Fermilab

May 22, 2025

Tritium Management Update for CAB

Chris Greer and Christine Salinas
Tritium Management Department

U.S. DEPARTMENT of ENERGY
Fermi National Accelerator Laboratory is managed by FermiForward for the U.S. Department of Energy Office of Science

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Fermilab safety

Your safety is our priority – please note the following:

For your safety, please use handrails, walk (don't run), stay alert for hazards, and follow all posted signs and security directions. When driving onsite, obey speed limits and watch for pedestrians, cyclists, and wildlife. In an emergency, follow your escort's instructions.

Emergency contacts ☎

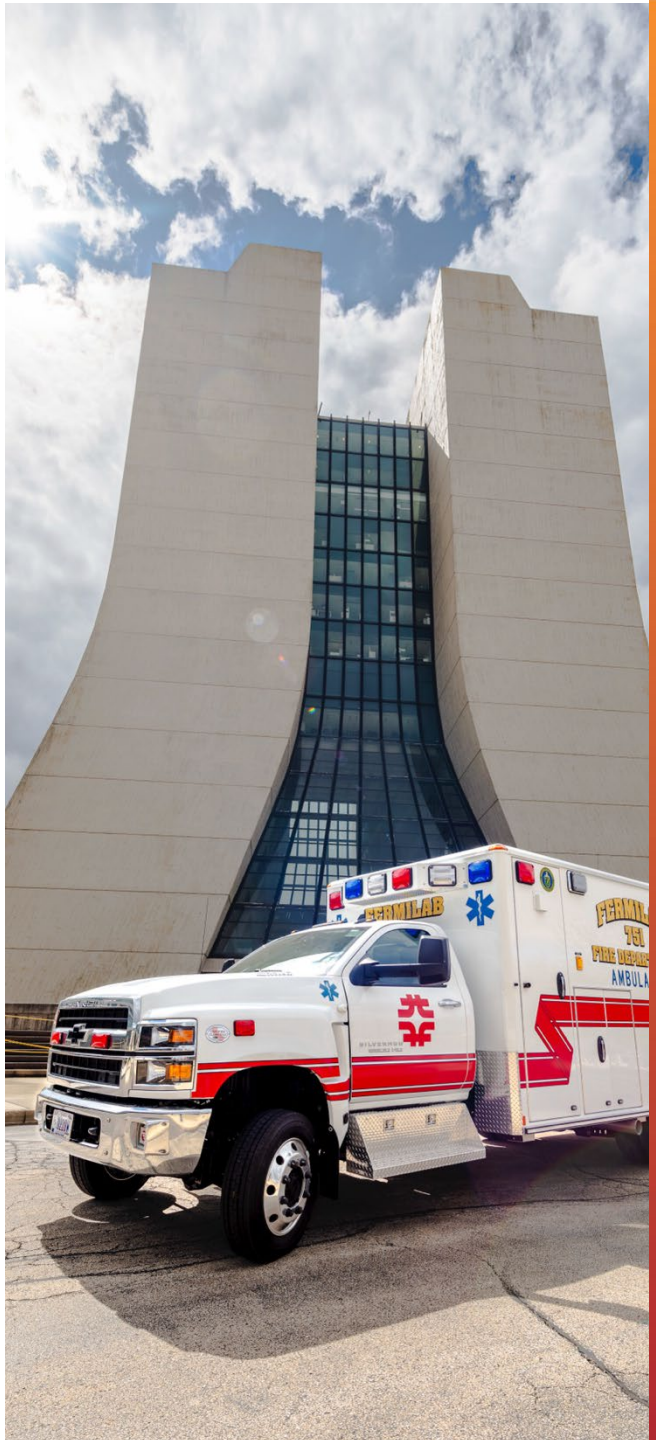
- **Emergencies (medical/security):** 630-840-3131
- **Nonemergencies:** 630-840-3414

Fire alarms

- Evacuate immediately using the nearest exit.
- Gather outside at the Ramsey Auditorium doors.
- Follow Fermilab personnel and **do not** re-enter until cleared by the Fire Department.
- Stay out of the road.

Tornado sirens

- Go to the nearest designated shelter in Wilson Hall's basement.
- Remain there until the warning is canceled or expires (via SEWS).
- Follow Fermilab personnel.



Agenda

Today

- ✓ Tritium History at Fermilab and Tritium 101
- ✓ Tritium Monitoring
- ✓ Tritium Management Actions
- ✓ Public Communication

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01

History at Fermilab and Tritium 101

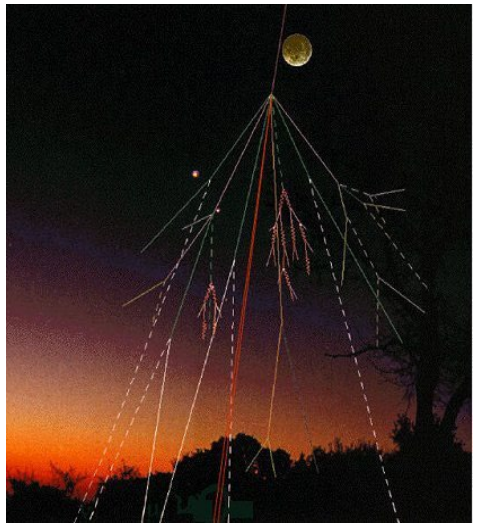
Tritium and Environmental Monitoring at Fermilab

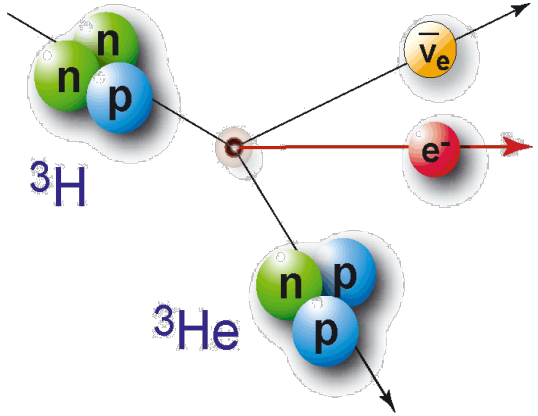
- Fermilab has had an environmental monitoring program for about 50 years.
- In 2005, the program detected, for the first time, tritium in surface water and in the sanitary sewer on the Fermilab site.
  - We immediately informed the regulatory agencies, our neighbors and employees and the public.
  - August 2024 article by Robert Crease: Had a leak from your science facility? Here's how to deal with the problem – Physics World (https://physicsworld.com)
- Levels were, and continue to be, well below already conservatively protective regulatory limits.
  - Highest level has been <20% of limit; the rest are <1% of limits
- We strive to minimize tritium discharges, keep the public informed, and seek input on our plans and goals.
- We have a Tritium Task Force and a Tritium Management Dept that implement improvements to reduce tritium levels
  - The TTF includes accelerator and engineering experts as well as Environment, Safety and Health (ESH) and DOE staff

Tritium 101

Background and basics

- Tritium (^3H) is a weakly radioactive form of hydrogen with a half-life of 12.3 years.
  - In nature, tritium is produced when cosmic particles hit the atmosphere.
  - Residual from nuclear tests (pre-1970s).
  - At Fermilab and other particle accelerators, tritium is a byproduct of operation.
- Its decay emits particles of very low energy that cannot penetrate the skin.
- Tritium can only be harmful if people drink water with high levels of tritium over many years.
  - Tritium does not build up in biological tissues; the biological half-life for tritiated water (HTO) is about 12 days.





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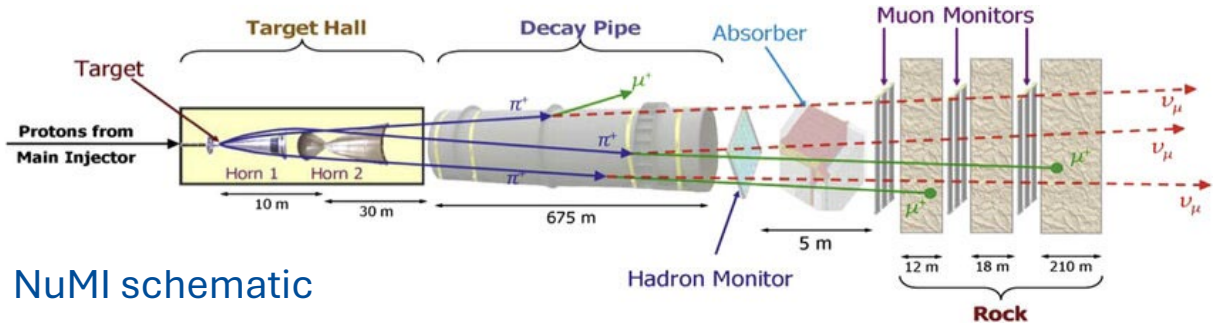
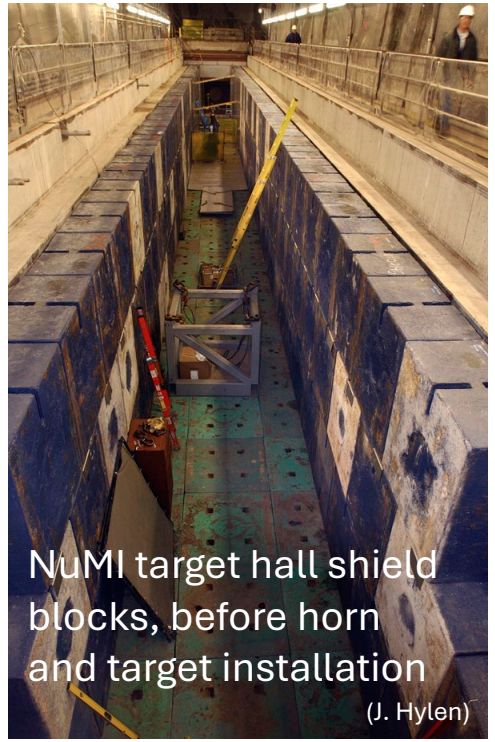
Tritium: A Byproduct of Accelerators

- High-energy protons hitting or traveling through materials produce tritium (^3H).
  - Typical materials used in experiments at Fermilab: iron, concrete, carbon, air, water, etc.
- When protons or other particles hit nuclei in the atoms in materials, they "shatter" these nuclei into pieces.
  - Some are stable, others are radionuclides like ^3H.
- Upon exposure to air, the ^3H atoms combine with oxygen to make HTO molecules (tritiated water) with the same structure as H_2O (water).
  - HTO "water" moves just like regular water.



NuMI schematic



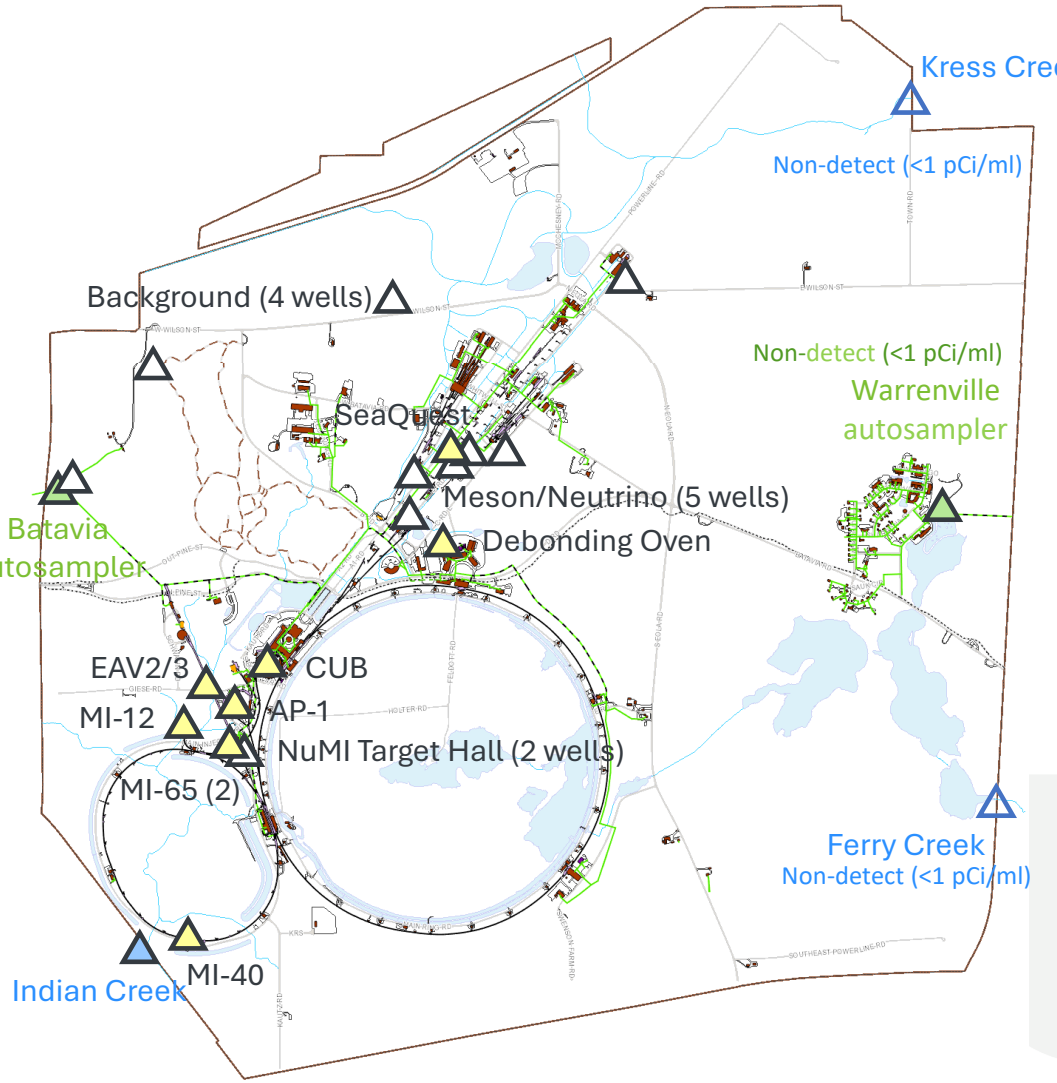
NuMI target hall shield blocks, before horn and target installation (J. Hylen)

Far detector in MN (no tritium production)

02

Tritium Monitoring

	2024 results as % of Limit:
Sanitary Sewer	
• 5 Ci in a year	**3.4%**
Surface Water	
• 2,600 pCi/ml	**<0.2%**
Groundwater	
• 1 pCi/ml (Class 1 Resource Aquifer in bedrock)	**Non-detect (<1 pCi/ml)**
Air (all Accelerator-Produced Isotopes, or APIs)	
• 10 mrem/year dose from all emissions	**All APIs: 1.49% Tritium: 0.0038%**
• 0.1 mrem/year from single highest emission point (monitoring goal)	**All APIs: 31.4% Tritium: 0.38%**



Tritium Discharges at Boundaries in 2024 Relative to Regulatory Limits

Aligned with DOE Orders and Standards, Illinois Administrative Code and NESHAPS Procedures (40 CFR Part 61 Subpart H: National Emissions Standards for Hazardous Air Pollutants from DOE Facilities)

Standards for Surface and Drinking Water

- DOE Surface water limit for offsite discharge: 2,600 pCi/ml (picocuries per milliliter).
- Federal limit for drinking water systems: 20 pCi/ml. Fermilab surface water is NOT drinking water.

What do these standards mean?

- 1 picocurie (pCi) = 0.037 atoms decaying each second.
- Threshold for measurement is usually taken to be 1 pCi/ml.
  - A user of 2,600 pCi/ml water for their household water source full time would receive a radiation dose of 100 mrem each year. For comparison, a head CT scan creates about 200 mrem (source: NRC). https://www.nrc.gov/about-nrc/radiation/around-us/doses-daily-lives.html
  - A user of 20 pCi/ml water for their household water source is assigned a dose of 4 mrem each year by U.S. EPA.
  - Globally, rainwater is 0.16 to 0.32 pCi/ml due to cosmic rays and leftovers from nuclear weapons tests (ending in 1960s).

How Surface Water at Fermilab Connects to the Community

3 creeks leave Fermilab

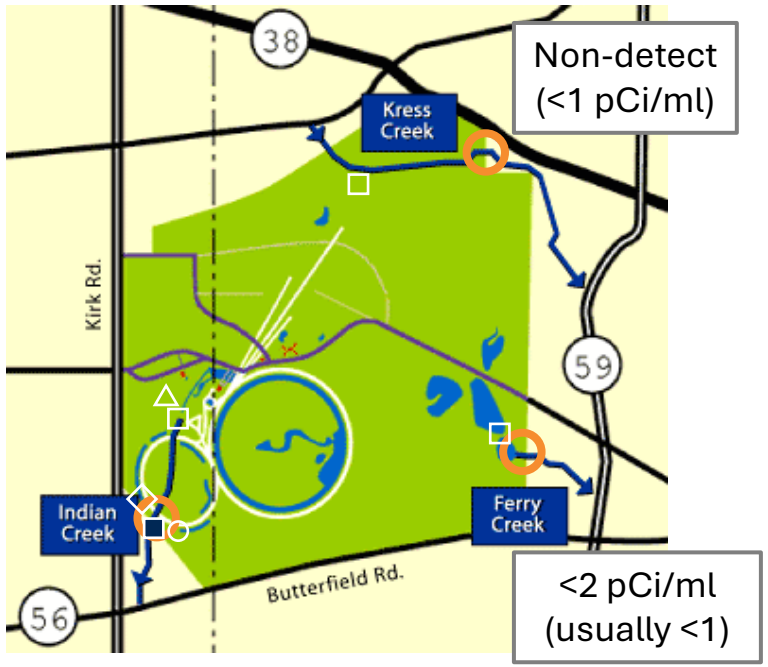
- The Fermilab site has numerous ponds and is the origin of Indian Creek and Ferry Creek
- Kress Creek originates offsite then flows onsite then offsite again

Fermilab uses water to cool accelerators and other equipment

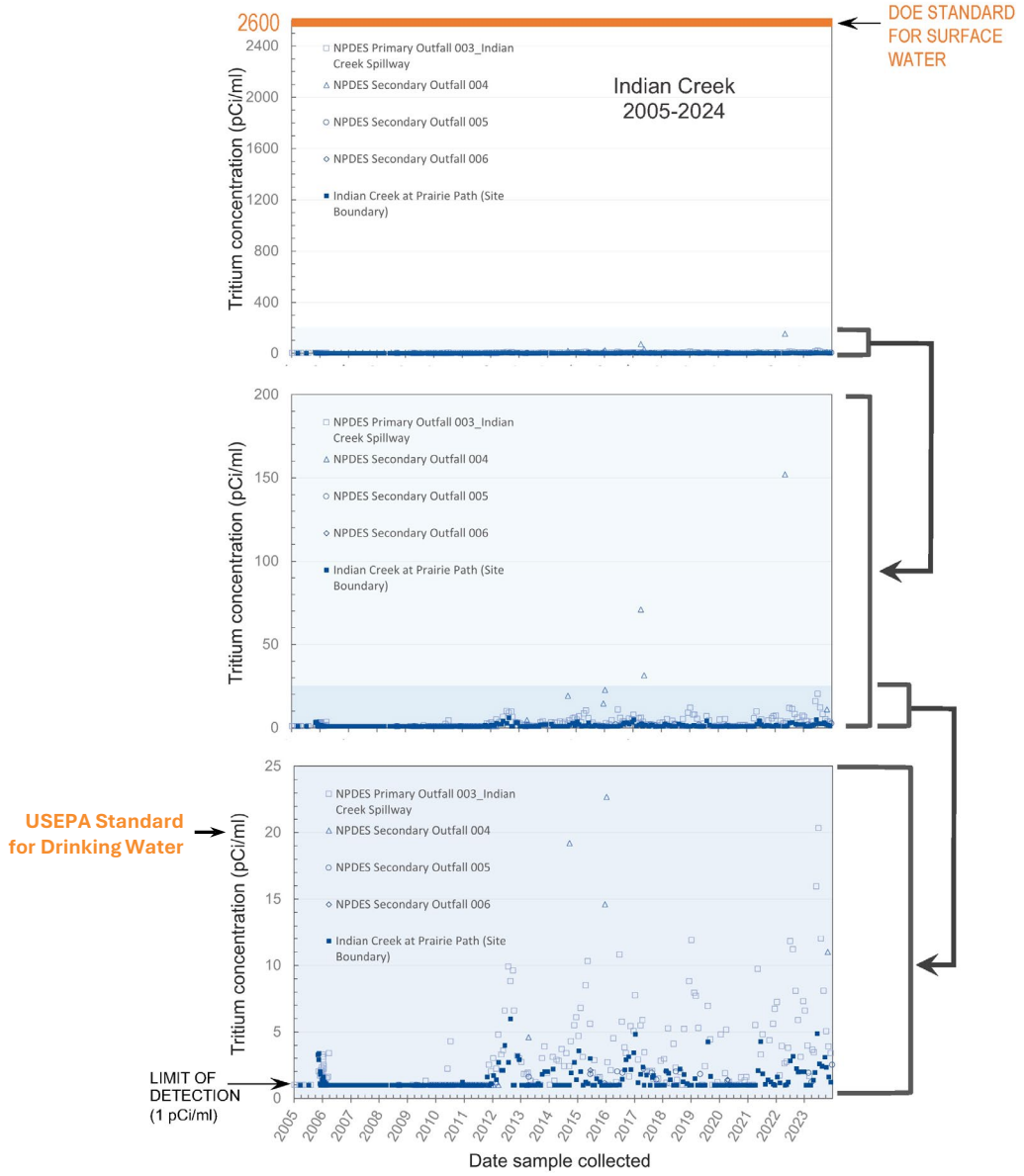
- Our pond system is part of an “industrial cooling water system” (ICW)
- A total of ~250,000,000 gallons, replenished primarily by precipitation

Surface Water Boundary Results: Indian Creek

- 6 pCi/ml or lower
- Regulatory limit: 2,600 pCi/ml
- Inputs: 1 primary and 3 secondary NPDES outfalls (National Pollutant Discharge Elimination System)



Data plots and maps for all three creeks online at: https://www.fnal.gov/pub/tritium



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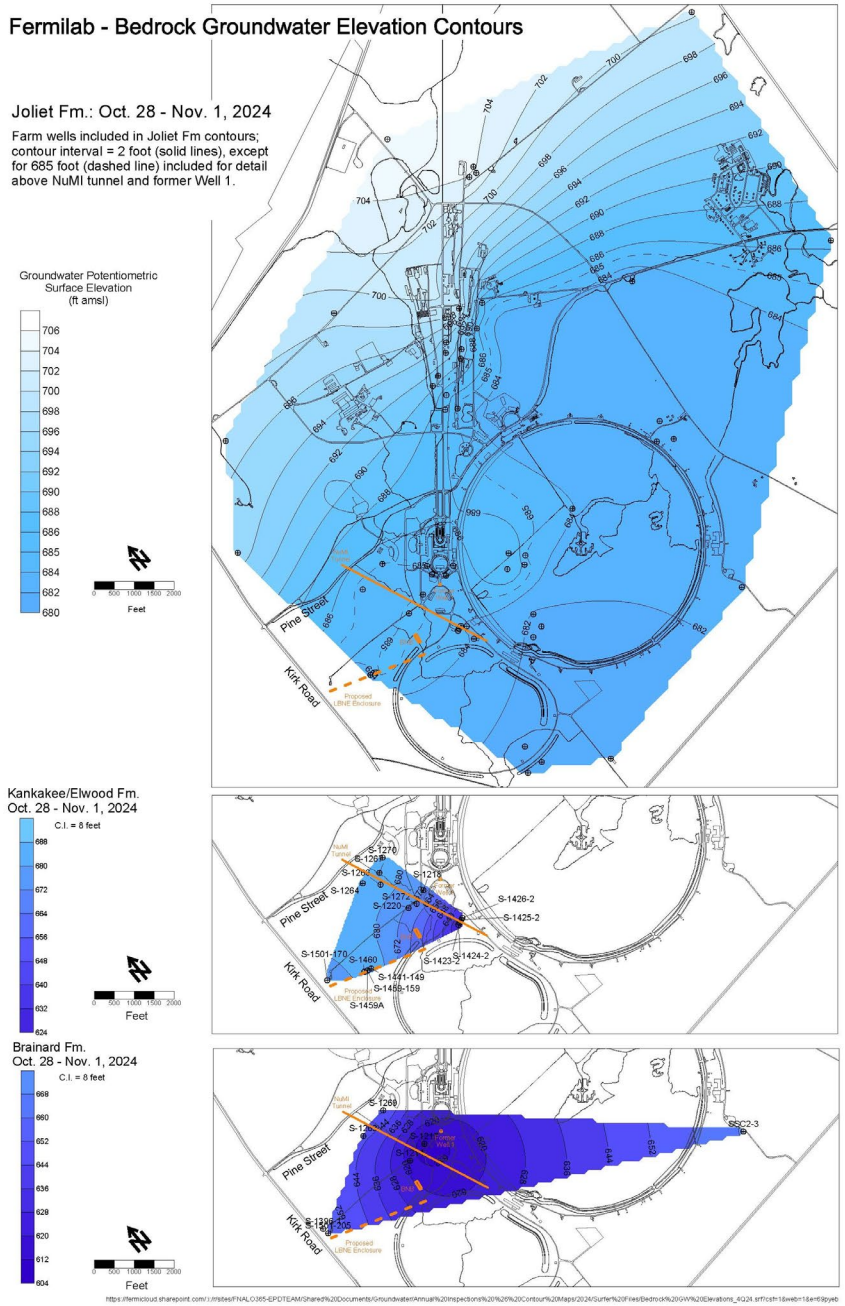
Groundwater

- We must protect Illinois Class I “Resource” Groundwater.
  - Found in bedrock beneath Fermilab (60-90 feet deep).
  - Must stay below 1 pCi/ml in Class I aquifers (i.e, those considered by Illinois to be “useful” for drinking water).
- We design and operate our experiments so that any tritium produced stays out of groundwater.
  - Fermilab employs a hydrogeologist on its staff as an advisor.
- We have never found tritium in Class I groundwater.
  - Eleven bedrock wells are sampled annually.
  - More than 100 wells are measured annually to determine flow directions.



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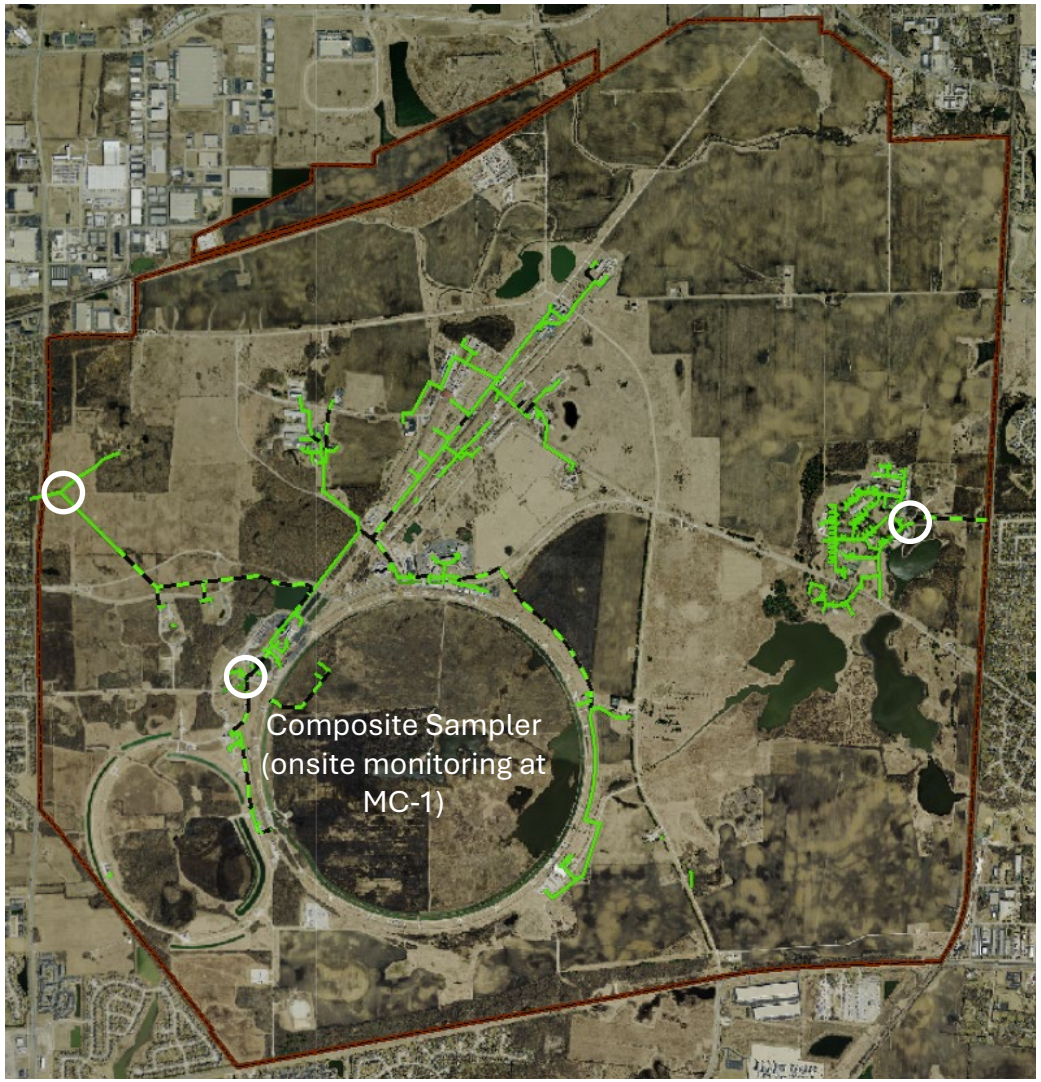
Sanitary Sewer

Routine Autosampler Locations (additional ad hoc sampled manhole vaults not shown)

Composite Sampler (to Batavia system, NPDES Permit)

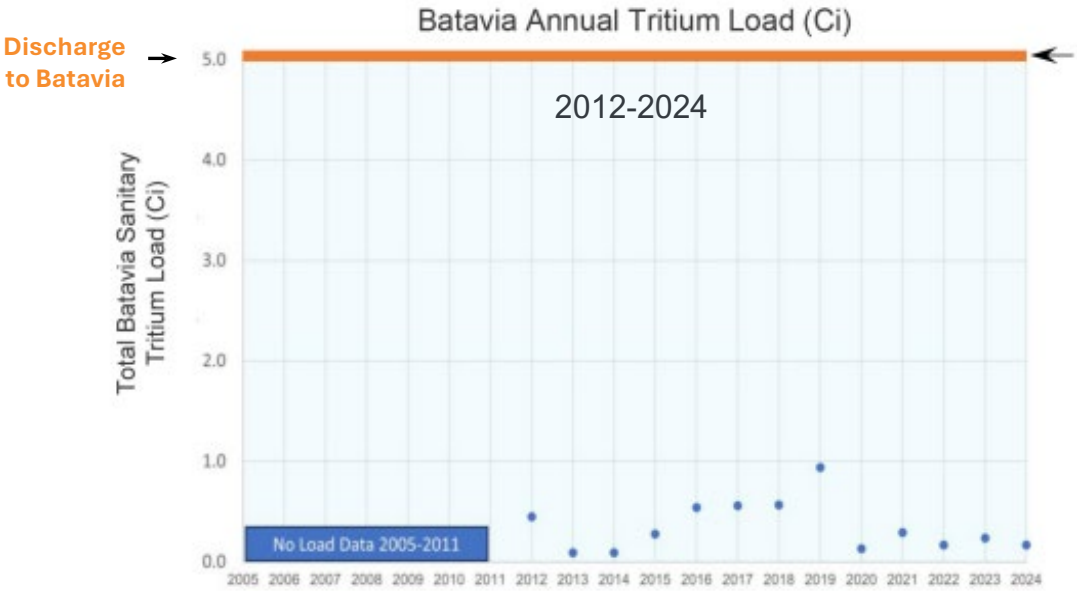


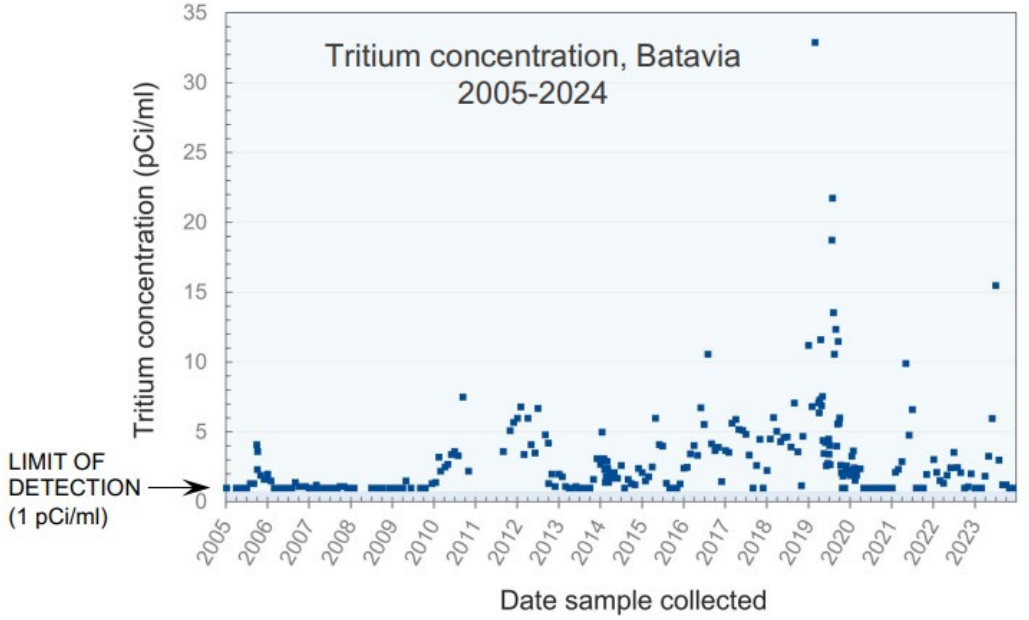
Composite Sampler (to Warrenville system, NPDES Permit)

Non-detect (<1 pCi/ml)

Sanitary Sewer Boundary Results: Batavia

- 2024 annual total activity load was 3.4% of the 5 Curie annual limit
  - Beam power was higher than in 2019 but condensate is now:
    - Routed away from sanitary sewer system during periods of high concentration and
    - Shipped offsite for disposal while a new evaporator system is being designed
- <35 pCi/ml (usually <20 pCi/ml)





Data plots online at: https://www.fnal.gov/pub/tritium

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03

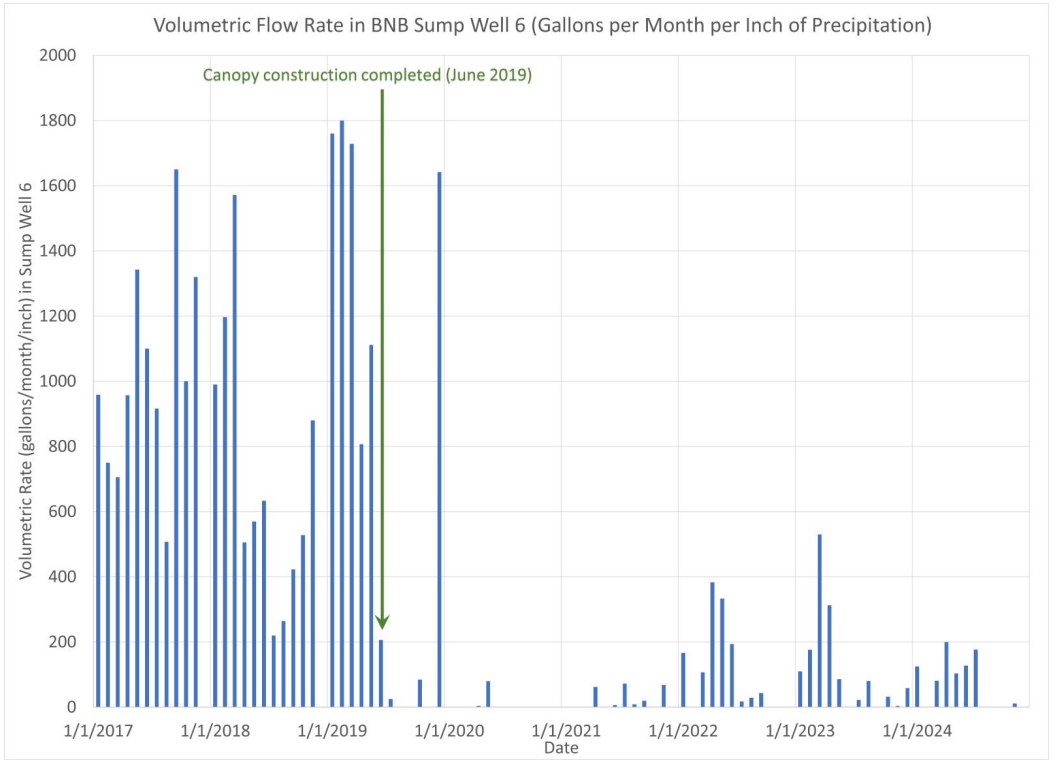
Tritium Management Actions

Tritium Management Actions

Booster Neutrino Beam (BNB)

- In 2019 we completed installation of a canopy and liner over the BNB berm, under which we produce neutrinos for Short Baseline Neutrino (SBN) experiments
  - Infiltration reduced by >90%, which means less HTO is produced
  - First phase shallow groundwater monitoring wells: all <1 pCi/ml since 2021
    - Bedrock wells to be installed this year and added to routine sampling program

BNB Canopy:
Highly-customized “farm shed” including skylight panels, egress doors and a removable section for absorber access



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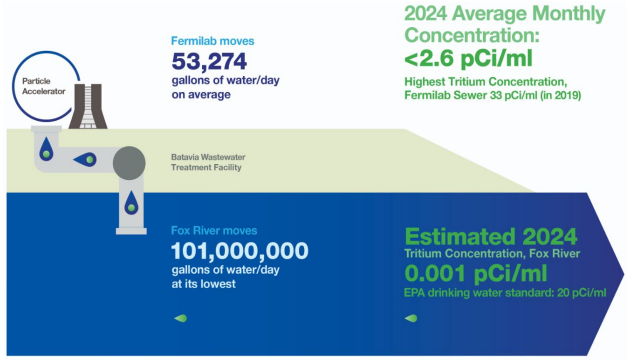
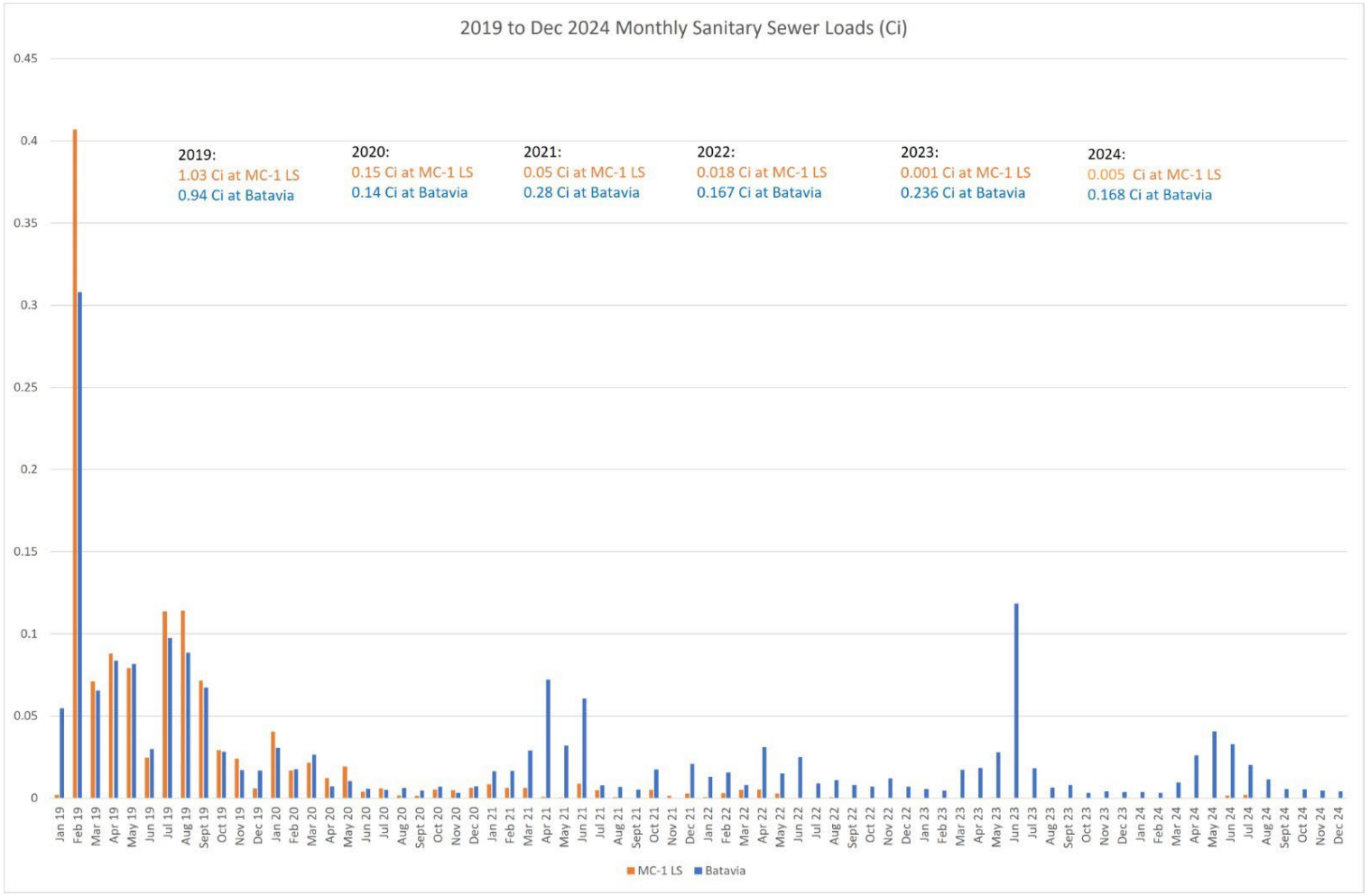
Tritium Management Actions

A Closer Look into the Sanitary Sewer

- Rerouting in Main Injector has reduced tritium load (total Ci) to 0.005 Ci at MC-1 Lift Station
  - Diverted water is presently being shipped offsite
- 2024 offsite flow (0.17 Ci) was well below the 5 Ci in a year limit
  - Resulting concentration in the Fox River (0.001 pCi/ml) is indistinguishable from background precipitation concentrations





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Tritium Management Actions

Recommendations from Latest External Review and DOE Assessment

2022 external review of Fermilab tritium management

- Commendations included: BNB canopy, applying lessons learned to LBNF design, public communication
- Recommendations included: expand automated and groundwater monitoring, elevate and expand tritium management and funding, Industrial Cooling Water management

2024 DOE Assessment of multiple programs, focusing on tritium

- Five commendations, including changes to Rad Worker training and Radionuclide Analysis Facility (RAF) data management and Quality Assurance/Quality Control
- Findings:
  - 11 recommendations, including: performing a self-assessment for new TM Dept., improve procedure formats, completing release and clearance programs, RAF incorporation of MARLAP testing, etc.
  - One sampling methodology non-conformance for passive diffuser vials
    - Implemented immediate adjustment from monthly to weekly sampling to eliminate non-conformance
    - A real-time monitor is in the pilot testing phase to replace the passive diffuser vial testing

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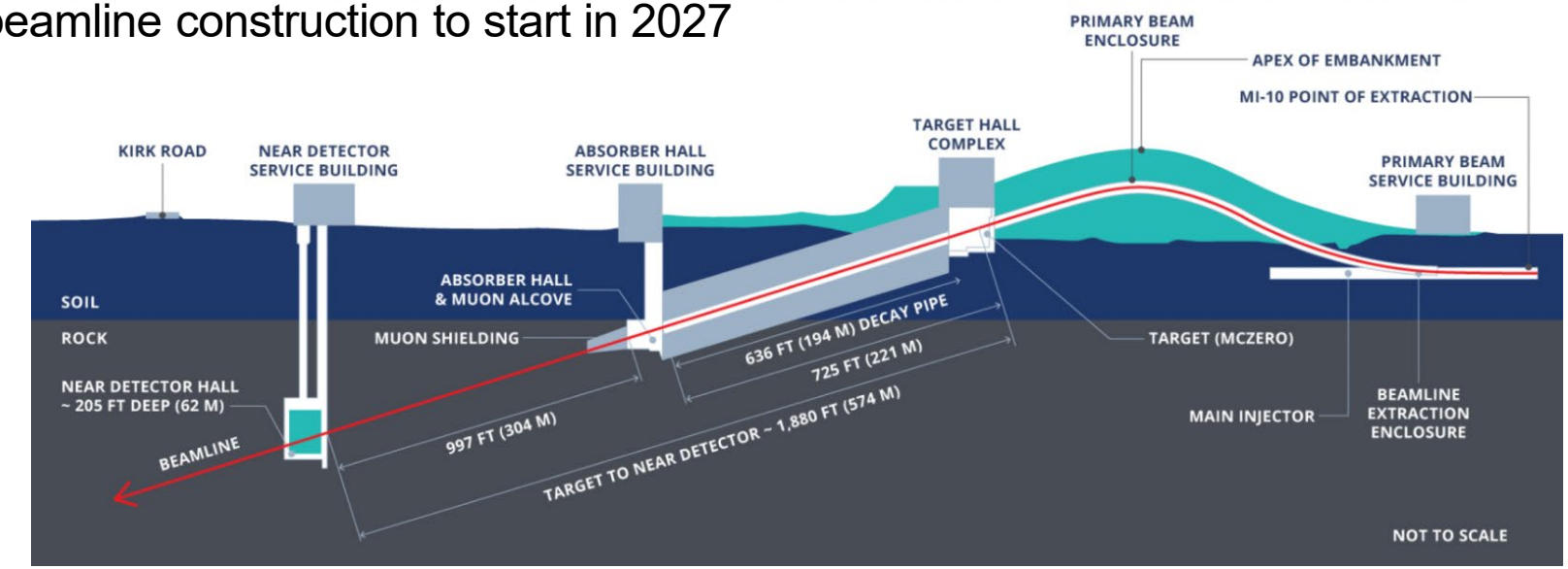
Tritium Management Actions

Long Baseline Neutrino Facility (LBNF) Near Site Design

Similar concept to NuMI, but keeping the production of tritium well below regulatory limits is a major focus on the design of this new, higher beam power facility via:

- Excluding, rather than capturing, groundwater along the active Near Site beamline at Fermilab
- Reducing the total depth of Near Site construction into bedrock, especially the active beamline portion
- Active beamline portion is separate from the Near Detector
- Changed the original decay pipe design to allow in-person verification and servicing of shielding to reduce tritium risks
- Maintaining a nitrogen atmosphere rather than ambient air atmosphere in the target chase during beam operation

Near Site beamline construction to start in 2027



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04

Public Communication

Keeping the Public Informed

- We held Environmental Assessment meetings for LBNF/DUNE in 2015.
- We inform the Community Advisory Board.
- We update and post tritium data on our public tritium webpages.
- The DOE Fermi Site Office sends a summary of tritium monitoring results at Fermilab to local officials every year.
- Also publicly available:
  - Annual environmental reports
  - FESHM Chapters
    - Fermilab ESH Manual

Questions for the CAB

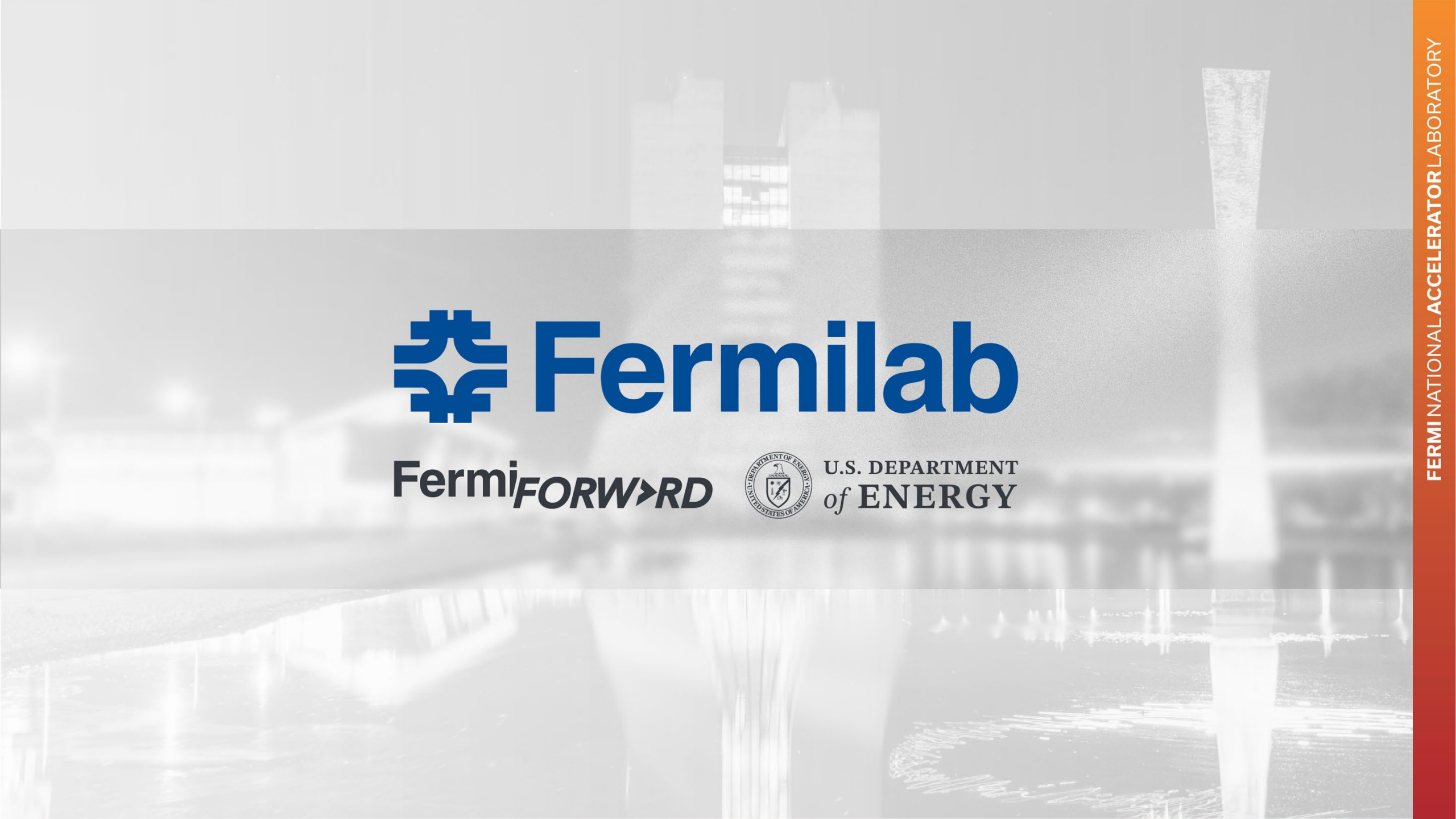
Members of the Community Advisory Board are one of Fermilab's connections to the community. As such, we'd like to know:

- How should we keep the community informed and maintain a dialogue?
- Are there specific groups or persons we should reach out to?
- What questions and recommendations do you have?

We strive to be good stewards of the Fermilab site. Please let us know if you have concerns.

Questions from the CAB?

1. …?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