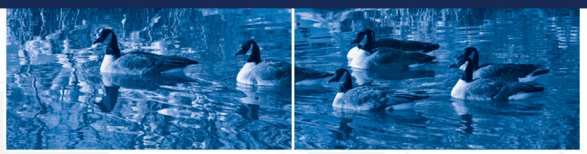
2022

FERMILAB ANNUAL SITE

ENVIRONMENTAL REPORT



Fermilab | U.S. DEPARTMENT OF ENERGY | Office of Science

TABLE OF CONTENTS

1.0 Introduction

Fermi National Accelerator Laboratory (Fermilab) is America's premier particle physics laboratory with a mission to drive discovery in particle physics, encouraging pioneering research by operating world-class accelerators and detector facilities. The laboratory takes pride in the ongoing stewardship of the site and works diligently to minimize the environmental footprint associated with operating the facility.

The Fermilab site is located within the greater Chicago area and consists of approximately 10.6 square miles (27.5 square kilometers) in Kane and DuPage counties. Approximately nine million people reside within 50 miles (80 kilometers) of the site. Communities within 2 miles (3 kilometers) of Fermilab include Batavia (population 27,701), Warrenville (population 13,363), and West Chicago (population 26,475). Primary features on the site include the accelerator complex and associated building infrastructure, an interconnected industrial cooling water system, a housing complex for visiting researchers (the Village), row crop agriculture, and natural areas in various states of restoration. The natural areas consist primarily of tall grass prairie, forest, and wetlands.

This Annual Site Environmental Report (ASER) documents the performance of Fermilab's environmental protection program. The report presents the status of environmental objectives for the laboratory and documents the compliance status of environmental requirements under the scope of Fermilab's Environmental Management System (EMS). The EMS conforms to the core set of standards described in the International Organization for Standardization (ISO) 14001 standard which specifies the requirements for an environmental management system. The EMS structure provides Fermilab a practical framework from which to assess, manage, and enhance the environmental impacts of site operations.

A core component of the EMS is the environmental monitoring and surveillance program. This program provides for the measurement and interpretation of the impact of Fermilab operations on the environment. Surveillance and monitoring tasks are conducted to confirm compliance with established standards and specific permit limits and ensure the early detection of an unplanned pollutant release. Sample locations and frequency are based on established routines, operational considerations, and process assessments as well as historic levels of pollutants found at a particular location. Sampling points are selected based on the potential for adverse impacts. Effluent samples and environmental media such as soil and groundwater are collected on the site and at the site boundary. Laboratory analytical results are compared to applicable guidelines and regulatory standards.

Discussed in this report are the results of Fermilab's environmental monitoring and surveillance activities, compliance with specific environmental regulations, progress on environmental restoration, and a summary of waste management and corrective action activities. The report is arranged by environmental topic and specific environmental requirements.

2.0 Summary of Significant Environmental Issues

Tritium Discharges

The generation of tritium is an expected outcome of operating the accelerator complex and it has been monitored throughout the history of the laboratory. Detectable amounts of tritium have been observed in surface water discharges from the site since 2005 and Fermilab maintains permits for the release of tritium from regulated points on the site. Sanitary effluent discharged from the site to the municipal wastewater treatment plants of Batavia and Warrenville/Naperville are monitored. Low concentrations of tritium are regularly recorded in the discharge to Batavia.

In response to the persistence of observable tritium and the expectation that future operations will continue to generate additional tritium, the Fermilab Director formed a Tritium Working Group beginning in 2012. This evolved into the Tritium Task Force which was established to identify, manage, and mitigate to the extent possible the quantity of tritium generated as a result of laboratory operations. Additional details concerning the management of tritium can be found in various sections of this report.

Reduction in Overall Environmental Emissions

The reduction of environmental emissions is a priority for Fermilab. Overall environmental emissions were reduced at Fermilab during 2021 due to the coronavirus disease 2019 (COVID-19) pandemic and the new flexible work arrangement that resulted in many employees working from home. Flexible work arrangements continue to be in place for those employees whose responsibilities allow them to work from home on a full or part-time basis. Details of the impacts of COVID-19 on environmental emissions are discussed throughout this report.

Nevis Block Removal

In Spring of 2021, the laboratory received funds from the Office of Environmental Management for use toward the management and disposal of the Nevis shielding blocks, potentially contaminated soils associated with storage of the shielding blocks, and the Nevis pole barn. Project planning is underway, and work is anticipated to be completed in CY23.

3.0 Ecological Stewardship

The Director of Fermilab established the Ecological Land Management (ELM) Committee to recommend management practices based on sound ecological principles that enhance the natural resources of the laboratory. The ELM committee provides an ELM plan to deliver these recommendations to Fermilab.

Infrastructure Services Division (ISD) Site Services and Roads & Grounds oversee the management of nearly 4,000 acres of natural areas, over half of which are being restored. These habitat communities include tallgrass prairie, oak savanna, open-water marsh, sedge meadow, buttonbush swamp, and floodplain forest, among others. The primary goal of ecological land management is to increase biodiversity of native flora and fauna while enhancing functional services of these ecological systems. This type of site stewardship includes prescribed burning, controlling invasive species, monitoring threatened & endangered species, surveying plants and wildlife and collecting seed from over 200 native species to spread into recently restored areas. A portion of this work is carried out by trained volunteers that are provided by Fermilab Natural Areas, a 501(c)(3) not-for-profit corporation.

Fermilab manages the population of whitetail deer on site by contracting annually with the U.S. Department of Agriculture Wildlife Services group. Population modeling using data from vegetation surveys, vehicle accident reports, and aerial surveillance indicated necessity for reduction of the herd in 2022. The herd was reduced by 46 deer between January and March 2022.

In addition to the management of whitetail deer, Fermilab has a Nuisance Animal Permit issued by the Illinois Department of Natural Resources (IDNR) that allows for the trapping and elimination of nuisance animals. During 2022, 49 reports of nuisance wildlife were received. Two birds of unknown species were taken to a rehabilitation center. No nuisance animals were euthanized onsite.

4.0 Sustainability

Fermilab is committed to minimizing the environmental impact of site operations. In response to goals established by the DOE to improve its environmental footprint, Fermilab has developed a Site Sustainability Plan that documents the laboratory's contribution towards meeting these goals. The primary emphasis of the plan is the reduction of greenhouse gas (GHG) emissions; a summary of GHG emissions is further described in Section 7.2. The sustainability plan addresses additional broad-ranging goals including more efficient building operations, reduction of water consumption, waste reduction and recycling, reduction of fossil fuel consumption for vehicle fleets, and improved energy efficiency.

In fiscal year (FY) 2022, the laboratory increased site access for employees and users as restrictions over COVID-19 were reduced. By the end of the fiscal year, Fermilab entered into a hybrid work mode where the number of days a week employees were on site varied by job function and requirements. As a result of increased on-site access, Fermilab saw an increase in fleet vehicle use, commuter travel, and air travel. Fuel consumption used by Fermilab's vehicle fleet remained lower than historical averages; however, there was an increase of three percent (%) over last year due to the reduction of maximum telework. Similarly, as telework was reduced by laboratory staff, the number of miles employees commuted to and from work increased over two million miles as compared to last year. The growth in commuter travel produced an associated increase in greenhouse gas tailpipe emissions of 28%. Air travel in FY 2022 also increased significantly compared to the greatly reduced air travel that occurred in FY 2021, with 5.7 million more miles flown in FY 2022.

Fermilab's energy consumption was 98.5% of anticipated use with the accelerator complex remaining at normal operation. Significant changes to the laboratory's projected future energy consumption are anticipated over the coming decade. Beginning in 2025, Fermilab expects to begin bringing the Proton Improvement Plan (PIP)-II accelerator complex online. This new installation, along with the Long-Baseline Neutrino Facility (LBNF) project once complete, are expected to increase Fermilab's electricity consumption by 30% over historic peak levels.

In FY 2022 the laboratory was awarded a Department of Energy's Assisting Federal Facilities with Energy Conservation Technologies (AFFECT) grant for the Fermilab Resilience and Efficiency Project (FREP). The FREP will execute an aggressive suite of energy conservation measures and also develop a two megawatt (MW) solar photovoltaic array, an energy storage facility, and micro/nanogrid infrastructure to improve the resilience of critical facilities onsite. Fermilab is working with DOE to use an Energy Services Performance Contract to execute the project, which will enable third-party financing to be leveraged along with the AFFECT grant to implement the scope of work.

Fermilab is ramping up sustainability efforts to address DOE's increased focus around addressing climate change through reduction of greenhouse gas emissions and improved resilience of site activities. Fermilab initiated development of a full-time sustainability team consisting of a Sustainability Manager and three full-time staff. Team recruitment began in 2022 with the goal of having the team fully staffed by the spring of 2023.

5.0 Environmental Management System (EMS)

Fermilab's EMS is the organizational framework that enables the laboratory to minimize environmental impacts due to operations. The system functions via an ongoing cycle that focuses on planning, implementing, evaluating, and improving environmental performance. This process is used as means to continuously focus on the environmental aspects of laboratory operations to ensure compliance with regulations and to demonstrate that the facility is operating in an environmentally responsible manner. In addition, the elements of the EMS have been aligned with the principles of Fermilab's Environment, Safety, and Health (ES&H) management system to form a combined management system that addresses facility operational liabilities that have the potential to impact individuals and/or the environment.

The laboratory routinely evaluates operations and seeks to improve environmental performance. The laboratory's significant environmental aspects have been identified and are reviewed annually. In areas where change is desired or required, goals are established with measurable targets that seek to improve a particular aspect of operations. Goals outlined in the Site Sustainability Plan document areas of significant emphasis where changes are being pursued.

Fermilab first received certification to the ISO 14001 standard for environmental management in 2007. During 2017, the laboratory transitioned towards EMS self-declaration to the standard which is an allowable option granted by DOE and ensures full compliance to the standard through internal assessments and third-party audits. The laboratory's EMS was most recently audited against the elements of the ISO14001 standard in April 2021. The results of this audit resulted in zero major nonconformances, two minor nonconformances, four opportunities for improvement, two strengths, and one noteworthy practice. A corrective action plan addressing the minor nonconformances was formulated and submitted to the DOE FSO in May 2021. A Memorandum of Conformance was received from FSO on August 20, 2021.

6.0 Environmental Monitoring and Surveillance

The goal of Fermilab's Environmental Monitoring Program is to assist laboratory management in decision-making by providing data relevant to the impacts the facility operations have on the surrounding environment. The program includes effluent monitoring which is used to confirm compliance with permits associated with various discharge points from the facility.

Environmental surveillance is typically conducted at locations to intercept the pathway of potential pollutants to receptors such as plants, animals, or members of the public. Fermilab collects environmental data for regulatory compliance, other reporting purposes, and for other purposes deemed necessary or useful in conducting the business of the laboratory. Line organizations have the responsibility to recognize and understand the environmental aspects of their operations and to conduct their work in an environmentally sound manner.

Collection and analysis of samples of various media and measurements of penetrating radiation (e.g., muons) are conducted within and at site boundaries. The pathways with the greatest potential for the transport of chemical or radioactive materials resulting from Fermilab operations to the environment include the atmosphere, surface water (including sewer systems), groundwater, and roadways (transportation of materials to and from the site).

In addition to monitoring for potential chemical constituents, surface water, groundwater, soil, sediment, and air samples are routinely analyzed for radionuclide concentrations. Groundwater and surface water are sampled at locations near operating areas, potential contamination sources, and along potential transport pathways. In addition to air and water surveillance, soil samples are collected and analyzed for radioactivity to ascertain whether build-up of radioactive materials has occurred in the environment due to long-term operations. While levels of penetrating radiation are measurable near some operational areas on the site, these levels have been shown to decrease rapidly with distance from the sources. External penetrating radiation and airborne emissions are routinely detected below instrument detection levels at the site boundary; further evaluation of these numbers include estimations to assess the maximum potential radiation doses to offsite populations.

The results of the environmental surveillance program are interpreted and compared with environmental standards where applicable. The Fermilab Environmental Monitoring Plan which is maintained by the Environmental Program Department (EPD) within the ES&H Division provides more details.

6.1 Air Quality

Fermilab has been qualified as a source of low chemical air emissions and is registered with the Illinois Environmental Protection Agency (IEPA) under the Registration of Smaller Sources (ROSS) program. This program is administered by IEPA and is available to facilities that emit only minor amounts of air pollution.

In addition, Fermilab monitors radioactive air emissions associated with operations. These emissions are kept as low as reasonably achievable (ALARA) and fall well below the United States Environmental Protection Agency (USEPA) emission standards.

6.1.1 Non-Radioactive Air Emissions

In 2022, Fermilab continued to operate under the ROSS program. Although Fermilab no longer operates under a Lifetime Operating Permit, it continues to monitor sources including those named in this permit. Management of these sources according to the former permit allows Fermilab to demonstrate compliance with the conditions under the ROSS program and also allows for continuity in the event that Fermilab returns to being a permitted source. These monitored sources include the following:

- Magnet de-bonding oven;
- Two natural gas-fired boilers (13.8 million British thermal units (mmBTU) and 12.25 mmBTU) at the Central Utility Building (CUB);
- 12,000-gallon gasoline storage tank with a stage 1 vapor balance system;
- Various radionuclide emission stacks;
- Standby diesel generator (2,200-horsepower); and
- Cavity Processing Lab (CPL).

These sources are monitored for particulate matter (PM), carbon monoxide (CO), nitric oxide (NOx), sulfur dioxide (SO_2), volatile organic material (VOM), GHG, and total hazardous air pollutants (HAP). A summary of the 2022 emissions from these sources is provided in the table below.

Description	PM	CO	NOx	SO2	VOM	GHG (as CO2e)	Total HAP
---	*Tons*						
Debonding Oven	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000
CUB Boilers	0.1047	1.1573	1.3777	0.0083	0.0758	1,663.2975	0.026038
Gasohol UST	---	---	---	---	0.0103	---	---
Radionuclide Emission Stacks	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000
Standby Generator	0.0301	0.2369	1.0336	0.0172	0.0304	438.4400	---
Cavity Processing Facility	0.0001	---	---	---	---	---	0.000088
Totals:	**0.1349**	**1.3941**	**2.4113**	**0.0255**	**0.1164**	**2,101.7375**	**0.026126**

6.1.2 Radioactive Air Emissions

Offsite

Airborne radionuclides are normally released to the atmosphere from operating target stations, accelerators, and beamlines. Measures to keep these releases ALARA are incorporated into operating processes and procedures at these facilities and in design efforts for new projects. Monitoring is conducted at areas where air emissions are considered a significant contributor to the overall transport of radioactive materials offsite.

The radiation doses potentially received by the offsite public due to Fermilab operations are calculated from data gathered through environmental surveillance of the onsite sources. Selected vent stacks are monitored directly with stack monitors and indirectly by taking soil samples near the stacks. The dose for the air pathway is calculated using a Gaussian plume computer simulation model called Clean Air Act Assessment Package-1988 (CAP88PC Version 4.1.1.0). This model was created by the USEPA to predict the movement of airborne radionuclides and its use is dictated by regulations governing hazardous air pollutants (40 Code of Federal Regulations [CFR] 61). Fermilab is subject to Subpart H of this regulation which specifically exempts Fermilab from the requirements of 40 CFR 61.10. Since Fermilab emissions have always been kept below 1% of the 10 millirem (mrem) per year maximum allowed by the standard (i.e., 0.1 mrem), continuous monitoring is not required. Maximum calculated concentrations off-site are predicted to be below the level that could be detected by direct monitoring. Because the doses are calculated based on actual radionuclide concentration release rates rather than directly measured concentrations, they represent potential or estimated doses.

In 2022, the accelerator and the experiments operated throughout the calendar year, except for the standard annual maintenance shutdown that lasted anywhere from ten to twelve weeks for different machines and periodic maintenance activities throughout the year. The Muon Campus used eight giga-electron volt (GeV) protons for muon production for the Muon g-2 experiment. The *NuMI Off-axis ν_e Appearance* experiment (NOvA) operated in the *Neutrinos at the Main Injector* (NuMI) beamline, approaching 900 kW proton beam. The MicroBooNE experiment on the Booster Neutrino Beam (BNB) beamline and a series of experiments that operated in the Meson Center and Meson Test Areas were the Fixed Target experiments operating during 2022. The MeV Test Area (MTA) operated as an irradiation test facility. No radioactive accelerator components were debonded at the Magnet Debonding Oven facility.

The total radioactive air emissions in 2022 was approximately 118.4 Curies.

Radionuclide	Half-life	Annual Quantity
O-15	2.0 minutes	1.64×10^1 Ci (6.07×10^2 GBq)
C-11	20.3 minutes	4.26×10^1 Ci (1.58×10^3 GBq)

Radionuclide	Half-life	Annual Quantity
N-13	10.0 minutes	2.10×10^{1} Ci (7.77×10^{2} GBq)
Ar-41	1.8 hours	2.75×10^{1} Ci (1.02×10^{3} GBq)
H-3	12.3 years	1.09×10^{1} Ci (4.03×10^{2} GBq)
Total		**118.4 Ci** (4.38×10^{3} GBq)

Doses to the public offsite from emissions in 2022 continued to be well below the USEPA standard of 10 mrem (1×10^{-1} millisieverts [mSv]) in a year and less than the USEPA's continuous monitoring threshold of 0.1 mrem (1×10^{-3} mSv) in a year. Using the CAP88-PC Version 4.1.1.0 Gaussian dispersion model and adult dose and risk factors from Federal Guidance Report 13, the highest dose equivalent to a member of the public offsite was estimated to be 7.96×10^{-2} mrem (7.96×10^{-4} mSv). Fermilab's 2022 Radionuclide Air Emissions Annual Report will be submitted to the DOE FSO in Spring 2023. The report is distributed by the DOE FSO to the USEPA and IEPA.

Onsite

The dose to the maximally exposed individual (MEI) onsite from air emissions was calculated using CAP-88PC Version 4.1.1.0, similarly to the dose offsite. For the purposes of the onsite dose, the location used was the public area onsite nearest the location of the stacks, approximately 300 meters in the north-northeast direction. For continuous occupancy, the dose received by the MEI onsite would be 0.34 mrem (3.4×10^{-3} mSv); however, since the public is only permitted onsite from dawn-to-dusk, the maximum potential dose to the onsite MEI would be 0.17 mrem (1.7×10^{-3} mSv). Adjusting for a more realistic occupancy of 400 hours per year (approximately 1 day per week or 1 hour per day), the potential dose to the onsite MEI from airborne emissions would be 0.017 mrem (1.7×10^{-4} mSv).

6.2 Penetrating Radiation

Offsite

Operation of the Fermilab accelerator and associated beamlines produces ionizing radiation such as neutrons and muons. Beamlines and experiments are designed so that most of the radiation is absorbed before reaching the ground surface and outdoor areas. The neutrons are absorbed by shielding; the remaining radiation that emerges above the surface presents a very small potential for radiation dose. Doses were calculated following Fermilab procedure ESH-RP-ERPP-03, *Radiological Dose Assessment for the Annual Site Environmental Report*.

Small muon fields have been measured in conjunction with the operation of the beamlines in the past. The Meson Test (MTest) and Meson Center (MCenter) beamlines operated in 2022. The muon dose offsite due to the operation of Mtest and MCenter was 0.042 mrem (4.2×10^{-4} mSv). Both the BNB and NuMI experiments have the potential to produce measurable muon flux; however, the eight GeV energy protons used in BNB are too low in energy to produce

muons that can escape the bulk shielding surrounding the experiment. The NuMI beamline bends the beam down so that the muons produced are absorbed deep underground as part of the beamline design.

Another potential source of exposure to ionizing radiation is the centralized radioactive materials storage area referred to as the Railhead. This source of penetrating radiation was monitored continuously in 2022 by a large ionization chamber located in the Railhead colloquially called a 'Hippo.' The Hippo measurements are supplemented by several environmental dosimeters placed around the storage area and by periodic onsite surveys. Based on measurements made, it is estimated that radioactive materials stored at the Railhead contributed no directly measurable equivalent dose at the site boundary in 2022.

Radiation doses at the site boundary can also potentially occur from skyshine, which is where radiation reaches the site boundary through reflection and scattering in the atmosphere back to the earth's surface. Skyshine doses are typically too low to be directly measurable; therefore, Fermilab estimates skyshine using conservative assumptions when evaluating new facilities or activities. The sum of the estimated skyshine for current Fermilab activities is approximately 0.61 mrem (6.1×10^{-3} mSv), primarily from the main injector and booster.

The three sources of penetrating radiation were highest at different locations at the site boundary; however, for purposes of calculating a maximum, bounding dose, they were added. The maximum total penetrating radiation equivalent dose in 2022 to an individual at the nearest offsite residence was thus estimated to be 0.65 mrem (6.5×10^{-3} mSv) and not directly measurable.

Onsite

Environmental dosimeters were placed in approximately 250 indoor locations and 70 outdoor locations to assess potential doses to Fermilab workers and members of the public. The dose in most publicly accessible areas is indistinguishable from background. Of the environmental dosimeters located in areas where public access is allowed, the highest potential dose was in a location along the Linac fencing. Assuming continuous occupancy of 24 hours per day, 365 days per year in the maximum public location, the maximum dose received from penetrating radiation would be 11 mrem (1.1×10^{-1} mSv) per year. Adjusted for the site access hours of dawn-to-dusk and assuming a member of the public resided in this location every day of the year, the maximum dose received from penetrating radiation by a hypothetical member of the public would be 5.5 mrem (5.5×10^{-2} mSv) per year. Adjusting for a more realistic occupancy of 400 hours per year (approximately 1 hour per day), the potential dose to the hypothetical maximum individual would be 0.6 mrem (6.0×10^{-3} mSv) per year.

6.3 Surface Water Quality

Fermilab releases minor amounts of contaminants to surface water bodies. As part of the management of these discharges, the laboratory holds National Pollutant Discharge Elimination System (NPDES) permits that govern releases to surface water from storm water runoff, cooling water, effluents from various onsite construction projects, and pesticide applications. In addition to monitoring for the physical and chemical parameters required by NPDES permits, samples of surface water are taken monthly from selected water bodies and

analyzed for radionuclides. These surface waters are sampled for radionuclides based upon their potential for contamination. The Fermilab Environment, Safety, and Health Manual (FESHM) Chapter 8026 Surface Water Protection describes regulatory aspects and responsibilities of the surface water program.

Aqueous process wastewaters are directed to sanitary sewers and ultimately discharged to publicly owned treatment works (POTWs) in the municipalities of Batavia and Warrenville/Naperville. Wastewater discharges are controlled by criteria described in FESHM 8025, Wastewater Discharge to Sanitary Sewers. There were no unplanned releases to sewer systems in 2022.

In addition, settleable solids at Fermilab are sampled at the discharge to the Batavia municipal treatment system, the discharge to the Warrenville/Naperville municipal treatment system, and the site boundaries of Indian Creek, Kress Creek, and Ferry Creek. A background sample is collected within Kress Creek upstream of the Fermilab site boundary.

6.3.1 Cooling Water System

Fermilab requires large amounts of non-contact cooling water that is circulated through various surface water bodies designed to dissipate heat. Fermilab's site-specific NPDES permit authorizes the treatment of Industrial Cooling Water (ICW) and the discharge of commingled cooling water and storm water runoff through outfalls into Kress, Indian and Ferry Creeks. The outfalls designate the location at which point Fermilab's surface water system becomes Waters of the State. A Storm Water Pollution Prevention Plan (SWPPP) is required by the site-specific NPDES permit. It addresses storm water discharges associated with Resource Conservation and Recovery Act (RCRA) Solid Waste Management Units (SWMUs), certain industrial activity areas, and services support areas. (Also see Section 7.12 National Pollutant Discharge Elimination System.) An inspection report was completed in March and filed with IEPA.

In 2022, Fermilab contracted with a state-licensed pesticide applicator to treat a limited number of ponds with aquatic herbicide to minimize plant growth. Additionally, an ongoing zebra mussel infestation occurring in the ICW system infrastructure was managed by using a continuous feed of sodium hypochlorite solution at the Casey's Pond pumphouse.

6.3.2 Non-Radioactive Releases to Surface Water

Monitoring for non-radiological chemical constituents in surface water was limited to NPDES permit parameters (temperature, flow, pH, and chlorine) this year. Discharge Monitoring Reports for six different outfalls were submitted monthly to IEPA. All outfall discharges were within the limits of permit parameters in 2022.

6.3.3 Radioactive Releases to Surface Water

Numerous sumps collect and drain water from building footings and from under beamline tunnels in the Main Injector, former Tevatron, and the experimental areas. Water collected by these sumps may contain detectable concentrations of radionuclides (primarily tritium) that have been leached by rainwater from radioactive soil near beam targets and absorbers or

released accidentally to sumps due to losses from beamline cooling water systems. These sumps discharge to ditches and ponds onsite.

In addition, water is also collected from the NuMI tunnel system. NuMI tunnel water contains measurable concentrations of tritium, and the primary source of the tritium comes from water contact with components within the tunnel. The water that is collected consists primarily of groundwater that has infiltrated into the tunnel. This high-quality water is pumped from the tunnel and directed into the ICW system where it is used primarily for make-up water for the CUB cooling towers. Excess NuMI water and effluent from the towers is directed to the ICW piped and pond system.

Fermilab continued to discharge measurable concentrations of tritium to surface waters off site. The concentrations measured were well below the DOE Order 458.1 Derived Concentration Standard of 2,600 picocurie per milliliter (pCi/ml). Releases depend on pond levels and the operational mode of the accelerator complex. Fermilab's site-specific NPDES permit includes monitoring requirements for tritium at all 6 outfalls in 3 watersheds. In 2022, during the first 5 months of the year, low concentration of tritium ranging from 1.2 pCi/ml to 2.3 pCi/ml were discharged to Ferry Creek. Indian Creek received low concentration tritium discharges throughout the year, with the highest concentration occurring during July at 11.8 pCi/ml. Detectable tritium with a concentration 1.4 pCi/ml occurred at the Kress Creek outfall only during July.

Monthly data from measurements taken at outfall and site boundary locations are made publicly available through the *Tritium at Fermilab* website. Monitoring for radioactivity in surface water continues to be a primary component of Fermilab's routine environmental surveillance program.

6.3.4 Releases to Sanitary Sewers

Fermilab maintains an onsite piping system for the conveyance of sanitary effluent. This effluent is directed to the cities of Batavia and Warrenville/Naperville for treatment. In addition, Fermilab operated two systems in 2022 that require pretreatment prior to release to the sewers. These operations require wastewater pretreatment permits issued by IEPA. The permits are as follows:

- Individual industrial wastewater pre-treatment permit that allows Fermilab to discharge wastewater effluent from deionized water regeneration operations occurring at the CUB to the City of Batavia sanitary sewer treatment works.
- Individual industrial wastewater pretreatment permit that allows for metal finishing wastewater from the Applied Physics and Superconducting Technology Division's (APS-TD) CPL at Industrial Building 4 (IB4) to be discharged to the City of Batavia sanitary sewage treatment works.

Monitoring stations located at the site boundary sample sewer discharges to the municipalities of Batavia and Warrenville. The discharge at these locations is a mixture of all effluents contributing to that sanitary sewer system. Analytical results for metals are compared to municipal discharge limits to track compliance. Fermilab occasionally exceeds the limit for iron (5.0 milligrams per liter (mg/L)) released to Warrenville. This did not occur in 2022. Aging pipes

are suspected to be the source of the exceedances and their cause has been discussed with the municipalities.

Low levels of tritium have been detected in effluent discharged to the Batavia treatment works since August 2005. All discharges in 2022 were well below the DOE Order 458.1 standard (total tritium 5 curies) and are summarized below. No other isotopes were detected.

Total Tritium in 2022	0.16 Curies
Average Concentration	1.6 pCi/ml
Highest Concentration	3.5 pCi/ml
Total Sanitary Volume	22,912 kGal

Fermilab's Tritium Task Force Working Group continued to investigate sources of tritium into both the sanitary sewer system and the ICW system. As part of this, a concerted effort is being undertaken to investigate sources of tritium in the sanitary system in the southern sections of the system.

6.4 Groundwater Quality

The IEPA publishes groundwater quality standards (35 IAC 620) and defines Class I groundwater as a non-degradable resource, which is to be highly protected. Water residing in or near the Silurian dolostone bedrock aquifer, the upper surface of which is 50 to 80 feet below the ground surface in the Joliet Formation at Fermilab (Figure 6.4-1), is classified as the top of Class I groundwater. Water in the glacial deposits overlying bedrock has been demonstrated to be Class II groundwater requiring less-stringent standards.

The locations of groundwater monitoring wells are shown in Figure 6.4-2, with approximate screen depth intervals for wells related to sampling programs illustrated in Figure 6.4-1. In 2022, nine glacial and Silurian dolostone (Joliet Formation) monitoring wells at the CUB Pipe and Clay Tile Field (SWMU 12) were sampled as part of ongoing RCRA Facility Investigation (RFI) corrective actions at this location.

During 2006, the Meson and Neutrino Soil Activation Areas were removed from the RFI as a SWMU; however, under the laboratory's environmental surveillance program, sampling continues in the five Joliet Formation wells in this region. For informational purposes, and as a courtesy, the results are reported to the IEPA annually. Four background wells (Joliet Formation) were sampled to assess base-line tritium levels at the up-gradient (north) edge of the laboratory property (BMW-1 through BMW-4) and two Elwood Formation wells were sampled to assess tritium levels near the NuMI Target Hall (S-1423-2 and S-1426-2). An additional 120+ wells with various screen depth intervals (Figure 6.4-2) are used as piezometers (pore-water pressure measuring apparatus) to gather information on groundwater flow directions site-wide. These data are used in conceptualizing the horizontal and vertical transport of potential contaminants from past and present operational areas of concern.

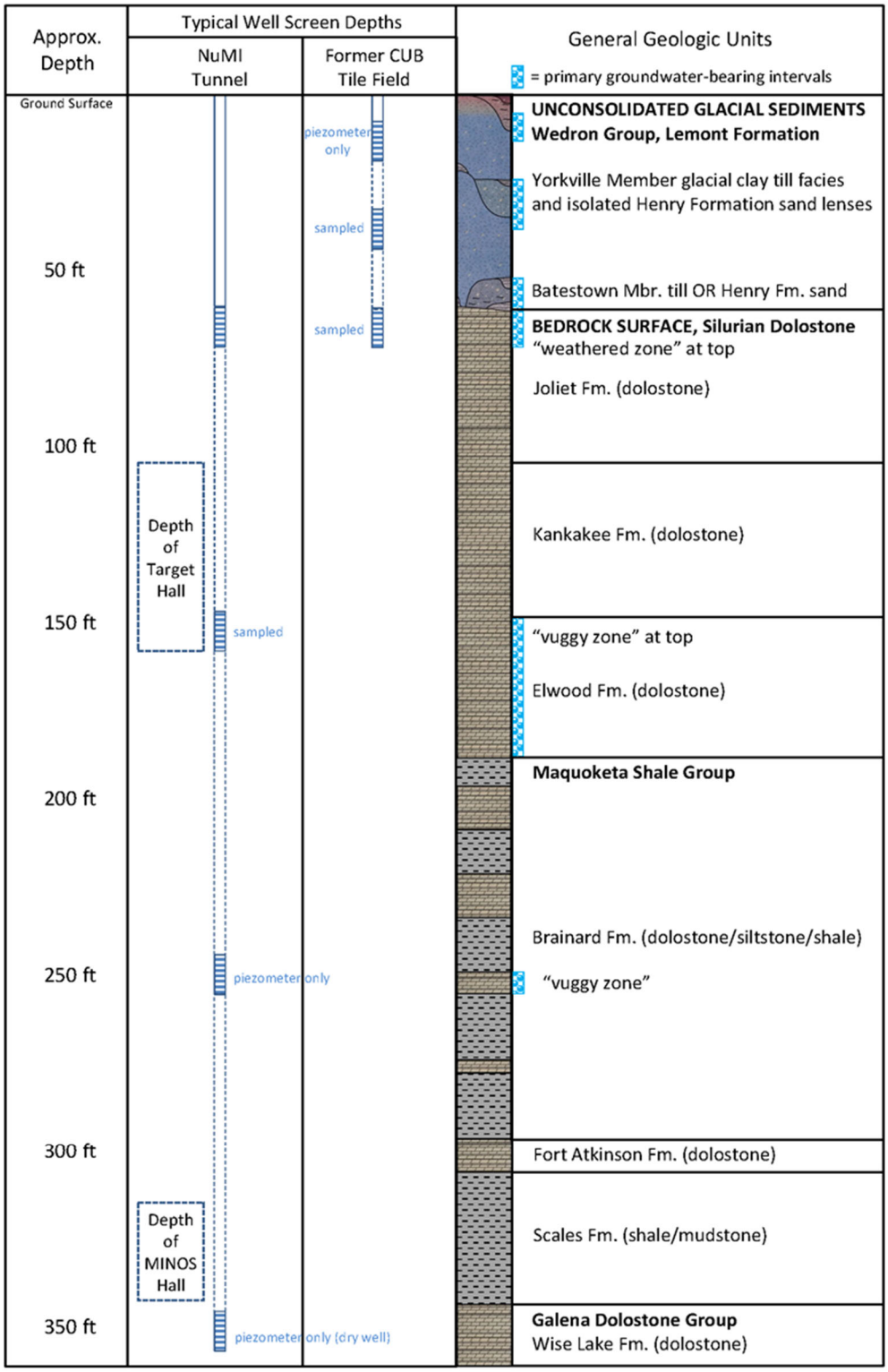


Figure 6.4-1. General Fermilab geologic section (based on the NuMI tunnel), with groundwater monitoring well screen depths and groundwater-bearing intervals. Sampling/piezometer status is for 2022.

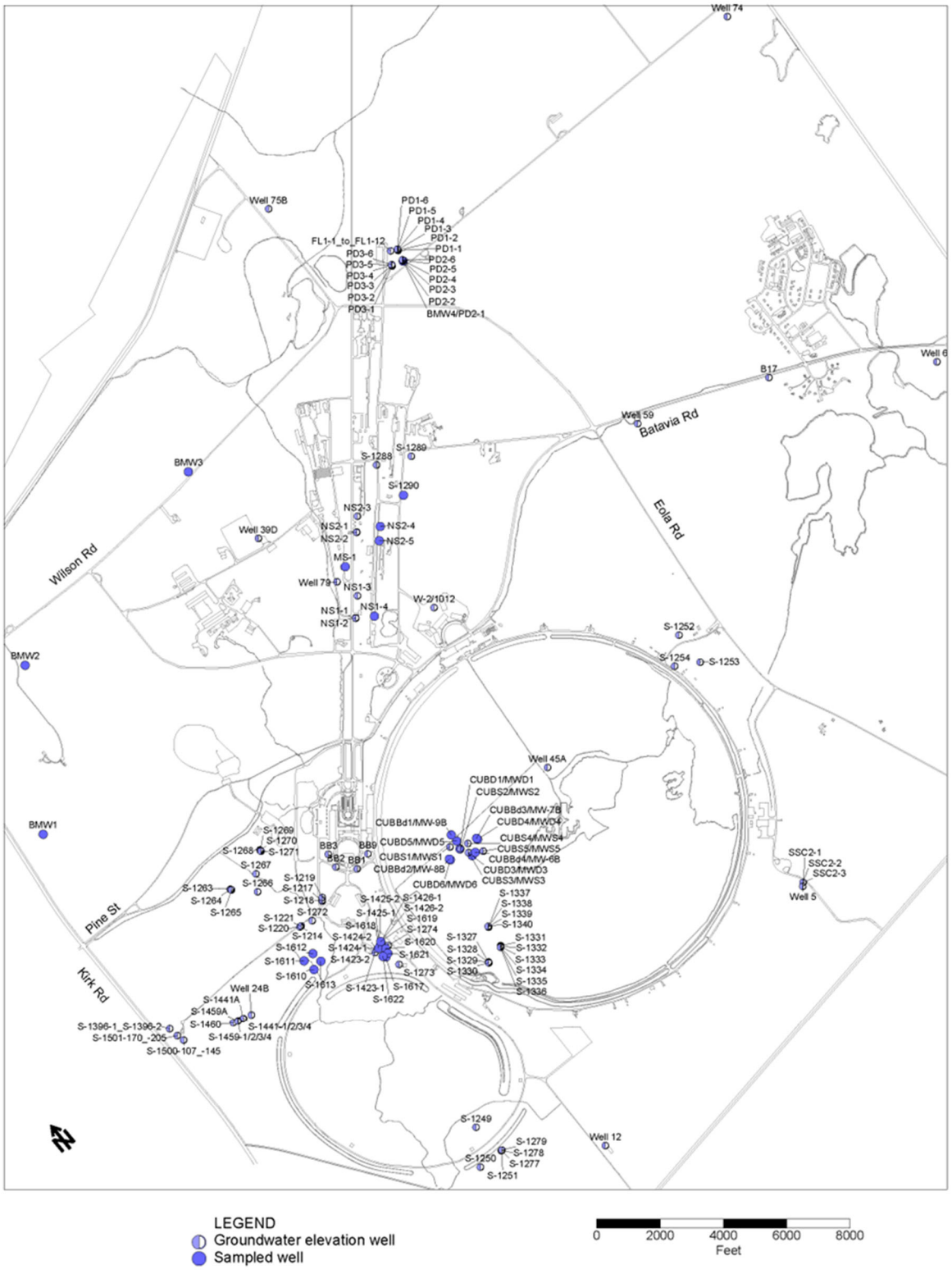


Figure 6.4-2. Groundwater monitoring well locations in 2022. Sampled wells represented by labeled, filled circles. Wells used only for groundwater elevations represented by half-open circles. (Original DUSAF projection)

6.4.1 Radionuclides in Groundwater

DOE policy on groundwater protection, as expressed in DOE O458.1, is consistent with the Illinois Class I groundwater standard of 20 pCi/ml. Samples were collected from ten locations for radionuclide analysis. Tritium and accelerator-produced radionuclides were not detected in any Class I groundwater samples during 2022.

There are six “sump” wells at BNB that are routinely sampled for tritium. They are not true groundwater wells, but rather drain the north and south ends of the interior, interstitial space and exterior of the dual-liner system around the decay pipe via lateral pipes. Water in the interior and interstitial sump wells originates from surface infiltration that makes its way through the damaged liner system near the north end, adjacent to the Main Injector (MI)-13A building. Most of the water in the exterior wells originates from surface and lateral infiltration that makes its way to the sides and underside of the liner system, and some water in these wells leaks from the laterals leading to the interior and interstitial sump wells. Tritium results in these wells in 2022 ranged between <1 and 12,300 pCi/ml and was either routed to the MI Ponds or Casey’s Pond, or it was contained and shipped for disposal if the concentration exceeded 2,600 pCi/ml. Further measures to redirect water away from the MI-12/BNB area (a canopy and surface liner) were implemented in 2018-2019. Tritium concentrations and infiltrating water volumes in the BNB sump wells have decreased through 2022 and will continue to be monitored to evaluate the potential impact to groundwater.

Four 33-foot deep wells were installed at BNB in September 2021 to evaluate lateral flow into or from the decay pipe liner system. Results of four quarterly rounds of samples through 2022 were all non-detect (<1 pCi/ml) for tritium. The next phase of monitoring within the top of the Class I groundwater zone in bedrock will be designed in 2023.

At MI-65, one groundwater well was installed in September 2021 immediately adjacent to the southwest roof downspout and one borehole was sampled for groundwater between the SW an SE downspouts in the shallow 7-12 foot deep groundwater zone. The monitoring well result was 83 pCi/ml, and the grab result was 251 pCi/ml. The next round of monitoring well(s) in the deep till zone (~30-40 feet deep) will be designed in 2023. Five utility-backfill wells were installed around MI-65 in September 2021 to evaluate utility line impact on subsurface migration. Most utility backfill wells were dry in 2021 and 2022, with non-detect results southeast of MI-65 and results of <10 pCi/ml in the sanitary sewer backfill northeast of MI-65. No additional utility-backfill wells are planned.

6.4.2 Chemicals in Groundwater

In 2022, quarterly and semi-annual groundwater sampling events were conducted at one SWMU. Chemical analyses were performed on these samples as required by the RFI. (See Section 7.14.1 RFI Activities.)

7.0 Compliance with Specific Environmental Requirements

The following sections are a summary of Fermilab's compliance with key environmental requirements during 2022.

7.1 Clean Air Act

The annual air emissions report for 2022 was not required due to Fermilab's registration as a ROSS source. In 2022, the actual annual air emissions for Criteria Air Pollutants (carbon monoxide, nitrogen oxides, particulate matter, sulfur dioxide, and volatile organic materials) were reported as 4.072 tons per year, which is less than the maximum allowed for a small emissions source. The ROSS report for 2022 will be submitted to FSO in December 2023.

Fermilab's 2022 Radionuclide Air Emissions Annual Report was submitted to the DOE FSO in May 2023, and distributed by the DOE FSO to the USEPA and IEPA. Doses to the public from radioactive emissions in 2022 continued to be well below the USEPA standard of 10 mrem/year, and less than the EPA continuous monitoring threshold of 0.1 mrem/year. In 2022, an estimated 118.4 Curies (4.3808 TBq) were released from various sources (see section 6.1.2 Radioactive Emissions). The CAP-88 Gaussian plume diffusion model calculated the maximum dose equivalent delivered to a member of the public (at distances to the site boundary to the nearest approximate 100 meters) to be 7.96×10^{-2} mrems/year (7.96×10^{-4} mSv/year) in 2022.

An open burn permit to allow prairie/land management burning was renewed by the IEPA in 2022.

7.2 Greenhouse Gas Emissions Reporting

Fermilab supports the DOE's effort to advance GHG reduction at its facilities. In 2022, the laboratory submitted GHG emissions data to the department via DOE's Sustainability Dashboard. GHGs are divided into three categories: Scope 1, 2, and 3. Scope 1 emissions are direct emissions from activities controlled by Fermilab (e.g., boilers, emergency generators, fleet vehicles, and fugitive emissions). Scope 2 emissions are indirect emissions and for Fermilab involve only purchased electricity. Scope 3 emissions are other indirect emissions such as employee air travel, electrical transmission and distribution losses, waste generation, ground travel, and employee commuting.

A summary of Fermilab's emissions, including the 2008 baseline are shown below. The performance status indicates that Fermilab has reduced Scope 1 and 2 emissions by 71.3% over the baseline year or a 2% improvement in the last year. The consumption of electricity is Fermilab's dominant source of Scope 1 and 2 emissions. Scope 3 emissions were reduced by 64.2%.

Fermilab is committed to assist DOE in meeting reduction goals for Scopes 1, 2 and 3. In FY 2022, Fermilab convened the Net Zero Task and created a Net Zero Roadmap for the laboratory. The Net Zero Roadmap identifies a number of strategies designed to achieve net zero carbon emissions lab wide by 2050. Fermilab plans to secure Environmental Attribute

Certificates (EACs) for carbon-pollution free electricity to serve as a primary mechanism to reduce Scope 2 emissions. EACs are in short supply in the laboratory's Regional Transmission Authority has a backlog of projects waiting to be build withing the Fermilab's service area. Fermilab intends to use Renewable Energy Certificates (RECs) in the near-term until EAC's are available for purchased. Fermilab is pursuing additional strategies for reducing greenhouse gas emissions including implementing best practices for operational efficiencies such as building retrofits and also partnering with the scientific staff to explore greenhouse gas emissions savings opportunities within our scientific activities.

Scope 1 & 2 Greenhouse Gas Emissions

Goal: Reduce direct GHG emissions by 50 percent by FY 2025 relative to FY 2008 baseline
Interim Target (FY 2022): -40.0%

Current Performance: -71.3%

	FY 2008	FY 2021 (PY)	FY 2022	% Change from Baseline	% Change from Last Year
Facility Energy	343,366.8	131,612.5	125,536.5	-63.4%	-4.6%
Non-Fleet V&E Fuel	142.6	116.0	113.7	-20.3%	-2.0%
Fleet Fuel	691.6	273.2	308.6	-55.4%	13.0%
Fugitive Emissions	40,165.1	441.4	308.9	-99.2%	-30.0%
On-Site Landfills	0.0	0.0	0.0	N/A%	N/A%
On-Site WWT	0.0	0.0	0.0	N/A%	N/A%
Renewables	0.0	0.0	0.0	N/A%	N/A%
RECs	0.0	-14,569.4	-15,865.8	N/A	8.9%
Total (MtCO2e)	**384,366.1**	**117,873.7**	**110,401.9**	**-71.3%**	**-6.3%**

Scope 3 Greenhouse Gas Emissions

Goal: Reduce indirect GHG emissions by 25 percent by FY 2025 relative to FY 2008 baseline
Interim Target (FY 2022): -19.0%

Current Performance: -64.2%

	FY 2008	FY 2021 (PY)	FY 2022	% Change from Baseline	% Change from Last Year
T&D Losses*	22,287.8	6,828.2	6,758.5	-69.7%	-1.0%
T&D RECs Credit	0.0	-959.7	-1,045.1	N/A	8.9%
Air Travel	2,215.8	144.2	1,236.0	-44.2%	757.1%
Ground Travel	168.9	111.2	77.6	-54.1%	-30.2%
Commute	4,633.3	2,634.2	3,372.4	-27.2%	28.0%
Off-Site MSW	191.8	157.2	150.8	-21.4%	-4.1%
Off-Site WWT	4.8	10.9	10.9	127.1%	0.0%
Total (MtCO2e)	**29,502.4**	**8,926.2**	**10,561.1**	**-64.2%**	**18.3%**

* Includes T&D losses for purchased renewable electricity

7.3 Underground Storage Tanks and Fuels

There are three (3) underground storage tanks (USTs) in use at the Site 38 Fuel Dispensing Facility. These are operated and maintained per current Illinois administrative statutes, codes, and regulations for USTs. The Illinois State Fire Marshall conducts an inspection on a biennial basis. The current UST dispensing permit was approved in December 2021 and is valid until December 31st, 2023.

The UST system continues to be inspected on a semi-annual basis by a qualified subcontracted vendor and on a daily, monthly, and quarterly basis by a Class A Certified UST Operator. These inspections ensure that the internal and external leak detection systems continue to function properly.

7.4 The Endangered Species Act of 1973

Impacts to endangered species are part of the Fermilab formal Environmental Review Process for all projects as required by the National Environmental Policy Act (NEPA). This review process includes definition of a project area and scope; if warranted, the review will identify threatened or endangered species within the area in addition to the potential to impact protected species and their critical habitat. No compliance issues were identified in 2022.

7.5 Executive Order 11988, "Floodplain Management"

Impacts to floodplains are considered as part of Fermilab's environmental review process under NEPA. Project information, such as total project area or if floodplain filling is required, are questions asked during a review. No floodplain issues were encountered during 2022. As part of Fermilab's Surface Water Management Program (SWaMP), on-site streams have been surveyed and mapped to collect data on sediment depth, field tile invert depths and in-stream structures. Hydrologic analysis was used to determine runoff from rainfall events of return frequencies ranging from 1-year to 100-years and durations of 1-hour to 48-hours. Hydraulic analysis has been completed to create flood profiles and inundation maps for 2-, 5-, 10-, and 100-year floods.

7.6 Clean Water Act (CWA) Section 404 (and Executive Order 11990, "Protection of Wetlands")

Evaluation of potential wetland impacts due to Fermilab activities continued to be accomplished primarily through the NEPA, ISD Design, and ISD Comment and Compliance review processes. The laboratory continued to use Task Manager/Construction Coordinator training to instruct participants in how to ensure that potential work areas are screened for the presence of wetlands and to be aware of all aspects of environmental compliance management. In July 2018, the U.S. Army Corps of Engineers issued a site-wide jurisdictional wetland determination for Fermilab. This determination allows the laboratory to perform work within non-jurisdictional exempt or isolated wetlands on site. The determination is valid for five years.

7.7 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

In 2022 the use of pesticides and herbicides at Fermilab were managed in accordance with FIFRA. Fermilab adheres to the principles of Integrated Pest Management to minimize pollution and adverse environmental impacts.

7.8 Illinois Department of Natural Resources "Rules for Construction and Maintenance of Dams"

The Department of Energy holds an IDNR issued permit that classifies the Main Injector berm as a small *Class III* dam. The dam provides limited flood control to areas downstream from Fermilab in the Indian Creek watershed. Fermilab reports to IDNR annually on the condition of the dam, and on a five-year cycle is required to perform a comprehensive inspection and file a detailed report on the condition of this structure. The comprehensive inspection was last conducted in April of 2018 and an "Owners Maintenance Report" was transmitted to the IDNR by DOE. The dam was again inspected in June 2022 and no non-routine action items were identified. A maintenance report was subsequently transmitted to IDNR.

7.9 The Migratory Bird Treaty Act

DOE has a memorandum of understanding (MOU) with the U.S. Fish and Wildlife Service (2013) which provides a number of measures designed to "protect and conserve" migratory bird habitat to the fullest extent practicable. Fermilab addresses this MOU by evaluating migratory bird impacts during completion of environmental reviews under

NEPA to avoid or minimize impacts to even the most common birds as much as reasonable.

Ecological land management across the Fermilab site continues to provide ample habitat communities and stopover resources for migratory birds. Additionally, Fermilab maintains a proactive approach to protection of the Canada goose population onsite while ensuring the safety of employees and visitors. Fermilab contracts with a firm to use dogs to harass geese to displace them from more heavily used operational areas on the site. The firm holds a valid permit from the IDNR to pursue this activity, which was carried out during the spring nesting season. Fermilab also possesses a Nuisance Wildlife Control Permit issued by the IDNR that allows for the destruction of Canada goose nests if they become a safety hazard. The permit allows the laboratory to destroy up to seven nests each year. During 2022, no nests were destroyed.

7.10 National Environmental Policy Act

Compliance with NEPA requires federal agencies to evaluate their proposed actions to determine the potential effects on the quality of the 'human environment,' which includes many different aspects of the natural environment, the built environment, and human health prior to carrying out those actions.

The Council on Environmental Quality and DOE NEPA regulations as well as DOE Order 451.1 prescribe an evaluation process to ensure that the proper level of review is performed before a commitment of resources is made. Categorical exclusions (CXs) are categories of actions that do not individually or cumulatively have a significant effect on the human environment and for which, therefore, neither an Environmental Assessment (EA) nor an Environmental Impact Statement (EIS) is required. During 2022, Fermilab met the NEPA requirements by continuing to implement a program to review all proposed activities and evaluate their potential effects; this program is set forth in the FESHM Chapter 8060 – National Environmental Policy Review. Most of the reviewed activities were considered "categorically excluded administrative actions" requiring no formal documentation (10 CFR 1021 Appendix A) or were designated to be within the list of DOE-preapproved Fermilab site-wide "categorically excluded routine maintenance activities" or "small-scale research and development projects" or "conventional laboratory operations". In 2022, four projects/actions needed to be addressed by submitting environmental evaluation notification forms to DOE for their review and approval.

7.11 National Historic Preservation Act (NHPA), Archaeological Resources Protection Act, Native American Graves Protection and Repatriation Act (NAGPRA) of 1990

Compliance with the National Historic Preservation Act (NHPA), Archaeological Resources Protection Act, Native American Graves Protection and Repatriation Act (NAGPRA) of 1990, as well as DOE Order 450.1 was accomplished through the NEPA review process. Fermilab follows a site-specific, DOE required Cultural Resources Management Plan (CRMP) based on guidelines outlined in DOE Publication DOE/EH-0501. The CRMP assures continued compliance with these Acts by providing a comprehensive overview for the locations and status of all cultural resources within the Fermilab site boundaries, facilitating future NEPA reviews. An evaluation of all proposed land-disturbing projects was conducted in 2022 to

assess potential impacts on historic resources. Updates to the CRMP will be completed by December 2023.

7.12 National Pollutant Discharge Elimination System

The IEPA has issued Fermilab three NPDES permits that were active in 2022. These permits are as follows:

1. *Individual NPDES permit for Non-Contact Cooling Water and Storm Water*
   This permit addresses combined storm water and non-contact cooling water discharges associated with industrial activities. Six outfalls are associated with this permit:

   - Outfall 001 discharging to Ferry Creek;
   - Outfall 002 discharging to Kress Creek; and
   - Outfalls 003, 004, 005, and 006 discharging to Indian Creek.

   Outfall 004 addresses potential discharges from the Main Injector Neutrino Oscillation Search (MINOS) experiment ICW holding tank. Outfalls 005 and 006 address discharges from the MI Pond system. The permit requires Fermilab to record and report to IEPA monthly certain physical and chemical discharge parameters. From all six outfalls water temperature, pH, flow and tritium are reported. Additionally, chlorine concentration is reported from outfalls 001 and 002 discharging to Kress and Indian Creeks.

   Permits are effective for five years. The most recent permit renewal became effective September 4, 2019. IEPA conducted a compliance evaluation inspection against elements of the permit on August 11th. No findings were reported.

2. *General NPDES Storm Water permit for Construction Activities*
   This permit is required for all projects that disturb greater than one acre. In 2022 the following projects were active.

   - Integrated Engineering Research Center Project
   - PIP II Project
   - LNBF Near Site Conventional Facilities Project

3. *General NPDES Permit for Pesticide Application Point Source Discharge*
   This permit applies to facilities that apply pesticides that may impact waters of the State. A 5-year permit renewal application was submitted to IEPA in 2021.

Additionally, Fermilab holds two industrial wastewater pre-treatment operating permits issued by IEPA (also covered under NPDES regulations and are described under Section 6.3.4, Releases to Sanitary Sewers).

7.13 Regulated Waste

Resource Conservation and Recovery Act

Federal RCRA regulations govern the management of hazardous waste. Fermilab maintains a permit under RCRA to manage for disposal or reclamation hazardous waste generated at the laboratory; Fermilab does not treat or dispose of regulated waste on site. Radioactive waste is not governed under RCRA and is managed following DOE requirements. All wastes are properly disposed though licensed waste handling, transport, or disposal facilities. An annual Hazardous Waste Report is transmitted to IEPA. Upon request, radioactive waste summaries are provided to DOE FSO.

RCRA Investigation Summary

On September 22, 2022, the USEPA performed a RCRA inspection of the Hazardous Waste Storage Facility (HWSF) located at Site 55 under observation of the IEPA. The purpose of the inspection was to evaluate compliance with the laboratory's Part B Permit for the storage of hazardous waste. The inspection revealed no violations.

Radioactive Waste

Fermilab's Hazard Control Technology Team (HCTT) is responsible for the overall management of Low-Level Radioactive Waste (LLRW); this includes all transportation related activities associated with shipping LLRW from Fermilab to designated DOE-approved disposal facilities. In FY 2022 (October 2021 through September 2022), Fermilab shipped 56.3 cubic meters of radioactive debris off-site.

Tritiated Water

The primary source of tritiated water requiring disposal from the laboratory is water accumulated from MI-65 due to the evaporator being out of operation. Water continues to be generated from MI-12, but the volume generated has decreased. At MI-12, a below-ground collection system is in place for the capture of water associated with a compromised liner surrounding the Booster Neutrino Beam Absorber at MI-12. Accumulated water is pumped to holding tanks at the surface where it is sampled for analysis of tritium. Water with tritium concentrations above the Derived Concentration Standard of 1,900 pCi/ml is characterized as low-level radioactive waste; this water is sent to EnergySolutions in Clive, Utah for treatment and disposal. In FY 2022, Fermilab disposed of 103,740 gallons of tritiated water.

Regulated Waste Disposal and Reclamation

Radioactive waste and non-radioactive waste are managed by HCTT. The following volumes of regulated waste were managed in calendar year 2022.

Waste Material	Volume (cubic meters)
Hazardous Waste (RCRA + Toxic Substances Control Act [TSCA])	8.7
Non-Hazardous Special Waste	40.2
Radioactive Waste (DOE Regulated)	449.0
"Mixed Waste" (Radioactive + RCRA Waste)	0.0

The following volumes of waste were generated by Fermilab and managed for reclamation/recycling by the HCTT in 2022.

Recycled/Reclaimed	Mass (kilograms)
Mercury Containing Equipment	19
Safety Kleen® Solvent	1,404
Oil Filters	204
Used Oil	5,389

7.14 RCRA Facility Investigation Activities

At SWMU 12, the pipes and clay tiles, along with all chromate-contaminated soil and gravel, have previously been removed. Contaminated soil was disposed of properly and the surrounding soil was sampled and analyzed. On a semi-annual frequency, Fermilab continues to sample monitoring wells installed at this unit. As approved by IEPA in 2017, the five shallow water table wells are no longer required to be monitored. Four new wells installed during summer 2019 are being sampled quarterly (required for a period of at least one year to evaluate any seasonal trends). Nine monitoring wells at SWMU 12 were sampled during 2022.

The following table summarizes the 2022 results at SWMU 12 from wells with results above either the Class I or Class II Groundwater Quality Standards.

Glacial deposit well MWD1 produced 2nd and 4th quarter total chloride results of 1,110 mg/L and 1,290 mg/L, respectively. The Class II Groundwater Quality Standard is 200 mg/L.

Parameter (mg/L)	Class II Groundwater Quality Standards	Glacial Deposit Monitoring Well: CUBD1/MWD1	
---	---	2Q2022	4Q2022
Chloride (total)	200	1,100	1,290
Lead (total)	0.1	U J	U J

Notes:
Grey Shading = Concentration Above the Class II Groundwater Quality Standard
U = Undetected
J = Estimated

Bedrock wells in 2022 produced no results above the Class I groundwater quality standards.

7.15 Safe Drinking Water Act

Fermilab's domestic water is purchased from the City of Warrenville. In addition, the laboratory currently retains five private wells at four sites: Site 29 [two wells]; Site 52 [Buffalo Barn]; Site 56 [Horse Barn]; and Site 58. These private wells did not require any water treatment or sampling in 2022. Estimates of water withdrawn from these wells are reported annually to the Illinois State Water Survey.

7.16 Superfund Amendments and Reauthorization Act TITLE III or Emergency Planning and Community Right-To-Know Act of 1986

Under the Superfund Amendments and Reauthorization Act (SARA) Title III Section 313, Fermilab is required to provide USEPA and the State of Illinois with an account of toxic chemicals over certain reporting thresholds that were manufactured, processed or otherwise used in a given year. Reporting is accomplished through the Toxic Release Inventory (TRI) reporting system on an annual basis. Fermilab reported three chemicals (lead, mercury, and polychlorinated biphenyls (PCBs) that exceeded the reporting threshold in calendar year 2022.

Additionally, under Tier II reporting requirements, Fermilab provides an annual report to state and local officials with a description of hazardous, toxic, and extremely hazardous chemicals used or stored onsite in quantities greater than their respective reporting thresholds.

7.17 Oil Spill Prevention

Fermilab's Spill Prevention Control and Countermeasures (SPCC) Plan complies with 40 CFR 112 – Oil Pollution Prevention. This USEPA-enforced regulation requires any facility that has the capacity to use or store more than 1,320 gallons of oil (petroleum, plant or animal oils, and fats) must write and implement a SPCC plan that encompasses all oil sources with a capacity of 55 gallons or more. In 2018, Fermilab updated its SPCC Plan

to ensure regulatory compliance, which was approved by a professional engineer familiar with both the regulation and Fermilab operations. The SPCC plan is detailed in FESHM Chapter 8031 as well as the laboratory's SPCC training required on an annual basis for those employees whose responsibilities include handling of oil in accordance with the regulation.

Fermilab has more than 700,000 gallons of oil on site, including more than 350 oil-filled transformers. In 2015, Fermilab developed a new SPCC database to improve overall management of the inventory. The database has helped to ensure the oil sources owned by each division/section remain in compliance with 40 CFR 112 by cataloging all inspections and the locations of oil sources. In 2022, the Lab continued compliance with 40 CFR 112. No reportable spills occurred in 2022.

7.18 Toxic Substance Control Act

There are no changes to the status of the groundwater at Main Ring service buildings B1 and B4 since it was determined in 2002 to be PCB-contaminated as a result of seepage of groundwater into the excavations after the completion of the phased cleanup in 2002. These locations could not be declared "clean", so Fermilab requested approval from USEPA to classify the residual PCB contamination as "disposed in place." USEPA approved the request with some conditions that included Fermilab placing a notice to the deed that identified the location of the contaminated groundwater and indicate that its use is restricted. This was accomplished in June of 2010. The laboratory was also required to notify the Agency in writing, at least 10 days prior to conducting any excavation activities that involve the removal of soil or other material in the area where the contaminated groundwater exists. If groundwater is encountered, it must be sampled, and all results must be reported to USEPA. Several internal mechanisms were created to ensure that these requirements were met, including placing signs at the affected locations, adding the locations to the Geographic Information System (GIS), and modifying ES&H review procedures.

7.19 Emerging Contaminants

The Fermilab Fire Department conducted limited training activities within the last few years with some expired 5-gallon buckets of foam that contained polyfluoroalkyl substances (PFAS). The foam was flowed onto a small section of a seldom-used asphalt road near the center of the Fermilab property. Due to the limited amount of foam used, the high percentage of clay in the subsurface deposits and the variable sorption information on PFAS compounds, there is a low likelihood that even the shallow groundwater zone would be impacted. USEPA-approved analytical methods for PFAS in soil are expected to be issued in 2023 and a sampling plan is being developed to evaluate Fermilab's PFAS impact at that time.

8.0 Pollution Prevention and Waste Minimization

Fermilab operates an established comingled recycling program that includes the recovery of paper, glass, plastic, and metal containers. In FY2022, Fermilab diverted for recycling 1,490 metric tons of municipal waste generated on site. The laboratory also recycles when possible various non-conventional items such as polystyrene packaging, disposable batteries, and scrap metal. Fermilab's scrap metal recycling program continued to be paused throughout 2022 as part of a review of laboratory's release criteria for materials.

Fermilab operates several additional non-conventional recycling and repurposing programs as part of the laboratory's waste management and diversion practices. These include a long-established agreement with local municipalities whereby neighboring cities are permitted to transport to Fermilab residential leaf litter they collect. The leaves are then used as a soil amendment for land used for row-crop agriculture on site. In 2022 1,307 metric tons of material was brought to the lab. Composting for kitchen/food scraps from the cafeteria and three other location sites generated one half ton that was taken off site for processing.

Fermilab recycled or donated for reuse 100% of eligible used computer equipment generated in 2022. This includes computing and electronic equipment including servers, printers, laptops, monitors, cellphones, tablets, and televisions. Donations for reuse is accomplished through DOE's Computers for Learning program. The total electronic waste generated for recycling in FY2022 was 2.7 tons. All recycled electronic waste was disposed of using a certified recycler.

Permanent dumpsters dedicated to recycling construction and demolition debris are staged on site. Fermilab maintains these dumpsters to encourage recycling of materials from small-scale construction projects and general maintenance activities. Fermilab Time and Materials (T&M) contractors have been directed to use these dumpsters for waste generated from projects. Additionally, larger fixed price construction projects typically include recycling opportunities. In FY2022, Fermilab diverted for recycling 728 metric tons of construction and demolition waste.

9.0 Environmental Radiological Protection Program and Dose Assessment

9.1 Radiological Dose Assessment

The total effective dose equivalent received by off-site and onsite members of the public during 2022 was a combination of the individual doses received through separate pathways. Doses were calculated following Fermilab procedure ESH-RP-ERPP-03, *Radiological Dose Assessment for the Annual Site Environmental Report*.

9.1.1 Dose to the Maximally Exposed Offsite Individual at the site boundary

The dose potentially received by the Maximally Exposed Offsite Individual (MEOI) from airborne emissions was calculated by the CAP-88PC Version 4.1.1.0 software to be 7.96×10^{-2} mrem (7.96×10^{-4} mSv). See Section 6.1 for additional details.

The dose received to the MEOI from penetrating radiation (including muons and skyshine) was estimated to be 0.65 mrem (6.5×10^{-3} mSv). See Section 6.2 for additional details.

The dose to the MEOI from the ingestion of water was estimated using the Derived Concentration Standard (DCS) from DOE-STD-1196-2021. The DCS is the concentration of the radionuclide in that medium that would result in an effective dose of 100 mrem (1 mSv) to a member of the public based on continuous exposure for one year. It should be emphasized that none of the water at the Fermilab outfalls is suitable for or known to be used as drinking water and would not be expected to be the only source of drinking water for an individual over the course of a year; however, this method is used to determine the maximum potential dose to the MEOI. In 2022, the only radionuclide detected in surface water was tritium. The highest annual average concentration of tritium at a Fermilab outfall was 5.8 pCi/mL at the Indian Creek outfall. Using this concentration as a fraction of the per capita DCS, the dose to the MEOI was estimated to be 0.22 mrem (2.2×10^{-3} mSv).

The maximum potential dose from the ingestion of fish in the water beyond the Fermilab outfalls was calculated using the per capita dose coefficient for tritiated water ingestion, 2.1×10^{-11} sievert per becquerel (Sv/Bq), from DOE-STD-1196-2021. For this calculation, the MEOI was assumed to consume 50 pounds of fish, conservatively rounded up from the United States Department of Agriculture (USDA) recommendation of 26 pounds per year. Other conservative assumptions include assuming that all fish consumed was caught in the water by the Indian Creek outfall, that the concentration of tritium within the fish was equivalent to the water concentration within the water, and that no water was lost during the cooking process of the fish. Using this calculation, the maximum potential dose from eating fish was estimated to be 1.0×10^{-2} mrem (1.0×10^{-4} mSv).

The potential total effective dose to the MEOI for 2022 was the sum of the airborne, direct radiation, and water pathways, 1.0 mrem (1.0×10^{-2} mSv). It is highly unlikely that such a combination of “maximized dose” to any single individual would occur, but the concept is useful for evaluating maximum potential dose and risk to members of the public. The potential total effective dose of 1.0 mrem (1.0×10^{-2} mSv) is well below the limit of 100 mrem/year (1 mSv/year) for a member of the public and is also far below the natural background dose

received by the typical American of 311 mrem (3.1 mSv) from National Council on Radiation Protection and Measurements (NCRP) Report No. 160, *Ionizing Radiation Exposure of the Population of the United States*.

9.1.2 Dose to the MEI onsite

The dose to the MEI onsite from air emissions was calculated using CAP-88PC Version 4.1, similarly to the dose offsite. For the purposes of the onsite dose, the location used was the public area onsite nearest the location of the stacks, approximately 300 meters in the north-northeast direction near the Lederman Science Center. For the purposes of determining a maximum, bounding dose, all emissions were assumed to be released from a central stack location in the Muon Campus; however, many stacks are located more than 300 meters from the location. For continuous occupancy, the dose received by the MEI onsite from air emissions would be 0.34 mrem (3.4×10^{-3} mSv); however, since the public is only permitted onsite from dawn-to-dusk, the maximum potential dose to the onsite MEI would be 0.17 mrem (1.7×10^{-3} mSv). Adjusting for a more realistic occupancy of 400 hours per year (approximately 1 day per week or 1 hour per day), the potential dose to the onsite MEI from airborne emissions would be 1.7×10^{-2} mrem (1.7×10^{-4} mSv).

As discussed in section 6.2, a network of environmental dosimeters was placed in indoor and outdoor locations to assess potential doses to Fermilab workers and members of the public. The dose in most publicly accessible areas is indistinguishable from background. Of the environmental dosimeters located in areas where public access is allowed, the highest dose would be received in a location along the Linac fencing. For continuous occupancy and assuming a member of the public occupied this location every day of the year, the maximum dose received from penetrating radiation by the onsite MEI would be 11 mrem (1.1×10^{-1} mSv) per year. Adjusted for the site access hours of dawn-to-dusk, the maximum dose received from penetrating radiation by the onsite MEI would be 5.5 mrem (5.5×10^{-2} mSv) per year. Adjusting for the more realistic occupancy of 400 hours per year, the potential dose to the onsite MEI would be 0.55 mrem (5.5×10^{-3} mSv) per year. It should be noted that it is extremely unlikely that a member of the public would reside in the location by the Linac fencing for the full 400 hours and would be more likely to occupy additional locations with lower dose rates during their time onsite.

The potential total effective dose to the onsite MEI for 2022 using realistic occupancy assumptions was the sum of the airborne and direct radiation pathways, 1.0 mrem (1.0×10^{-2} mSv). As with the MEOI, it is highly unlikely that such a combination of “maximized dose” to any single individual would occur, but the concept is useful for evaluating maximum potential dose and risk to members of the public. The potential total effective dose for 2022 of 1.0 mrem (1.0×10^{-2} mSv) is well below the limit of 100 mrem/year for a member of the public and is also far below the natural background dose received by the typical American of 311 mrem (3.1 mSv) from NCRP Report No. 160, *Ionizing Radiation Exposure of the Population of the United States*.

9.1.3. Collective Dose

Approximately nine million people were estimated to live within 50 miles (80 kilometers) of Fermilab according to the 2020 census. For air emissions, the collective effective dose

equivalent was calculated using CAP-88 as required for reporting under 40 CFR 61, Subpart H. The collective dose equivalent for 2022 was calculated to be 4.6 x 10^{-1} person-rem (4.6 x 10^{-3} person- sievert [Sv]).

For direct radiation, the site boundary dose discussed in section 9.1.2 was adjusted by the inverse square law to the midpoint distance of the population grid for each sector. This estimated dose was assigned to the population within the sector and the dose for each sector was summed. The estimated dose from direct radiation for 2022 was 1.4 person-rem (1.4 x 10^{-2} person-Sv).

The only liquid discharge which is used for a community drinking water system is from the Batavia sanitary treatment plant, which is discharged into the Fox River. The City of Aurora (population 180,542 persons as of the 2020 census) uses the Fox River as a community drinking water system. Accounting for the minimum flow volume of the Fox River (101,000,000 gallons/day), the average tritium concentration in the Fox River in Aurora is estimated to be 1.9 x 10^{-3} pCi/mL (7.0 x 10^{-2} Bq/L). This average concentration resulted in an estimated collective dose of 1.3 x 10^{-2} person-rem (1.3 x 10^{-4} person-Sv) using the per capita DCS from DOE-STD-1196-2021.

The total collective dose from all pathways was 1.9 person-rem (1.9 x 10^{-2} person-Sv). There is no regulatory limit for collective dose.

9.1.4 Summary

The dose to the MEOI and the collective population compared to the respective limits and doses received from natural background are summarized below.

Pathway	Dose to the MEOI mrem/year (mSv/year)	MEOI Percent (%) of the DOE 100 mrem/year Limit	Estimated Natural Background mrem/year (mSv/year)	Estimated Annual Collective (population) Dose person-rem (person-Sv)	Population within 80 km	Estimated Annual Background Radiation Population Dose person-rem (person-Sv)
Air	8.0 x 10^{-2} (8.0 x 10^{-4})	0.08%	N/A	4.6 x 10^{-1} (4.6 x 10^{-3})	9.1 x 10^{6} persons	N/A
External	6.5 x 10^{-1} (6.5 x 10^{-3})	0.65%	N/A	1.4 x 10^{0} (1.4 x 10^{-2})	9.1 x 10^{6} persons	N/A
Water	2.3 x 10^{-1} (2.3 x 10^{-3})	0.19%	N/A	1.3 x 10^{-2} (1.3 x 10^{-4})	180,542 (City of Aurora)	N/A
All Pathways	1.0 (9.6 x 10^{-3})	1.0%	311 (3.1)	1.9 (1.9 x 10^{-2})	9.1 x 10^{6} (9.1 x 10^{4})	2.8 x 10^{6} (2.8 x 10^{4})

The dose to the onsite MEI compared to the respective limits and doses received from natural background is summarized below.

Pathway	Dose to the Onsite MEI (400 hr. occupancy time) mrem/year (mSv/year)	Onsite MEI Percentage of the DOE 100 mrem/year Limit	Estimated Natural Background mrem/year (mSv/year)
Air	1.7×10^{-2} (1.7×10^{-4})	0.02%	N/A
External	5.5×10^{-1} (5.5×10^{-3})	0.55%	N/A
Water	N/A	N/A	N/A
All Pathways	5.7 x 10-1 (5.7×10^{-3})	0.6%	311 (3.1)

9.2 Radiological Clearance of Property and Metals Release Suspension

Fermilab has an established program that requires potentially activated or contaminated material and equipment to be monitored prior to release from control. Fermilab uses DOE pre-approved authorized limits for radioactive surface contamination. DOE Order 458.1 does not prescribe a specific limit for release of volumetrically activated materials; therefore, Fermilab survey procedures require monitoring such that equipment and materials being released contain no detectable radioactivity. The program involves many hundreds of radiological surveys annually. Fermilab does not release any residual radioactive material, such as contaminated concrete or soil, so there are no resulting dose impacts to the public.

Fermilab has operated an active scrap metal recycling program for many years. The program includes policies and procedures to ensure that the DOE secretarial mandates regarding the moratorium and suspension on the release of scrap metals from departmental sites is not violated. Historically, as a general operating principle, Fermilab has not released radioactive metals as scrap. Beginning in 2000, to comply with the suspension directive, the laboratory began holding non-radioactive scrap metals originating from radiological areas (as defined by 10 CFR 835). This material has been accumulating since the suspension became effective. Direct impacts as a result of the suspension include the loss of scrap revenue, the costs associated with the management and storage of this material and the potential future cost of disposal if it cannot be scrapped.

Fermilab's established material screening process has incorporated numerous ongoing improvements that have been made since 2000, including a Material Move Request (MMR) form to clearly identify and document which metals are eligible for recycling. These metals were then subjected to multiple hand-held radiation surveys and must have passed successfully through the vehicle scrap monitor before leaving the site. In 2021, Fermilab paused the clearance of metal to develop and implement enhancements to the program to incorporate the guidance from DOE-STD-6004-2016, *Clearance and Release of Personal*

Property from Accelerator Facilities (May 2016). The new process was approved in 2022; however, metal was not cleared for recycling in 2022.

Fermilab did not release any real property in 2022.

9.3 Biota Dose Assessment

DOE O 458.1 requires the protection of populations of aquatic animals, terrestrial plants, and terrestrial animals in local ecosystems from adverse effects due to radiation and radioactive material released from DOE operations. DOE O 458.1 also provides a graded (tiered) approach to evaluating biota protection. In 2022, Fermilab used the DOE Technical Standard, DOE-STD-1153-2019, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (February 2019) and the associated RESRAD-BIOTA code (Version 1.8) to evaluate compliance with the biota protection requirements. Doses were assessed for compliance with the DOE standard presented in DOE-STD-1153-2019, as summarized below.

DOE Category	Average Dose Rate Criteria
Aquatic Animals	Absorbed dose < 1 rad per day (rad/d) (10 milligray per day [mGy/d])
Riparian Animals	Absorbed dose < 0.1 rad/d (1 mGy/d)
Terrestrial Plants	Absorbed dose < 1 rad/d (10 mGy/d)
Terrestrial Animals	Absorbed dose < 0.1 rad/d (1 mGy/d)

Doses to aquatic and terrestrial organisms were estimated using the maximum measured concentrations of radionuclides in surface water, sediment, and soil. In 2022, the only radionuclide detected in surface water was tritium. The maximum surface water concentration was 16.6 pCi/ml (614 Bq/L) in the Booster Pond E. No radionuclides were detected in soil samples. Tritium and Be-7 were detected in sediment samples with the highest concentrations of 5.57 pCi/g (0.21 Bq/g) and 0.9 pCi/g (0.03 Bq/g) respectively. The summed total ratio for aquatic organisms was 1.05×10^{-4}. The summed total ratio for terrestrial organisms was 7.19×10^{-5}. Therefore, all locations passed the general screening phase using maximum radionuclide concentrations and default parameters for Biota Concentration Guides.

9.4 Unplanned Releases

There were no unplanned releases of radionuclides during 2022.

10.0 Conclusion

Fermilab operations during 2022 had no significant adverse impact on the environment or on public safety. An emphasis on compliance with regulations and requirements and environmental stewardship remains a high priority for the laboratory.

11.0 Acronyms

The following acronyms and abbreviations are used in this report.

AFFECT	Assisting Federal Facilities with Energy Conservation Technologies
ALARA	As Low as Reasonably Achievable
APS-TD	Applied Physics and Superconducting Technology Division
ASER	Annual Site Environmental Report
BNB	Booster Neutrino Beam
CAP88PC	Clean Air Act Assessment Package – 1988
CFR	Code of Federal Regulations
Ci	Curie
CO	Carbon Monoxide
COVID-19	Coronavirus Disease 2019
CPL	Cavity Processing Lab
CRMP	Cultural Resources Management Plan
CUB	Central Utility Building
CWA	Clean Water Act
Cx	Categorical Exclusion
DCS	Derived Concentration Standard
DOE	Department of Energy
EA	Environmental Assessment
EAC	Environmental Attribute Certificate
ELM	Ecological Land Management
EMS	Environmental Management System
EH&S	Environment, Safety, and Health
EIS	Environmental Impact Statement
EPCRA	Emergency Planning and Community Right-To-Know Act
EPD	Environmental Program Department
Fermilab	Fermi National Accelerator Laboratory
FESHM	Fermilab Environment, Safety, and Health Manual
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FREP	Fermilab Resilience and Efficiency Project
FSO	Fermilab Site Office
FY	Fiscal Year
GBq	Gigabecquerel
GeV	Giga-electron Volt
GHG	Greenhouse Gas
GIS	Geographic Information System
HAP	Hazardous Air Pollutants
HWSF	Hazardous Waste Storage Facility
HCTT	Hazard Control Technology Team
IAC	Illinois Administrative Code
IB4	Industrial Building 4
ICW	Industrial Cooling Water

IEPA	Illinois Environmental Protection Agency
IDNR	Illinois Department of Natural Resources
ISD	Infrastructure Services Division
ISO	International Organization for Standardization
kGal	1,000 Gallons
kW	Kilowatt
LBNF	Long-Baseline Neutrino Facility
LLRW	Low-Level Radioactive Waste
MCenter	Meson Center
MEI	Maximally Exposed Individual
MEOI	Maximally Exposed Offsite Individual
mg/L	Milligrams per Liter
MOU	Memorandum of Understanding
mrem	Millirem
mSv	Millisieverts
MTest	Meson Test
MI	Main Injector
mGy/d	Milligray per Day
MINOS	Main Injector Neutrino Oscillation Search
mmBTU	Million British thermal units
MMR	Material Move Request
MTA	MeV Test Area
MW	Megawatt
NAGPRA	Native American Graves Protection and Repatriation Act
NCRP	National Council on Radiation Protection & Measurements
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NOvA	NuMI Off-axis ν_e Appearance
NOx	Nitric Oxide
NPDES	National Pollutant Discharge Elimination System
NuMI	Neutrinos at the Main Injector
%	Percent
PCB	Polychlorinated Biphenyl
pCi/ml	Picocurie per milliliter
PFAS	Polyfluoroalkyl Substances
PIP	Proton Improvement Plan
PM	Particulate Matter
POTWs	Publicly Owned Treatment Works
Rad/d	Rad per Day
RCRA	Resource Conservation and Recovery Act
REC	Renewable Energy Certificate
RFI	RCRA Facility Investigation
ROSS	Registration of Smaller Sources
SARA	Superfund Amendments and Reauthorization Act
SO_2	Sulfur Dioxide
SPCC	Spill Prevention Control and Countermeasures
Sv	Sievert

Sv/Bq	Sievert per Becquerel
SWaMP	Surface Water Management Program
SWMU	Solid Waste Management Unit
SWPPP	Storm Water Pollution Prevention Plan
T&M	Time and Materials
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act
USDA	United States Department of Agriculture
UST	Underground Storage Tank
USEPA	United States Environmental Protection Agency
VOM	Volatile Organic Material

12.0 References

Fermilab, “Annual Site Environmental Report, Calendar Year 2021”

Fermilab, Chemical Waste Tracking System

Fermilab, Radioactive Waste Tracking System

Littleton, B., “CAP88-PC Version 4.1 User Guide”, (last accessed 04/17/2023) https://www.epa.gov/sites/default/files/2019-11/documents/cap88-pc_4.1_user_guide.pdf

National Council on Radiation Protection and Measurements, “Ionizing Radiation Exposure of the Population of the United States”, NCRP Report No. 160 (2009).

U.S. Code of Federal Regulations, Title 40, Part 61, Subpart H, “National emissions standard for hazardous air pollutants (NESHAP) for the emission of radionuclides other than radon from Department of Energy Facilities” (1989).

U.S. Department of Energy, “Radiation Protection of the Public and the Environment”, DOE O 458.1 (Initial issue February 11, 2011, current version as of this writing is Chg. 4, September 15, 2020).

U.S. Department of Energy, “Clearance and Release of Personal Property from Accelerator Facilities”, DOE-STD-6004-2016 (May 2016).

U.S. Department of Energy, “A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota”, DOE-STD-1153-2019 (February 2019).

U.S. Department of Energy, “Derived Concentration Technical Standard”, DOE-STD-1196-2021 (July 2021).