 - 12.5	30
	Gross Beta	35	5	3.5 - 8.5	30
	H-3	268	36	0.3 - 28.0	30
	K-40 (Gamma)	69	3	3.8 - 14.0	30
	Ni-63	10	2	14.4 - 27.3	30
	Sr-89	17	2	3.5 - 9.7	30
	Sr-90	17	3	7.9 - 18.2	30
LO/LR	C-14 (RAD)	14	0		30
	H-3	40	15	0.0 - 25.4	30
LCSD's	Am-241 (AS)	32	32	0.1 - 22.7	30
	C-14 (RAD)	27	27	0.0 - 29.1	30
	Cs-137 (RAD)	9	9	1.1 - 16.4	30
	Fe-55	83	24	0.3 - 23.8	30
	Gross Alpha	37	37	0.0 - 25.1	30
	Gross Beta	38	38	0.0 - 25.4	30
	H-3	28	28	0.2 - 15.9	30
	I-129	62	40	0.6 - 26.3	30
	Ni-63	95	95	0.0 - 25.7	30
	Pu-239/240 (AS)	33	33	0.2 - 29.8	30
	Sr-89	28	25	0.1 - 28.7	30
	Sr-90	44	44	0.0 - 29.7	30
	Tc-99	24	24	0.7 - 14.4	30
	Th-230 (AS)	13	13	0.5 - 18.1	30
	U-238 (AS)	26	26	1.5 - 25.8	30
MSD's	Pb-210	3	3	5.4 - 8.6	30

**NOTE: Duplicates for Gamma analyses on this form are only for nuclides reported for QC data packages (All Gamma nuclides are duplicated at the time of analysis)*

Precision is not evaluated if results are < 5x MDC* ***or *if both results are non-detect*

[1] *2nd Qtr QA report contained erroroneous numbers of samples - should have been 1 instead of 5 (each)*

[2] *3rd Qtr QA report correct values: 6 samples, 0 evaluated (13.2 RPD was for with K-40, not H-3)*

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ATTACHMENT C

Non-Conformance Reports (NCRs)

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: 21-01

2. Responsible Manager: Sharon Northcutt

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Environmental Lab	4. Client/Project Affected: TBE MRAD
5. Requirement Reference: TBE-4006	6. Affected Data: L# L91286
7. NCR Description: Unacceptable WO Fe-55 result	
8. Client Notification: ☐ YES ☒ NO	9. Associated CC #: NA
10. Prepared By: Sharon Northcutt	11. Date: 05/25/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See Attached Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 06/25/21	
14. Prepared By: Sharon Northcutt	15. Date: 05/25/21
16. Approved By: Keith Jeter	17: Date: 7/7/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☑ Accepted ☐ Rejected ☐ Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date:

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☐ YES ☒ NO Description:	22. Date:
23. Prepared By: Sharon L Northcutt	24. Date: 07/07/21

Supplemental Sheet

NCR No: 21-01

Description of Nonconformance:

MRAD water Fe-55 result of 579 pCi/L was unacceptable. The known result was 275 pCi/L with a range of 162-400 pCi/L.

Investigation:

When reviewing the original sample data, it was found that the carrier yield was 52.6% (lower than typical water samples for Fe-55). Also looked at the etched plate that was counted and noticed that some loss of sample could have occurred. The sample was logged for reanalysis (R1). This sample was also run as the workgroup duplicate. The sample results were 197 +/- 69.7 pCi/L (R1) and 221 +/- 35.9 pCi/L (WG dup). The yields for these samples were 97.4% and 105.7% respectively (more typical of water samples for Fe-55). The plates also were centered with no apparent loss of sample. Typical yields for water samples run 90-100%

Root Cause:

There was an unexpected loss of sample during the plating process which caused an artificially low yield, producing in an artificially high sample result.

Corrective Action to Prevent Recurrence:

The loss of sample leading to a low yield was discussed with the lab tech The lab and countroom techs will more closely inspect the plates for possible sample loss and will automatically reprocess samples that display such loss in combination with lower yield results.

Keith Jeter 7/7/21

Department Manager or Designee Date

Sharon L Northcutt 07/07/21

Quality Assurance Manager or Designee Date

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: 21-02

2. Responsible Manager: Sharon Northcutt

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Environmental Lab	4. Client/Project Affected: TBE MAPEP
5. Requirement Reference: TBE-4006	6. Affected Data: L# L91129
7. NCR Description: Unacceptable AP Gross Alpha result	
8. Client Notification: ☐ YES ☒ NO	9. Associated CC #: NA
10. Prepared By: Sharon Northcutt	11. Date: 06/09/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See Attached Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 0709/21	
14. Prepared By: Sharon L Northcutt	15. Date: 06/09/21
16. Approved By: Keith Jett	17: Date: 6/18/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☑ Accepted ☐ Rejected ☐ Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date: 06/18/21

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☐ YES ☒ NO Description:	22. Date:
23. Prepared By: Sharon L Northcutt	24. Date: 06/18/21

Supplemental Sheet

NCR No: 21-02

Description of Nonconformance:

MAPEP AP filter Gross Alpha result of 0.371 Bq/sample was unacceptable. The known result was 1.77 Bq/sample with a range of 0.53 - 3.01 Bq/sample.

Investigation:

A recount was scheduled on the sample and also the failure was discussed with the countroom technician. She mentioned that several years ago, we had a similar failure due to the filter being placed with the wrong side up on the detector. Our prep technician began to place a small dot on the filter upon receipt to insure that there was no repeat of this type of failure. The countroom technician stated that the sample was still in the detector. When we pulled the sample, the small dot was on the side facing the detector. The sample was recounted just as the original and then flipped over and counted. The flipped sample result was 0.661 +/- 0.0060 Bq/sample, which was in the acceptable range.

Root Cause:

The MAPEP instructions state that "the spiked side of the filter is placed in the packet facing 'up' toward the label...the filters are not marked, so carefully note the spiked filters and their orientation before moving them from the packets". Since our tech did place a mark on the "up" side prior to removal from its packaging and we counted the sample as instructed, the only conclusion is that the spiked sample was placed in the packaging upside down.

Corrective Action to Prevent Recurrence:

With client AP samples, there is little doubt as to the correct side that should be facing the detector, as they are usually very dirty-looking (see attached comparison picture); so this is not an issue except with cross-check samples that are spiked and appear clean. We have made a request to MAPEP that they place a small indicator on these filters so that there can be no mistake as to the correct orientation (see picture for our example). Until such time that they make a change, we will: (1) continue to place an indicator mark on the filters when they are received and (2) count MAPEP AP filters twice - once on each side. This actually defeats the purpose of analyzing cross-checks in the same manner as client samples, but we also desire to receive an "acceptable" result for this analyses.

Keith Jete 6/18/21

Department Manager or Designee Date

Sharon L Northcutt 06/18/21

Quality Assurance Manager or Designee Date

Northcutt, Sharon

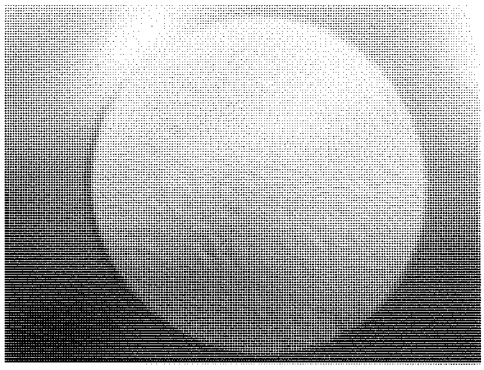
From: Northcutt, Sharon
Sent: Friday, June 18, 2021 2:01 PM
To: DOEIDmapep@id.doe.gov
Subject: Air Particulate Filters
Attachments: AP XCHK Filter with dot.jpg; AP client filter.jpg

Hello! We would like to make a request for your packaging of AP Filters for Gross Alpha/Beta - would you all make some kind of mark on the filter (outside edge or whatever) for the spiked side? We have been adding a small dot with a Sharpie to the filter prior to removing completely from the packet just to make sure we know how it was received - this was due to having an unacceptable result years ago with the filter being flipped unknowingly by our technician. It's just a small dot but it is very handy to confirm the "correct" spiked side of the filter and it doesn't interfere with the analysis. We do not have an issue with actual client samples, as they are dirty when we receive them. We feel that this would be of great benefit to MAPEP's clients so that these filters would be more indicative of the correct side to load into the detector. I'm attaching a picture of how we mark our filters and a picture of a typical client filter.

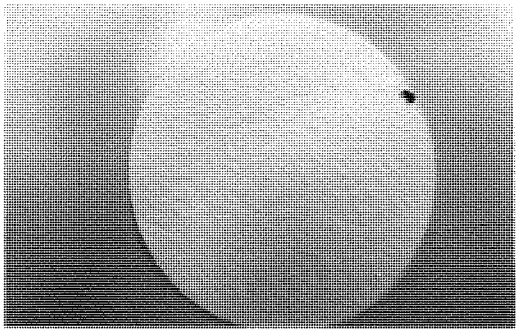
Thank you for your consideration.

Thanks!
Sharon L Northcutt
Quality Assurance Manager
Teledyne Brown Engineering
2508 Quality Lane
Knoxville, TN 37931
865 934-0374

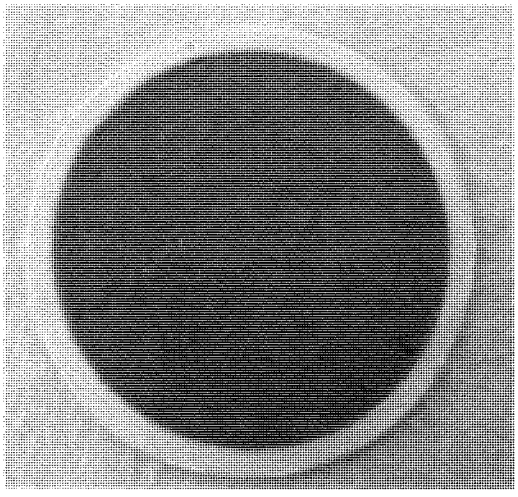
MAPEP Cross Check as received



MAPEP Cross Check with TBE marking prior to complete removal from packaging



Client AP Filter example



TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: 21-03

2. Responsible Manager: Sharon Northcutt

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Environmental Lab	4. Client/Project Affected: TBE MAPEP
5. Requirement Reference: TBE-4006	6. Affected Data: L# L91129
7. NCR Description: Unacceptable Soil Ni-63 result	
8. Client Notification: ☐ YES ☒ NO	9. Associated CC #: NA
10. Prepared By: Sharon Northcutt	11. Date: 06/09/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See attached Supplemental Page	
13. Planned Completion Date(s) for Actions(s): 07/15/21	
14. Prepared By: Sharon L Northcutt	15. Date: 06/22/21
16. Approved By: Keith Jeter	17: Date: 7/22/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☒ Accepted ☐ Rejected ☐ Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date: 07/22/21

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☐ YES ☒ NO Description: [Qtrly QA Rept]	22. Date:
23. Prepared By: Sharon L Northcutt	24. Date: 07/22/21

Supplemental Sheet

NCR No: 21-03

Description of Nonconformance:

MAPEP soil Ni-63 result of 310 Bq/kg was unacceptable. The known result was 699 Bq/kg with a range of 482 - 896 Bq/kg.

Investigation:

The procedure for Radionickel soils had been updated just prior to the analysis of this sample, but no improvement was seen. All QC was reviewed and was within acceptable TBE requirements. Looking at historical data, the carrier yields for MAPEP soils have been above 108%, while workgroup blanks and spikes average around 95%. MAPEP water Ni-63 sample yields average around 95%. For the 37 environmental soil samples that have been analyzed since 2019 (including cross-checks), the average yield has been 106% with a range of 68-119%. Around 27% of the soils have had yields of 100% or less (more in line with QC samples).

The MAPEP soil sample analyzed for Ni-63 is also spiked for gamma analysis and contains known interfering nuclides. If added interferences (such as iron or cobalt) are not removed during separation and/or precipitation, chemical yields may be artificially inflated. Co-60 exhibits similar chemical behavior as Ni-63. According to published literature, "*The complexing agent DMG also complexes with other metal elements, such as cobalt, copper, cadmium & palladium, leading to interferences during Ni-63 separation. Also, the presence of Fe-55 can hinder the formation of $Ni(DMG)_2$ complex/precipitate because of its precipitation at basic pH. Citric acid prevents its precipitation (and other metal elements) at basic pH. However, their chelating properties may not be sufficient in case of high iron amounts.*" Also, it is recommended to wet-ash with strong acids to better dissolve solid samples.

Root Cause:

Although the yields appear to be very good for the MAPEP soil samples, it is likely that this number includes interferences that have not been completely removed in the precipitation and/or separation process. Because it is factored into the activity calculation, the higher yield caused the result to be lower.

Corrective Action to Prevent Recurrence:

The procedure for soils has been re-evaluated against other national standards and re-written to better remove known interferences in samples and to ensure that there is limited loss of Ni during the process.

Keith Jete — 7/22/21

Department Manager or Designee — Date

Sharon L Northcutt — 07/22/21

Quality Assurance Manager or Designee — Date

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: 21-04

2. Responsible Manager: Sharon Northcutt

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Quality Assurance Manual	4. Client/Project Affected: NELAP (Utah)
5. Requirement Reference: TNI Std 2016 V1M2 4.7	6. Affected Data: N/A
7. NCR Description: Audit finding - the laboratory did not have a process to seek feedback from clients	
8. Client Notification: ☐ YES ☒ NO	9. Associated CC #: N/A
10. Prepared By: Sharon Northcutt	11. Date: 06/28/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See Attached Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 07/28/21	
14. Prepared By: Sharon Northcutt	15. Date: 06/28/21
16. Approved By: Keith Jett	17: Date: 6/28/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☒ Accepted ☐ Rejected ☐ Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date: 06/28/21

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☐ YES ☒ NO Description:	22. Date:
23. Prepared By: Sharon L Northcutt	24. Date: 06/28/21

Supplemental Sheet

NCR No: 21-04

Description of Nonconformance:

Utah Department of Health NELAP audit finding that the laboratory did not have a process to seek feedback from clients. Reference: TNI 2016 Standard V1M2 4.7.2:

"The laboratory shall seek feedback, both positive and negative, from its customers. The feedback shall be used and analyzed to improve the management system, testing and calibration activities and customer service. NOTE: Examples of the types of feedback include customer satisfaction surveys and review of test of calibration reports with customers."

Root Cause:

The prior NELAP audit conducted in 2018 by the State of New York was based on the 2003 NELAC/2009 TNI Standard, which did not directly address this issue. The TBE QA Manual was completely reformatted and updated with Rev. 34, issued March 1, 2021. This revision included the updated regulatory requirements of the 2016 TNI Standard and ISO17025:2017.

Section 8.6.4 states: "In order to understand customer needs and to ensure satisfaction, TBE-ES encourages both positive and negative feedback from clients. The first line of client communication is with the project management team who serve as the primary contact for login, sample results, reporting, turnaround time and complaints Any feedback given to the lab is used to improve the overall management system, analytical procedures and most importantly, customer satisfaction."

While we appreciate and welcome client feedback, there was no official mechanism in place to pro-actively gather this valuable information.

Corrective Action to Prevent Recurrence:

TBE Procedure TBE-1016 "Documentation of Customer Complaints" will be revised, expanded and renamed to include Client Feedback. A client survey will be made readily available in client correspondence and on the website. Once the survey is completed, the results will be sent to the QA Manager, who will evaluate and summarize the comments. The summary will be discussed with the Lab Manager & Project Manager(s) for any needed follow up actions. Results will be communicated to the staff and included in the Annual Management Report.

Keith Jeter — 6/28/21

Department Manager or Designee — Date

Shawn L Norcross — 06/28/21

Quality Assurance Manager or Designee — Date

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: NCR-21-05

2. Responsible Manager: Abbygail Ochs

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Environmental Lab	4. Client/Project Affected: CONFIDENTIAL
5. Requirement Reference:	6. Affected Data: L#92730
7. NCR Description: An incorrect volume was logged for L92730-9 resulting in revised results.	
8. Client Notification: ☐ YES ☒ NO	9. Associated CC #: N/A
10. Prepared By: Abbygail Ochs	11. Date: 08/10/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See Attached Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 09/10/21	
14. Prepared By: Sharon Northcutt	15. Date: 08/15/21
16. Approved By: Keith Jete	17: Date: 8/20/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☒ Accepted ☐ Rejected ☐ Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date: 08/20/21

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☒ YES ☐ NO Description: Revised report sent to client.	22. Date: 9/1/21
23. Prepared By: Abbygail	24. Date: 9/1/21

Supplemental Sheet

NCR No: 21-05

Description of Nonconformance:

The volume for L97230-9 was logged erroneously which lead to incorrect results being reported for Gamma, Gross Alpha & Sr-90.

Root Cause:

The sample was received, logged and reviewed on 07/16/21. Each step of the process for this sample was completed by different staff than normal daily operation in order to deliver the samples for counting over the weekend. Out of the 35 samples included in this login, one has an incorrect volume (logged as 7905 CUM instead of 79.5 CUM). The typographical error was not caught in review or by the client after receiving the sample acknowledgement or the original report issued on 08/04/21. The Project Manager discovered the error when logging the monthly composite sample on 08/16/21. After the volume was corrected, the results were recalculated and a revised report sent to the client.

Corrective Action to Prevent Recurrence:

Project Managers have a tool to Excel that can assist with login review including dates, times, volumes. This tool wasn't used in this instance, as different staff were involved with login and review. Corrective action was to make both the sample login and the sample reviewer aware of the error. To prevent occurrence, the project managers will be more diligent in using all of the review tools available.

Keith Sete — 8/20/21

Department Manager or Designee — Date

Shawn L Northcutt — 08/20/21

Quality Assurance Manager or Designee — Date

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: NCR 21-06

2. Responsible Manager: Abbygail Ochs

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Environmental Lab	4. Client/Project Affected: CONFIDENTIAL
5. Requirement Reference: TBE-4003	6. Affected Data: L#93084
7. NCR Description: Human error resulted in incorrect analysis logged on the part of the sample custodian and project manager.	
8. Client Notification: [X] YES [ ] NO	9. Associated CC #: CC 21-06
10. Prepared By: Abbygail Ochs	11. Date: 09/08/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See attached supplemental sheet.	
13. Planned Completion Date(s) for Actions(s): 10/08/21	
14. Prepared By: Sharon L Northcutt	15. Date: 09/30/21
16. Approved By: Keith Jett	17: Date: 9/30/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) [X] Accepted [ ] Rejected [ ] Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date: 09/30/21

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: [x] YES [ ] NO Description: Revised report	22. Date: 09/14/21
23. Prepared By: Kimberly Thurman	24. Date: 09/14/21

Supplemental Sheet

NCR No: 21-06

Description of Nonconformance:

Incorrect analyses were reported to the client - gamma instead of gross alpha. The error was discovered after the client received the report of analysis and noticed the missing analysis.

Root Cause:

Human error and not following procedure caused the nonconformance. The sample custodian did not enter the analysis requested on the chain of custody (monthly list) because he copied the previous sample analyses (quarterly list). . The chain of custody requested H-3, gross alpha & HTD's but was logged for several additional analyses, not including gross alpha.

After the project manager reviewed the login, she only partially corrected the error, but did not remove gamma and add gross alpha. The project manager failed to follow TBE-4003 which requires a secondary peer review when analyses are changed from the original login.

To further add to the issue, the client did not alert the project manager until after the report of analysis was received on 09/02/21 regarding incorrect analyses. The analysis was immediately added to the sample and a revised report was sent to the client on 09/16/21. (The original due date was 09/15/21).

Corrective Action to Prevent Recurrence:

The sample custodian did not notice the difference between the QCOMP (L92666) and the MCOMP sample ID's and copied from the previous sample. The QCOMP and MCOMP samples were the first that TBE has received from the client. He has been made aware now of the differences in ID's and requested analyses.

The project manager was reminded that procedure must be followed when reviewing sample logins and especially having a secondary review done if analyses are changed from the original login.

Keith Jete — 9/30/21

Department Manager or Designee — Date

Quality Assurance Manager or Designee — 09/30/21 — Date

TELEDYNE BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: NCR 21-07

2. Responsible Manager: Karli Arterburn

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Environmental Lab	4. Client/Project Affected: CONFIDENTIAL
5. Requirement Reference: TBE-4003	6. Affected Data: L#93017
7. NCR Description: Samples incorrectly labelled led to incorrect analytical result	
8. Client Notification: [ ] YES [X] NO (Client notified TBE)	9. Associated CC #: CC 21-07
10. Prepared By: Karli Arterburn	11. Date: 09/15/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See Attached Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 10/15/21	
14. Prepared By: Shawn L Northcutt	15. Date: 09/30/21
16. Approved By: Keith Jett	17: Date: 10/15/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) [✓] Accepted [ ] Rejected [ ] Follow-up Needed	
19. Prepared By: Shawn L Northcutt	20. Date: 10/15/21

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: [x] YES [ ] NO Description: Revised report	22. Date:
23. Prepared By: Kimberly Thurman	24. Date: 10/19/21

Supplemental Sheet

NCR No: 21-07

Description of Nonconformance:

Incorrect analytical results for Sr-89 were reported. The NCR was initiated after TBE received a client complaint regarding unexpected sample results.

Root Cause:

After reviewing the associated data and recounting the sample, the initial result appeared to be correct. The project manager then verified that the sample containers were labeled correctly, which they were not. The actual samples were the same between the two bottles, except that SPL3-21 was distilled and not acidified, whereas SPL3-21R was not distilled and acidified. The containers were relabeled, prepped and analyzed promptly. The revised results were more in line with client expectations.

Corrective Action to Prevent Recurrence:

This was the first NCR due to sample label switching in over a year. As a secondary review, the lab technicians will verify that the sample bottle label from which they are taking an aliquot actually matches the sample ID information on the container and on their paperwork.

Keith Jete — 10/15/21

Department Manager or Designee — Date

Quality Assurance Manager or Designee — 10/15/21

Date

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: 21-08

2. Responsible Manager: Karli Arterburn

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Sample Receipt/Control	4. Client/Project Affected: CONFIDENTIAL
5. Requirement Reference: TBE-4003	6. Affected Data: L#: L93616
7. NCR Description: Second Sample container could not be found for reanalysis.	
8. Client Notification: [×] YES [ ] NO	9. Associated CC #:
10. Prepared By: Karli Arterburn	11. Date:11/09/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See attached Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 12/09/21	
14. Prepared By: Sharon Northcutt	15. Date: 11/15/21
16. Approved By: Keith Jete	17: Date: 11/29/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) [✓] Accepted [ ] Rejected [ ] Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date: 11/29/21

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: [ ] YES [✓] NO Description:	22. Date:
23. Prepared By: Karli Arterburn	24. Date: 12/3/21

Supplemental Sheet

NCR No: 21-08

Description of Nonconformance:

The laboratory was unable to perform confirmatory analyses on milk due to not being able to find the second container in the storage cooler.

Root Cause:

All analyses were initially taken from the first container. When all of the sample from the first container was consumed, the second container (storage cooler DCOOLER6) could not be found. The search was done by the analyst, sample custodian, and two project managers. All sample coolers as well as the warehouse shelves were searched, but the container was not found.

Sample containers were received on 10/04/21 (Monday) and placed into DCOOLER6. This cooler had been emptied of older samples and disposed on 10/01/21 (Friday) to make room for new samples. Only two other sets of samples were in this cooler the day they were placed there. By the time the sample could not be located, this cooler was full and no samples from this cooler have been disposed to date.

There seems to be insufficient evidence for accidental disposal or possible sample switching, Unfortunately, no absolute root cause to be found for this nonconformance.

Corrective Action to Prevent Recurrence:

Because we could not determine a root cause for this incident, effective corrective action cannot be planned. We feel that this is an isolated incident.

Keith Jeter — 11/29/21

Department Manager or Designee — Date

Shawn L Northcutt — 11/29/21

Quality Assurance Manager or Designee — Date

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: 21-09

2. Responsible Manager: Karli Arterburn

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Sample Receipt/Control	4. Client/Project Affected: CONFIDENTIAL
5. Requirement Reference: TBE-4003	6. Affected Data: L#: L93679
7. NCR Description: Sample container needed for composite not found.	
8. Client Notification: [×] YES [ ] NO	9. Associated CC #:
10. Prepared By: Karli Arterburn	11. Date:11/11/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See attached Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 12/11/21	
14. Prepared By: Sharon Northcutt	15. Date: 11/15/21
16. Approved By: Keith Peter	17: Date: 11/29/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) [✓] Accepted [ ] Rejected [ ] Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date: 11/29/21

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: [ ] YES [✓] NO Description:	22. Date:
23. Prepared By: Karli Arterburn	24. Date: 12/3/21

Supplemental Sheet

NCR No: 21-09

Description of Nonconformance:

The laboratory was unable to include all samples for a quarterly composite for Milk Sr-89/90 because the August sample could not be located.

Root Cause:

According to LIMS, the August sample (L92976-3) has not been consumed., but the sample container could not be located after a thorough search. This same incident has occurred with this client in 2018, 2019 and 2020. We have made several changes over the past 3 years to avoid further issues:

a. 2018 - LIMS programming - The lab tech's outstanding nuclide list has an additional column indicating that the sample is to be part of a composite so that the sample will not be consumed.
b. 2019 - The project information was not updated correctly and the composite notification was not on the technician's outstanding nuclide list. Also, the Sample Technician also began writing "Hold 4 Composite" on several areas of the sample container as a visual reminder for the lab techs.
c. 2020 - LIMS programming was enhanced by the addition of a "pop-up" window alert in the aliquot screen in which the lab tech must verify that the sample has not been consumed after taking their aliquot for analysis.

Also, several requests have been made to the client to increase the amount of sample being sent to the lab. We have to analyze for Gamma and low-level iodine for the initial analysis from one cubitainer. An additional aliquot from this container is taken for the strontium composite. At this time, we are still only receiving the single cubitainer sample volume of about 4 liters.

Corrective Action to Prevent Recurrence:

The Project Manager is now taking an aliquot of sample prior to the lab doing any processing. The aliquot is taken from the original sample, put in a different container and then placed in a box in a different cooler than the original sample with DO NOT CONSUME instructions on the container.

Keith Jeter — 11/29/21

Department Manager or Designee — Date

Shawn L Rothrock — 11/29/21

Quality Assurance Manager or Designee — Date

TELEDYNE
BROWN ENGINEERING, INC.
A Teledyne Technologies Company

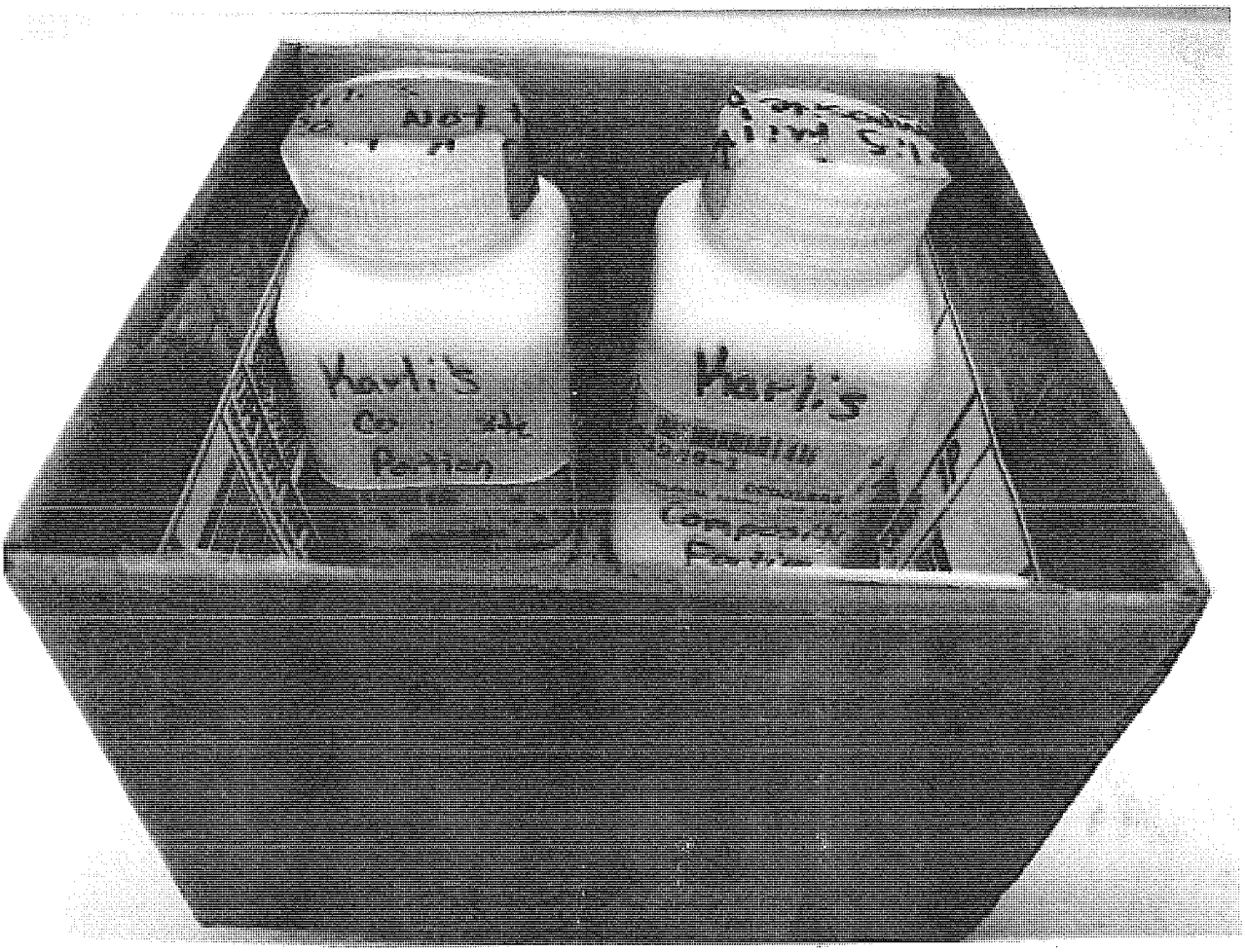
Case Narrative

11/11/2021 14:25

L93679

CONFIDENTIAL

Sample L92976-3 (August CP2 sample) was not able to be found after an extensive search when the quarterly composite was being created. NCR 21-09 has been initiated. The composite is composed of July and September samples only.



TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: 21-10

2. Responsible Manager: Sharon Northcutt

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Environmental Lab	4. Client/Project Affected: TBE ERA RAD
5. Requirement Reference: TBE-4006	6. Affected Data: L93788
7. NCR Description: Unacceptable WO Gross Beta result (high)	
8. Client Notification: ☐ YES ☒ NO	9. Associated CC #: NA
10. Prepared By: Sharon Northcutt	11. Date: 11/29/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See Attached Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 12/29/21	
14. Prepared By: Sharon Northcutt	15. Date: 11/29/21
16. Approved By: Keith Jete	17: Date: 11/30/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☑ Accepted ☐ Rejected ☐ Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date:

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☐ YES ☑ NO Description: (QA Report)	22. Date:
23. Prepared By: Sharon L Northcutt	24. Date: 11/30/21

Supplemental Sheet

NCR No: 21-10

Description of Nonconformance:

TBE's ERA RAD (drinking water) Gross Beta cross check reported result was "not acceptable". TBE's result was 63.0 pCi/L and the known was 55.7 pCi/L with a range of 38.1 - 62.6 pCi/L (high at 113 % of the known).

Root Cause:

ERA's narrow upper acceptance range, which goes from 68.4 - 112%. TBE's QA acceptance limits are 70-130%. *NOTE: The lower ERA range is below the TBE limit.* (For comparison, the reported Gross Alpha result was 114% of the known and deemed acceptable). The actual result obtained with a 2-sigma error was 63.0 ± 6.8 pCi/L (>0.4 pCi/L of the upper range), placing it well within the acceptance range. All other QC with the sample workgroup was satisfactory and no client data was effected.

Corrective Action to Prevent Recurrence:

We do not believe that any corrective action is merited in this case. Although ERA deemed this result as "not acceptable", it falls well within TBE's passing QC standard. TBE has, however, ordered a "Quick Response" cross check to be received and reported within the next month.

Keith Peter — 11/30/21

Department Manager or Designee — Date

Quality Assurance Manager or Designee — 11/30/21

Date

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: 21-11

2. Responsible Manager: Sharon Northcutt

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Environmental Lab	4. Client/Project Affected: TBE ERA RAD
5. Requirement Reference: TBE-4006	6. Affected Data: L93788
7. NCR Description: Unacceptable WO tritium result (low)	
8. Client Notification: ☐ YES ☒ NO	9. Associated CC #: NA
10. Prepared By: Sharon Northcutt	11. Date: 11/29/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See Attached Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 12/29/21	
14. Prepared By: Sharon Northcutt	15. Date: 11/29/21
16. Approved By: Keith Jete	17: Date: 11/30/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☑ Accepted ☐ Rejected ☐ Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date:

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☐ YES ☑ NO Description: (QA Report)	22. Date:
23. Prepared By: Sharon L Northcutt	24. Date: 11/30/21

Supplemental Sheet

NCR No: 21-11

Description of Nonconformance:

TBE's ERA RAD (drinking water) tritium (H-3) cross check reported result was "not acceptable". TBE's result was 13,800 pCi/L and the known was 17,200 pCi/L with a range of 15,000 - 18,900 pCi/L (low at 80.2% of the known).

Root Cause:

ERA's acceptance reported/known ratio for tritium was 87 - 110%. TBE's QA acceptance limits are 70-130%. The actual result obtained with a 2-sigma error was 13,800 ± 1,430 pCi/L, placing it within the acceptance range. The workgroup LCS was a little low at 83.8% and all other QC was satisfactory and no client data was effected.

Corrective Action to Prevent Recurrence:

We do not believe that any corrective action is merited in this case. This is the first "not acceptable" for tritium on record. Typical reported/known cross-check ratios for tritium have been 91 - 116%. Although ERA deemed this result as "not acceptable", it falls well within TBE's passing QC standard. TBE has, however, ordered a "Quick Response" cross check to be received and reported within the next month.

Keith Dater — 11/30/21

Department Manager or Designee — Date

Sharon L Norman — 11/30/21

Quality Assurance Manager or Designee — Date

TELEDYNE BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: NCR-21-12

2. Responsible Manager: Kim Thurman

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Inplant Lab	4. Client/Project Affected: CONFIDENTIAL
5. Requirement Reference: TBE-4006	6. Affected Data: L#92650-6
7. NCR Description: Crosscheck results for Ni-63 (LR) did not agree with client results.	
8. Client Notification: ☐ YES ☒ NO (Client notified us)	9. Associated CC #: CC-21-12
10. Prepared By: Kim Thurman	11. Date: 12/28/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: Sample reanalysis result 4.14E-03 uCi/ml, passed the evaluation criteria. (see attached supplemental sheet)	
13. Planned Completion Date(s) for Actions(s): 01/28/22	
14. Prepared By: Sharon L Northcutt / Kim Thurman	15. Date: 12/28/21
16. Approved By: Keith Jett	17: Date: 12/28/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☑ Accepted ☐ Rejected ☐ Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date: 01/27/22

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☑ YES ☐ NO Description:	22. Date: 01/27/22
23. Prepared By: Kimberly O'Dell	24. Date: 01/27/22

Supplemental Sheet

NCR No: 21-12

Description of Nonconformance:

The reported client liquid cross-check Ni-63 result was not in agreement with the known value. TBE reported 1.13E^{-3} +/- 3.66E^{-5} µCi/ml and the known result was 4.25 E^{-3} µCi/ml (27% ratio).

Root Cause:

The client notified TBE on 12/16/21 that the cross-check result from May was not in agreement. The sample was logged for a recount (C1) and reanalysis (R1). The result of the recount (original sample) was 3.43E^{-3} +/- 6.37E^{-5} µCi/ml. The reanalysis result was 4.14E^{-3} +/- 4.29E^{-5} µCi/ml. The R1 was also the workgroup duplicate (result of 4.20E^{-3} +/- 4.59E^{-5} µCi/ml). The C1 and R1 results were within 80.7% and 97.4% respectively (98.8% for the WG DUP).

After an extensive review of the data from the original, recount and reanalysis sample and associated workgroups and workgroup samples, no determination can be made as to why the original count was significantly lower than the recount and reanalysis. No other samples counted during this timeframe had the same counts as the known result, so it's unlikely that the sample was switched in the counting process. It is possible that there could have been some human error in data transcription but we could find no evidence to support this. All QC data was acceptable and no other client samples were affected.

Corrective Action to Prevent Recurrence:

The investigation took place almost 6 months after the sample was counted and reported, making it difficult to make a determination for the root cause. Unfortunately, no effective corrective action can be done at this time.

Keith Jete — 1/27/22

Department Manager or Designee — Date

Shawn L Westcott — 01/27/22

Quality Assurance Manager or Designee — Date

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: NCR-21-13

2. Responsible Manager: Sharon Northcutt

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Inplant Lab	4. Client/Project Affected: TBE-MAPEP
5. Requirement Reference: TBE-4006	6. Affected Data: L#93268
7. NCR Description: Ni-63 (S) did not agree with known result	
8. Client Notification: ☐ YES ☒ NO	9. Associated CC #:
10. Prepared By: Sharon Northcutt	11. Date: 12/16/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 01/31/22	
14. Prepared By: Sharon L Northcutt	15. Date: 01/14/22
16. Approved By: Keith Jete	17: Date: 1/14/22

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☑ Accepted ☐ Rejected ☑ Follow-up Needed — Results of client ms for 2021	
19. Prepared By: Sharon L Northcutt	20. Date: 01/27/22

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☐ YES ☑ NO Description: (Included in QA Report)	22. Date:
23. Prepared By: Sharon L Northcutt	24. Date: 01/27/22

Supplemental Sheet

NCR No: 21-13

Description of Nonconformance:

TBE's MAPEP soil Ni-63 result of 546 Bq/kg was evaluated as unacceptable. The known result was 1280 Bq/kg with a range of 896 - 1664 Bq/kg. TBE's result was 42.7% of the known.

Investigation Background:

TBE had no issues with successfully passing Ni-63 soils until the 2nd half of 2019. It appears that at that point there was added interference(s) not seen in our typical environmental samples. After receiving an "unacceptable" result for the 2nd half of 2020 (45% of the known), the procedure was revised in February 2021 (increased acid digestion time from 1 to 2 hours and added stirring). The result for the 1st half of 2021 was also 45% of the known and further research was done to address possible interferences. Further modifications were tested on the February sample with positive results of 86.2% and 113% of the known; so we felt that this had effectively dealt with the issue. The procedure was modified in August, prior to the next MAPEP samples being analyzed.

Root Cause:

After receiving the "unacceptable" evaluation for the August 2021 study, the original sample was recounted with a comparable result. The sample was then reanalyzed to verify that the modified procedure was being followed exactly as written. The result was still unacceptable and the yield had increased from ~69% to 107%.

It is believed that added interferences are effecting the recovery of nickel during the prep.

Corrective Action to Prevent Recurrence:

Until a more definitive solution for MAPEP cross-checks can be put into place, a matrix spike will be added all client environmental Ni-63 soil/sediment samples.

Keith Jeter 1/14/22

Department Manager or Designee Date

Quality Assurance Manager or Designee 01/14/22

Date

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: NCR-21-14

2. Responsible Manager: Sharon Northcutt

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Environmental Prep Lab	4. Client/Project Affected: TBE-ERA
5. Requirement Reference: TBE-4006	6. Affected Data: L#93499
7. NCR Description: Gross Beta (WO) did not agree with known result	
8. Client Notification: ☐ YES ☒ NO	9. Associated CC #:
10. Prepared By: Sharon Northcutt	11. Date: 12/27/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): N/A	
14. Prepared By: Sharon L Northcutt	15. Date: 12/27/21
16. Approved By: Keith Jett	17: Date: 12/28/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☑ Accepted ☐ Rejected ☐ Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date: 12/27/21

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☐ YES ☑ NO Description: (will be included in QA Report)	22. Date:
23. Prepared By: Sharon L Northcutt	24. Date: 12/27/21

Supplemental Sheet

NCR No: 21-14

Description of Nonconformance:

TBE's ERA RAD (drinking water) Gross Beta QR cross check reported result was "not acceptable". TBE's result was 47.6 pCi/L and the known was 39.8 pCi/L with a range of 26.4 - 47.3 pCi/L (high at 120 % of the known).

Root Cause:

This Quick Response was done due to the ERA RAD 127 unacceptable result. ERA's narrow upper acceptance range goes from 66.3 - 119%. TBE's QA acceptance limits are 70-130%. *NOTE: The lower ERA range is below the TBE limit.* The actual result obtained with a 2-sigma error was 47.6 ± 6.1 pCi/L (>0.3 pCi/L of the upper range), placing it well within the acceptance range. All other QC with the sample workgroup was satisfactory and no client data was effected.

After the report was generated, the sample was logged for recount on a different detector. The C1 result was 40.3 ± 6.27 pCi/L (within the acceptable range @ 101%).

Corrective Action to Prevent Recurrence:

No beneficial corrective action can be done for this "unacceptable" result. With the 2-sigma error, all results (both the original RAD 127 and the QR sample) fell within the acceptable range. The recount result of the QR sample was at 101% of the known.

Keith Jete — 12/28/21

Department Manager or Designee — Date

Sharon L Abbott — 12/28/21

Quality Assurance Manager or Designee — Date

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ATTACHMENT D

Audit Reports

E.1

INTERNAL AUDITS

TELEDYNE BROWN ENGINEERING
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INTERNAL AUDIT REPORT

Audit Plan

Auditor: Charles Hurst, Lead Auditor	Audit Date: 6-9 December 2021	Audit No.: 2021-038
Auditee(s): Sharon Northcutt, TBE Knox Lab	Methods: Review of objective evidence, documentation, and through interview of personnel	
Scope: TBE Knoxville Lab Operations Criteria: TBE Knoxville Quality Manual	Tools: AS9100D Aerospace Standard (or other standard as noted in Scope & Criteria), K-QAM-1 Rev 34, Process Specifications, Internal Audit Checklists, associated forms, and other tools as needed	

Date	Time	Area / Department / Process / Function	Key Contact
6 Dec-9 Dec	0830-1630	TBE Knoxville Lab operations	Sharon Northcutt

Process Effectiveness Assessment Report (PEAR)

Process Name: TBE Knoxville Quality System and Operations

Process details, including associated process interfaces:

Applicable AS9100 clause(s): N/A. This annual internal audit was conducted for the purpose of assessing TBE Knoxville Lab's quality system as documented in the Quality Assurance Manual for Teledyne Brown Engineering Environmental Services, Document K-QAM-1, Rev 34, effective April 15, 2021, and associated implementing Procedures. A specific checklist was developed and used for this audit. The completed checklist is attached to this form.

Organization's method for determining process effectiveness:

- Customer satisfaction
- Audit results
- NCRs generated

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INTERNAL AUDIT REPORT

Auditor observations and comments supporting process effectiveness determination:

The quality program of TBE Lab Knoxville was well documented, organized and implemented. All required information was readily available, and all involved in the audit were very helpful and knowledgeable.

Statement of Effectiveness Level:

The process is:

☐ 1. Not implemented; planned results are not achieved.

☐ 2. Implemented; planned results are not achieved, and appropriate actions not taken.

☐ 3. Implemented; planned results are not achieved, but appropriate actions being taken.

☒ 4. Implemented; planned results are achieved.

Auditor Name(s): Charles Hurst	Auditee Representative Acknowledgement Name: Sharon Northcutt

Audit Summary

The audit results documented in the checklist consists of two observations. There were no findings identified during the course of this audit.

Based on the results of this audit, I believe the lab's QA program remains effectively implemented.

Previous Year's Finding

REF	Requirements	Observation, Comments, Objective Evidence	ACC	REJ
	TBE-1010	Not all non-retest customer complaints were being processed through the NCR procedures as required by TBE-1010. – Finding was addressed and closed during the 2020 audit.	X	

Current Year Audit Findings and Opportunities for Improvement (OFI's)

REF	Requirements	Observation, Comments, Objective Evidence	ACC	REJ
K-QAM-1	6.2.5.3g Periodic annual reviews	**Observation (1)**: The 2020 annual review was not completed until July 2021. While the report was well done and extensively detailed, the significant	X	

		lag between the end of the calendar year and generation of the actual report lessons the assessment/evaluation potential of the report. It is recommended the report be completed as close to the end of the calendar year as possible to assure the data and analysis is relevant at the time of review.		
K-QAM-1	8.6.3 Audits are performed to identify trends and offer suggestions for improvement.	**Observation (2)**: When improvements are identified in a surveillance, they are noted there but not collected in manner to readily show how many and what types of improvements were achieved over a given time. Recommend that as improvements are identified, an NCR be opened and identified as an "Improvement Action" to take credit for the improvement and to track overall improvement progress. The NCR log could be retitled, accordingly, as the NCR/Improvement Action log.	X	

Checklist – See Attached Checklist				
REF	Requirements	Observation, Comments, Objective Evidence	ACC	REJ

Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 6.2 Personnel		
6.2.1	The QA Manager maintains the training matrix for the lab and ensures that procedure update or annual quality and/or safety-related training is complete	SAT	Reviewed training matrix. Pulled three records to compare to requirements of the matrix: • Megan Demarse • Kenny Cooper • Kimberly Thurman No anomalies noted. All records were clear, legible, and well maintained.
6.2.2	Job descriptions that include duties and responsibilities for all staff are available for review.	SAT	Job descriptions are specifically maintained, beyond the standard HR position descriptions, to clearly lay out the duties and responsibilities assigned. The following were reviewed: • Megan Demarse (Lab Tech) • Kenny Cooper (Receiving) • Kimberly Thurman (PM)
6.2.4	Analysts must be recertified if: a) not enough QC data has been generated to support annual requirement or b) there are significant changes to a procedure	SAT	Generated QC data is tracked by the QA Manager as the employee and method level to identify progress toward meeting annual requirements and to highlight when recertification might be required.
6.2.5.3	Quality Assurance Manager g. conducting or arranging for periodic internal audits and management reviews, as well as coordinating external audits;	SAT	The 2021 Internal Audit Schedule was reviewed. The following audits were reviewed: • 4015 completed 1/1 • 1013 completed 10/8 • 2012 completed 6/18

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			The Quality Manager is consistently producing both Quarterly and Annual Quality Assurance Management Reviews. The following were reviewed: • Q3 2021 Quarterly Quality Assurance Management Review • 2020 Quality Assurance Management Review **Observation(1)**: The Annual review was not completed until July 2021. Given this review covers CY20, it was seem the usefulness of such a review is somewhat degraded if not completed until 7 months into the new year. While the report contains an excellent rundown of very detailed information, it would be more effective as a management tool if the review was conducted closer to the end of the calendar year in the event actionable decisions needed to be made to address identified process or other shortfalls from the previous year. **Recommendation** is to conduct this annual as soon after the conclusion of the previous year as possible. The QA Manager is of the same mind in this regard and had already noted her intention to improve in this area.
6.2.5.4	Project Managers (PMs) b. entering and maintaining client information for contacts, reporting, billing, and technical specifications into the LIMS h. documenting and investigating client complaints j. maintaining a storage system for lab reports and other documents required to be kept for a specified time period	SAT	Interview confirmed PMs serve as the primary interface with he client. Client complaints come to the lab through the PM. Customer complaint documentation was reviewed for the following: • CC-21-03 • CC-21-11 PM provides document retention for lab reports. The following reports were reviewed as OE: • L93331 • L93380 • L93340 All we found to be complete, fully documented and well organized.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
6.2.5.5	Sample Custodian b. thoroughly reviewing paperwork and containers received with shipped packages and noting inconsistencies or damage and informing the Project Manager Immediately	SAT	Interviewed Sample Custodian and observed him full processing a sample shipment. He was well versed on the requirements of the position and followed procedural requirements as documented in the quality system.
6.2.5.6	Laboratory Technicians d. identifying potential sources of error and correcting problems that could affect data quality	SAT	Observed two separate Lab Techs in preparing samples for TBE-2007 (WG38153) and TBE-2011 (WG38151). Both were well versed on the requirements of each method and followed the written procedures as required.
6.2.5.9	Health & Safety Officer c. performing safety checks and audits	SAT	Reviewed Healthy and Safety inspection reports covering the previous four-month period. Checks appeared to be comprehensive and thorough.
6.2.5.10	Radiation Safety Officer (RSO) b. coordinating scheduled radiological surveys and administer personal dosimetry and sealed radioactive source leak test programs	SAT	The Lab Manager serves in the role of RSO. Regular radiological surveys are being conducted as required. The following were reviewed: • Weekly report ending 11/29 • Monthly report for November 2021 • Quarterly report for Q4 dated 10/31/21

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 7.0 Process Requirements **7.1 Review of Requests, Tenders and Contracts**		
7.1.1	Review of Requests, Tenders and Contracts Initial requests for quote or for additional analytical work are assigned a project manager who verifies that the scope of work is clearly defined and reviews the request against current laboratory procedures and capabilities.	SAT	Through interview it was confirmed the PMs are the conduit for responding to requests for quote, tenders and contracts. Q677 was reviewed which showed evidence of Dunn and Bradstreet review, forbidden course review and final response to the prospective clients. Files are maintained locally in could condition and readily available.
7.1.2	The response to request will include lab procedure and/or analytical method with appropriate accreditation information (where needed).	SAT	Required elements of the response with found in the files examined.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 7.0 Process Requirements **7.2 Selection, Verification and Validation of Methods**		
7.2.1.3	The laboratory verifies proper performance of any new methods prior to processing samples to ensure that required performance criteria can be achieved. Verification records are maintained by the QA Manager. Method revisions to national standards require verification to the extent necessary.	N/A	No new methods have been implemented in many years so there was nothing recent to review. The lab does have a procedure, TBE-4007 Rev 6, covering this process, however. TBE-4007 Rev 6 was last revised in 2017 and should be reviewed in accordance with every three-year requirement to assurance the document remains current.
7.2.2.1	Controls have been established to assure computer software validity and track verification of validity. All computer programs used in laboratory operations have documented verification and validation prior to first use and after program modification.	N/A	V & V was done years ago during the initial deployment of LIMS.
7.2.2.3	Method validation includes demonstration of detection capability, precision, bias, and measurement uncertainty for each matrix. It also may include comparing results achieved against other validated methods.	N/A	No V &V performed in recent years.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 7.0 Process Requirements **7.4 Handling of Test Items**		
7.4.2	Sample Acceptance Upon receipt, a log is kept documenting each shipping container received	SAT	As observed in witnessing Sample Receiving process, the log is maintained electronically in LIMS.
7.4.3	Identification Once approved, each sample is given a LIMS-generated unique laboratory ID (L#). Information associated with each sample is carried through the entire analytical process included: sample ID, collection date and/or time, receipt date/time, requested analysis, results of sample inspection. All sample containers are given a durable label using indelible ink that indicates the project ID, L#, the number of containers and the storage locations(s).	SAT	Identification created in LIMS during the receiving process was noted as being carried through all processes at TBE Knox, including work group creation to final ROA.
7.4.4	Sample Storage Samples are stored away from standards, reagents, and food for human consumption.	SAT	Dedicated storage space was inspected. Storage appeared to be safe, well organized and conveniently located. Storage includes dry and cold storage. All is well labeled and properly segregated as required.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 7.0 Process Requirements **7.5 Technical Records**		
7.5.1	The laboratory maintains a documentation system for quality records of the analytical process.	SAT	The entire process is well documented, both in hard copy and electronically through LIMS. Receipt records, processing records, data output, QA documentation of machine performance and final output records are all well maintained and efficiently organized.
7.5.2	Amendments to original records are signified by a single stroke through the incorrect information with a brief explanation (unless obvious). The person making the change initials and dates the change.	SAT	Very few amendments to records were noted during this audit. The few records that did show evidence of physical amendment, were done so according to local instruction for single line through, initials and dates.
7.5.3	Physical records are retained onsite for 2-3 years and then logged and shipped to the TBE Huntsville storage facility. (TBE-1003, TBE-1008, TBE6004)	SAT	Records retained locally as required. Beyond 3 years, records are inducted into long term storage through the TBE Huntsville records storage program.
	Section 7.0 Process Requirements **7.6 Evaluation of Measurement Uncertainty**		
7.6.3	TBE includes a 1- or 2-sigma combined standard uncertainty (CSU) [aka Total Propagated Uncertainty (TPU)] value with all analytical results, depending on client request.	SAT	Observed on reports are required by the respective client.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 7.0 Process Requirements **7.7 Ensuring the Validity of Results**		
7.7.3	Analytical Batches The Lab's analytical system is shown to be in control using batch and sample-specific QC. All samples must be placed in a workgroup batch and processed with appropriate QC. Batch size is dependent upon the method, but generally consists of one (1) to twenty (20) samples plus QC. All batch samples are processed together in the same manner (preparation, analysis, data reduction and reporting). Batch samples are not required to be analyzed concurrently on the same detection system. The lab does not systematically or preferentially use specific detectors, equipment, or glassware for analyzing QC samples. Two types of batches in the radiochemical lab are: a. Preparation Batch - samples require physical or chemical processing that affect the outcome of the analysis. Samples are prepared with the same process, personnel and lot(s) of reagents, with a maximum time between the start of processing of the first and last sample to be 24 hours. b. Radiation Measurements Batch (RMB) - samples require no physical or chemical processing that could affect the outcome of the test. Examples are: non-destructive gamma spectrometry, air filters	SAT	Reviewed the following workgroups: • WG38137 (TBE-2011) • WG38151 (TBE-2011) • WG38153 (TBE-2007) All batches were processed IAW written procedures as noted. Lab Technicians appear knowledgeable and well trained for their assigned roles.

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	for alpha/beta counting, or swipes on gas proportional detectors. Samples may be processed within fourteen (14) calendar days (start of the first sample to the last sample).		
7.7.4	QC Samples Process control checks demonstrate consistent lab quality. These checks that include QC and proficiency samples, constitute 10% of the annual processing workload for lab analytes and methods.	SAT	Extensive control checks are tracked and available throughout the process. The following checks were specifically reviewed: • Gamma • Alpha • X and Y
7.7.5	Interlaboratory and Client Proficiency Testing To further ensure the validity of results, TBE regularly participates in various proficiency testing (PT) studies during the year. These external performance checks (aka cross-checks) are samples with an unknown amount of analyte added. Internal PT samples are obtained from and reported to accredited proficiency testing providers. Some clients also routinely send their own cross-check samples. All PT samples are received, analyzed, and processed in the same manner as routine samples. Internal PT results are reported directly to the PT provider and the results sent back to the lab and its accrediting body (where applicable). Clients report their cross-checks to the PT provider directly and final evaluations are not always shared with the lab. Although all radionuclide or matrix combinations are not available for proficiency testing. TBE makes every effort to analyze PT samples that are representative of routine client samples. Cross-check results that are not within the provider's acceptance criteria are documented with a root cause investigation, corrective action (where merited) and a non-conformance report (NCR). (TBE-4006 "Interlaboratory Performance Evaluation Programs")	SAT	The Cross Check program is extensively detailed in Appendix A.1 of the Q3 Quarterly Assurance Report. Conforming and non-conforming status is presented in detail with links to NCRs where applicable.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 7.0 Process Requirements **7.8 Reporting of Results**		
7.8.2	Required Items Sample results are compiled into a report and contain the following items: a. title (Report of Analysis or ROA) b. name and address of the laboratory (where analyses are performed) c. unique identification that correlates individual pages to the entirety of the report d. contact name/address of the client e. sample description information (ID, collection date/time) and lab ID information f. sample receipt date, condition and any sample acceptance criteria variance g. TBE Procedure (SOP) ID h. test result (activity) directly as obtained with appropriate number of significant figures, measurement uncertainty estimation, detection limit (MDC), measurement units, reference date, count date/time, and flagged values (results outside of technical specifications) i. notation for method changes (if applicable) j. name, title and signature of the person(s) authorizing the report k. statement that results relate only to the items tested l. statement that the report shall not be reproduced, except in full without approval of the laboratory m. clear identification of any subcontracted analyses and results	SAT	The following were reviewed as objective evidence for this requirement: • L93340 o Palisades Nuclear Plant o TBE-2008 o TBE-2010 • L93331 o Mayo Clinic o TBE-2007 • L93380 o PSEG Nuclear LLC o TBE-2007 o TBE-2011 All elements of this requirement were noted in each of the three above ROAs).

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 7.0 Process Requirements **7.9 Client Complaints**		
7.9.2	Complaint Resolution Process a. Staff receives and documents complaint on TBE KQA-22 Complaint Detail Form. b. Complaint is investigated promptly and if warranted a Non-Conformance Report that includes a root cause evaluation and corrective action is initiated. (Section 7.10) c. A decision is made regarding the complaint resolution such that all parties involved are in agreement and are satisfied with the outcome (client notification and approval). d. Suitable response is taken by the lab to prevent recurrence (where applicable).	SAT	Customer complaints are documented via KQA-22 as required here. A Customer Complaint Log is maintained by PM and QA Manager which includes relevant information and current status. Extensive details are included in the Quarterly Quality Assurance Reviews.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 7.0 Process Requirements **7.10 Nonconforming Work, Corrective and Preventative Actions**		
7.10.3	When a nonconformity is discovered, the following steps are taken: a. Nonconformance is initiated by the responsible staff and documented on form KQA-9 Nonconformance Report (NCR) Form. The nonconformance is given a unique identifier, added to the NCR log, and a brief summary including requested completion date recorded on the form. b. The NCR is relinquished to the appropriate manager for evaluation of significance, including work stoppage where appropriate. The manager conducts a root cause investigation to determine the source of the departure from the standard. The manager will also update the parties involved as to the progress towards resolution. c. After the root cause analysis is completed, a corrective action plan is developed with the Operations Manager (or other involved staff). The Operations Manager or designee determines the acceptability of nonconforming work and where necessary, the client may be notified, and the work recalled. d. The Operations Manager or designee authorizes the resumption of work (where necessary). The QA Manager tracks the progress of the NCR through closure and evaluates the effectiveness. (Section 8.7). The target date from NCR initiation to corrective action plan is 30 days. Note: More complex issues may require more time.	SAT	Nonconformities are handled in accordance with TBE procedures. The following NCRs were reviewed: • 21-03 • 21-04 • 21-07 • 21-11 All reviewed NCRs included evidence of processing as required.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 7.0 Process Requirements **7.11 Control of Data and Information Management**		
7.11.2	Any changes to the LIMS software configuration or modifications to commercial software are authorized, documented and validated before use.	SAT	The only LIMS software configuration that occurs locally is through revision of the user interface of existing forms, creation of addition data extraction reports, and other minor user interface modifications that do not adjust the underlying code of LIMS or alter the calculation methodology employed by LIMS. Extensive documentation is maintained regarding requests to modify forms and any actions taken that modify LIMS forms as a result.
7.11.3	TBE-ES LIMS is only accessible by trained staff with assigned security levels based upon job function. Changes to LIMS programming are documented and can only be accessed by the LIMS Manager.	SAT	Access to LIMS is controlled by a single local IT member (with backups provided through IT Shared Services in Huntsville). Local IT grants remote access that allows employees to get to the LIMS application then he also assigned specific LIMS access that correspond to job responsibilities as assigned.
7.11.6	Only the most current document revisions are available on the shared network drive. This includes TBE procedures as well as the Safety and QA Manuals. All staff have access at all times to these documents.	SAT	Current revisions of manuals and procedures are maintained on a network drive that is controlled by local IT. It provides lab-wide access to the most recent procedures and other documents. Superseded documents are maintained independently by the QA Manager for historical purposes, both electronically and in hardcopy.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 8.0 Quality Management System (Option A) **8.2 Management System Documentation**		
8.2.3	The QMS allows only qualified personnel to review/update/perform specific procedures. It encourages integrity, impartiality and consistency in daily lab operations at all levels.	SAT	Reviews/Updates to procedures are fully controlled by the QA Manager. Assignment to perform specific procedures is monitored by the QA Manager through the Training matrix, job description and documentation of completed training.
	Section 8.0 Quality Management System (Option A) **8.3 Control of Management System Documents**		
8.3.1	TBE-ES maintains control of documents that relate to the QMS, including training, procedures, audits, corrective actions, management reviews, forms, and the QA Manual. (TBE-1008 "Documents and Document Control")	SAT	Current revisions of manuals and procedures are maintained on a network drive that is controlled by local IT. It provides lab-wide access to the most recent procedures and other documents. Superseded documents are maintained independently by the QA Manager for historical purposes, both electronically and in hardcopy.
8.3.2	Controlled documents are periodically reviewed and updated as necessary. Only authorized personnel can approve and issue controlled documents. All staff whose work is affected by changes are notified and trained to the revision.	SAT	Reviewed 24 procedures. 3 of those 24 had surpassed the 3-year review requirement (when considered month to month); 3006, 1012, 4007. 3006 and 1012 we due in 2021 and are being tracked for completion by the end of CY21 to meet the intent of the requirement. 4007 was due for review in 2020. QA Manager has this for review at this time.
8.3.4	Original signed QMS documents are stored in the QA Manager's office and/or stored electronically on TBE's shared computer network drive. Only current pdf copies of QMS documents are available for access and distribution and include the disclaimer "DOWNLOADED or PRINTED copies are UNCONTROLLED".	SAT	QA Manager maintains in fireproof cabinets in the QA Manager's office. Only documents were verified to only by the most current revisions.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 8.0 Quality Management System (Option A) **8.4 Control of Records**		
8.4.1	Quality and technical records are maintained in accordance with TBE Procedures TBE-1003 "Control and Retention of Quality Assurance Records" and TBE-1008 "Documents and Document Control".	SAT	As noted throughout this audit, all documents reviewed were found to be maintained in accordance with this requirement.
	Section 8.0 Quality Management System (Option A) **8.6 Improvement**		
8.6.2	Actions are taken in response to trends signifying deterioration in lab performance indicators such as quality data, repeated audit findings or turnaround times.	SAT	Regular audits and surveillances are assessed during quarterly reviews for trends and effectiveness of previous corrective actions.
8.6.3	Audits are performed to identify trends and offer suggestions for improvement.	SAT	Extensive audits are scheduled and completed. Many showed evidence of improvements identified during the audit or surveillance. **Observation (2)**: When improvements are identified in a surveillance, those are noted there but not collected in manner to readily show how many and what types of improvements were achieved over a given time. Would recommend that as improvements are identified, an NCR be opened with it identified as an "Improvement Action" to take credit for the improvement. The NCR log could be retitled, accordingly, as the NCR/Improvement Action log.

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8.6.3.4	Lab quality performance is reviewed and summarized in a quarterly QA Report. Audits and nonconformance/corrective actions are also included in the report. This report is distributed to TBE management and is also available for clients. A summary of this report is included with the Annual Management Report.	SAT	Reviewed the Q3 2021 QA report. This is an outstanding document that provides excellent levels of detail to management as a tool for monitoring/improving the performance of the program.

Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 8.0 Quality Management System (Option A) **8.7 Corrective Actions**		
8.7.1	Corrective action is taken as the result of a departure from specifications imposed by client contract, regulatory requirement or TBE stated policy or procedure. They are measures taken to discover the source of a deviation and to avoid similar issues going forward. Corrective action is taken promptly and to a degree appropriate to the magnitude and risk of the issue. Conditions adverse to quality are documented and tracked with proposed and actual completion dates. (TBE-1012 "Corrective and Preventative Action")	SAT	Nonconformities are handled in accordance with TBE procedures. The following NCRs were reviewed: • 21-03 • 21-04 • 21-07 • 21-11 All reviewed NCRs included evidence of processing as required.

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8.7.2	Nonconformities are documented on a Non-Conformance Report (NCR) Form. After investigation and analysis is complete, appropriate corrective action is taken and consequences are determined (where applicable). A target completion date is set for 30 days from initiation to corrective action plan. This date may be adjusted as deemed necessary due to the complexity of the nonconforming issue. Where analytical results are involved, data is monitored carefully until the issue is fully resolved. Notification is made to appropriate parties (where applicable). All NCR's are included with the quarterly/annual QA Report.	SAT	See 8.7.1 above.
8.7.3	Corrective action effectiveness is evaluated periodically to verify that measures put into place have been successful and/or to ensure that any nonconforming issue has not been repeated. A summary evaluation of corrective action of effectiveness is included in the annual management report.	SAT	Extensive evaluation is included in the Annual QA Management review.
8.7.4	Risks and opportunities based on corrective actions taken are evaluated periodically by management. Changes to the management system may be made to limit vulnerability or exposure to potential risk or to promote more efficient lab operation.	SAT	Assessed during Annual QA Management.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 8.0 Quality Management System (Option A) **8.8 Internal Audits**		
8.8.1	In order to detect actual or potential nonconformities before data quality could be affected, internal audits are planned and conducted. These audits verify conformance of lab operations and the management system to regulatory and accreditation requirements, and to the lab's own policies and procedures. (TBE-1013 "Audits and Management Review")	SAT	The 2021 Internal Audit Schedule was reviewed. The following audits were reviewed: • 4015 completed 1/1 • 1013 completed 10/8 • 2012 completed 6/18
8.8.2	An internal audit plan is generated annually and includes the procedures and surveillances that are planned during the year. The goal is to review each area of the lab in some fashion. The plan is maintained by the QA Manager, but audits may be performed by other staff. Auditors are trained in performing audits, have some technical background in the subject matter, and are independent of the activity to be audited (not directly involved or have supervisory responsibility).	SAT	The internal audit schedule for 2021 was reviewed and found to include over 50 audits that covered the following areas: • Client • Equipment/Calibration • LIMS • Non-Conformance/Client Complaint • Organization/Management • Lab Procedure/Forms • QS Stds • Rad/Safety/Facilities • Training

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
8.8.4	An analytical procedure surveillance is scheduled to observe analysts as they perform a method to verify that it is being done as written and to note any changes that may need to be made to the written procedure. The results of the QC workgroup are included to show that the results are within control limits. All audit results are evaluated by the Operations Manager and any necessary changes are made where needed.	SAT	A ***Method Procedures for Surveillance*** is maintained by the QA Manager and was found to include 10 surveillances in CY21. The following were reviewed during this audit: • TBE-2003, completed 5/12/21 • TBE-2005, completed 7/26/21 • TBE-2007, completed 11/24/21 • TBE-2018, completed 11/21
8.8.6	Audit findings of nonconformances are documented and timely corrective action is taken, tracked to closure, and evaluated for effectiveness. An audit response including corrective action is sent to the auditor, (and to the Director of Quality Management Systems for the annual Quality System audit). Any findings that could cast doubt on the validity of results are disclosed in writing to the affected client(s) within 7 days. The QA Manager (or designee) verifies that the client was contacted properly.	SAT	For CY21, no findings were noted during scheduled audits.

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Item	Line of Inquiry	Status	Summary of Observations/Objective Evidence Reviewed/Audit Notes. Listed procedures / documents should also indicate revision number and date of implementation.
	Section 8.0 Quality Management System (Option A) **8.9 Management Reviews**		
8.9.1	In conjunction with the Internal Audits (Section 8.9 above), the laboratory conducts an annual management review to ensure continuing suitability, adequacy, and effectiveness of stated policies and objectives in this Quality Manual. (TBE-1013 "Audits and Management Review")	SAT	The most recent Management Review was completed 7/1/2021 for CY20. See **Observation (1)** earlier in this audit.
8.9.2	The review includes: • a summary of any changes to the QA program from the previous year • adequacy of staff and equipment resources • a list of staff specialty training certificates with expiration dates • highlights from the 4th Qtr (annual) QA Report (QC sample and proficiency results and audits) • an analysis of QA results (indication of analytical bias) • internal/external audit results and associated investigations and corrective actions • commentary on effectiveness of corrective actions • a listing of current accreditations and/or plans for any changes • comparisons of sample volume and turnaround times to previous years • client feedback not included with the QA Report	SAT	All elements listed in this requirement were found to be included in the CY20 Annual review completed on 7/1/2021

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	• observations by staff for improvements • results of risk identification • any changes/updates to methodology • a statement of management system effectiveness and fulfillment of objectives		
8.9.3	Upon completion of the draft review, the information is submitted to and signed by the Operations Manager and then signed by the QA Manager. Action items are assigned to designated responsible staff with an agreed-upon schedule for completion. The QA Manager ensures that actions are documented and completed. A copy of the signed report is sent electronically to the Sr VP of Energy & Environment and to the Director of Quality Management Systems (both TBE Huntsville management).	SAT	The CY20 Annual Review included signatures by both the QA Manager and the Operations Manager. The final report was subsequently distributed as required.

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E.2

EXTERNAL AUDITS

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EA 21-01

Utah Department of Health
NELAP Certification On-Site Audit

Intentionally left blank

Northcutt, Sharon

From: Robert Aullman <raullman@utah.gov>
Sent: Monday, June 28, 2021 8:35 AM
To: Northcutt, Sharon
Subject: Onsite Report
Attachments: AuditResultsFindings.pdf

External Email

I have attached a copy of your onsite report. Please respond so that I have documentation of the receipt of the report. Thank you for your time and cooperation with the assessment. Let me know if you have any questions or concerns.

--

Robert Kyan Aullman
Environmental Lab Certification Officer
Phone: 385-977-1255
Fax: 801-536-0149

State of Utah
Spencer J. Cox
Governor
Deidre Henderson
Lieutenant Governor

Utah Department of Health
Richard G. Saunders
Executive Director

Division of Disease Control and Prevention
Janae Duncan
Division Director

6/17/2021

Keith O. Jeter

Teledyne Brown Engineering Environmental Services

2508 Quality Lane

Knoxville, TN 37931

Dear Keith O. Jeter,

An on-site assessment of Teledyne Brown Engineering Environmental Services was performed beginning 06/10/2021. The purpose of the on-site assessment was to evaluate your facility and determine Teledyne Brown Engineering Environmental Services's compliance with Utah Rule R444-14 Rules for the Certification of Environmental Laboratories and the TNI standard. The on-site assessment was performed by staff of the Utah Environmental Laboratory Certification Program (ELCP) and included participation by Teledyne Brown Engineering Environmental Services's personnel listed at the end of this report.

Areas of Assessment

TNI Environmental Standard 2016 V1M1 Proficiency Testing
TNI Environmental Standard 2016 V1M2 Quality Systems General Requirements
TNI Environmental Standard 2016 V1M6 Radiochemistry Testing

I. Introduction

This assessment report reflects only the findings and decisions germane to the on-site evaluation and related application information, including personnel qualifications, laboratory procedures, detection limit studies, training records, quality assurance records, and quality assurance manual.

This assessment report does not attempt to comprehensively address all ongoing certification requirements prescribed in the Utah Rule (R444-14), promulgated methods, and applicable Code of Federal Regulations (40CFR 136, 141, and 261).

The on-site assessment portion for the evaluation of the laboratory included the following steps:

1. Opening conference.
2. Interviews with laboratory management, quality assurance personnel, and technical staff.
3. Review of sample collection, preservation, handling, and transport practices.
4. Review of procedures used for the analysis of environmental samples.
5. Inspection of laboratory facilities and equipment.
6. Review of data reporting, record keeping, instrument maintenance, and self-monitoring (QA records).
7. Discussion of assessment results with the laboratory director and/or personnel.

- If a CAR indicating unacceptable CAs for any General Laboratory Findings is received, Teledyne Brown Engineering Environmental Services will be notified. You may experience a delay and/or lapse in Teledyne Brown Engineering Environmental Services's certification status until acceptable CAs are received by the ELCP. Teledyne Brown Engineering Environmental Services's certification will expire on the date cited in Teledyne Brown Engineering Environmental Services's latest certificate letter (if applicable).

- If a CAR indicating unacceptable CAs for any Method Specific Findings is received, the ELCP will issue a certificate letter without approval for the affected parameter (method(s) and associated analyte or interdependent analyte group). The current certification cycle will be complete. The affected parameter (method and associated analyte or interdependent analyte group) may be requested again at any time in the future, by notifying the ELCP in writing. A parameter change fee may be assessed.

-Certificate extensions for previously certified laboratories will be issued only if a delay in the certification process is caused by the ELCP.

III. Assessment Findings, Requirements, and Recommendations

Findings

TNI 2016 V1M2 4.7 Service to the Client (Quality Systems)

1 **Citation**

V1M2 4.7.2/TNI 2016 V1M2 4.7 Service to the Client (Quality Systems)

The laboratory shall seek feedback, both positive and negative, from its customers. The feedback shall be used and analysed to improve the management system, testing and calibration activities and customer service.
NOTE: Examples of the types of feedback include customer satisfaction surveys and review of test or calibration reports with customers.

ELCP Finding

The laboratory did not have a process to seek feedback from clients.

Recommendations

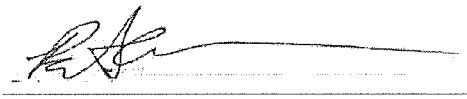
TNI 2016 V1M6 1.7 Technical Requirements (Radiochemical)

IV. Conclusion

Based upon the findings of the on-site evaluation, I will recommend to the Certification Authority that Teledyne Brown Engineering Environmental Services be certified for analyses pertaining to environmental compliance monitoring applicable to the Clean Water Act and Safe Drinking Water Act -- provided that the items listed in section III of this report have been adequately addressed within the time frame specified in section II of this report.

If Teledyne Brown Engineering Environmental Services needs additional clarification, or believes that any of the findings and requirements have been improperly evaluated, please feel free to contact me for clarification or re-evaluation. I can be reached by phone at 385-977-1255.

Sincerely



Robert Aullman
Certification Officer (Lead Assessor)
Utah Environmental Laboratory Certification Program

TELEDYNE
BROWN ENGINEERING
A Teledyne Technologies Company

July 19, 2021

Robert Aullman
Certification Officer (Lead Assessor)
Utah Environmental Laboratory Certification Program
Utah Department of Health
4431 South 2700 West
Taylorsville, UT 84129

Dear Mr. Aullman,

Please find attached the corrective action plan (CAP) which was prepared in response to the National Environmental Laboratory Approval Program (NELAP) audit report, issued on June 17, 2021 and received via email on June 28, 2021. The onsite audit was conducted June 10, 2021.

This CAP is arranged by suggestions/deficiency in the order presented in the audit report and includes objective evidence for the action item identified.

Teledyne Brown Engineering would like to note the professional and technically competent manner in which this audit was conducted. We appreciate the identification of these opportunities for improvement, as well as your department's assistance in our NELAP certification process. Please do not hesitate to contact us with any questions regarding this transmittal or with any request for additional information.

Contacts:

Keith Jeter	Laboratory Operations Manager	(865) 934-0373
Sharon Northcutt	Quality Assurance Manager	(865) 934-0374

Sincerely,

Sharon L Northcutt

Sharon Northcutt
Quality Assurance Manager
Teledyne Brown Engineering

Findings:

1. V1M2 4.7.2/TNI 2016 V1M2 4.7 Service to the Client (Quality Systems)
   The laboratory did not have a process to seek feedback from clients.

   Response: Please see NCR 21-04 Form attached.

Recommendations:

1. V1M6 1.7.2.1 a (Assignment of a Preparation Batch or RMB for samples & QC)
   It is recommended that the laboratory batch nonprepared samples in radiation measurement batches (RMBs).

   Response: Currently, the LIMS issues one type of workgroup batch for no more than 20 samples plus QC (blank, spike, dup, etc). Additional LIMS programming is being implemented to designate between Prep Batch (physical or chemical processing of samples) vs. RMB (non-destructive gamma spectrometry, alpha/beta counting of air filters, or swipes on gas proportional detectors).

TELEDYNE
BROWN ENGINEERING

NONCONFORMANCE REPORT (NCR) FORM

1. NCR No.: 21-04

2. Responsible Manager: Sharon Northcutt

PART 1. TO BE COMPLETED BY ORIGINATOR OF NCR	
3. Laboratory Area: Quality Assurance Manual	4. Client/Project Affected: NELAP (Utah)
5. Requirement Reference: TNI Std 2016 V1M2 4.7	6. Affected Data: N/A
7. NCR Description: Audit finding - the laboratory did not have a process to seek feedback from clients	
8. Client Notification: ☐ YES ☒ NO	9. Associated CC #: N/A
10. Prepared By: Sharon Northcutt	11. Date: 06/28/21

PART 2. TO BE COMPLETED BY NCR INVESTIGATOR	
12. Root Cause, Corrective/Preventative Action: See Attached Supplemental Sheet	
13. Planned Completion Date(s) for Actions(s): 07/28/21	
14. Prepared By: Sharon Northcutt	15. Date: 06/28/21
16. Approved By: Keith Jett	17: Date: 6/28/21

PART 3. TO BE COMPLETED BY QUALITY ASSURANCE MANAGER	
18. Review and Verification of Corrective Action (where applicable) ☒ Accepted ☐ Rejected ☐ Follow-up Needed	
19. Prepared By: Sharon L Northcutt	20. Date: 06/28/21

PART 4. TO BE COMPLETED BY RESPONSIBLE MANAGER	
21. Client Follow-Up Notification: ☐ YES ☒ NO Description:	22. Date:
23. Prepared By: Sharon L Northcutt	24. Date: 06/28/21

Supplemental Sheet

NCR No: 21-04

Description of Nonconformance:

Utah Department of Health NELAP audit finding that the laboratory did not have a process to seek feedback from clients. Reference: TNI 2016 Standard V1M2 4.7.2:

"The laboratory shall seek feedback, both positive and negative, from its customers. The feedback shall be used and analyzed to improve the management system, testing and calibration activities and customer service. NOTE: Examples of the types of feedback include customer satisfaction surveys and review of test of calibration reports with customers."

Root Cause:

The prior NELAP audit conducted in 2018 by the State of New York was based on the 2003 NELAC/2009 TNI Standard, which did not directly address this issue. The TBE QA Manual was completely reformatted and updated with Rev. 34, issued March 1, 2021. This revision included the updated regulatory requirements of the 2016 TNI Standard and ISO17025:2017.

Section 8.6.4 states: "In order to understand customer needs and to ensure satisfaction, TBE-ES encourages both positive and negative feedback from clients. The first line of client communication is with the project management team who serve as the primary contact for login, sample results, reporting, turnaround time and complaints Any feedback given to the lab is used to improve the overall management system, analytical procedures and most importantly, customer satisfaction."

While we appreciate and welcome client feedback, there was no official mechanism in place to pro-actively gather this valuable information.

Corrective Action to Prevent Recurrence:

TBE Procedure TBE-1016 "Documentation of Customer Complaints" will be revised, expanded and renamed to include Client Feedback. A client survey will be made readily available in client correspondence and on the website. Once the survey is completed, the results will be sent to the QA Manager, who will evaluate and summarize the comments. The summary will be discussed with the Lab Manager & Project Manager(s) for any needed follow up actions. Results will be communicated to the staff and included in the Annual Management Report.

Keith Jeter — 6/28/21

Department Manager or Designee — Date

Shawn L Nebeker — 06/28/21

Quality Assurance Manager or Designee — Date

Procedure	Number: TBE-1016	Revision: 4
	Issue Date: 11/10/06	Revision Date: 08/02/2021
Responsible Individual:	Quality Assurance Manager	Next Review Date: 08/02/2024
Subject:	Documentation of Customer Complaints	

TELEDYNE BROWN ENGINEERING ENVIRONMENTAL SERVICES

TBE-1016

Revision 4

Documentation of Client Complaints and Feedback

Prepared by: _____ **Date:** _____
Sharon Northcutt
Quality Assurance Manager

Reviewed by: _____ **Date:** _____
Sharon Northcutt
Quality Assurance Manager

Approved by: _____ **Date:** _____
Keith O. Jeter
Laboratory Operations Manager

Procedure	Number: TBE-1016	Revision: 4
	Issue Date: 11/10/06	Revision Date: 08/02/2021
Responsible Individual:	Quality Assurance Manager	Next Review Date: 08/02/2024
Subject:	Documentation of Customer Complaints	

1.0 SCOPE AND APPLICABILITY

1.1 This procedure describes the process to document client complaints and feedback.

2.0 SUMMARY OF METHOD

2.1 It is the responsibility of management to record all client complaints and to proactively seek out both positive and negative feedback regarding client satisfaction.

2.2 Complaints are recorded in the Complaint Log and documented on a customer complaint form in enough detail to enable reconstruction of the event. The documentation should include personnel receiving the complaint, date of complaint, steps taken to investigate and resolve the complaint. If complaints result in data changes to a report, the non-conformance and corrective action systems are used to resolve the issue and record all actions taken.

2.3 Client feedback is gathered via survey link information included with staff-to-client correspondence (primarily email) and/or the TBE website. Survey results assess TBE customer service and are used to make improvements. The results and effectiveness of client feedback is evaluated by the QA Manager in the Annual Management Report.

3.0 DEFINITIONS

3.1 See QA Manual, Appendix B.

4.0 PERSONNEL

4.1 Personnel shall be trained, qualified and certified as per procedure TBE-1007, "Training, Qualification and Certification of Personnel".

4.2 The applicable managers, working with Quality Assurance, are responsible for documenting the customer complaint and supporting corrective and preventive actions where applicable. QA coordinates the analysis of the complaint and initiation of corrective action where merited.

4.3 The QA Manager is responsible for gathering survey results and relating them to management. A summary is included in the Annual Management Report. The Lab Manager is responsible for communicating results to staff as applicable.

5.0 PROCEDURE

5.1 Customer Complaints and Follow Up

5.1.1 Complaint Log Documentation

Go to the G:\QACustomerComplaint Log and Attachments directory and open the

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"Customer Complaint Log Running 2016 to current" (EXCEL) file. Assign the next complaint number (CC-YY-##) and enter the date of complaint, staff filing the complaint, a brief description, the relevant L#/WG#, and the Client/Project ID.

5.1.2 Complaint Investigation and Follow Up

5.1.2.1 Complete Form KQA-22, "Customer Complaint Detail Form" to document the complaint (WORD document). A blank form can be found in the G:\QA\Customer Complaint Log and Attachments or G:\Forms directories. The customer complaint form includes a space for a related NCR – include this information if available at the time. The following information should be supplied:

a. The complaint number (YY-##).

b. The date the complaint was received and the person handling it.

c. Client contact, company name, associated L#/WG#, NCR # (if known)

5.1.2.2 Record the complaint in detail and note any requests made by the customer for resolution of the complaint (reanalysis, revised report, etc.).

5.1.2.3 Record in detail the steps that were taken to investigate and determine the cause of the discrepancy.

5.1.2.4 Document the results of the investigation and the resolution of the complaint.

5.1.2.5 Print a copy and save the completed & signed document in G:\QA\Customer Complaint Log and Attachments. Print/scan pertinent documents and save along with the form. The attached documents must contain the complaint number.

5.1.2.6 If the validity of results is affected, contact the Quality Assurance Manager and initiate a non-conformance and corrective action per procedures TBE-1010, "Nonconformance Controls" and TBE-1012, "Corrective and Preventive Action". Note the non-conformance number on the complaint form.

5.2 Client Feedback and Follow Up

5.2.1 Client feedback is requested via a survey that can be accessed through a link included on client correspondence (primarily email) and on the TBE website.

5.2.2 Survey results are sent directly to the QA Manager, who will document the feedback. A summary is generated for the Lab Manager and Project Manager(s) for discussion and any follow up needed. Any opportunities for improvement are documented on Form

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KQA-21 with a target completion date of 1 month. The QA Manager tracks the progress and retains all associated records.

5.2.3 The Lab Manager communicates survey results to staff as appropriate.

5.2.4 A summary and evaluation of effectiveness is included in the Annual Management Report

6.0 CRITERIA, CHECKLISTS AND STANDARDS

6.1 N/A

7.0 DATA RECORDS MANAGEMENT

7.1 See procedure TBE-1003, "Control and Retention of Quality Assurance Records".

8.0 QA/QC

8.1 QA/QC is as stated in the procedure.

9.0 REFERENCES

9.1 TBE-ES QA Manual, current revision.

9.2 TBE-1003 "Control and Retention of QA Records", current revision.

9.3 TBE-1007 "Training, Qualification and Certification of Personnel", current revision.

9.4 TBE-1010 "Nonconformance Controls", current revision.

9.5 TBE-1012 "Corrective and Preventative Action", current revision.

9.6 The NELAC Institute "TNI Standard EL-V1M2-2016-Rev2.1" Volume 1, Module 2: Quality Systems Requirements, 2016.

9.7 International Standard ISO/IEC 17025 "General Requirements for the Competence of Testing and Calibration Laboratories", 3rd Edition, 2017.

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ATTACHMENT B - KQA-21

PREVENTIVE ACTION FORM

PA NO.: _____

Initiator Name:	Date:
Identified Through (check one) : ☐ Daily Operations ☐ Management Review ☐ Customer Feedback ☐ Audit ☐ Other (_____)	
Description of Problem Area:	
Description of Possible Solution (if available):	

To be completed by Quality Assurance Manger

Assigned to:	Priority : ☐ High ☐ Medium ☐ Low	Date :
Solution approval signatures required from:		
Comments:		

To be completed by Assignee (Attach additional information as necessary)

Relevant background information collected? ☐ Yes	Existing processes investigated and understood? ☐ Yes
Summary of Proposed Solution:	
Documents Requiring Update :	
Solution approval signatures :	

To be completed by Quality Assurance Manager

Documentation Updated? ☐ Yes	Has the solution been effective? ☐ Yes ☐ No	Date Closed :
Closing Comments: *(If the solution has not been effective, reference the new preventative action form to readdress the problem area.)*		

END OF DOCUMENT