Fermilab

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August 30, 2012

Mr. Michael J. Weis
Site Manager
Fermi Site Office
U. S. Department of Energy
P. O. Box 2000
Batavia, Illinois 60510-5011

Dear Mr. Weis,

SUBJECT: National Environmental Policy Act (NEPA) Environmental Evaluation Notification Form (EENF) for the Long Baseline Neutrino Experiment Project

Teri Dykhuis, of the Environment, Safety & Health Section, has concluded that a NEPA determination is needed for the above mentioned action. Please review the attached notification and let us know of your decision.

If you have any questions concerning this information, please contact Teri at X3607.

Sincerely,

Jack W. Anderson
Chief Operating Officer

Attachments: EENF (31 pages)

cc w/o attachment: S. Arnold (DOE)
N. Grossman (ESH)
R. Hersemann (DOE)
Y.-K. Kim (DIR)
P. Oddone (DIR)
J. Scott (DOE)

ES&H File: NEPA EENFs

FERMILAB ENVIRONMENTAL EVALUATION NOTIFICATION FORM (EENF)

for documenting compliance with the National Environmental Policy Act (NEPA), Department of Energy (DOE) NEPA Implementing Regulations, and the DOE NEPA Compliance Program of DOE Order 451.1

Project/Activity Title: Long Baseline Neutrino Experiment (LBNE)
ES&H Tracking Number: 01097

I hereby verify, via my signature, the accuracy of information in the area of my contribution for this document and that every effort would be made throughout this action to comply with the commitments made in this document and to pursue cost-effective pollution prevention opportunities. Pollution prevention (source reduction and other practices that eliminate or reduce the creation of pollutants) is recognized as a good business practice which would enhance site operations thereby enabling Fermilab to accomplish its mission, achieve environmental compliance, reduce risks to health and the environment, and prevent or minimize future Department of Energy (DOE) legacy wastes.

Fermilab Project Director: Elaine McCluskey (X2193)
Signature and Date Elaine McCluskey

Fermilab Project ES&H Manager: Mike Andrews (X8472)
Signature and Date

Introduction

This Project was reproposed in June 2012 to be a phased program under the existing DOE Critical Decision (CD)-0 Mission Need. The Phase 1 LBNE Project would be presented for CD-1 approval and its scope is listed in this EENF. The Phase 2 LBNE Project is proposed to be managed as a separate project with a new CD-1 to begin several years later.

However, if non-DOE funding for Phase 2 can be found before the Phase 1 CD-2, the Phase 2 scope may be incorporated into the Phase 1 project before base lining. The currently understood Phase 2 scope would include a near neutrino detector at the Near Site (Fermilab) and the replacement of the 10 kiloton surface far detector at the Far Site (Sanford Underground Research Facility at Homestake or Sanford Laboratory) with the same size detector at the 4850 Level of Sanford Laboratory. The Phase 2 scope and environmental impacts are described in Section 4 of this document.

Description of the Purpose and Need for the Proposed Action and Alternatives Considered

1 Justification for the Project

This section outlines why the project is needed and what alternatives have been considered.

1.1 Purpose and Need

On January 8, 2010, the Department of Energy approved the Mission Need for a new long-baseline neutrino experiment that would enable this world-class program and firmly establish the U.S. as the leader in neutrino science. The LBNE Project is designed to meet this Mission Need.

With the facilities provided by the LBNE Project and the unique features of the experiment – in particular the long baseline, the broad-band beam and the high resolution of the detector – the LBNE Science Collaboration proposes to mount a broad attack on the science of neutrinos with sensitivity to all known parameters in a single experiment. The focus of the program would be the explicit demonstration of leptonic Charge Parity (CP) violation, if it exists, by precisely measuring the asymmetric oscillations of muon-type neutrinos and antineutrinos into electron-type neutrinos and antineutrinos.

The experiment would enable the most precise measurements of the neutrino oscillation parameters, in particular, the CP-violating phase in the three-flavor framework, and the search for new physics that would show up as deviations from this model. A configuration of the LBNE facility, in which a large neutrino detector is located deep underground, could also provide opportunities for research in other areas of physics, such as nucleon decay and neutrino astrophysics, including studies of neutrino bursts from locally occurring supernovae.

Specifically, the goals of the experiment are:
1. Is there CP violation in the neutrino sector? The existence of matter this late in the universe's development requires CP violation at an early stage, but the amount seen in the quark sector is much too small to account for the matter that we observe in the universe. CP violation in the lepton sector may provide the explanation.
2. Is the ordering of the neutrino mass states the same as that of the quarks, or is the order inverted? In addition to being an important question on its own, the answer has a major impact on our ability to determine whether the neutrino is its own antiparticle. If true, it could reflect physics at energy scales much greater than those probed at the Large Hadron Collider.
3. Is the proton stable? Proton decay would require violation of baryon number conservation, and such violation is needed to account for the matter-antimatter asymmetry in the universe. The answer would provide clues to the unification of the forces of nature.
4. What physics and astrophysics can we learn from the neutrinos emitted in supernova explosions?

1.2 Alternatives Considered

Many alternatives have been considered in developing the configuration for the LBNE Project. The decision process has involved the LBNE Collaboration, the LBNE Project Management, the Fermilab Directorate, and the DOE Office of High Energy Physics and the Office of Science.

A conceptual design was prepared in March 2012 for a robust LBNE configuration after many alternates were studied [1]. DOE determined that this configuration was not affordable and

asked for a phased program and possible alternates through a reconfiguration process [2]. The process and its outcome are described in the LBNE Reconfiguration Report [3]. This outcome produced a phased LBNE program with the concurrence of DOE [4].

The following sections describe alternatives that were studied and choices that were made during both the original conceptual design process leading to the full LBNE configuration in March 2012, as well as additional studies done during the reconfiguration process and the choices made for the resulting configuration.

1.2.1 Detector Technology

Two far detector technologies were studied and evaluated prior to a decision in January 2012. Extensive design work and physics sensitivity studies looked at both a 200-kiloton single-module water Cherenkov detector and a 34-kiloton dual-module liquid argon time projection chamber (LAr-TPC). Although a configuration using a combination of both technologies would be preferable for physics, the cost was prohibitive.

After an extensive decision-making process involving multiple stakeholders, the LAr-TPC option was selected based on scientific capabilities and potential to expand detector technologies. As noted in the decision document [5] "...a LAr TPC offers the best opportunities for LBNE to do world-leading science. It would give us the cleanest oscillation signals and ultimately provide the best chance of observing CP violation; it would produce the best limits on proton decay, relative to other operating detectors in the world; and would produce unique information about a galactic supernova, should one occur during the lifetime of the experiment, and, together with other existing or planned experiments, provide the broadest view of such a once-in-a-lifetime event. This path would bring this important detector technology to full maturity, with potential applications to future experiments. The potential for substantial international collaboration would make a stronger LBNE."

1.2.2 Far Site Selection and the Experimental Baseline

The location of the Far Detector determines the experiment baseline, defined as the distance been the proton source and the Far Site detector, which is a key parameter in the experiment's sensitivity to neutrino oscillations. To obtain the appearance spectrum of electron neutrinos with the best physics sensitivity, the longest practical baseline length consistent with the expected energy spectrum of muon neutrinos from the available proton accelerator sources is needed. The optimum baseline for scientific reasons for LBNE is between 1000 and 1500 kilometers.

In addition to the baseline, the location of the far detector should be in a location where the detector can be placed at a substantial depth underground to improve the performance for the accelerator-based neutrino oscillation measurements, and to enable the non-accelerator-based research of LBNE. The rock at such a location must, furthermore, be of sufficient strength and quality to allow reliable excavation of large caverns required for the massive LBNE Far Detector and yield structures that would permit reliable access to and operation of the LBNE detectors for several decades. It is desirable, although not required, that the rock be of relatively low

radioactivity to improve capabilities to do utilize low-energy signatures for the non-accelerator-based physics program. Finally, it must be in a direction from Fermilab in which it is feasible to construct a neutrino beam, given the constraints of the location of the Main Injector and other components of the Fermilab complex relative to the site boundaries.

As part of the LBNE March 2012 conceptual design, the Sanford Laboratory underground site at 4850L had been chosen as the optimum for the physics topics to be studied. As part of the LBNE Reconfiguration process after March 2012, additional sites at other baselines were studied:

- Siting the detector on the surface at Sanford Laboratory with a 1300 km baseline
- Siting the detector on the surface at the University of Minnesota Ash River site of the NOvA detector with a 810 kilometer baseline
- Siting the detector underground at the University of Minnesota Soudan Underground Laboratory with a 735 kilometer baseline

To achieve all of the fundamental science goals listed above, it was recognized that a reconfigured LBNE would need a very long baseline (>1,000 km from accelerator to detector) and a large detector deep underground. However, it is not possible to meet both of these requirements in a first phase of the experiment within the budget guideline of approximately $700M – $800M. With the determination that the two most important initial physics goals were #1 and #2, as outlined in section 1.1, detector masses were estimated that would fit within the cost cap for each option.

With these and other factors in mind, the LBNE Reconfiguration Steering Committee identified the pros and cons for the three options [3]. As stated in their report, The Steering Committee "... strongly favored the option to build a new beamline to Homestake with an initial 10 kiloton LAr-TPC detector on the surface. The physics reach of this first phase is very strong; more over this option is seen by the Steering Committee as a start of a long-term world-leading program that would achieve the full goals of LBNE in time and allow probing the Standard Model most incisively beyond its current state. Ultimately this option would exploit the full power provided by Project X. At the present level of cost estimation, it appears that this preferred option may be ~10% more expensive than the other two options, but cost evaluations and value engineering exercises are continuing."

This option also allowed for the far detector in Phase 2 to move underground to the 4850L at Sanford Laboratory.

The head of the Office of Science, Dr. William Brinkman, provided his concurrence with the preferred option in a letter to Dr. Pier Oddone on June 29, 2012.

1.2.3 Proton Beamline

The point at which the proton beam is extracted from the Fermilab Main Injector depends on the direction the resulting neutrino beam is to be aimed. Therefore, one needs to choose the destination of the neutrino beam before designing the extraction point and primary beamline. The proton beam for the NuMI neutrino beam is extracted from the Main Injector at MI-60 and is

aimed northwest toward the Soudan Mine in northern Minnesota. For the LBNE conceptual design, the former Homestake Mine in Lead, South Dakota is chosen as the destination for the neutrino beam, setting the experiment baseline at 1,300 km. Although Lead is nearly due west of Fermilab and extraction from a different region of the Main Injector may seem more practical, the initial choice was for the LBNE beam to use the same extraction point as the NuMI beam.

As part of Conceptual Design Value Engineering efforts, the Project developed four different variations on the beamline configurations: extraction at MI-60 with a deep beamline; extraction at MI-60 with a shallow beamline; extraction at MI-10 with a deep beamline; and extraction at MI-10 with a shallow beamline. Cost ranges and feasibility concepts were developed for each of the options and were presented to the DOE in April 2011. The four options were reviewed extensively by the Neutrino Beamline Technical Board between March and June 2011, and in the end of June 2011 two of the four options were selected for further development and consideration. The selected options are being referred to as MI-60 Deep and MI-10 Shallow, see Figures 1 and 2. Both options were compared with the same decay pipe length and muon range-out distance (the minimum length/distance required to achieve the physics goals). The MI-10 Shallow option presented a number of challenges, but offered a substantial cost savings.

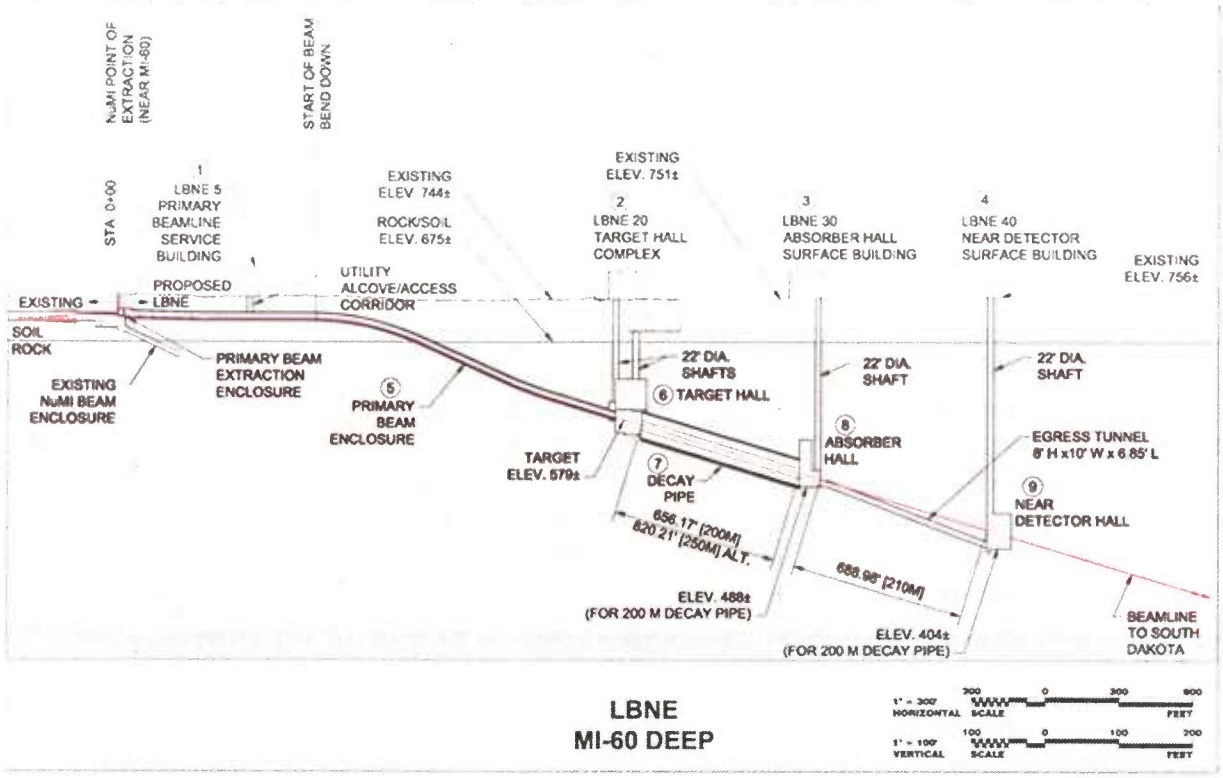

Figure 1 MI-60 Deep Longitudinal Section/Profile with an exaggerated vertical scale of 3 to 1.

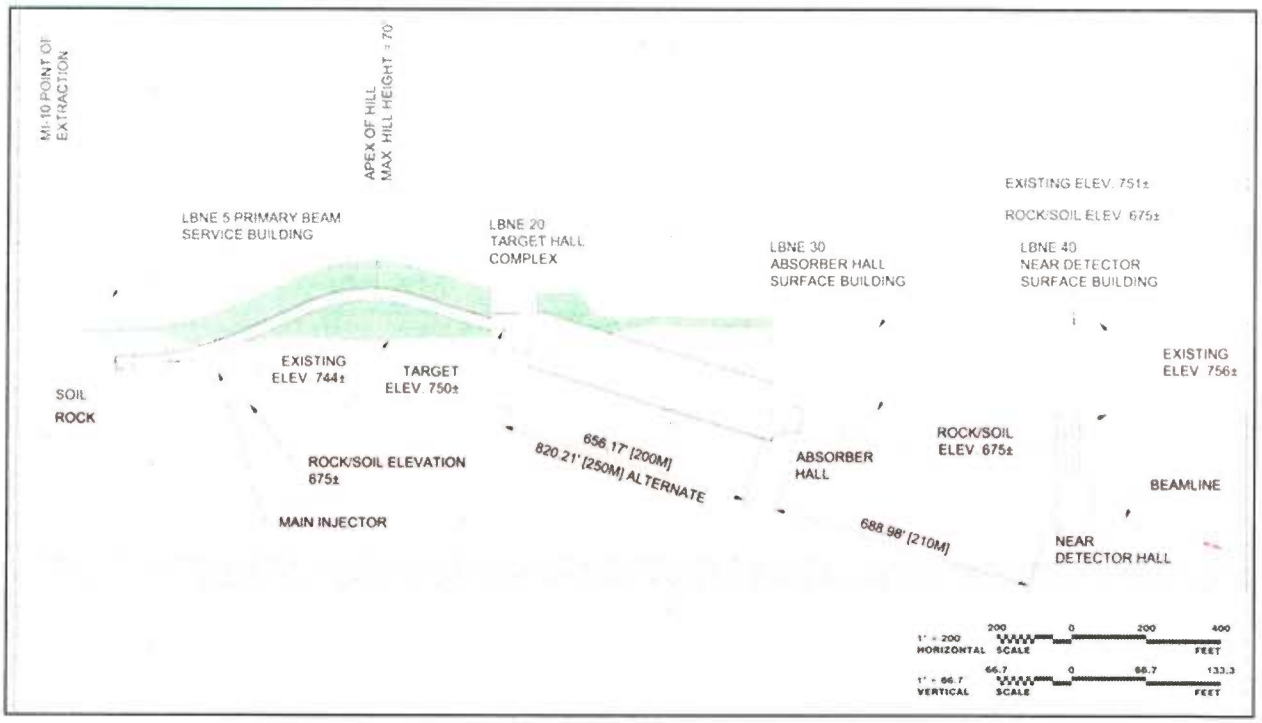

Figure 2 MI-10 Shallow Longitudinal Section/Profile with an exaggerated vertical scale of 3 to 1.

The primary reasons for choosing the MI-10 Shallow option are detailed in the report on the "Decision on the LBNE Beamline Depth and Extraction Point" paper [6], and are as follows:

1. Site boundary constraints do not prohibit the feasibility of either option.
2. Moving the majority of the facility closer to the surface makes much of the construction, installation, maintenance, operations, decommissioning and disposal of the facility and components more affordable.
3. The MI-10 Shallow configuration technical component installation is easier as it includes a shorter beamline and more straightforward magnet installation.
4. Innovative decay pipe cooling methods can be utilized in a more affordable way without introducing water cooling.
5. Locating the Target Hall above existing grade reduces the humidity and allows for the tritium mitigation to occur further downstream in the beamline facility.

1.2.4 No Action Alternative

The 'no action' alternative would not fulfill the purpose and need.

2 Proposed Action

This section provides an overall picture of the proposed action for the LBNE Project, including as much information as currently exists at this pre-conceptual level.

2.1 Narrative Description

The LBNE Project scope includes construction of experimental systems and facilities at two separate geographical locations. We present a reference design for achieving LBNE's mission in which a proton beam extracted from the Fermilab Main Injector (MI) is used to produce a neutrino beam. The neutrino beam traverses near detectors a few hundred meters downstream before traveling through the Earth's mantle to a detector located 1,300 km away in the Sanford Underground Laboratory, the site of the former Homestake Mine in Lead, South Dakota. The 1,300-km separation between the sites presents an optimal baseline for LBNE's neutrino-oscillation physics goals.

The main Phase 1 scope elements on the Fermilab site, also referred to as the Near Site, include:

- magnets and support equipment to transport the extracted protons to the target (where approximately 85% of them interact, producing pions and kaons)
- a target and target hall
- magnetic focusing horns to direct pions and kaons into a decay tunnel
- a decay pipe where these particles decay into neutrinos
- a beam absorber at the end of the decay pipe to absorb the residual secondary particles
- near detectors to make beamline measurements
- conventional facilities at Fermilab to support the technical components of the primary proton beam, the neutrino beam and the near detectors

The main scope elements at the Sanford Laboratory site, the Far Site, include:

- the Far Detector
- infrastructure required for the Far Detector
- conventional facilities at Sanford Laboratory to house and support the technical components of the Far Detector

2.1.1 The Near Site

The Phase 1 design for the LBNE Project at the Near Site incorporates extraction of a proton beam from the MI-10 location at the Main Injector, which then determines the location of the future Phase 2 Near Neutrino Detector and supporting Near Site Conventional Facilities. The Near Site Conventional Facilities not only provide the support buildings for the underground facilities, but also provide the infrastructure to direct the beamline from the below-grade extraction point to the above-grade target.

The Near Site layout at Fermilab is shown in Figure 3. Following the beam from southeast to northwest, or from right to left is the underground Beamline Extraction Enclosure, the underground Primary Beam Enclosure/Pre-target Tunnel and its accompanying surface-based Service Building (LBNE 5), Target Complex (LBNE 20) located in the engineered fill embankment, the Decay Pipe, and the underground Absorber Hall and its surface-based Service Building (LBNE 30). Also shown for completeness is the proposed location of the Phase 2 underground Near Detector Hall and its surface-based Service Building (LBNE 40).

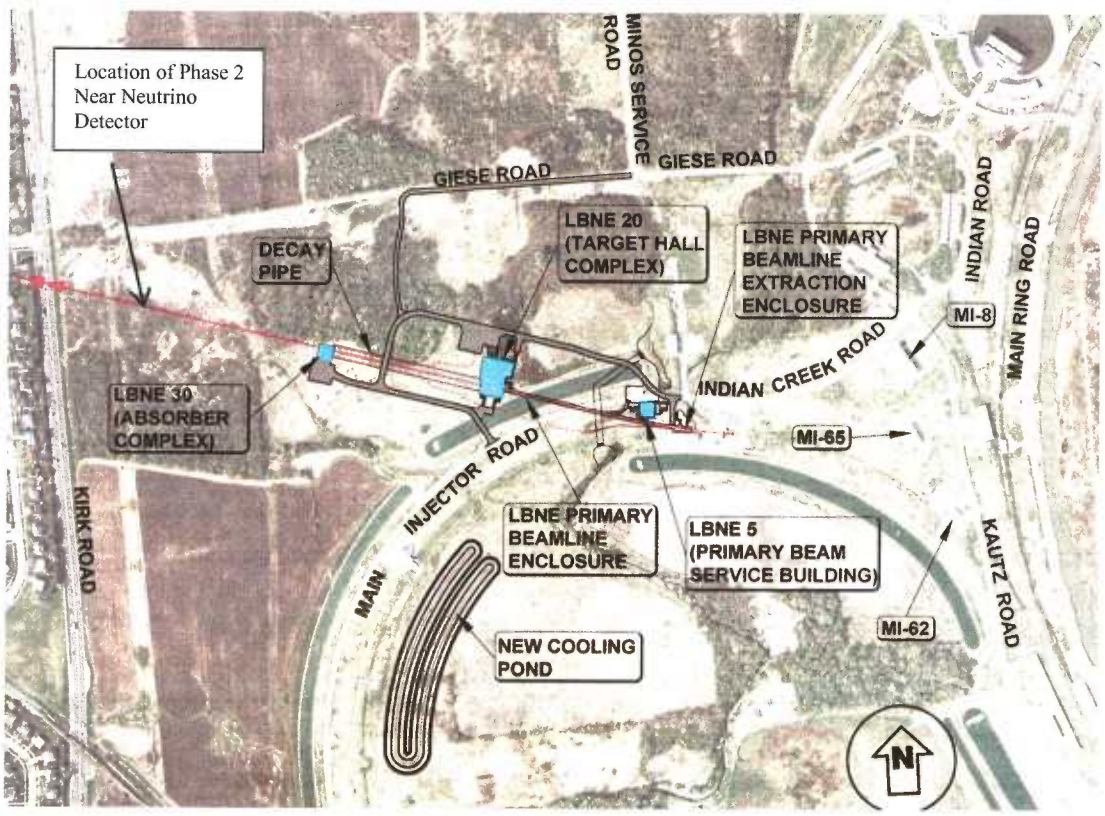

Figure 3 LBNE Overall Project Layout at Fermilab with North at the top of the image

2.1.2 The Far Site

The Far Site is the Sanford Underground Laboratory at Homestake, in Lead, S.D. The land was donated by Barrick Gold Mining to the state of South Dakota, and the state created the South Dakota Science and Technology Authority (SDSTA) to own and manage the facility. Figure 4 and Figure 5 show the context of the site in the region.

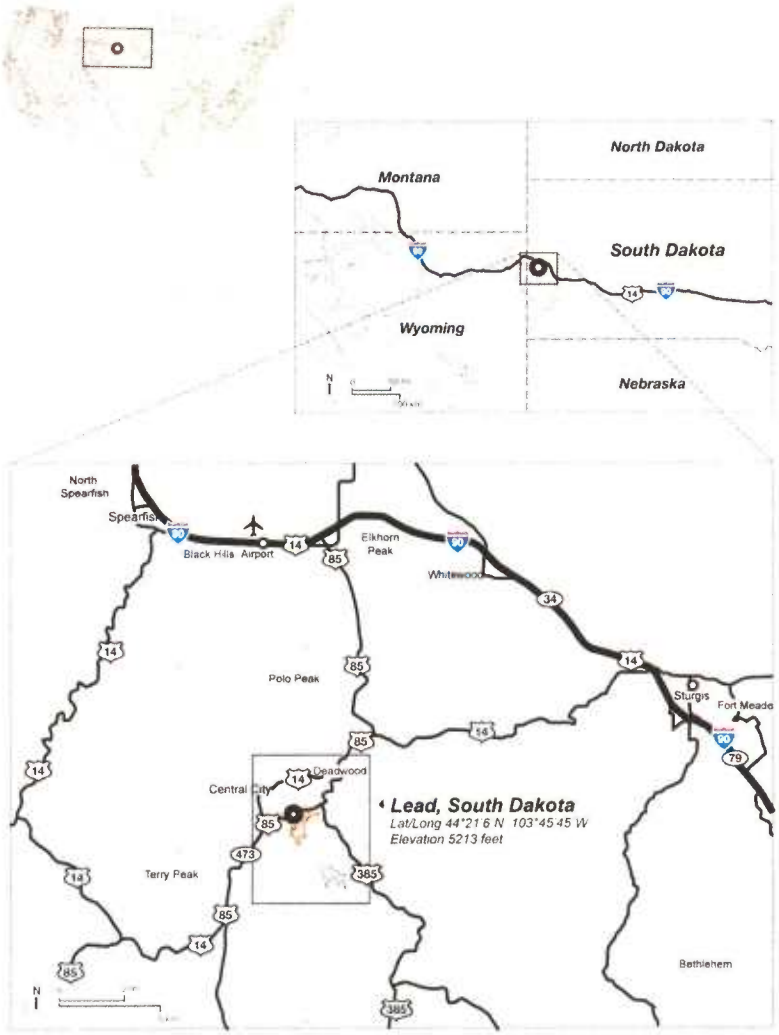

Figure 4 Regional Context showing the city of Lead, South Dakota. [Dangermond Keane Architecture, Courtesy Sanford Laboratory]

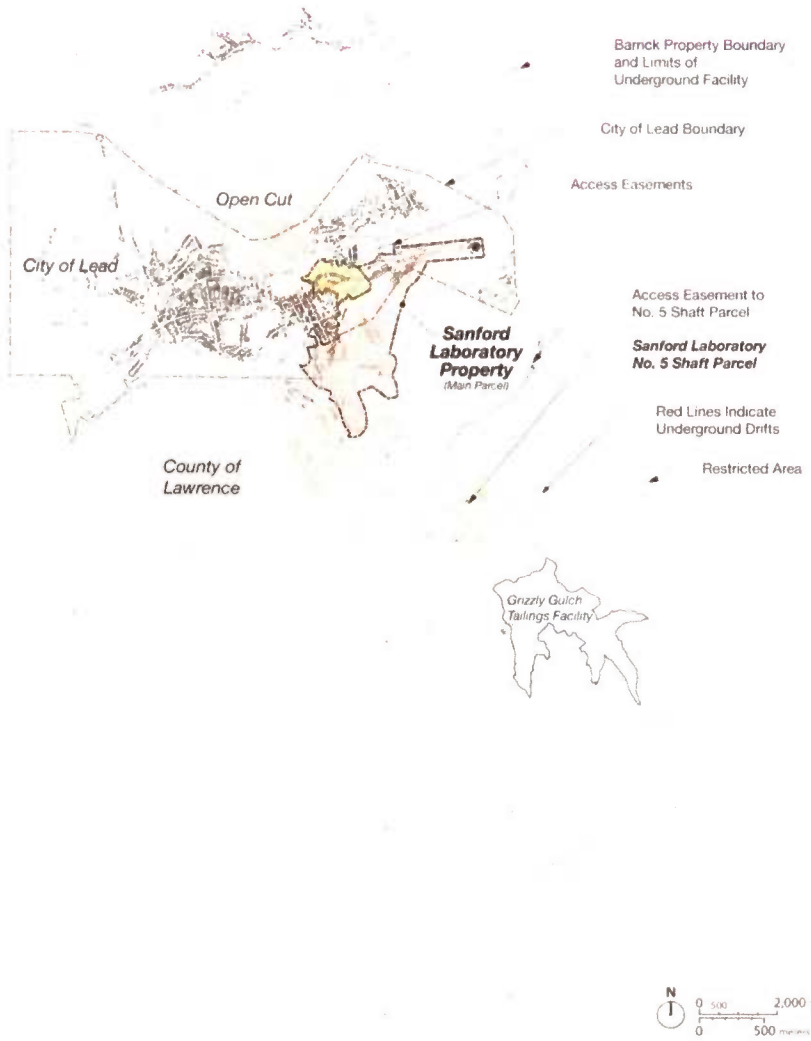

Figure 5 Sanford Laboratory Complex shown in the context of the city of Lead, South Dakota, and the property remaining under ownership of Barrick. Area shown in yellow is a potential future expansion of the SDSTA property. [Dangermond Keane Architecture, Courtesy of Sanford Laboratory]

The site for the LBNE far detector is east of the Oro Hondo fans, shown in the photograph of the area in Figure 6. The scope of the facilities required for the Liquid Argon Far Detector (FD) includes new excavated space at the surface rock for the detector, utility spaces for experimental equipment, and utility spaces for facility equipment. Infrastructure for the facility includes power to experimental equipment, domestic water, industrial water for process and fire suppression, ventilation supply and exhaust, fire detection and alarm, normal and standby power systems, sump pump drainage system for detector pit, and cyberinfrastructure for communications and security. The detector requires an excavation of a rectangular shape and a concrete lined pit that supports the cryostat. Above the detector, ~3-4 m of concrete and excavated rock would provide shielding from cosmic rays.

Figure 6 View of Far Detector Siting at Sanford Laboratory Oro Hondo collar with the site circled in red

The siting is chosen to help shield the detector from additional low angle cosmic rays in the direction of the neutrino beam from Fermilab to help reduce background in the detector. This requires placement of the detector on the west side of a sufficiently high hill to provide the necessary shielding. With this placement, some excavation into the hillside is required. The site includes a portion of land slightly beyond the existing SDSTA property, and an agreement has been reached with the owner, Barrick Gold Mining, for SDSTA to annex the land required for the detector.

The Liquid Argon (LAr) Time Projection Chamber (TPC) far detector includes a cryostat to contain the LAr, a TPC detection mechanism immersed in the LAr, readout electronics, and a cryogenic system to keep the LAr temperature at 89 degrees K and maintain the required purity. The FD consists of two 5-kt cryostats placed side by side in a single excavated pit, oriented along the beam direction (roughly east-west), with the top of the detector approximately at grade level.

2.2 *Magnitude of the Project*

2.2.1 Near Site Magnitude

2.2.1.1 Beamline

The Beamline is designed for initial operation at proton-beam power of 700 kW, with the capability to support an upgrade to 2.3 MW. The design proton energy ranges from 60 to 120 GeV. Approximately 4.9×10^{13} protons are extracted every 1.33 seconds at 120 GeV, resulting in a beam power of 700 kW. Extraction of the proton beam occurs at MI-10. After extraction, the primary beam establishes a horizontally straight compass heading west-northwest toward the Far Detector, but would be bent upward to an apex before being bent downward at the appropriate angle, 101 milliradians (5.79 degrees) as shown in Figure 7. The primary beam would be above grade for about 700 feet; this design minimizes expensive underground construction and significantly enhances capability for ground-water radiological protection. The design requires, however, construction of an earthen embankment, or hill, whose dimensions are commensurate with the bending strength of the dipole magnets required for the beamline. Using conventional dipole and quadrupole magnets to guide the beam in the right direction and focus it on the target, the beam must reach the target with very low losses to ensure both efficient production of neutrinos as well as minimal radiological activation of components in the beamline.

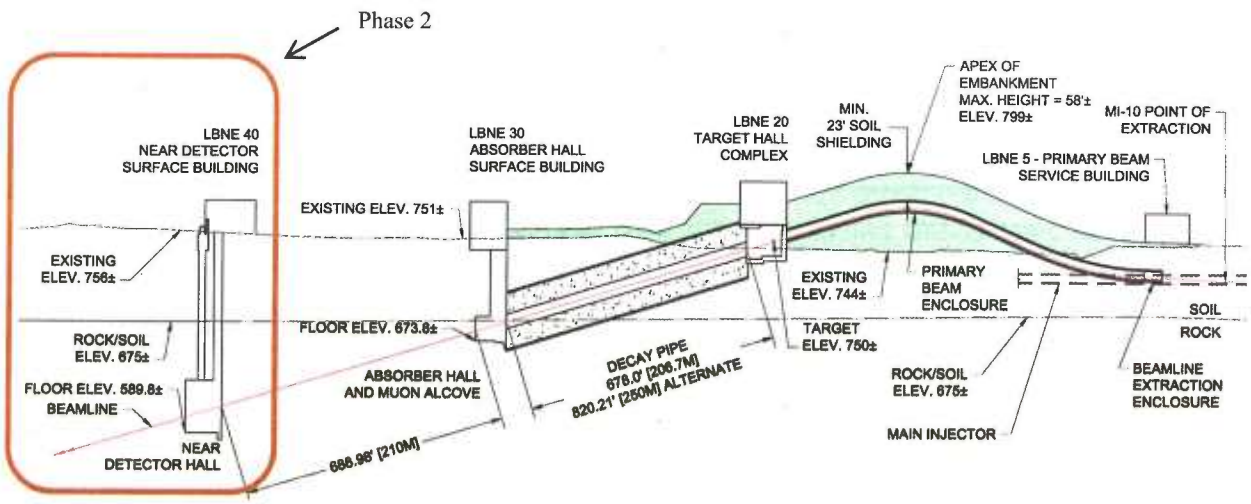

Figure 7 LBNE Near Site schematic longitudinal section view

The target marks the transition from the intense, narrowly directed proton beam to the more diffuse, secondary beam of particles that in turn decay to produce the neutrino beam. The secondary particles are short-lived and each decay generates a muon (in addition to a neutrino), which penetrates deep into the surrounding rock and a neutrino that continues on toward the near and far detectors. The neutrino beam would be created from the primary (proton) beam in a three-step process.

1. The primary beam strikes the neutrino production target in the Target Hall. The target interacts with approximately 85% of the primary protons and minimally absorbs the charged pions and kaons created in these interactions.
2. The charged products of these interactions, mostly pions and kaons, are collected in the heavily shielded Target Chase and focused with horn magnets in the direction of the Far Detector. Over the lifetime of the experiment, the target and focusing horns would need to be replaced. Accommodating the safe, routine replacement of parts in a radioactive environment is an essential part of the Target Hall design.
3. Those pions and kaons that are aimed correctly enter the long pipe of the decay volume, where they decay into neutrinos forming the neutrino beam.

This decay volume is a pipe of circular cross section with its diameter and length optimized such that decays of the pions and kaons result in neutrinos in the energy range useful for the experiment. The beam power in the decay tunnel implies creation of radioisotopes within the walls surrounding the pipe, requiring shielding and sealing from the surrounding groundwater. The design uses a minimum of 5.5 meters of concrete shielding between the pipe and the native earth.

The decay volume is followed immediately by the absorber, comprised of an aluminum and steel pile, which removes the remaining beam hadrons and transforms the beam's kinetic energy into heat, thus protecting the rock from beam-activated nuclides. The absorber is positioned in the Absorber Hall at the end of the decay pipe.

Concrete radiation shielding surrounds the decay pipe to minimize activation of surrounding ground water. Heat generated in materials due to beam reactions would be removed by airflow through the decay pipe. Impermeable membranes surround the decay-pipe concrete to act as a barrier for minimizing ground-water inflow. Any ground water that penetrates the barrier system would be collected in pipes and conveyed to sumps located in the Absorber Hall.

2.2.1.2 Near Site Conventional Facilities

As described in the Beamline Section 2.2.1.1, a proton beam is extracted from MI-10 at the Main Injector, which then determines the location of supporting Near Site Conventional Facilities (and the future Phase 2 Near Site Neutrino Detector (ND)). The Near Site Conventional Facilities not only provide the support buildings for the underground facilities, but also provide the infrastructure to house the Beamline technical systems from the extraction point, through the target to the absorber.

After the proton beam is extracted at the existing MI-10, about 30 feet below grade, the Beamline would travel through the 8 feet x 10 feet concrete Primary Beam Enclosure at an incline into and through an embankment constructed of engineered fill which reaches a maximum height of about 58 ft above existing grade. After reaching the apex of the embankment the Beamline declines back down toward existing grade and through the reinforced concrete Target Hall where it interacts with a target and a focusing horn system to create an intense neutrino beam. The beam continues through, and into, a 200–meter long Decay Pipe and into a hadron absorber in the Absorber Hall. The beam is directed toward a

detector located more than 1,300 km (~808 miles) away at the Sanford Underground Laboratory at Homestake located in Lead, South Dakota.

The Phase 1 conceptual design scope contains both cut-and-cover and rock excavation; precast and cast-in-place concrete; three new surface service buildings; and one new cooling pond. In addition to major structures, the new facilities include domestic water, industrial water, power distribution, and communications infrastructure. New access roads as shown in Figure 3 would be constructed to access the facility.

The below grade facilities would be constructed using standard open cut methods. This includes much of the Beamline Extraction Enclosure and Primary Beam Enclosure, the Target Complex, the Decay Pipe and the Absorber Hall. However, some of the Primary Beam Enclosure and all of the Target Complex would be constructed in a 58 feet high embankment constructed of engineered fill. The extent and height of the embankment would cause consolidation (settlement) of native in situ soils resulting in potential adverse impacts to existing facilities including the Main Injector. Figure 8 shows the embankment and the locations, limits, and types of braced excavation and retaining wall systems that are planned to provide protection of the Main Injector. Because of the consolidation of in situ soils caused by the embankment some of the Primary Beam Enclosure and the Target Hall Complex may be supported using drilled shaft deep foundations.

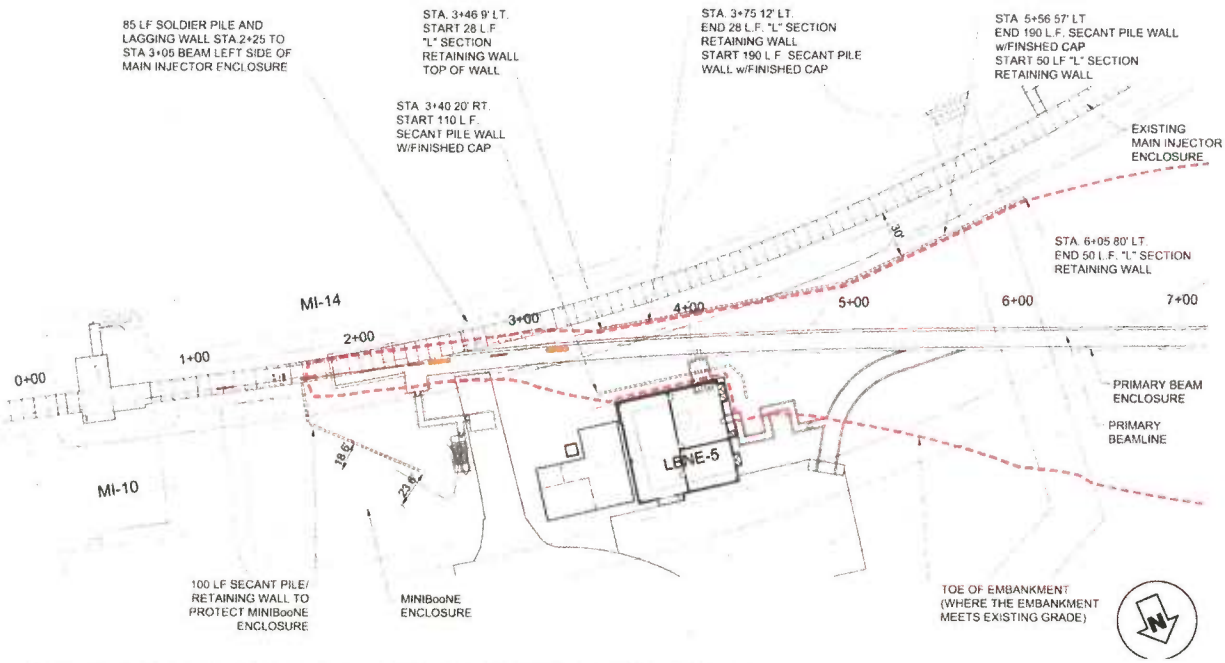

Figure 8 Near Site Braced Excavation and Retaining Walls

The existing Main Injector Cooling Pond F and associated infrastructure would be entirely removed/filled-in to create space required for the embankment and the Target Complex (LBNE 20). Any compensatory cooling water capacity and flood plain storage volume that is required due to filling and for site grading and drainage would be mitigated (reconstructed) in the infield of the Main Injector near the LBNE beamline.

The Decay Pipe and the Absorber Hall would be constructed using open cut methods requiring excavation down to, and into, the bedrock underlying the project site. Open cut excavations expected to be about 25 ft below the rock-soil interface. Rock would be excavated using quarry type drill and blast techniques. All structures would be covered with the required minimum 23 feet of earth shielding above and around all beamline enclosures.

2.2.2 Far Site Magnitude

2.2.2.1 Far Detector

In a LArTPC a uniform electric field is created within the TPC volume between cathode wire planes and anode wire planes. Charged particles passing through the TPC release ionization electrons that drift to the anode wire planes. The bias voltage is set on the anode plane wires so that ionization electrons drift between the first several (induction) planes and are collected on the last (collection) plane. Readout electronics amplify and continuously digitize the induced waveforms on the sensing wires at several MHz, and transmit these data to the data acquisition (DAQ) system for processing. The wire planes are oriented at different angles allowing a 3D reconstruction of the particle trajectories. In addition to these basic components, a photon-detection system provides a trigger for proton decay and galactic supernova neutrino interactions.

The long axis of the detector would point towards Fermilab, parallel to and in line with the neutrino beamline. The below-grade pit provides the cavity inside of which the cryostats fit side-by-side. Dimensions are detailed in Figure 9.

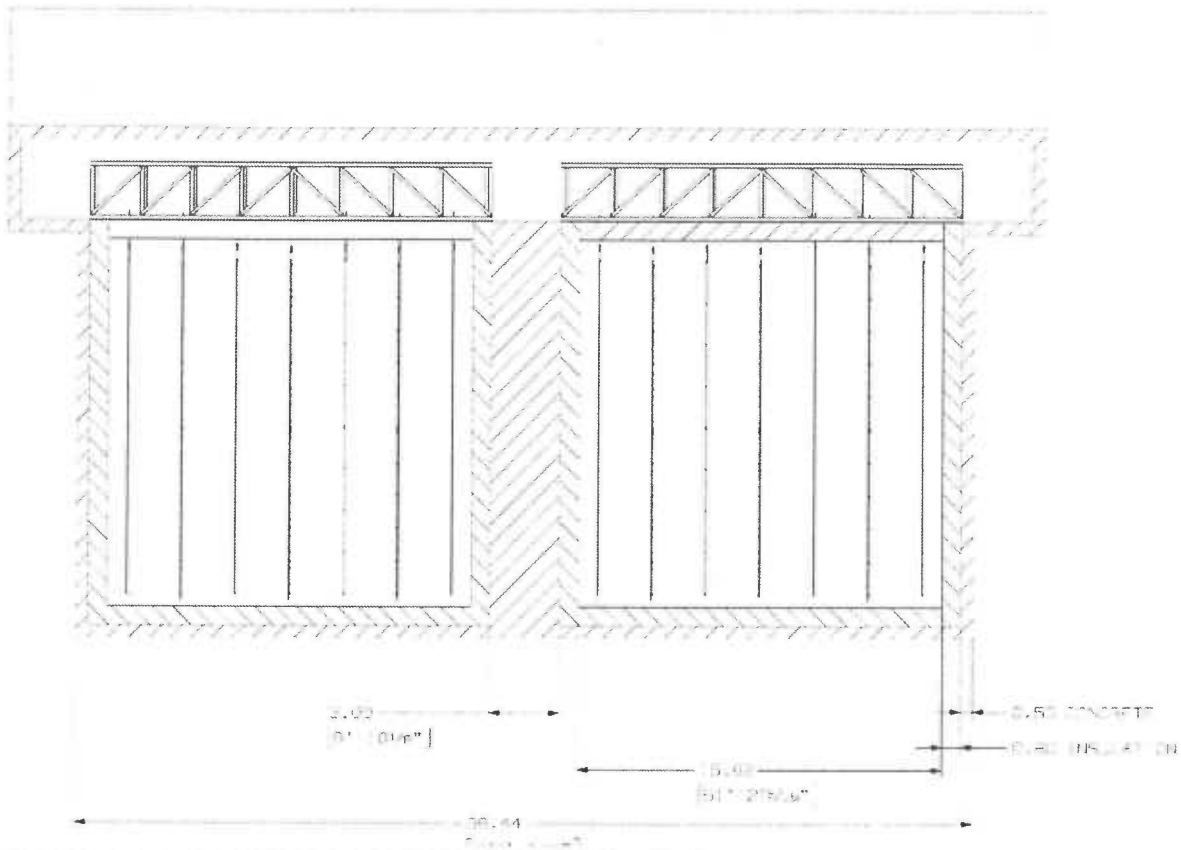

Figure 9 Cross-section view of side-by-side LAr TPC modules

The membrane cryostat uses commercial stainless-steel membrane technology from liquefied natural gas tanker ships and tanks. The cryostats are sealed containers supported by the surrounding rock. The in-ground configuration offers access only from the top and protects against possible cryogen leaks out of the tank. The thick side wall composite consists of a series of membranes, foam insulation, and reinforced concrete that is poured against the rock. The inner (primary) stainless steel liner is corrugated to provide strain relief from temperature-related expansion and contraction. The top of the cryostat is supported by tall steel trusses.

Equipment and vessels used for filtering LAr to achieve high purity levels would be placed in a surface building. The nitrogen refrigerators, nitrogen compressors and necessary cryogen-storage vessels would also be placed in separate surface buildings and pads. Cryogens would be delivered to the facility in tanker trucks. During installation, deliveries would be daily. When the experiment is running, deliveries would be intermittent.

2.2.2.2 Far Site Conventional Facilities

The Far Detector would be sited on the far side of a hill on the edge of the Sanford Laboratory property to take advantage of the rock mass to shield the detector from low cosmic rays that are sub-parallel to the neutrino beam. This site is adjacent to the Grizzly Gulch Road, and the Oro

Hondo exhaust fan, which serves the underground excavations of Sanford Laboratory. Figure 10 shows the proposed site in the Kirk Road valley.

Figure 10 Far Detector Siting at Oro Hondo

The detector pit would be excavated in rock which can be seen in outcroppings at the site. A low, thick, concrete roof topped with rock would be placed over each cryostat to provide additional shielding from cosmic rays and protect electronics equipment to be placed on top of the cryostats. Surface buildings would be steel-framed with shallow footings on rock.

Utilities would be supplied from existing Sanford Laboratory infrastructure. The nearby Oro Hondo substation would be the source for power, with ductbanks connecting it to the site. Water for fire protection and experiment use, process water sewer, and cyberinfrastructure would be run from the Ross Shaft the existing 300L Oro Hondo portal and across Kirk Road to the site. Natural gas is available from the utility along Kirk Road for heating, and propane tank could be used for backup heating if required. If restrooms are determined to be necessary inside the building, a sewage tank would be provided with periodic pumping.

3 Potential Environmental Effects

Potential Environmental Effects (Provide comments for each checked item and where clarification is necessary.)

A. Sensitive Resources: Would the proposed action result in changes and/or disturbances to any of the following resources?

☒ Threatened or endangered species

- ☐ Other protected species
- ☒ Wetland/Floodplains
- ☒ Archaeological or historical resources
- ☐ Non-attainment areas

B. Regulated Substances/Activities: Would the proposed action involve any of the following regulated substances or activities?

- ☒ Clearing or Excavation
- ☒ Demolition or decommissioning
- ☐ Asbestos removal
- ☐ PCBs
- ☒ Chemical use or storage
- ☐ Pesticides
- ☒ Air emissions
- ☒ Liquid effluents
- ☐ Underground storage tanks
- ☒ Hazardous or other regulated waste (including radioactive or mixed)
- ☒ Radioactive exposures or radioactive emissions
- ☒ Radioactivation of soil or groundwater

C. Other relevant Disclosures

- ☐ Threatened violation of ES&H permit requirements
- ☐ Siting/construction/major modification of waste recovery or TSD facilities
- ☐ Disturbance of pre-existing contamination
- ☒ New or modified permits
- ☒ Public controversy
- ☐ Action/involvement of another federal agency
- ☐ Public utilities/services
- ☐ Depletion of a non-renewable resource

Comments on checked items

3.1.1 Near Site Effects

There are several environmental impacts from the proposed Near Site Beamline and facilities that would be described in this section by topic.

3.1.1.1 Wetlands, Floodplain, Threatened/Endangered Species, & Cultural Sites

A wetland delineation and wetland study was conducted in areas that were anticipated to be disturbed by Near Site construction activities. The *Wetland Report* was prepared by Patrick Engineering, Inc., in August 2010 [7]. The wetland delineation and floodplain limits seen in Figure 11 show that limited wetlands would be encountered in the area of LBNE 20, LBNE 30, and the future Phase 2 LBNE 40, as well as possibly other areas.

In compliance with U.S. Army Corp of Engineers requirements, LBNE would require a Section 404/Clean Water Act wetland permit and would need to mitigate the disturbance of wetland

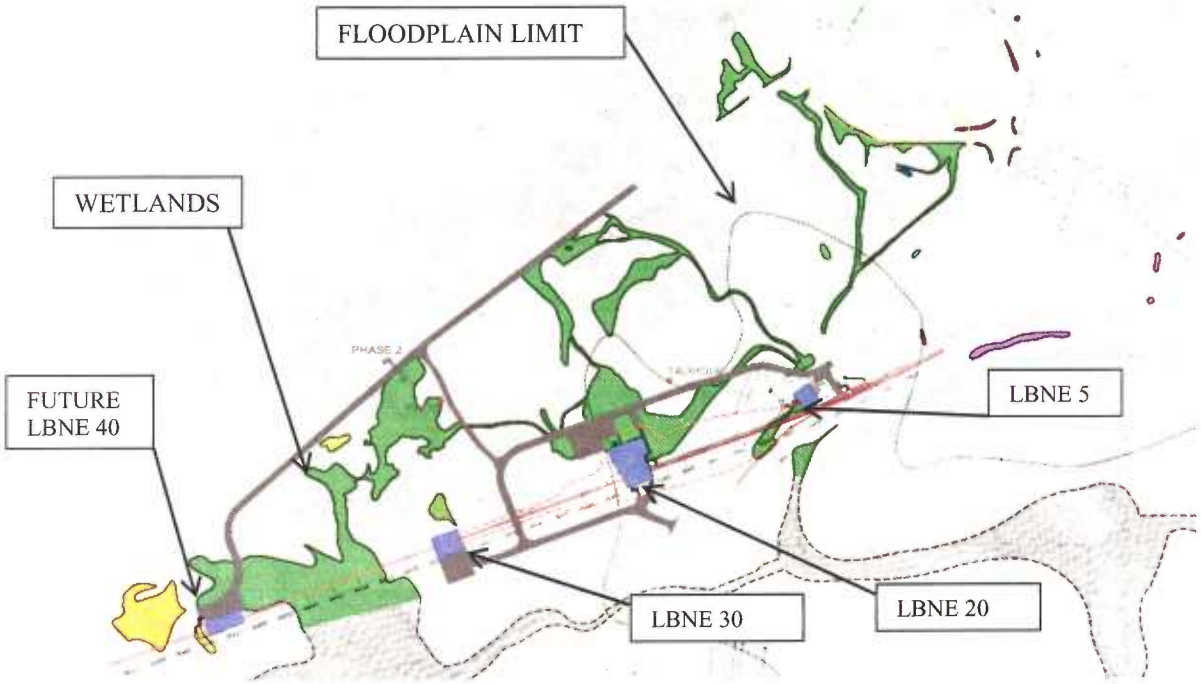

Figure 11 Wetland and Floodplain Map

areas caused by construction activities. To mitigate impacts, LBNE intends to purchase wetland credits from a wetland bank. The number of credits to be purchased would be based on the area and quality of wetland acres disturbed.

Any volume of the floodplain along the Project alignment that may require filling, notably at and near the LBNE 20 site and along the shielding embankment over the Primary Beam Enclosure, would be delineated and the required compensatory floodplain storage volume would be designed, permitted, and constructed according to Federal Emergency Management Agency regulations.

The *Wetland Report, Appendix C,* identified two state-listed endangered species that may be encountered in the proposed area, the black-crowned night heron and the upland sandpiper. In addition, one federally protected species was identified for which suitable habitat is present, the Eastern prairie fringe orchid.

The Fermilab Cultural Resource Management Plan, dated September 13, 2012, describes two possible archaeological sites in the vicinity of the proposed Near Site facilities. These are noted and circled in red in Figure 12. At the conceptual level, it is believed these sites can be protected from disturbance.

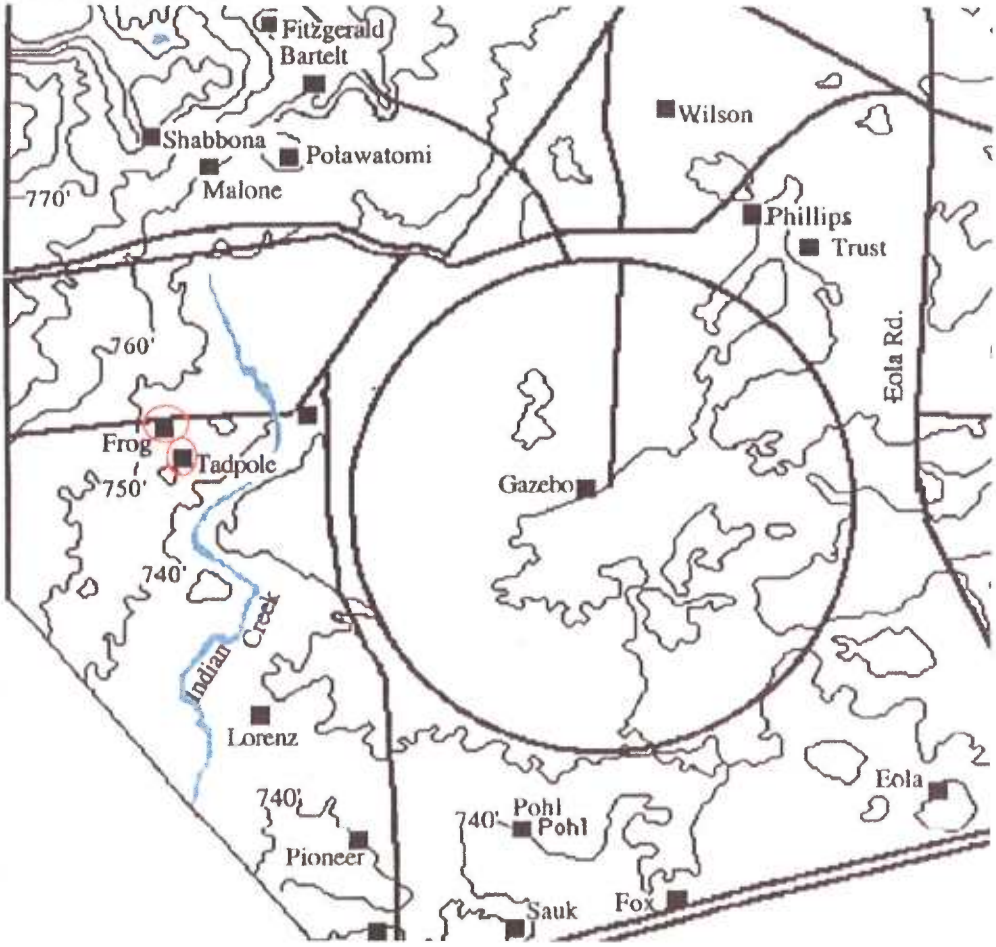

Figure 12 Portion of Fermilab Archaeological Site Map

3.1.1.2 Excavation

The construction would include earth and rock excavation. The spoils would be used to create the necessary embankment shielding along the beamline. The presence of the embankment would require more fill than cut. Embankment fill soils are anticipated to be taken from a location near the southwest corner of the Fermilab site. Any excess rock generated from LBNE excavations would be taken to existing stockpiles on the Fermilab site. During construction, a Storm Water Pollution Prevention Plan would be prepared and its provisions followed to control sediment and soil erosion. In some areas that have been previously disturbed around Fermilab, there is a possibility that low levels of contamination have been transported via use of fill material from other locations around the Fermilab site. The site selected for LBNE has not been used for material stockpiling. Excavated soils for the LBNE project would be characterized, but are not expected to contain contamination.

3.1.1.3 Decontamination/Decommissioning/Demolition

The Beamline facilities are designed for the expected experiment lifetime of 20 years, plus another 10 years for possible extended operations. Demolition of the facility soon after shut-down may be challenging due to longer term activation of the facility itself. Thus the facility must contain all radioactive hazards until those hazards have decayed to safe levels. When hazards are manageable, the experimental apparatus and beamline would be disassembled. The components would be reused elsewhere at Fermilab, shipped to other laboratories for use, or made available as surplus equipment according to standard procedures for disposition of United States Government properties. For the duration of the proposed LBNE Project, information necessary for eventual decommissioning would be collected, documented, and retained for future reference in accordance with existing Fermilab policies. This information would include the details of the design, the history of operation, and records of environmental monitoring.

Each component of the beamline would be surveyed by health physics personnel in order to identify, label and isolate all components made radioactive by beam operations. It is anticipated that many components, excluding some of the beamline and target station items, the decay pipe, and beam absorber material would be free of radioactivity. Radioactive components for which there is no longer a use would be packaged for shipment and disposed of as radioactive waste according to DOE specifications and Federal, State, and Local regulations in effect at the time of disposal. Non-radioactive wastes would be properly disposed, in accordance with applicable regulatory requirements. There are no disposal sites for any waste materials on the Fermilab site and none would be planned for the future. Review under the National Environmental Policy Act would be performed for these activities at that time.

The buildings and underground structures could be reused if needed when radioactively safe, or demolished and the site returned to its previous condition.

3.1.1.4 Radiological Effects

The Beamline facilities are designed to minimize radiation exposures, radioactive air emissions, and radioactivation of soil and groundwater, in accordance with the Fermilab Radiological Controls Manual. The facilities are designed for 700kW beam operation, but those parts of the facility that would be difficult to upgrade in the future are designed for 2.3 MW operation. The areas affected are the primary beam transport line, target hall, decay pipe, and absorber hall.

The shielding requirement for the primary beam is 23 feet, providing for both normal and accidental losses for 2 localized full beam pulses lost/hour at 2.3 MW. Since the primary transport line is located in soils including the glacial till with no direct connection to the aquifer, all radionuclides produced in the soil below the enclosure would have to move down through the different soil layers to reach the aquifer. The seepage velocities, for the layers in the glacial till, are very small and the concentration of the radionuclides are expected to be reduced by 5 to 7 orders of magnitude, well below the regulatory standard detection limits. The current accepted detection limits are 1 pCi/ml for tritium and 0.04 pCi/ml for sodium-22. To reduce the accidental dose from muons at the site boundary to less than 1 mrem, 326 feet (99 m) of soil in the path of

the muons is required. However, because of the offsite annual dose limit, the shielding for the longitudinal muons either must be increased to 400 feet (122 m) or beam control should limit full beam losses to less than one pulse per day.

The Target Hall shielding is designed to contain prompt radiation, residual radiation, activated air and accidental spills of radioactivated water, to reduce a thirty-year buildup of the radionuclides in the soil outside the shielding to below the standard detection levels. The goal of the design is to have an average dose rate of less than 100 mrem/hr in the Target Hall during the normal beam operations. A combination of steel, marble and borated polyethylene is used for shielding on top of the target chase. Because of the skyshine considerations, the walls and the ceiling of the Target Hall are required to be 5 feet (1.5 m) and 7 feet (2.1 m) of concrete, respectively. For the sides and the bottom of the target chase, combinations of steel and concrete shielding are used. In addition to the shielding, a water impermeable membrane would be installed outside the shielding to protect against a possible diffusion of the tritium out of the outer shielding into the surrounding soil.

Decay pipe shielding consists of 18 feet (5.5 m) of concrete followed by two layers of impermeable geo-membrane designed to render the concentration of the radionuclides of interest, accumulated over 30 years, to be less than the current standard detection limits.

The Absorber Hall is located in the water bearing rock region. The groundwater shielding strategy is similar to that used successfully for the NuMI beam line. The absorber would be shielded such that the maximum concentration of the radionuclides, accumulated over 30 years, would be well below the current regulatory standard detection limits. In addition to the shielding, a water impermeable membrane would be installed outside the shielding to protect against a possible diffusion of the tritium out of the shielding into the surrounding rock.

3.1.1.5 Hazardous and other Regulated Waste

As with other similar Fermilab operations, small amounts of chemical and radioactive waste would be generated and disposed of off the Fermilab site in accordance with appropriate regulations.

3.1.1.6 Chemical Use and/or Storage

During the operation of the LBNE facility, materials such as paints, epoxies, solvents, oils, and lead shielding may be used. The industrial hygiene program, which is detailed in the Fermilab ES&H Manual, addresses potential hazards to workers using such materials. Specific procedures would provide for the safe handling, storing, transporting, inspecting and disposing of hazardous materials.

3.1.1.7 Air Emissions

There would be some temporary rise in air emissions due to construction (e.g., from vehicles and other equipment). Other increases would reflect the modest increased use of steam, chilled

water, and electricity for constructing and operating the facility. As with all accelerator operations, there would be some radionuclide air emissions.

3.1.1.8 Liquid Effluents

Roof and parking lot drains would empty to storm water basins. Sump water from the Target and Absorber Halls would be monitored for tritium and pumped to surface ponds. All other water used at LBNE facilities would be disposed of through the sanitary waste stream.

3.1.1.9 Potential Public Controversy

The Near Site facilities construction would require a small volume of excavation in rock, which would require some blasting. Based on the NuMI rock excavation experience, this work would need to be planned to minimize impacts on the public and adjacent neighbors across Kirk Road. To that end, Fermilab and the LBNE Project met in 2010 with the Fermilab Community Advisory Board to alert them to conceptual-level planning for this work, and received good feedback on ways to work with the community moving forward. This construction is not expected to be especially controversial.

3.1.2 Far Site Effects

There are several environmental impacts from the proposed Far Site Detector and facilities that would be described in this section by topic.

3.1.2.1 Wetlands, Floodplain, and Threatened/Endangered Species

No wetland delineation has been done in the proposed site area. According to Sanford Laboratory employees, some wetlands are present in the area (~ 2 acres) and may need mitigation, which could be through wetlands creation on the Sanford Laboratory site.

No evaluation of threatened or endangered species has been made.

The proposed Far Detector siting near the Oro Hondo fan site is above the 100-year floodplain by approximately 30 ft elevation, according to the Floodplain Analysis of Whitewood Creek performed as part of the Surface Design for the 800L Liquid Argon Detector configuration design in 2011 [8]. The floodplain limits and the far detector siting are shown in Figure 13.

Whitewood Creek 100 Year Floodplain

Figure 13 100 year Floodplain Map of Whitewood Creek

3.1.2.2 Excavation

The excavation for the two 5 kiloton detector modules would be done in one excavation volume in rock. It is anticipated that this rock would be reused on at the site for road building, hardstands, and rock cover for detector shielding. None is expected to be removed from the site. During construction, a Storm Water Pollution Prevention Plan would be prepared and its provisions followed to control sediment and soil erosion.

3.1.2.3 Decontamination/Decommissioning/Demolition

The experiment is planned to run for 20 years, and the facility is planned for a 30-year life for allow for extended running. When operations cease, the detector and cryogenic equipment would be removed and is expected to be reused by other experiments. The cryostat materials would be removed, leaving the concrete liner. Consistent with the SDSTA Property Donation Agreement with Barrick Gold Mining Co., facilities must be demolished when they are no longer needed. Therefore, the plan would be to demolish the surface building to few feet below the grade level, backfill the concrete detector pit to grade, and restore the surface to its original condition. Underground utilities serving the site would be abandoned in place.

3.1.2.4 Air Emissions

There would be some temporary rise in air emissions due to construction (e.g., from vehicles and other equipment) and deliveries for experiment installation. Other increases would reflect the modest increased use of utilities for constructing and operating the facility.

3.1.2.5 Liquid Effluents

Roof and parking lot drains would empty to the surface. Sump water from around the pit liner and process industrial water would be managed to prevent its discharge to the surface – one solution is to route it back to Sanford Laboratory to be disposed into the existing waste water treatment plant either via process sewer back to the site or via a shaft to the underground where it would mix with other waters for transport to the treatment plant.

3.1.2.6 Hazardous and other Regulated Waste

As with other similar operations, small amounts of chemical and radioactive waste would be generated and disposed of off the Sanford Laboratory site in accordance with appropriate regulations.

3.1.2.7 Chemical Use and/or Storage

During the operation of the far detector, materials such as paints, epoxies, solvents, and oils may be used. The industrial hygiene program, which is detailed in the Sanford Laboratory ES&H Manual, addresses potential hazards to workers using such materials. Specific procedures

would provide for the safe handling, storing, transporting, inspecting and disposing of hazardous materials.

3.1.2.8 Potential Public Controversy

Historic Site

The former Homestake Gold Mine site is a major component of the Lead Historic District. Most of the Sanford Laboratory is within the historic district and work in this area must conform to the National Historic Preservation Act of 1966, as amended. These standards recognize that historic buildings and sites must change with time if they are to meet contemporary needs but that alterations to meet these needs can be done in a manner that is sensitive to the historic property. Figure 14 shows the boundaries of the Lead historic district. The proposed LBNE far detector would be located outside the historic district, but the historic assessment process to date is included here for completeness.

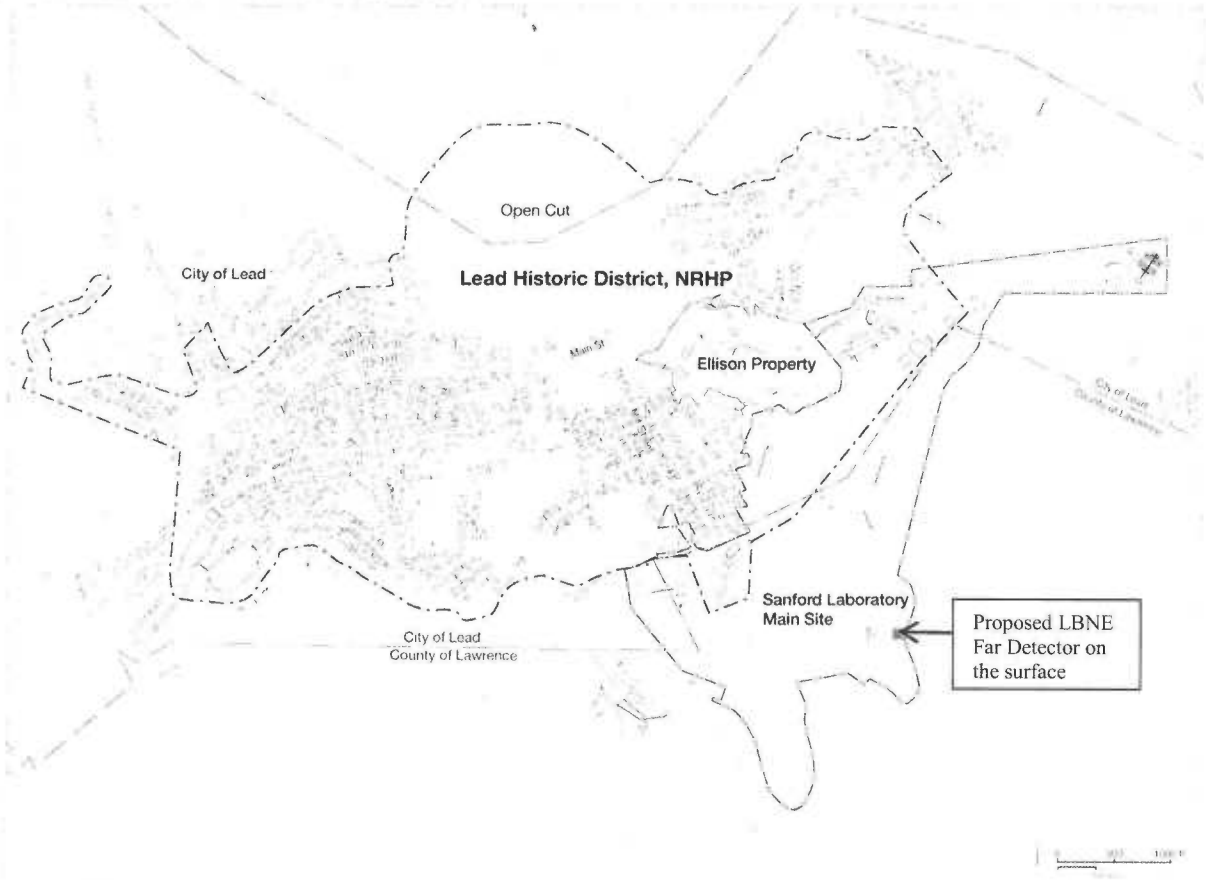

Figure 14 Map of Lead Historic District. [Dangermond Keane Architecture, Courtesy of Sanford Laboratory]

The historic assessment performed by the Deep Underground Science and Engineering Laboratory (DUSEL) Project consisted of the full assessment of 10 transcendent and eight support buildings. Of the 10 transcendent buildings, nine were deemed to have significant historic value while one held only moderate historic value. Seven of the support buildings held

moderate historic value, while the eighth has only limited historic value. Sixteen other buildings received a preliminary historic assessment. Two were deemed to have moderate historic value, 13 held limited historic value, and the last was deemed to be of limited historic value. To assist the Sanford Laboratory in understanding the historic requirements for work on its site, two meetings have been held with the South Dakota State Historic Preservation Office (SD SHPO), one in June 2010 and one in February 2012.

Native American Tribes

The historic legacy of the Native Americans in the Black Hills uniquely binds them to the land upon which Sanford Laboratory lies. Sanford Laboratory has been reaching out to the tribes since the lab was initiated, and this process would continue.

Access, Noise, and Dust during Construction and Operations

The proposed site is accessed from Kirk Road, a gravel-surfaced county road. This road would require maintenance during construction and would increase traffic on that road compared to its current use. During experiment installation, some increase in traffic above current use is also expected. Semi-tractor trailers carrying detector parts and tanks of liquid cryogens would visit the site several times daily over several months. During operations, the experimental facility would be lightly visited with intermittent material deliveries.

Construction would produce noise and dust, especially from the excavation activities. Mitigation strategies would need to be developed to minimize this impact on nearby residents in Lead. Noise from operations of the experiment (cryogenic compressors) and facility equipment (HVAC) would also need to be minimized through the design process.

4 LBNE Phase 2

The LBNE Project is a proposed phased program under one CD-0 Mission Need. Phase 2 includes a Near Neutrino Detector at Fermilab and a 10 kiloton Far Detector at 4850L at Sanford Laboratory. LBNE could accelerate its phasing by obtaining sufficient non-DOE funding before CD-2 to include a near neutrino detector at Fermilab and to change the surface far detector at Sanford Laboratory to a deep detector. This would allow all four science goals of LBNE to be achieved within the accelerated program. In order to benefit from this possible acceleration, the Project is preparing for the Phase 2 work in parallel with the Phase 1 scope described in Chapters 1 through 3.

This Chapter would describe the Phase 2 scope additions and possible changes to Phase 1 if funding is accelerated along with their environmental impacts.

4.1 Near Neutrino Detector

The addition of a near neutrino detector to the LBNE Project would add scope back to the Project that was removed in the June 2012 Reconfiguration effort. Therefore, the scope and impacts are well understood, as the work was basically integrated into the rest of the plans for the Near Site in the March 2012 conceptual design.

4.1.1 Proposed Near Neutrino Detector

The proposed scope is to construct a Near Detector Hall underground about 170 ft below the surface to house a near neutrino detector to assess the neutrino beam on the Fermilab site. The Hall would be excavated in rock and would have two access shafts from the surface. The surface Near Detector Service Building (LBNE 40) would house utilities and provide assembly and access space. The facilities are shown on the Near Site cross-section in Figure 7 and on the site map in Figure 3. Utilities serving the facility would be extended from the LBNE 20 and LBNE 30 areas, including power, industrial water, domestic water, and communications.

There are several options for the detector itself that are under consideration. Existing detectors on the Fermilab site could be reused, or a liquid argon or strawtube tracker detector could be constructed.

4.1.2 Environmental Impacts

This section would describe the impacts that would additive to, or changed from, the Near Site impacts described in Section 3.1.1.

The excavated rock volume would be substantially larger, but still stockpiled on site. A modest volume of soil excavation from building foundations would also be stockpiled on site.

The volume of affected wetlands would be increased by about one third.

When the experiment is complete, the detector would be dismantled for use by other experiments. The building and underground shafts and hall could be reused if needed. The building could be demolished and the site returned to its previous condition. The underground enclosures could be capped and left to fill with groundwater.

Since the Phase 2 Near Detector Hall is close to the site boundary, this construction work would need to be planned to minimize impacts on the public and adjacent neighbors across Kirk Road. The Fermilab Community Advisory Board has already discussed this proposed work.

4.2 4850L Far Detector

Siting the LBNE far detector deep underground at Sanford Laboratory was the reference design for the LBNE conceptual design in March 2012 before the Reconfiguration effort, but at a larger size than currently envisioned. The detector itself is very similar to the surface siting with only a few changes. The conventional facilities (CF) to support the detector are quite different from the surface siting, but well understood since a 4850L siting was previously developed to the CD-1 level. This section would describe the changes from the proposed design for a surface detector and the associated additional environmental impacts.

4.2.1 Proposed 4850L LAr TPC

The change in the detector scope from surface to underground requires the detector to be placed in a cavern at the 4850L near the Ross shaft as shown in Figure 15 while much of the cryogenic equipment stays on the surface. It is proposed to place the surface equipment in the existing Ross Boiler Building, shown in Figure 16. The gaseous cryogens would be delivered via piping segregated in a chase in the Ross Shaft, to the detector, and reliquified in the cavern. The cavern ventilation exhaust would be routed to the existing underground exhaust stream exiting through the Oro Hondo Shaft.

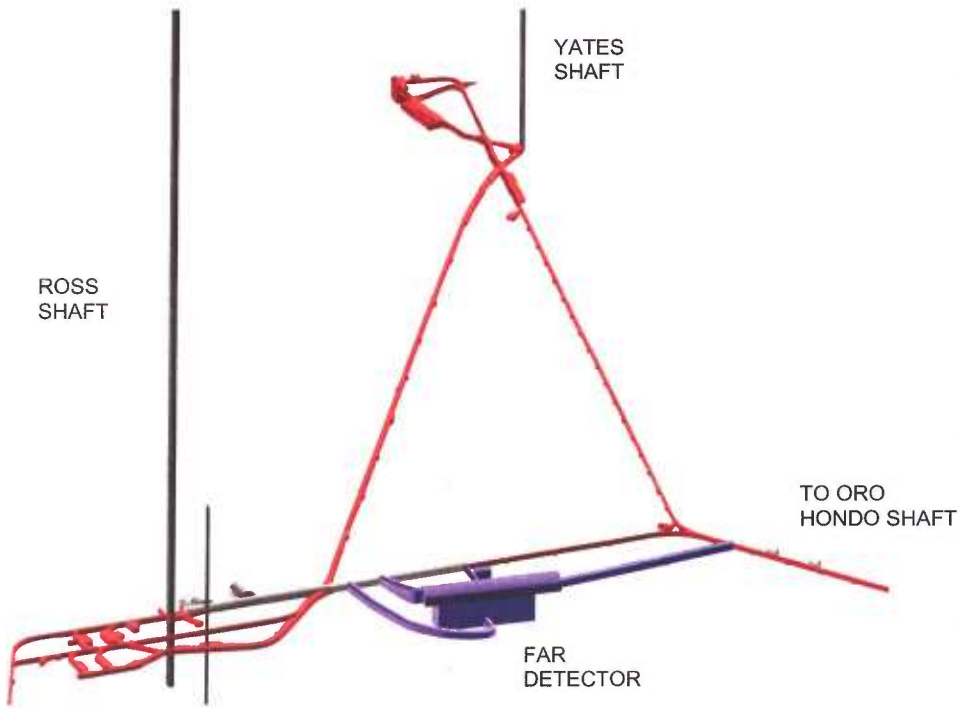

Figure 15 Siting of 10 kt LBNE Far Detector

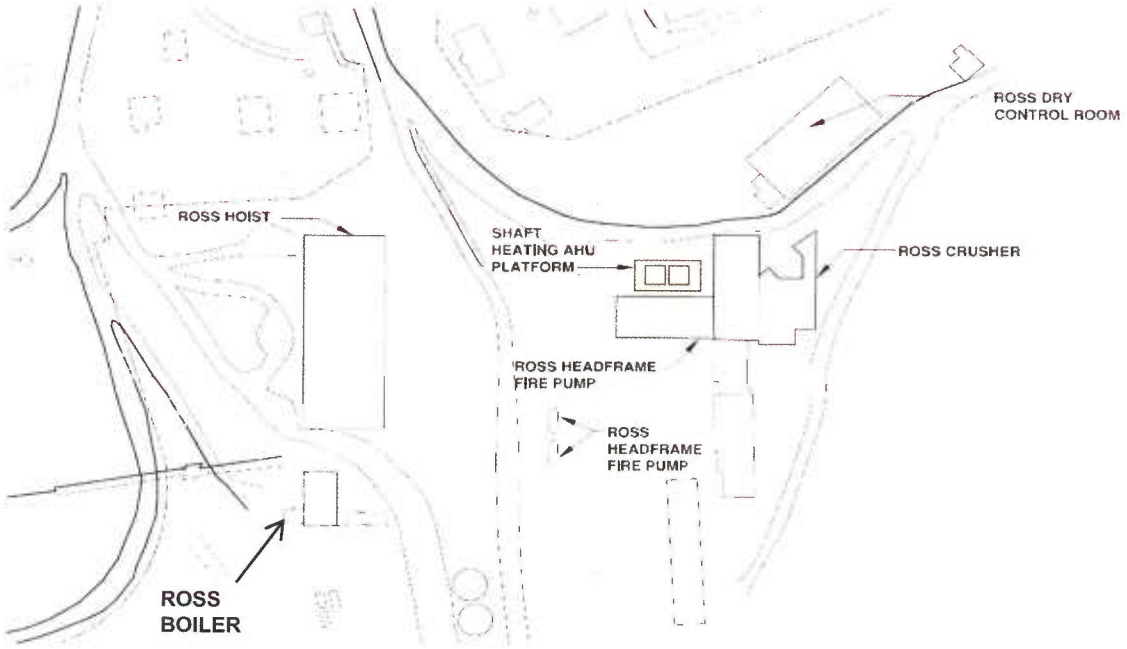

Figure 16 4850L Ross Complex Site (north up)

Proposed 4850L Far Detector CF

The scope of the 4850L facilities required for the LAr includes new excavated spaces for the detector, utility spaces for experimental equipment, utility spaces for facility equipment, drifts for access, Area of Refuge (AoR) for emergencies, as well as construction required spaces. The detector requires a cavity excavation of a mailbox shape. Just above the detector, a domed excavated space is required for a service area.

Waste rock would be removed through the Ross Shaft and trucked to the Open Cut across town in Lead.

On the surface, the unused Ross Boiler Building would be repurposed for the cryogenic equipment. A small purity check building would be constructed nearby.

Underground infrastructure for the facility includes power to experimental equipment, domestic water, industrial water for process and fire suppression, ventilation supply and exhaust, fire detection and alarm, normal and standby power systems, sump pump drainage system for conveying native infiltration water to the facility-wide pump discharge system, and cyberinfrastructure for communications and security. Where this infrastructure exists underground, the LBNE facilities would tie into it. Some new utilities would be routed down the Ross Shaft for LBNE.

4.2.2 Environmental Impacts

Placing the experiment at the 4850L and locating the experimental access to the Ross Complex area creates several changes in impacts from those described for the surface siting in Section 3.1.2.

No wetlands would be affected in this siting.

All liquid effluent would be handled with the existing sanitary and storm sewerage at the Ross Complex on the surface and at the 4850L would be combined with the underground water management.

Experiment cryogen deliveries would be on Mill Street to the Ross Boiler Building through the city of Lead and would increase truck traffic more heavily during experiment installation.

Waste rock removal would increase truck traffic through the city during the construction period. Rock would be deposited in the Open Cut.

The Ross Boiler Building is within the Lead Historic District and its remodeling would need to be coordinated with of those requirements. The building contains asbestos that would need to be removed prior to reuse for the Far Detector equipment.

Experiment decommissioning would be similar to the surface siting: the detector equipment would be removed and reused where possible by other experiments. The underground cavern would be left with only the concrete liner in place and then abandoned, if it were not needed by another experiment.

References

[1] Long-Baseline Neutrino Experiment Project, "Alternatives Analysis (LBNE-doc-4382),".

[2] William Brinkman. (2012, March) Letter from William Brinkman to Pier Oddonne, dated 19-March-2012. [Online]. http://www.fnal.gov/pub/today/images12/031912-brinkman-oddone.pdf

[3] Kim, Young-Kee. (2012, June) LBNE Reconfiguration Report. [Online]. https://indico.fnal.gov/conferenceDisplay.py?confId=5622

[4] William Brinkman. (2012) Letter from W. Brinkman to P. Oddone, dated 29-June-2012. [Online]. http://www.fnal.gov/directorate/lbne_reconfiguration/files/2012-0629-brinkman-to-oddone.pdf

[5] "LBNE Far Detector Decision -- Request for Concurrence (LBNE-doc-4099),".

[6] Vaia Papadimitriou, "Decision on the LBNE Beamline Depth and Extraction Point (LBNE-doc-5122)," November 28, 2011.

[7] Patrick Engineering, Inc., "The Wetland Report," August 9, 2010.

[8] HDR, "LAr 800L Final Conceptual Design Report for LBNE Surface Facilities at Sanford Lab (LBNE-doc-4337)," September 30, 2011.

NEPA Recommendation

Fermilab has reviewed this proposed action and determined that it does not fit in the classes of actions, predetermined by DOE in 10 CFR Part 1021, Subpart D, Appendix A and B, that do not individually or cumulatively have a significant effect on the human environment (categorical exclusion). Therefore, this project would require either an Environmental Assessment (EA) or Environmental Impact Statement (EIS) determination from the DOE.

Fermilab NEPA Reviewer: Teri L. Dykhuis
Signature and Date Teri L. Dykhuis 8/30/2012