DOE/EA-1943

DRAFT ENVIRONMENTAL ASSESSMENT FOR THE CONSTRUCTION AND OPERATION OF THE

Long Baseline Neutrino Facility and Deep Underground Neutrino Experiment

at Fermilab,
Batavia, Illinois

and

Sanford Underground Research Facility,
Lead, South Dakota

U.S. Department of Energy
Office of Science, Fermi Site Office

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EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) is proposing to construct and operate the Long-Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE) with facilities at Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois, and the Sanford Underground Research Facility (SURF or Sanford Lab) in Lead, South Dakota. Throughout this document, the Proposed Action is referred to as LBNF/DUNE. The Project was formerly referred to as the Long Baseline Neutrino Experiment (LBNE), but changed to LBNF/DUNE with the addition of international science partners. This resulted from the May 2014 recommendation of the Particle Physics Project Prioritization Panel (P5), that the U.S. partner with the international neutrino physics community to develop a leading-edge facility for neutrino science and proton decay studies. This facility will be an internationally designed, coordinated and funded program, hosted at Fermilab, comprising the world's highest-intensity neutrino beam and advanced underground detectors designed to both exploit this beam and observe galactic neutrinos from supernovae.

NATIONAL ENVIRONMENTAL POLICY ACT

This Environmental Assessment (EA) for LBNF/DUNE (DOE/EA-1943) evaluates the potential environmental impacts of the Proposed Action. The EA was prepared in compliance with the National Environmental Policy Act (NEPA) of 1969 (42 U.S. Code [U.S.C.] 4321 et seq.), regulations of the President's Council on Environmental Quality (40 Code of Federal Regulations [CFR] 1500–1508), and DOE's NEPA implementing regulations (10 CFR 1021). The EA and supporting documentation also supports compliance with Floodplain and Wetland Environmental Review Requirements (10 CFR Parts 1021 and 1022), and Section 106 of the National Historic Preservation Act (NHPA). Given that the impacts of operation of the proposed LBNF/DUNE would be similar in nature to other DOE accelerator projects, including existing projects at Fermilab, DOE has determined that an EA is the appropriate level of NEPA review. EAs are screening tools which have two functions; 1) to assist DOE in determining whether to prepare a more exhaustive Environmental Impact Statement (EIS), if there are potentially significant environmental impacts, or 2) to justify a Finding of No Significant Impact (FONSI), if there are no potentially significant impacts.

PURPOSE AND NEED

DOE's Office of Science is the Nation's largest supporter of fundamental research in the physical sciences, which it pursues in partnership with national laboratories, universities, institutions, and other organizations with related missions. Fundamental research involves investigation and analysis focused on obtaining a better or fuller understanding of a subject, phenomenon, or a basic law of nature, not necessarily specific practical application of the results. One important research area within the physical sciences is Elementary Particle Physics, which has, as one of its goals, helping us to understand the physical nature of our Universe.

LBNF/DUNE would help to advance our understanding of the basic physics of the elementary particles called neutrinos. Neutrinos are elementary subatomic particles that have no electrical charge and are one of the most abundant particles in the Universe. In nature, they are produced in great quantities by sources such as our sun, from stellar explosions known as supernovas, and in smaller quantities on earth by man-made facilities, such as nuclear power plants. Neutrinos stream to the earth each day. The very small size of neutrinos means that they pass right through matter largely unimpeded, and only very rarely interact with other particles. In the lab, at facilities such as Fermilab, scientists can make neutrino beams for experimental purposes with particle accelerators. Appendix A-2 contains an article (Piergrossi 2013) describing what physicists know about neutrinos and the questions that could be answered by further research.

LBNF/DUNE would make use of an existing high-energy particle accelerator at Fermilab in Batavia, Illinois (the Near Site) to generate a beam of neutrinos and would utilize particle detectors to analyze the beam; one at Fermilab and another detector with one or more modules approximately 800 miles away at SURF (the Far Site). Although DOE has other neutrino experiments currently underway, where the neutrino source and detector are separated by 500 miles or less (see Appendix A-1), the longer baseline has been determined by scientists to be the optimal distance for this experiment and would enable scientists to gather important new information about neutrinos. The Far Site detector would be underground, to eliminate cosmic radiation that could interfere with the detector.

Neutrinos in flight naturally transform themselves quantum mechanically, by oscillating back and forth between three different states or "flavors" (muon neutrinos, electron neutrinos, and tau neutrinos). LBNF/DUNE would enable the most precise measurements yet of this neutrino oscillation phenomenon, which could potentially help physicists discover whether neutrinos violate the fundamental matter-antimatter symmetry of the Universe. If they do, then physicists would be a step closer to answering the puzzling question of why the Universe currently is filled preferentially with matter, while the antimatter that was created equally by the Big Bang has all but disappeared. So far, other sub-atomic particles known as quarks are the only elementary particles known to violate the fundamental symmetry between matter and antimatter. However, the observed violation of this symmetry in the physics of quarks is not sufficient to explain the observed abundance of matter over antimatter in the Universe.

Constructing LBNF/DUNE with a Near Site detector at Fermilab and with a Far Site detector deep underground would produce the best data for answering these questions. The Near Site detector would provide data on the quality of the beam as it leaves Fermilab and add to the precision of the measurements. The deep detector at the Far Site, shielded from cosmic radiation, would provide the most sensitive measurements of oscillations of the neutrinos sent from Fermilab. A deep detector would also enable sensitivity to proton decay and the capability for measuring electron neutrinos from a supernova should one occur in our galaxy during the Experiment's lifetime. The SURF site would provide the necessary long baseline (800 miles from accelerator to detector) and the capability to construct a large detector deep underground to shield the detector modules from interference by cosmic rays. For these reasons construction of a LAr detector deep underground (4,850 feet deep) at SURF would generate the most accurate data, and is recommended by the international collaboration.

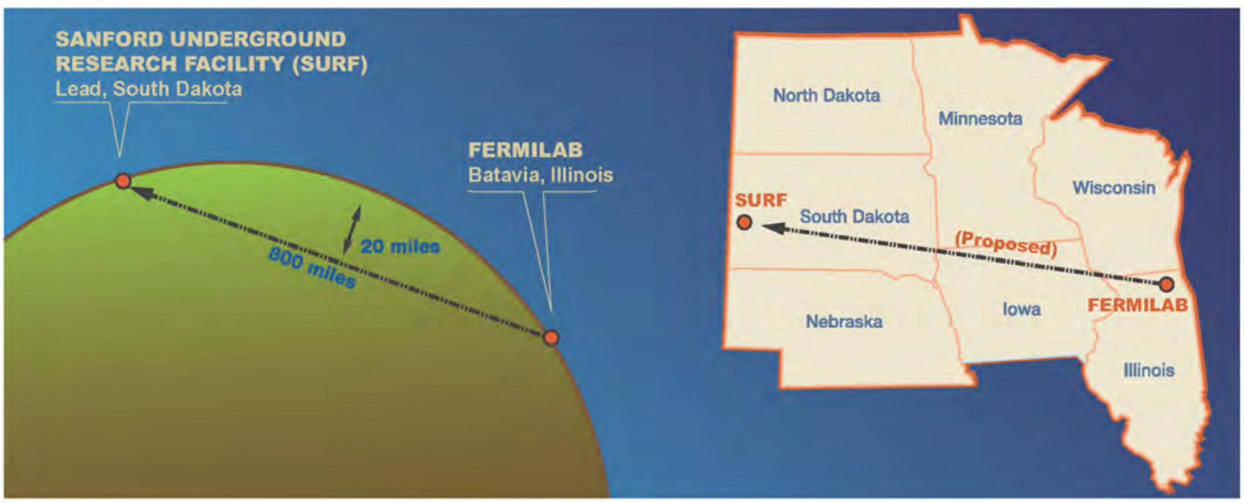
As these questions are pursued by LBNF/DUNE, other experiments that would make use of the same detectors and/or laboratory infrastructure may provide additional opportunities for basic research in other areas of physics. In short, LBNF/DUNE and ancillary experiments would enable scientists potentially to transform our understanding of neutrinos and their role in shaping our Universe.

DESCRIPTION OF THE PROPOSED ACTION

Under the Proposed Action, Fermilab would construct facilities that would extract a proton beam from Fermilab's existing particle accelerator, generate a high-intensity neutrino beam, and direct the beam at a detector to be constructed 800 miles away at the Sanford Underground Research Facility (SURF). The beam would be generated underground and would travel through the Earth at depths of up to 20 miles (see Figure S-1). The Fermilab components of the Proposed Action would be constructed adjacent to Fermilab's existing accelerator ring and would include beamline facilities to extract and focus the beam (by means of target horns and magnets). The primary structures would include a Primary Beam Enclosure, Target Hall, Absorber Hall, Decay Pipe, and Near Neutrino Detector (NND). Most of these facilities would be constructed underground or within an earthen embankment to shield the surrounding environment from beamline radiation. The facilities and work areas would be housed in a series of underground experimental halls and aboveground service buildings. Proposed facilities at SURF would include a large, underground liquid argon (LAr) detector with one or more detector modules, associated supporting facilities, and an aboveground service building. Construction of the underground detector would require excavation and transportation of a large volume of rock. The rock would be transferred to either the Gilt Edge Superfund site, or to the Open Cut in Lead, a former surface mining pit that was part of the former Homestake Mine. The Gilt Edge Superfund site is a highly disturbed former gold mine in Deadwood—the Proposed Action would cover only transportation to the Gilt Edge superfund site and not other activities being planned for its remediation. At both Fermilab and SURF, the Proposed Action would include implementation of Standard Environmental Protection Measures (SEPM), such as post-construction revegetation, erosion control, and traffic control. The planned SEPMs are introduced in Section 2, Description of Proposed Action and Alternatives, and described in detail in Section 3, Affected Environment and Environmental Consequences.

The facilities would be designed for an expected experimental lifetime of approximately 20 years. Ultimate decommissioning, including potential repurposing, dismantling and disposal of radioactive and non-radioactive components, would not occur for many years and DOE has determined that it would be too speculative to evaluate future decommissioning impacts in this EA. Therefore, the environmental impacts of decommissioning would be evaluated in a future NEPA document.

Figure S-1 Pathway of the LBNF/DUNE Neutrino Beam from Fermilab to SURF



ALTERNATIVES

As required by Council on Environmental Quality (CEQ) regulations, the LBNF/DUNE EA evaluates a No Action Alternative to serve as a basis for comparison with the action alternatives. Under the No Action Alternative, LBNF/DUNE would not be constructed and operated and the enhanced opportunities for neutrino research would not be pursued. In addition, a second alternative (Alternative A) consisting of other smaller, reasonably foreseeable experiments being considered at SURF was evaluated. These alternatives are not mutually exclusive and if selected by DOE, the Alternative A experiments could be constructed in addition to the Proposed Action, or they could be constructed independently. DOE also considered other siting alternatives and a less ambitious alternative with fewer facilities at Fermilab and a smaller surface detector at SURF (see EA Section 2.4). However, these alternatives were eliminated and not evaluated in the EA because they did not meet the Purpose and Need for the LBNF/DUNE and/or certain other criteria deemed necessary for the project.

AFFECTED ENVIRONMENT

Fermilab is located 38 miles west of downtown Chicago, Illinois, in an area of mixed residential, commercial, and agricultural land use. Fermilab is an established national laboratory that has designed, constructed, and operated proton accelerators and high-intensity neutrino beams for years, beginning with the Main Ring in 1972, followed by the Tevatron in 1983 and later facilities. The Tevatron closed in 2011 when the more powerful Large Hadron Collider (LHC) opened in Geneva, Switzerland. However, Fermilab has been operating the Neutrinos at Main Injector (NuMI) project with a detector in Soudan, Minnesota, since 2005, and recently completed construction of the NuMI Off-axis ν_e Appearance (NOνA) project, with a detector in Ash River, Minnesota (note that the ν is the designation for the neutrino particle, in this case the electron neutrino). These projects have extensive underground and surface facilities including a large accelerator, the site's Main Injector (MI); and existing power and cooling water systems, research laboratories, and other facilities. The LBNF/DUNE construction site consists of uplands and wetlands as well as Indian Creek and adjacent farmland and floodplain areas.

SURF is an existing physics research facility in Lead, South Dakota, within the underground workings of the former Homestake Mine. The site has an extensive history of mining activity, including excavation and rock processing and disposal. SURF has existing mining infrastructure including facilities for hoisting and processing rock, deep access shafts, and several underground caverns used for existing physics experiments. Construction of LBNF/DUNE at SURF would take advantage of this existing configuration but would construct the detector in a new, deep underground cavern.

ENVIRONMENTAL IMPACTS

The LBNF/DUNE EA evaluates the potential environmental effects that could result from implementing the Proposed Action, Alternative A, and the No Action Alternative. The EA covers a range of potential designs and environmental impacts, including some dealing with radiation, both contamination and exposure. The potential environmental impacts evaluated in the LBNF/DUNE EA are summarized below.

Land Use and Recreation

Fermilab Site

Construction and operation of the Proposed Action would have very low adverse impacts on existing or future land uses at Fermilab in that LBNF/DUNE is entirely consistent with Fermilab's mission: conducting state-of-the-art high-energy physics research. Nor would LBNF/DUNE have direct or indirect impacts on off-site land use, such as the character or use of land in the surrounding community. Recreational users of the Illinois Prairie Path, located approximately 2,500 feet to the southwest, would have views of the embankment, which would be landscaped accordingly to reflect the surrounding environment. However, these recreational users now have views of existing Fermilab facilities, including Wilson Hall.

The No Action Alternative would have no adverse effects on on-site or off-site land uses, including adjacent residential and recreational land uses. Fermilab's high-energy physics mission would be unchanged, and the lab would continue to pursue ecological research and natural resources restoration.

SURF Site

Construction and operation of the Proposed Action would not adversely affect land use because the land is owned by SURF or Homestake, is previously disturbed, and would not require a zoning change. However, the Proposed Action would require a building permit from the City of Lead and easements from the Lawrence County Highway Department and McGas for land adjacent to Kirk Road. The Gilt Edge Superfund Site is one location for the transport of excavated rock. The site is owned by the State and is managed as a Superfund site by the U.S. Environmental Protection Agency (EPA) and no land use impacts would result. Alternatively, transport and placement of rock at the Open Cut would have low impacts on adjacent land uses; however, it would require a revision of Homestake's mining permit, a right-of-way, and an agreement between SURF and Homestake.

Alternative A would not require land use changes on SURF property or either rock placement site, if rock was hoisted to the surface. The No Action Alternative would not affect current land use or recreation. SURF would continue to operate as an underground physics research facility. Recreational resources, such as the Mickelson Trail, would be unaffected by this alternative.

Biological Resources

Fermilab Site

The Proposed Action would affect vegetated wetlands and Indian Creek, including placement of clean fill material. Construction would affect approximately 5.0 acres of wetland and would require a culvert to re-direct the creek under the embankment and proposed structures, resulting in temporary impacts on stream invertebrates and fish. These impacts would be minimized to the extent practicable and would require authorization by the U.S. Army Corps of Engineers (USACE) under the Clean Water Act (CWA), Section 404 and compensatory wetlands mitigation to offset the impact, either on-site or off-site. The Proposed Action would also affect vegetation, including approximately 250 to 300 trees, and could have potential impacts on migratory birds, and potentially Indiana bat (*Myotis sodalis*) and northern long-eared bat (*Myotis septentrionalis*). To avoid such impacts, Fermilab would schedule removal of vegetation outside the typical nesting and roosting season to the extent practicable and would consult with the U.S. Fish and Wildlife Service (USFWS) and Illinois Department of Natural Resources (IDNR). Operations would have low biological impacts as it would occur within the area disturbed by construction. In addition, shielding and surface and groundwater management systems would be designed to minimize radiation exposure to biota.

The No Action Alternative would not involve wetland or stream excavation or fill placement. Fermilab would continue to operate existing experimental facilities and manage operations to minimize biological effects in accordance with DOE, state and Federal requirements.

SURF Site

The Proposed Action at SURF would occur in an urban, industrial setting, heavily disturbed by historical mining activity, including both the Gilt Edge Superfund site and the Open Cut. Neither alternative site for the transport or transport/placement of rock would have direct impacts on biological resources and would use existing wastewater treatment facilities and SEPMs, including stormwater best management practices (BMP), to minimize aquatic habitat effects downstream in Whitewood Creek. Because construction would occur deep underground and in other areas disturbed by mining, the Proposed Action would not have substantial effects on vegetation or terrestrial wildlife habitat. Wildlife that inhabit areas adjacent to the Proposed Action, such as deer, small mammals and raptors (e.g., hawk), are generally acclimated to human activity. To minimize potential impacts on bats and migratory birds, SURF would conduct clearing and grubbing outside of the migratory bird nesting and bat roosting season to the extent practicable. Vegetation would be restored following construction. Operation of the LBNF/DUNE would have no impacts on wetlands and very low impacts on other biological resources as it would not require excavation or construction in previously undisturbed areas.

The construction and operation of Alternative A experiments would not impact biological resources as they would be constructed and operated deep underground. Excavated rock transported to the Gilt Edge Superfund site or Open Cut would be used similar to the Proposed Action and thus have no or very low biological impacts.

The No Action Alternative would not involve construction or operation of the LBNF/DUNE detector or Alternative A experiments and thus would have no impacts on biological resources. Existing operations at SURF would continue with no additional or incremental environmental effects.

Cultural Resources

Fermilab Site

There are no known historic properties or paleontological resources in the proposed construction area and DOE has completed consultations with the Illinois State Historic Preservation Office (SHPO). Should unanticipated resources be encountered during construction, Fermilab and DOE would stop construction in that area and notify an archaeologist or paleontologist, who would implement the procedures outlined in the Fermilab Cultural Resources Management Plan (CRMP). Operations would not require excavation and would therefore have no impacts on cultural resources.

Under the No Action Alternative, there would be no excavation, grading or other new ground disturbance in these areas; therefore, no effects on historic properties or paleontological resources would occur. Existing Fermilab projects and research would continue and would comply with the CRMP.

SURF Site

DOE and SURF have conducted extensive consultations with local government, the South Dakota SHPO, and the American Indian tribes regarding Section 106 compliance, and have developed a draft Programmatic Agreement (PA) for the LBNF/DUNE project. The PA provides a framework for evaluating/addressing potential impacts of the proposed action. The Proposed Action would affect the Ross boiler building; although the modifications to this building would be made consistent with the Secretary of the Interior's *Standards for the Rehabilitation of Historic Properties* (*Rehab Standards*) as outlined in the PA, the SHPO has determined the modifications would be considered an adverse effect pursuant to Section 106. Resources within the Lead Historic District along the trucking or conveyor routes would be evaluated under the PA. Operation of the Proposed Action would be largely underground and would have no impacts on cultural resources.

Although the Proposed Action would take place within the Black Hills region, it would largely occur within an area that has already been significantly disturbed by past mining activities and other development. Redeployment of the Homestake Mine via the Proposed Action, i.e., science projects like LBNF/DUNE, would begin the rehabilitation process in a way that would have multiple benefits; from educational programs for children to the possibility of scientific discovery that could inspire members of tribal and non-tribal community alike. Therefore, impacts to traditional cultural resources would be low.

Alternative A would have no impact on historic properties or traditional cultural resources beyond those described in the Proposed Action. There would be no new ground disturbances with the exception of minor use or modification of existing surface buildings such as the Ross or Yates Complexes. Future experiments under Alternative A would be subject to Section 106—any potential adverse effects from these specific, yet undetermined projects would be avoided or minimized through the procedures outlined in the PA.

The No Action Alternative would not involve construction or operation and would have no impact on traditional or historic cultural resources. Existing experiments would continue to operate underground.

Health and Safety

Fermilab Site

During construction of the Proposed Action, the primary potential health and safety risk would be worker accidents and injuries. To minimize potential health and safety effects on workers and the public and to protect the environment, construction activities would conform to Fermilab SEPMs such as health and safety requirements and safety specifications for electrical systems. Based on Fermilab health and safety statistics, the Proposed Action would potentially result in approximately 4.0 recordable work-related injuries or illnesses over 7 years of construction (less than one per year). Construction workers would not be exposed to radiation with the exception of excavation of the Cooling Pond F. This work could result in minor radiation exposures, which would be minimized by complying with SEPMs outlined in the Fermilab Radiological Control Manual (FRCM), such as worker training and monitoring of excavated soil by a radiological control technician.

Operations would result in potential exposure to radiation similar to other Fermilab experiments; however, these risks would be managed by adhering to existing SEPMs and would be minimized by engineering controls. Radiation exposures would be reduced to As Low as Reasonably Achievable, or ALARA, and would be below Fermilab and DOE exposure standards (1,500 mrem per year, 5,000 mrem per year, respectively) for involved and non-involved workers. Exposures to the public would be less than the DOE standard of 10 mrem per year. Because no new positions would be created for operations, the Proposed Action would not result in an increase in potential injuries/illnesses.

The No Action Alternative would not result in new occupational or radiological health or safety impacts on workers or the public. Existing health and safety hazards at Fermilab would continue to be managed in accordance with established programs, policies, and procedures.

SURF Site

Workers constructing the LBNF/DUNE at SURF would encounter typical workplace hazards associated with underground construction, materials handling and storage, blasting and hauling excavated rock to the surface. Based on the industry incident rate for Heavy Construction, 21 accidents/injuries would be expected to occur over the seven year construction period. Because there have been no accidents or injuries associated with operating experiments at SURF, no accidents/injuries would be expected during operations. These hazards would be minimized by adhering to existing SURF and Fermilab SEPMs and safety practices. Operational hazards would include working underground as well as potential exposure to cryogens (i.e., a liquid, such as liquid nitrogen, that is used to attain very low temperatures). SEPMs would include extensive training and use of personal protective equipment. Safety and health hazards would be identified during work planning and the risks minimized by engineering and administrative controls.

Construction of future underground experiments under Alternative A would have low effects on workers, operators, or the public, similar in scope to the Proposed Action but lesser in scale. Construction would be limited to underground areas and operations would follow SURF safety requirements. Both construction and operations would be removed from residences and public areas and potential impacts on health and safety would be low.

Under the No Action Alternative, there would be no additional health or safety impacts at SURF. Existing health and safety hazards would continue to be addressed by ongoing implementation of established engineering and administrative controls.

Hydrology and Water Quality

Fermilab Site

During construction of the Proposed Action, potential impacts on surface water hydrology may result from construction of the embankment and service buildings near Indian Creek, as well as the culvert required to re-direct Indian Creek under the embankment. The culvert would remove a portion of the existing streambed; however, the stream's hydraulic capacity would be replaced and these impacts would be short term. These modifications would require permits from the USACE and IDNR, and construction in the floodplain would require compliance with Executive Order (EO) 11988 - Floodplain Management and Federal regulations. Operation of the LBNF/DUNE would have no impacts on flooding in the project area.

The Proposed Action could have potential impacts on surface water quality during excavation of borrow areas, construction of the embankment, and other ground-disturbing activities. Fermilab would apply for a construction stormwater general permit and stormwater would be managed according to Fermilab's existing Storm Water Pollution Prevention Plan (SWPPP). Construction of the culvert in Indian Creek would require CWA Section 401 Water Quality Certification. Thus, impacts to hydrology and water quality would be low.

Excavations would require temporary dewatering of groundwater, which would result in low impacts on groundwater elevations. Groundwater pumped for dewatering would be treated and discharged to Indian Creek, requiring modification of the Fermilab National Pollutant Discharge Elimination System (NPDES) permit. Impacts on groundwater quality would be minimized by grouting the bedrock at the base of excavations to minimize groundwater inflow and contact. Groundwater contamination would also be minimized by SEPMs including spill prevention and stormwater BMPs designed to minimize releases of oil, fuel, solvents, and other construction materials.

Operations would have low effects on surface water quality. Pumped groundwater would be collected in Fermilab's existing cooling water ponds or discharged into tributaries to Indian Creek. Radionuclide concentrations in these ponds are very low and in either drought or overflow conditions would be anticipated to be below surface water quality standards, such as the DOE surface water standard of 1,900 picoCuries per milliliter (pCi/ml) (10 CFR 835). The Proposed Action would be designed with thick shielding for radiation and other engineering controls. For instance, this 13-foot-diameter steel Decay Pipe would be surrounded by approximately 18 feet of concrete shielding to protect the surrounding soil from radiation produced in the pipe. The shielding would be lined with a geosynthetic barrier system and equipped with a moisture interceptor system to prohibit groundwater from infiltrating into the Decay Pipe. The proposed liner system would include an outer geomembrane barrier layer, a geosynthetic clay liner (GCL) barrier, and a leak detection layer placed between the GCL and the inner geomembrane barrier layer.

Fermilab's shielding calculations (Mokhov 2011) demonstrate that groundwater radionuclide concentrations would be below DOE surface water and U.S. Environmental Protection Agency (EPA) drinking water standards (e.g., 20 pCi/ml for tritium). Furthermore, the groundwater near the LBNF/DUNE shielding would be part of the glacial drift aquifer, which is subject to institutional controls on the Fermilab property, and not available for consumption as part of a Class 1 groundwater resource.

Operation of vehicles and maintenance activities could affect groundwater quality without protective measures in place. However, operations would only allow chemical use indoors and in small quantities, and impacts on groundwater would be minimized through SEPMs and by implementing the Spill Prevention, Control, and Countermeasure (SPCC) and SWPPP, which both contain operational BMPs.

Under the No Action Alternative, no impacts on surface water, groundwater hydrology, or water quality would occur because Fermilab would not conduct excavation or construction and would not operate the beamline. Hydrology and water quality impacts from current construction and operations would continue, and those impacts would continue to be addressed through existing water quality controls and flood abatement measures.

SURF Site

Construction of the Proposed Action would occur deep underground in the same areas mined by Homestake. Excavated rock would be transported to the Gilt Edge Superfund site in Deadwood or transported to and placed at the Open Cut in Lead. Concerning the latter, surface runoff from the Open Cut area would drain to the underground pool via tunnels and would be treated at the SURF wastewater treatment plant (WWTP) prior to discharge to Whitewood Creek. Overall, construction of the underground detector would have low impacts on groundwater and surface water because water not meeting discharge or groundwater standards would be captured and treated by existing water treatment facilities.

The operation of the Proposed Action would not measurably affect groundwater or surface water. Condensate from the mine air interacting with the cold detector would be less than 5 gallons per minute (gpm) and would be collected in a sump and discharged to mine water. SURF would monitor the condensate to ensure it would not reduce the quality of the mine water. If the condensate water were found to be of lower quality than mine water, an EPA underground injection control (UIC) permit would be obtained. In general, the small amount of condensate water added to overall mine water quantity (estimated in the billions of gallons) would not change mine water quality within the range of analytical error.

Alternative A construction would occur underground with excavated rock retained underground or transported to either the Gilt Edge Superfund site or Open Cut. Water quality impacts would be similar to the Proposed Action and would be minimized through SEPMs. Operations would generate small quantities of reverse osmosis (RO) brine (a concentrated salt solution) that would be discharged to the underground pool.

The No Action Alternative would have no impact on surface water or groundwater. Past disturbance and existing experiments would continue to generate runoff and leachate that would be collected and treated by SURF prior to discharge.

Noise and Vibration

Fermilab Site

Construction of the Proposed Action would require the use of heavy earth-moving equipment, including a crane near Kirk Road (not to be confused with Kirk Road at the Far Site in South Dakota). Construction would increase noise levels by approximately 5 decibels (dBA) above existing ambient conditions at residences directly across Kirk Road, which would be noticeable. However, noise levels would diminish rapidly with distance because much of the construction of the underground facilities would be conducted within excavations that would attenuate much of the sound. In addition, construction would normally be completed during the day and within the day, during which activities (and their associated noise levels) would be exempt from the City of Batavia's noise code. The construction noise would also be temporary.

The Proposed Action would also incorporate blasting with approximately four events per day over several months. Blasting would result in vibration levels of up to approximately 82.5 VdB (velocity or vibration decibels) and could be noticeable for the nearest residents. Accordingly, Fermilab would incorporate several SEPMs to reduce adverse effects, including communication with local residents through public meetings and announcements regarding the blasting schedule. In addition, the construction contractor would monitor vibration levels to adjust the size of the charges.

Operational noise impacts would be low. Chillers and heating, ventilation and air conditioning (HVAC) units would be designed to include quiet equipment and incorporate sound dampening equipment or enclosures, if needed, to maintain noise at below State of Illinois octave band threshold limits.

Under the No Action Alternative, there would be no construction or operational noise or vibration impacts. Ongoing activities associated with current Fermilab construction activities and ongoing experiments would continue, as would existing ambient noise sources such as Kirk Road.

SURF Site

Construction of the deep underground detector would require trucking to the Gilt Edge Superfund site in Deadwood, or the use of either a rail or pipe conveyor or loading and driving trucks to the Open Cut in Lead. Although underground construction would not result in substantial noise or vibration, aboveground construction would result in noise increases of 4 to 16 dBA, including noise from trucking along the trucking routes. Alternatively, construction of a conveyor system to the Open Cut would generate temporary noise levels of approximately 16 dBA above background levels for a period of up to 2 months However, based on the history of the Lead area being a mining area, noise and vibration increases are familiar to the community and thus increased impacts in this context would be low. Moreover, increases in noise and vibration would also be temporary occurring during only during construction of the proposed action.

Operational noise from the planned Cryogen Support Building would increase noise by 7 dBA above existing nighttime ambient noise levels. Noise dampening equipment would be used to reduce nighttime noise.

Noise and vibration levels from construction of Alternative A would be similar to the Proposed Action but of shorter duration. Operational noise and vibration would be similar to that from the Proposed Action.

The No Action Alternative would not involve excavation, blasting, conveyance of rock, or operation of detectors and would have no noise or vibration impacts. Existing SURF experiments would continue to operate.

Transportation

Fermilab Site

The Proposed Action would result in a minor increase in the annual average daily traffic (AADT) on public roadways near Fermilab. If all construction traffic used the same route, no road would experience an AADT increase of greater than approximately 4 percent. Based on published accident rates, construction may result in 23 accidents, 7 injuries, and zero (0.075) fatalities. Operations would have a low impact on traffic and would potentially result in 3 traffic accidents, 1 injury, and zero (0.01) fatalities over the 20 year operating period. SEPMs would include preparing and implementing a traffic control plan.

Under the No Action Alternative, existing research programs at Fermilab would continue; however, LBNF/DUNE would not be constructed or operated. The traffic impacts associated with LBNF/DUNE construction and operation would not occur, and there would be no incremental increase in impacts on traffic volumes or accident rates. Public travel on Kirk Road, Butterfield Road, Interstate 88 (I-88), and other nearby travel routes, as well as the on-site roads within the Fermilab property, would be consistent with existing conditions and trends.

SURF Site

Construction of the deep detector would occur deep underground and would require trucking of rock. Assuming each truck carries approximately 12 cubic yards of rock, LBNF/DUNE would require transport of approximately 460,000 cubic yards to the Gilt Edge Superfund site or the Open Cut over approximately 2 years. Aboveground construction would increase traffic on local streets by approximately 7 percent. For rock transport, trucks would travel public roadways to the Gilt Edge Superfund site or to the Open Cut in Lead for approximately 10 to 12 hours per day. Based on an average of 75 round trips per day, with a peak of 150 round trips, traffic would increase by approximately 96 percent on Kirk Road and 146 percent on Gilt Edge Road. Truck trips to the Open Cut, if selected, would result in the same traffic increase on Kirk Road and a substantial traffic increase on the Open Cut access road. However, based on the history of the Lead area being a mining area, these increases would have low impact to transportation in the community in this context. Based on published total accident rates for all motor vehicles, the total vehicle miles traveled for the Proposed Action (with the alternative of rock transport to the Gilt Edge Superfund site) would have the potential to result in 9.3 traffic accidents, 2.5 injuries, and zero (<0.1) fatalities.

Accident incidence due to trucking would be lower if rock placement were to occur at the Open Cut, which would result in an estimated 8.8 traffic accidents, 2.3 injuries, and zero (<0.1) fatalities.

Construction traffic impacts would be reduced through SEPMs, including preparing and implementing traffic control plan. Operational traffic impacts would be very low. Truck traffic would also increase in Lead, due to tanker truck deliveries of LAr (liquid argon) and LN (liquid nitrogen) to the Ross shaft, using Mill Street.

Traffic impacts of Alternative A would be similar in type but lesser in scale to the Proposed Action during construction and very low during operations. The No Action Alternative would not involve construction or operation and there would be no related traffic impacts or potential accidents. Existing experiments at SURF would continue to utilize area roadways and traffic patterns from local and regional changes in population and development would continue.

Air Quality

Fermilab Site

Under the Proposed Action, construction would generate particulate emissions from dust and combustion emissions from construction equipment and vehicles. Construction would generate both attainment and non-attainment pollutants; however, emissions would be minimized by SEPMs and would be temporary and would not exceed the general conformity *de minimis* threshold (100 tons) for non-attainment pollutants (e.g., ozone precursors such as nitrous oxides [NO_x]). Air emissions from excavation, soil stockpiling, and embankment construction activities would be minimized by using SEPMs including erosion and dust control BMPs. The increase in criteria pollutant emissions for operations would be less than 1 ton per year of any criteria pollutant. Potential releases of hazardous air pollutants (HAP) from operations could include radionuclides; however, these emissions would be controlled and monitored to ensure the emissions would be well below regulatory limits.

Under the No Action Alternative, Fermilab's existing research programs would remain unchanged, and the LBNF/DUNE would not be constructed or operated. Therefore, air emissions would be unchanged. The No Action Alternative would have no additional impacts on air quality standards.

SURF Site

LBNF/DUNE construction at SURF would occur primarily deep underground; however, a large volume of excavated rock would be transported to the Gilt Edge Superfund site or the Open Cut via truck or conveyor. SURF would employ SEPMs including dust and other emission controls such as watering trucks, spraying surfactants on unpaved roads, and requiring Tier 3 and 4 engines for underground equipment. Assuming trucking of rock 8 miles to the Gilt Edge Superfund site as a conservative scenario, construction air emissions would not exceed air quality standards. Operational emissions from the LBNF/DUNE would be low.

Alternative A impacts on air quality would be similar to the Proposed Action during construction and low during operations as these activities would be of small scale and would occur underground. Under the No Action Alternative, there would be no construction or operations and thus no emissions. Existing research programs at SURF and related emissions would be unchanged and would continue without LBNF/DUNE.

Fermilab and SURF Greenhouse Gas Emissions

The CEQ published draft guidance on the inclusion of a greenhouse gas (GHG) evaluation for NEPA projects (CEQ 2014). In addition, EPA published draft guidance to assist Federal agencies in analyzing environmental effects of GHG emissions and climate change in NEPA documents (EPA 2010). Federal agencies are advised to consider opportunities to reduce GHG emissions caused by proposed Federal actions and adapt their actions to reduce climate change impacts. Further, the guidance states that actions having annual direct GHG emissions of greater than 25,000 metric tons (MT) of carbon dioxide (CO_2)-equivalent warrant description under NEPA.

The Proposed Action at Fermilab would emit the equivalent (CO_2 and other GHG) of approximately 188,000 MT of GHG, with approximately 133,000 MT during construction and 54,700 MT during 20 years of operations. SURF would generate approximately 16,800 MT during construction and 19 MT during operations). Therefore, LBNF/DUNE as a whole, including construction and operations at Fermilab and SURF, would emit approximately 205,000 MT of GHG over a period of approximately 27 years.

While estimated GHG emissions would be below 25,000 MT per year at each site, aggregated annual GHG emissions and the total for the Proposed Action would exceed this guideline. To offset GHG emissions, the Federal government has taken steps to reduce overall emissions, conserve energy, reduce demand, and promote development of renewable energy sources and technologies. These steps include publication of a series of Executive Orders, beginning with EO 13423, Strengthening Federal Environmental, Energy, and Transportation Management, dated January 24, 2007, EO 13514, Federal Leadership in Environmental, Energy, and Economic Performance and EO 13693, Planning for Federal Sustainability in the Next Decade on March 19, 2015. Furthermore, both Fermilab and SURF have developed site-specific sustainability plans to comply with these EO.

Visual

Fermilab Site

Construction of the Proposed Action would be visible from Kirk Road during site preparation, removal of Cooling Pond F, and construction of the embankment. This impact would be temporary and the embankment would blend in with the existing landscape as vegetation re-establishes. Some construction would be visible from Kirk Road for people driving both north and south, but would not be visible from other public roads or recreation areas.

During operations, the completed embankment and one service building would be visible briefly to motorists on Kirk Road. Its design would be similar to other Fermilab facilities to minimize visual effects. The embankment would be set in the distance, and revegetation would reduce contrast with adjacent grassy areas, agricultural fields, and restored prairie. In addition, these facilities would be constructed near existing Fermilab buildings with Wilson Hall in the background.

Under the No Action Alternative, LBNF/DUNE facilities would not be constructed or operated, and there would be no short- or long-term incremental visual impacts. Existing Fermilab facilities that can be seen from off-site, including the Pine Street entrance, the MI (main injector), and Wilson Hall (a prominent Fermilab feature), would remain.

SURF Site

Construction of the new LBNF/DUNE cryogen support building would be partially visible from Kirk Road in Lead and from several residences more than 1 mile away. The new building would be smaller and would have a lower profile than the existing Ross Boiler. The conveyor that would be used to load trucks (if selected) would be located at the top of Kirk Gulch and would be visible from Kirk Road and two homes. Transport of rock to the Gilt Edge Superfund site or transport to and placement at the Open Cut would have low visual impacts in this isolated area. The conveyor from the Ross Shaft to the Open Cut (if selected) would be partially visible throughout the City of Lead. A substantial portion of the conveyor route would be underground and thus visual impacts would be minimized. The visible portion would be similar to mining operations over the past 135 years. Operation of the LBNF/DUNE would occur deep underground and would have very low impacts.

Alternative A would have use same transportation and support facilities as the Proposed Action, so no or very low new visual impacts would result from these experiments.

Under the No Action Alternative, there would be no new visual impacts. Existing SURF facilities visible from Kirk Road and Lead would remain. Other SURF activities would continue in Kirk Gulch, such as ventilation of exhaust, stormwater management, substation maintenance, and security monitoring.

Geology and Soils

Fermilab Site

The Proposed Action would unavoidably affect soils during excavation and construction of the embankment and aboveground and underground facilities. Up to 950,000 yd^3 of soils would be removed; however, topsoil would be preserved to the extent practicable and reused to restore other areas. Geological resources (i.e., rock) would be affected by the unavoidable excavation of bedrock; however, this would not result in loss of important geological resources (i.e., mineral resources of commercial quality) or unique scientific data. The Proposed Action would also affect farmland that is not in cultivation. SEPMs would include developing and implementing an LBNF/DUNE-specific SWPPP to minimize erosion. Operations would have very low impacts on soils or bedrock.

The No Action Alternative would not involve excavation or grading; therefore, no impacts on soils or geological resources would result. Existing soil conditions at Fermilab would be maintained through erosion control and site restoration activities.

SURF Site

The Proposed Action would require excavation of approximately 460,000 cubic yards (yd^3) of rock from underground areas and would have a very low effect on soils as much of the area is developed. SEPMs would include erosion control. Operation of the LBNF/DUNE would be primarily underground and would not require additional excavation or grading aboveground.

Alternative A experiments would require excavation of an additional approximately 153,000 yd^3 of rock but there would be very low impacts on soil from construction and operations.

The No Action Alternative would have very low impacts on soils and geology.

Socioeconomics and Environmental Justice

Fermilab Site

LBNF/DUNE construction and operation would have a beneficial economic impact on the local construction industry and associated industries and potentially negative impacts would not disproportionately impact minority and low income communities. In accordance with DOE's Environmental Justice Strategy (DOE 2008b), DOE's NEPA process would provide residents, including the minority populations, with access to information regarding the selected alternative. Potential impacts of LBNF/DUNE (e.g., increased traffic during construction, noise during construction and operation) are low and would be borne equally by both minority and non-minority municipalities. Most impacts would occur along the Kirk Road corridor in Batavia, which is the closest off-site location to the Proposed Action. Batavia is neither a low income nor a disproportionately minority municipality. Hence there is no environmental justice concern.

Under the No Action Alternative, Fermilab operations would continue with ongoing and planned experiments. Existing and future impacts from these experiments would be borne equally by both minority and non-minority municipalities. Most impacts would occur along the Kirk Road corridor in Batavia, which is the closest off-site location to the Proposed Action. Batavia is neither a low income nor a disproportionately minority municipality. Hence there is no environmental justice concern.

SURF Site

Construction and operation of the Proposed Action would result in both direct and indirect beneficial economic effects. The Lead area has a slightly higher percentage of low-income people and a lower percentage of minority populations than the state as a whole. As described for Fermilab, DOE would implement its Environmental Justice Strategy to provide residents with information. Impacts (e.g., increased traffic) would be borne uniformly by the area's (defined as the Cities of Lead and Deadwood) entire population, which does not contain disproportionately high levels of minority or low-income residents compared to the Lawrence County. Although median household and per capita income are collectively less in Lead and Deadwood than in Lawrence County or the State of South Dakota, the population below the poverty level in Lead and Deadwood is similar to that of the County and the State. Hence there is no environmental justice concern.

Individual Alternative A experiments would be similar in impact but lesser in scope than the Proposed Action. Similar to the Proposed Action, impacts (e.g., increased traffic) would be borne uniformly by the area's entire populations, which does not contain disproportionately high levels of minority or low-income residents. Hence there is no environmental justice concern.

Under the No Action Alternative, the LBNF/DUNE would not be implemented. Existing and planned experiments at SURF would continue and socioeconomic trends in the area would be unaffected. Similar to the Proposed Action, impacts would be borne uniformly by the area's entire populations, which does not contain disproportionately high levels of minority or low-income residents. Hence there is no environmental justice concern.

Sustainability

Fermilab Site

The Proposed Action would comply with EO 13693, Federal Leadership in Environmental, Energy, and Economic Performance; DOE Order 436.1, Departmental Sustainability; as well as the Fermilab Site Sustainability Plan (SSP) goals of energy efficiency, waste reduction, sustainable acquisition, greenhouse gas emissions reduction, water use efficiency, and recycling. Although the Proposed Action would increase energy consumption, its operation would minimize the net increase by complying with the energy efficiency measures outlined in the SSP (e.g., using renewable energy, installing meters, and employee training) and continuing to purchase Renewable Energy Certificates (REC).

Under the No Action Alternative, there would be no construction or operational generation of additional GHGs, use of additional energy or water, or generation of additional waste materials. Existing operations would continue to use water and energy, and would continue to generate and dispose of waste materials in a manner consistent with the SSP.

SURF Site

The Proposed Action, as well as Alternative A, would be consistent with EOs and with SURF sustainability plan goals of reducing energy use, efficient use of resources, minimizing emissions, and minimizing waste. The Proposed Action would consume substantial energy and fuel in hoisting excavated rock out of the mine and transporting it to the selected placement area. Accordingly, SURF would incorporate design measures to minimize energy consumption.

The No Action Alternative would not generate GHG or use water or energy or generate waste. Existing operations would continue to use water and energy, and would continue to generate and dispose of wastes in a manner consistent with the SURF sustainability plan.

Utilities

Fermilab Site

The Proposed Action would require utility construction and relocation. The physical disturbance required to upgrade utilities would occur primarily within the boundaries of the existing Kautz Road substation and within the shoulder of Kautz Road and Indian Creek Road where new duct banks would be installed. This area consists of grassy and industrial areas, is previously disturbed, and has no waterway crossings.

Construction would require limited power, water, wastewater treatment, and natural gas. Power for construction would be temporary and would be limited to lighting construction trailers, operating small tools, and powering ventilation and pumps. Other utility requirements, including water required for construction, including for potable water and dust control, would be supplied by the construction contractor and would have no impacts on water supply or wastewater treatment utility capacity.

The Proposed Action would require approximately 9 megawatts (MW) of power for operations beginning in approximately 2026, when Fermilab's projected power demand (without LBNF/DUNE) would be approximately 60 to 70 MW. The power load required by LBNF/DUNE for construction and then 20 years of operation would not exceed power or distribution system capacity. The Proposed Action would also require other utilities for operation, including potable water, wastewater treatment, and natural gas. LBNF/DUNE's utility needs would be within the capacity of local providers.

Under the No Action Alternative, LBNF/DUNE would not be constructed or operated and Fermilab would not require power or other utility upgrades. Fermilab would continue to operate existing experiments, with power and water provided by local utilities.

SURF Site

Construction of the underground detector would require a total of 7 MW of power for hoisting rock. Operation of the detector would require 10.5 MW of additional power over the current 3 MW. The increased usage would not affect municipal utilities and would be well within the power delivery capability of the Ross substation and Black Hills Power. Drinking water would be provided by the City of Lead and LBNF/DUNE would not exceed capacity.

Construction of Alternative A experiments would require similar power and water consumption as the Proposed Action but over a shorter period of time. Consequently, there would be no additional demand impacts on utilities beyond those described for construction of the LBNF/DUNE. Operation of Alternative A experiments would result in less power consumption than the Proposed Action.

Under the No Action Alternative, LBNF/DUNE would not be constructed and no changes to utilities would be needed to supply a new underground detector. Existing operations would continue and utility maintenance and upgrades needed to supply existing SURF physics experiments would continue. The ongoing replacement of underground utilities would continue.

Waste Management

Fermilab Site

Construction activities for the Proposed Action would generate an estimated 18,000 yd^3 of construction debris, which would largely be recycled. A small volume of regulated waste (estimated 50 yd^3) would also be generated. Regulated waste would be properly disposed of via incineration or recycling at a licensed facility.

Construction would result in potential short-term impacts from increased waste generation. However, LBNF/DUNE would require compliance with Federal, state, local, and Fermilab SEPMs. Solid waste volumes would be well within Fermilab's existing capacity and would have low impacts on waste disposal handling capacity and facilities, and would not require construction of new facilities on-site or off-site.

Operation of the LBNF/DUNE would generate non-hazardous, hazardous, and radioactive waste similar to those of past and present Fermilab experiments, including Tevatron and NuMI. The estimated volumes would be approximately 40 yd^3 of regulated chemical waste, 8500 yd^3 of domestic (i.e., dumpster) waste, and 100 yd^3 of low level radioactive waste.

However, the Proposed Action would not generate new waste streams that would require development of new procedures or new facilities.

The No Action Alternative would not generate additional solid, hazardous, or radioactive waste requiring management and disposal. The types and quantities of waste generated at and disposed by Fermilab would remain the same as for existing experiments.

SURF Site

Construction of the Proposed Action would generate petroleum wastes, solid waste, and small volumes of hazardous waste. Petroleum products would be recycled to the extent feasible. Solvents would be managed as hazardous waste by a licensed contractor. Construction debris would be recycled to the extent practicable. Hazardous waste generated and managed by the construction contractor would be audited by SURF. Excavated rock would be transported to either the Gilt Edge Superfund site or the Open Cut. At the far site, an estimated 400 yd^3 of non-regulated waste and 10 yd^3 of regulated chemical waste is expected due to construction activities.

Operation of the LBNF/DUNE would use LAr and LN; however, these materials would not produce a residual waste. Other aspects of operations would generate small quantities of solid waste, petroleum products, and hazardous wastes that would be managed according to existing SURF SEPMs.

Alternative A would generate the same types of waste materials as the Proposed Action but in lower quantities. Waste materials would be managed and disposed of in accordance with SURF policies and SEPMs.

The No Action Alternative would not generate additional waste and would have no impact on waste management practices or existing landfill facilities. SURF's existing operation would continue to generate the same types and quantities of waste materials and these would be handled under existing waste management programs with no need for increased handling or disposal on-site or off-site.

Accident Analysis

Fermilab Site

Because of design measures and existing safety programs, there is no reasonably foreseeable "major" accident scenario arising from construction of the Proposed Action or an intentional destructive act. However, major accidents with a probability of occurrence between one in one million and one in 10 million were considered. Operational incidents would be minimized by shielding and safety procedures; however, mis-steering of the beam and failure of safety systems caused by an accident or malevolent act would result in irradiation of beamline components, potentially resulting in severe damage. Repairing the facility would create short- and long-term exposure risks to workers involved in entering the beam enclosure and replacing irradiated or damaged components. In this event, workers would isolate the damaged component and would be exposed to activated components over short work periods as required to move the damaged component to a concrete-shielded cell. Hazards to radiation workers would be managed by limiting the exposure time to individuals, based on dose measurements, to ensure that administrative radiation limits for workers were not exceeded. Public exposure would be very low because the damaged components would be contained within the underground enclosures.

Under the No Action Alternative, LBNF/DUNE would have no impact on the probability of accidents or malevolent acts with the potential to affect human health or the environment. Existing facilities would have the same potential for accidents as they do under existing conditions.

SURF Site

High consequence accident scenarios for SURF with a probability of occurrence between one million and one in 10 million could involve an underground fire or accidental release of LAr or LN creating an oxygen deficiency hazard. The potential for a major fire would be minimized by engineering methods installed throughout the underground spaces, such as carbon monoxide sensors, air doors, training, and a trained mine rescue team. These measures would also minimize the potential effects of an intentional destructive act. Cryogen deliveries could result in an accidental release of LAr or LN. These super-cooled liquids can cause burns on contact and can displace oxygen. An accident involving a tank truck could result in a release that would affect a localized area but would dissipate quickly, minimizing the potential effects of an accident or intentional destructive act.

The risk of an underground fire or cryogen spill during construction or operation of Alternative A would be low. These experiments would be smaller than the Proposed Action and would not require large quantities of explosives or cryogens. Alternative A would employ the same fire and spill accident prevention measures described above during all phases.

The No Action Alternative would not involve underground work or use of cryogens and there would be no risk of accidents. Accidents associated with existing underground experiments would continue to be addressed through existing SURF safety procedures.

Cumulative Impacts

Fermilab Site

Cumulative impacts of the Proposed Action at Fermilab were evaluated in view of past, present, and reasonably foreseeable projects, which were primarily projects at Fermilab, such as the recently constructed NuMI and NO*ν*A projects. Additionally, Fermilab seeks to continually improve accelerator beam efficiency and intensity through accelerator improvement activities. A potential future project at

Fermilab would be the Proton Improvement Project-II (PIP-II), which would upgrade Fermilab's proton accelerator and deliver higher beam intensity—2.3 mW—to on-site neutrino experiments. Other projects with potential cumulative impacts include only those in the immediate area, including improvement of adjacent roadways, including Butterfield Road and Kirk Road. Construction of PIP-II could impact wetlands and undiscovered cultural resources; however, these impacts would be offset by purchase of wetland credits and by implementing Fermilab's CRMP. This facility would also have potential impacts on worker radiation exposure and groundwater quality; however, Fermilab would use design measures and SEPMs to minimize exposure and cumulative impacts would be low. In general, there would be low cumulative impacts on air quality, geology, health and safety, storm water, land use, noise, socioeconomics, sustainability, traffic, utilities and waste disposal. Cumulative impacts would be minimized through implementation of existing environmental and health and safety regulations for all projects and through Fermilab's SEPMs, which would include measures such as revegetation, dust and erosion control, reducing GHG emissions, and a stringent health and safety program.

Under the No Action Alternative, Fermilab would not construct the LBNF/DUNE facilities, resulting in no impacts. Impacts from other past, present, and reasonably foreseeable future Fermilab projects and activities, as well as off-site projects, would continue. Potential impacts on biological, cultural, geological, and water resources as well as the noise environment would be avoided or minimized by complying with local, state, and Federal laws as well as by employing Fermilab's own environmental management and sustainability guidelines. Other future projects, including those at Fermilab, could have cumulative impacts that would be minimized by existing plans, regulatory programs, and BMPs.

SURF Site

Cumulative impacts of the Proposed Action at SURF were evaluated in view of past, present, and reasonably foreseeable future projects, which were primarily projects at SURF, as well as several small local projects in Lead and remediation at the Gilt Edge Superfund site. The Proposed Action would generate noise and additional traffic; however, cumulative impacts with other SURF activities, such as the Yates Shaft rehabilitation would be low as they would occur underground. Excavated rock from the Proposed Action utilized in the Gilt Edge Superfund site remediation (which is not part of the Proposed Action) would have no effect on runoff volume or water quality as runoff and infiltration water would be collected and treated as part of the ongoing Superfund remedy. Water quality at the Gilt Edge Superfund site would likely be improved by the addition of the acid neutralizing rock. In general, there would be low cumulative impacts for a range of reasons including the location and type of other projects in the SURF area. Cumulative impacts would be minimized through implementation of existing environmental and health and safety regulations for all projects and through SURF SEPMs, which would include measures such as revegetation, dust and erosion control, traffic control, reducing GHG emissions, and a stringent health and safety program.

Alternative A would involve multiple experiments occurring over different timeframes, either in conjunction with the Proposed Action or independent of it. As described for the Proposed Action, cumulative impacts would be low and would be addressed through compliance with environment, health and safety requirements, and SEPMs.

Under the No Action Alternative, SURF would not construct the LBNF/DUNE facilities, resulting in no cumulative impacts. Impacts from ongoing SURF projects, as well as off-site projects, would continue. However, impacts would be avoided or minimized by complying with local, state, and Federal laws as well as SURF environmental programs.

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TABLES

Figures

APPENDICES

Acronyms and Abbreviations

μCi	microcurie(s)
μm	microns
μS/cm	microSeimens per centimeter
2D	two dimensional
3D	three dimensional
A	amps
AADT	average annual daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ac	acre(s)
ACAMS	Asset Control and Alarm Monitoring System
ACGIH	American Congress of Governmental Industrial Hygienists
ACHP	Advisory Council on Historic Preservation
ADA	Americans with Disabilities Act
ADAAG	Americans with Disabilities Act Accessibility Guidelines
ADID	Advanced Identification (Cane County Study)
AEE	Association of Electrical Engineers
AET	American Engineering Testing
AFV	Alternative Fuel Vehicle
AHR	Air Handling Room
AHU	Air Handling Unit
ALARA	As Low as Reasonably Achievable
APE	Area of Potential Effect
AQI	Air Quality Index
Argon-41	Argon-41 radionuclide
ARR	Accelerator Readiness Review
B.P.	before present
bgs	below ground surface
BHP	Black Hills Power
BLM	Bureau of Land Management
BLS	Bureau of Labor Statistics
BMP	Best management practice
BNL	Brookhaven National Laboratory
BOA	Bureau of Air
BTU	British Thermal Units
C	Celsius

CAA	Clean Air Act
CadnaA	Computer Aided Noise Abatement (computer model)
CAS#	Chemical Abstract Service Number
CD	Critical Decision
CDR	Conceptual Design Report
CEDR	Comprehensive Energy Data Report
CEHSP	Construction Environment, Health and Safety Plan
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERN	European Organization for Nuclear Research
CESQC	Conditionally Exempt Small Quantity Generator
CF	Conventional Facilities (Civil design and construction)
CFC	chlorofluorocarbon
cfm	cubic feet per minute
CFR	Code of Federal Regulations
cfs	cubic feet per second
CGA	Compressed Gas Association
CH_4	methane
Ci	curie(s)
cm	centimeter(s)
CMS	Compact Muon Solenoid
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	CO_2 equivalent
CR	communications room
CAP	Criteria Air Pollutant
CRMP	Cultural Resources Management Plan
CUB	Central Utility Building
CUBED	Center for Ultralow Background Experiments at the Dakotas
CWA	Clean Water Act
CY	Calendar year
DAQ	data acquisition
DART	Days Away, Restricted, or Transferred
dBA	decibel – A weighting
DCG	Derived Concentration Guide
DOE	Department of Energy

DOT	Department of Transportation
DUNE	Deep Underground Neutrino Experiment
EO	Executive Order
EA	Environmental Assessment
EENF	Environmental Evaluation Notification Form
EIS	Environmental Impact Statement
EISA	Energy Independence and Security Act
EMI	Electromagnetic Interference
EMS	Environmental Management System
EPA	Environmental Protection Agency
ES&H	Environment, Safety and Health
ESPC	Energy Savings Performance Contract
eV	electron-Volt, unit of energy (also keV, MeV, GeV, etc.)
F	Fahrenheit
FAARM	Facility for Acquisition and Assay of Radiopure Materials
FEMA	Federal Emergency Management Agency
Fermilab	Fermi National Accelerator Laboratory, Batavia, Illinois
FESS	Facilities Engineering Services Section (at Fermilab)
FGT	fine-grained straw-table tracker
FIRM	Flood Insurance Rate Map
FMCSA	Federal Motor Carrier Safety Administration
FONSI	Finding of No Significant Impact
FQI	Floristic Quality Index
FRA	Fermi Research Alliance
FRCM	Fermi Radiological Control Manual
FSO	Fermi Site Office
ft^2	square feet
FTA	Federal Transit Administration
FY	Fiscal Year, Federal (October 1 through September 30)
gal	gallon(s)
GBV	ground-borne vibration
GCL	Geosynthetic clay liner
GDAQ	Global Data Acquisition
GeV	Giga electron volt; Billion electron volts
GHG	Greenhouse gas
gpd	gallons per day

gpm	gallons per minute
HA	Hazard Analysis
ha	hectare(s)
HAP	Hazardous Air Pollutant
HEPAP	High Energy Physics Advisory Panel
hp	Horsepower
HPSB	High Performance Sustainable Building
HQAR	High Quality Aquatic Resource
HUD	Department of Housing and Urban Development
HVAC	heating ventilating and air conditioning
Hydrogen-3	Tritium, radioactive isotope of hydrogen
Hz	Hertz
IAC	Illinois Administrative Code
IARC	Illinois Accelerator Research Center
IBC	International Building Code
ICRP	International Commission on Radiological Protection
ICW	Industrial Cooling Water
IDOT	Illinois Department of Transportation
IEPA	Illinois Environmental Protection Agency
IFC	International Fire Code
IGA	Inter-governmental Agreement
IH	Industrial Hygiene
IHPA	Illinois Historic Preservation Agency
ILA	Industrial, Landscaping and Agricultural (water)
in	inch
IPCC	Intergovernmental Panel on Climate Change
ISCORS	Interagency Steering Committee on Radiation Standards
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
ISO	International Standards Organization
IT	Information Technology
JHA	Job Hazard Analysis
K	Kelvin
kg	kilogram
km	kilometer(s)
kt	kiloton

kV	kilo (1000) volts
kVA	kilo volt amps (or kilowatt, electrical power)
kW	kilowatt(s)
L level	indicates depth in feet underground at the far site, e.g., 4850L
L	liter(s)
L/E	length to energy ratio
LAr	Liquid Argon
LAr-TPC	liquid argon time projection chamber
LBCF	low background counting facility
LBNF	Long Baseline Neutrino Facility
lbs	pound(s)
LCF	Latent cancer fatality
Ldn	day-night average sound exposure
LEED	Leadership for Energy Efficient Design
LEED-NC	Leadership in Energy and Environmental Design – New Construction
LEPC	Local Emergency Planning Committee
Leq	Equivalent Sound Level
lf	linear feet
LHC	Large Hadron Collider
LLRW	low-level radioactive waste
LN	liquid nitrogen
LNG	liquefied natural gas
LOTO	lockout/tagout
LUX	Large Underground Xenon
LZ	LUX ZEPLIN
m	meter(s)
m^3	cubic meter
MARS	Midwest Archaeological Research Services, Inc.
MBTA	Migratory Bird Treaty Act
MDU	Montana-Dakota Utilities
MEP	Mechanical, Electrical, and Plumbing
MER	Mechanical Electrical Room
mg/m^3	milligrams per cubic meter
MI	Main Injector (at Fermilab)
mi	mile(s)
MicroBooNE	Micro Booster Neutrino Experiment

MINERvA	Main Injector Experiment with vs on As
MiniBooNE	Mini Booster Neutrino Experiment
MINOS	Main Injector Neutrino Oscillation Search
MIPP	Main Injector Particle Production
ml	milliliter
mm	millimeter
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MPa	megapascal
mrem	millirem
MSHA	Mine Safety and Health Administration
MSL	mean sea level
MT	metric ton
MUTCD	Manual of Uniform Traffic Control Devices
MVA	Mega Volt Amps
MW	Megawatt
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NCRP	National Council on Radiation Protection & Measurements
NEC	National Electric Code
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESC	National Electric Safety Code
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NHIP	National Heritage Information Program
NHPA	National Historic Preservation Act
Nitrogen-13	Nitrogen-13 radionuclide
NND	Near Neutrino Detector
NO_2	nitrogen dioxide
NOI	Notice of Intent
NO*v*A	NuMI Off-axis νe Appearance
NO_x	oxides of nitrogen
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NRCS	National Resource Conservation Service

NREL	National Renewable Energy Laboratory
NRHP	National Register for Historic Places
NSF	National Science Foundation
NuMI	Neutrinos at Main Injector (Neutrino Beam at Fermilab)
O_3	ozone
ODH	Oxygen Deficiency Hazard
OHEP	Office of High Energy Physics
ORM	Office of Risk Management
ORNL	Oak Ridge National Laboratory
OSHA	U.S. Occupational Safety and Health Administration
Oxygen-15	Radioactive isotope of oxygen
PA	programmatic agreement
PCB	polychlorinated biphenyl
pCi	picocurie
PEL-TWA	Permissible Exposure Limit – Time Weighted Average
PGA	peak ground acceleration
PHAR	Preliminary Hazard Analysis Report
PIP-II	Proton Improvement Project-II
plf	Pounds per Linear Foot
PM_{10}	particulate matter less than 10 microns in diameter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
POC	point of concern
POTW	publicly owned treatment works
ppb	parts per billion
PPE	Personal Protective Equipment
ppm	parts per million
PPV	peak particle velocity
psf	Pounds per Square Foot
PSHA	Probabilistic Seismic Hazard Analysis
psi	pounds per square inch
psig	pounds per square inch gauge
PUE	Power Usage Effectiveness
PVC	polyvinyl chloride
QA	quality assurance
R&D	Research and Development
RAW	Radioactive Water

RCMRF	Rapid City Municipal Recycling Facility
RCRA	Resource Conservation and Recovery Act of 1976
REC	renewable Energy Certificate
RF	Radio Frequency
RMP	Risk Management Plan
RMS	root mean square
RO	reverse osmosis
ROSS	Registration of Small Sources
SA	Sustainable Acquisition
SAAQS	State Ambient Air Quality Standards
SARA	Superfund Amendments and Reauthorization Act
SARC	South Dakota State Archaeological Research Center
SDDENR	South Dakota Department of Environmental and Natural Resources
SDDOT	South Dakota Department of Transportation
SDGFP	South Dakota Game Fish and Parks
SDS	Safety Data Sheet
SDSMT	South Dakota School of Mines and Technology
SDSTA	South Dakota Science and Technology Authority
SDWA	Safe Drinking Water Act
sf	square feet
SF_6	sulfur hexafluoride
SHPO	State Historic Preservation Office
SIP	State Implementation Plan
SO_2	sulfur dioxide
Sodium-22	Radioactive isotope of sodium
SOP	Standard Operating Procedure
SPCC	Spill Prevention Control and Countermeasures
SQCEG	small quantity conditional exempt generator
SQG	small quantity generator
SSECP	Site-Specific Erosion Control Plan
SSP	Site Sustainability Plan
SSPP	Strategic Sustainability Performance Plan
SURF	Sanford Underground Research Facility
Sv	Sievert
SWPPP	Storm Water Pollution Prevention Plan
T&E	Threatened and Endangered

TAP	Trip Action Plan
TDS	Total Dissolved Solids
TPC	time projection chamber
TRC	Total Recordable Cases
TSCA	Toxic Substances Control Act
TSD	Treatment, Storage, and Disposal
TSP	total suspended particles
U.S.C.	U.S. Code
UIC	underground injection control
USACE	U.S. Army Corps of Engineers
USBM	U.S. Bureau of Mines
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
v	volt
VdB	velocity in decibels
VMT	vehicle miles travelled
VOC	volatile organic compound
VOM	volatile organic material
W	watt (also MW, kW)
WAC	Waste Acceptance Criteria
WAD	weak acid dissociable
WCD	water Cherenkov detector
WET	Whole Effluent Toxicity
WWTP	Waste Water Treatment Plant
yd	yard(s)
yd^3	cubic yard
ν_e	Electron neutrino

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CONVERSION CHART

Into metric units			Into English units		
If you know	*Multiply by*	*To get*	*If you know*	*Multiply by*	*To get*
Length			**Length**		
inches	25.40	Millimeters	millimeters	0.03937	inches
inches	2.54	Centimeters	centimeters	0.393701	inches
feet	0.3048	Meters	meters	3.28084	feet
yards	0.9144	Meters	meters	1.0936	yards
miles (statute)	1.60934	Kilometers	kilometers	0.62137	miles (statute)
Area			**Area**		
square inches	6.4516	square centimeters	square centimeters	0.155	square inches
square feet	0.09290304	Square meters	Square meters	10.7639	square feet
square yards	0.8361274	Square meters	Square meters	1.19599	square yards
square miles	2.59	square kilometers	square kilometers	0.386102	square miles
acres	0.404687	Hectares	hectares	2.47104	acres
Mass (weight)			**Mass (weight)**		
ounces (avoir.)	28.34952	Grams	grams	0.035274	ounces (avoir.)
pounds (avoir.)	0.45359237	Kilograms	kilograms	2.204623	pounds (avoir.)
tons (short)	0.9071847	tons (metric)	tons (metric)	1.1023	tons (short)
Volume			**Volume**		
Ounces (U.S., liquid)	29.57353	Milliliters	milliliters	0.033814	Ounces (U.S., liquid)
Quarts (U.S., liquid)	0.9463529	Liters	liters	1.0567	Quarts (U.S., liquid)
Gallons (U.S., liquid)	3.7854	Liters	liters	0.26417	Gallons (U.S., liquid)
cubic feet	0.02831685	cubic meters	cubic meters	35.3147	cubic feet
cubic yards	0.7645549	cubic meters	cubic meters	1.308	cubic yards
Temperature			**Temperature**		
Fahrenheit	subtract 32 then multiply by 5/9ths	Celsius	Celsius	multiply by 9/5ths, then add 32	Fahrenheit
Energy			**Energy**		
kilowatt hour	3,412	British thermal unit	British thermal unit	0.000293	kilowatt hour
kilowatt	0.94782	British thermal unit per second	British thermal unit per second	1.055	kilowatt
British thermal units (BTU)	1054.18	Joule	Joule	0.00094845	BTU
Million electron volts (MeV)	1.602×10^{-13}	Joule	Joule	6.24×10^{12}	MeV
Force/Pressure			**Force/Pressure**		
pounds (force) per square inch	6.894757	Kilopascals	kilopascals	0.14514	
Torr	133.32	Pascals	Pascals	0.0075	

Source: *Engineering Unit Conversions*, M.R. Lindeburg, PE, third Ed., 1993, Professional Publications, Inc., Belmont, California.

Power 1 watt = 3.414 BTU/hr; 1 BTU/hr = 0.2929 watt
Radiation
1 becquerel = 2.703 × 10-11 curies; 1 curie = 3.70 × 1010 becquerels
1 sievert = 100 rem; 1 rem = 0.01 sievert
1 Kelvin (K) = -272.15 degrees Celsius (˚C); 1 Kelvin (K) = -457.87 degrees Fahrenheit (˚F)

SCIENTIFIC NOTATION CONVERSION CHART

Numbers that are very small or very large are often expressed to scientific or exponential notation as a matter of convenience. For example, the number 0.000034 may be expressed as 3.4×10^{-5} or 3.4E-05, and 65,000 may be expressed as 6.5×10^{4} or 6.5E+04. In this document, some of the numerical values less than 0.001 or greater than 9999 are generally expressed in exponential notation, or 1.0E-03 and 9.9E+03, respectively.

Multiples or sub-multiples of the basic units are also used. A partial list of prefixes that denote multiple and sub-multiples follows, with the equivalent multiplier values expressed in scientific and exponential notation:

Name	Symbol	Value Multiplied by:		
pico	P	0.000000000001	or 1×10^{-12}	or 1E-12
nano	N	0.000000001	or 1×10^{-9}	or 1E-09
micro	µ	0.000001	or 1×10^{-6}	or 1E-06
milli	M	0.001	or 1×10^{-3}	or 1E-03
cento	C	0.01	or 1×10^{-2}	or 1E-02
deci	D	0.1	or 1×10^{-1}	or 1E-01
--		1	or 1×10^{0}	or 1E+00
deka	Da	10	or 1×10^{1}	or 1E+01
hecto	H	100	or 1×10^{2}	or 1E+02
kilo	K	1,000	or 1×10^{3}	or 1E+03
mega	M	1,000,000	or 1×10^{6}	or 1E+06
giga	G	1,000,000,000	or 1×10^{9}	or 1E+09
tera	T	1,000,000,000,000	or 1×10^{12}	or 1E+12

The following symbols are occasionally used in conjunction with numerical expressions.

Symbol	Indicates the preceding value is:
<	less than
≤	less than or equal to
>	greater than
≥	greater than or equal to

In some cases, numerical values in this document have been rounded to an appropriate number of significant digits to reflect the accuracy of data being presented. For example, the numbers 0.021, 21, 2100, and 2,100,000 all contain 2 significant digits. In some cases, where several values are summed to obtain a total, the rounded total may not exactly equal the sum of its rounded component values.

GLOSSARY

Accelerator. A device that accelerates charged particles (such as electrons, protons, and atomic nuclei) to high velocities, thus giving them high kinetic energies.

Ambient Air. The surrounding atmosphere, usually the outside air, as it exists outside the proximity of an emission source.

Aquifer. A body of rock or sediment that is capable of transmitting groundwater and yielding usable quantities of water to wells or springs.

Attainment. An area is designated as being in attainment by the U.S. Environmental Protection Agency (EPA) if it meets the National Ambient Air Quality Standards (NAAQS) for a given criteria pollutant. Nonattainment areas are areas in which any one of the NAAQS have been exceeded, maintenance areas are areas previously designated as nonattainment and subsequently redesignated as attainment, and unclassifiable areas are areas that cannot be classified on the basis of available information as meeting or not meeting the NAAQS for any one criteria pollutant.

Background radiation. Radiation present in the environment from cosmic sources, naturally occurring radioactive materials, and global fallout.

Criteria Pollutants. The Clean Air Act requires EPA to set air quality standards for common and widespread pollutants after preparing criteria documents summarizing scientific knowledge on their health effects. Currently, there are standards in effect for six criteria pollutants: sulfur dioxide (SO_2), carbon monoxide (CO), particulate matter equal to or less than 10 microns in diameter (PM_{10}), nitrogen dioxide (NO_2), ozone (O_3), and lead (Pb).

Cryogenics. The branches of physics and engineering that involve the study of very low temperatures, how to produce them, and how materials behave at those temperatures. Cryogenic cooling of devices and material is usually achieved via the use of liquid nitrogen or liquid helium.

Cultural resources. The prehistoric and historic districts, sites, buildings, objects, or any other physical activity considered important to a culture, subculture, or a community for any scientific, traditional, religious, or other reasons.

Cumulative impact. The impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Davis Campus. Research area of the Sanford Underground Research Facility located nearly one mile underground in the former Homestake mine.

Radioactive decay. The change of one radionuclide into a different radionuclide by the spontaneous emission of radiation such as alpha, beta, or gamma rays, or by electron capture. The end product is a less energetic, more stable nucleus. Each decay process has a definite half-life.

Decibel (dB). A logarithmic measurement unit that describes a particular sound pressure level compared to a standard reference value. A-weighted decibels (dBA) refer to measured decibels whose frequencies have been adjusted to correspond to the highest sensitivity of human hearing, which is typically in the frequency range of 1,000 to 4,000 hertz.

Detector. A particle detector is any device used to sense the passage of atomic or subatomic particles or to measure their properties. For many particle detectors, this involves observing and measuring the radiation (electromagnetic or ionizing) released as particles interact with a gaseous, liquid, or solid medium or an electromagnetic field.

Electron volt. A unit of energy equal to the kinetic energy (or energy of motion) an electron gains when being accelerated through a potential difference on 1 volt. Another unit of energy is the joule and 1 joule equals 6.2415 x 1018 electron volts. One joule is roughly the energy needed to lift 1 kilogram (2.2 pounds) on the surface of the earth 0.1 meter (4 inches) high.

Electron neutrino. Neutrinos are elementary particles, which exist in three different types or “flavors”. They are uncharged, non-ionizing and only rarely interact with ordinary matter.

Fluvial. Of, pertaining to, or inhabiting a flowing river or stream.

Groundwater. Water below the ground surface in a zone of saturation.

General Conformity Rule. The General Conformity Rule is applicable to nonattainment or maintenance areas (see attainment) as designated by EPA, and ensures that Federal actions conform to each State Implementation Plan for air quality. These plans, approved by EPA, are each state’s individual plan to achieve the NAAQS as required by the Clean Air Act. The EPA is required to promulgate a Federal Implementation Plan if a state defaults on its implementation plan. A conformity requirement determination for the action is made from influencing factors, including, but not limited to, nonattainment or maintenance status of the area, types of emissions and emission levels resulting from the action, and local impacts on air quality.

Greenhouse gases. Gases that trap heat in the atmosphere and may contribute to climate change, including global warming. Some greenhouse gases are emitted to the atmosphere through natural processes. Other greenhouse gases are created and emitted solely through human activities. The principal greenhouse gases are carbon dioxide, methane, nitrous oxide, water vapor, ozone, and fluorinated gases.

Half-life. The time during which half the (large number of) atoms of a particular radionuclide disintegrate. The half-life is a characteristic property of each radioactive isotope.

Hazardous Air Pollutant. Hazardous Air Pollutants, also known as toxic air pollutants, are those pollutants that are known or suspected by USEPA to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects.

Hazardous chemical. Any chemical that is a physical or health hazard.

Hazardous Material. The U.S. Department of Transportation defines a hazardous material as a substance or material, which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety and property when transported. The term includes hazardous substances, hazardous wastes, marine pollutants, and elevated temperature materials as defined in 49 CFR 172.8, materials designated as hazardous under the provisions of 49 CFR 172.101, and materials that meet the defining criteria for hazard classes and divisions of 49 CFR 173.

Hazardous waste. Waste that contains chemically hazardous constituents regulated under Subtitle C of the Resource Conservation and Recovery Act (RCRA), as amended (40 CFR 261) and regulated as a hazardous waste and/or mixed waste by the EPA.

Hectare. Land area equal to approximately 2.47 acres.

Kaon. A kaon (also called K-meson) is any one of a group of four mesons distinguished by the fact that they carry a quantum number called strangeness.

Kilowatt. A thousand watts.

Latent cancer fatalities. Deaths from cancer resulting from, and occurring after, exposure to ionizing radiation or other carcinogens.

Liquid Argon Time-Projection Chamber (LAr-TPC). Is the type of neutrino detector planned for LBNF/DUNE. The detector consists of a chamber filled with liquid argon and a network of wire planes. The detection method is based on the collection of ionization electrons, which result from particle interactions between the neutrinos and the liquid argon, onto wire planes immersed in the fluid. Under the influence of an electric field, the electrons drift to the wire planes, thereby creating a signal. Three planes of wires allow 3D reconstruction of the electron's track and provide information on the neutrinos.

Mesic. Of, characterized by, or adapted to a moderately moist habitat.

Millirem. A unit of radiation dose equivalent that is equal to 1/1000 of a rem.

Muon. The muon is a fundamental particle that is part of the Standard Model of particle physics. It is unstable subatomic particle of the same class as an electron (a lepton), but with a mass around 200 times greater. They exist for only a fraction of a second (about 10-6 seconds) before decaying usually into an electron, and electron-antineutrino, and a muon neutrino. Muons make up much of the cosmic radiation reaching the earth's surface.

Muon neutrino. Neutrinos are elementary particles, which exist in three different types or “flavors”. They are uncharged, non-ionizing and only rarely interact with ordinary matter.

Palustrine. Of, pertaining to, or living in, a marsh or swamp; marshy.

PicoCurie (pCi). One trillionth of a curie

Pion. A pion (abbreviation for pi meson) is the collective name for three subatomic particles: π^0, $_{\pi}+$, and π^-. Pions are the lightest mesons and play an important role in explaining low-energy properties of the strong nuclear force.

PM_{10}. Particulate matter having a median aerodynamic diameter less than 10 micrometers.

$PM_{2.5}$. Particulate matter having a median aerodynamic diameter less than 2.5 micrometers.

Prompt radiation. radiation produced by an accelerated beam or through interaction of the beam with matter.

Proton. One of the basic particles that make up an atom. The proton is found in the nucleus and has a positive electrical charge equal to the negative charge of an electron and a mass similar to that of a neutron: a hydrogen nucleus.

Radiation dose. The amount of energy from ionizing radiation deposited within tissues of the body; it is a time-integrated measure of potential damage to tissues from exposure to radiation and as such is related to health-based impacts.

Radiation. The emitted particles (alpha, beta, neutrons) or photons (X-rays, gamma rays) from the nuclei of unstable (radioactive) atoms as a result of radioactive decay. Some elements are naturally radioactive; others are induced to become radioactive by bombardment in a nuclear reactor or other particle accelerator. The characteristics of naturally occurring radiation are indistinguishable from those of induced radiation.

Radioactive waste. Materials that are radioactive and for which there is no further use.

Rem. The unit dose representing the amount of ionizing radiation needed to produce the same biological effects as one roentgen of high-penetration x-rays (about 200,000 electron volts).

Risk. The product of the probability of occurrence of an event or activity and the impacts resulting from that event or activity. For example, an accident that is expected to occur once in 100 years and result in a 1 in 1,000 probability of latent cancer fatality (LCF) in the affected population would be associated with a risk of (0.01 per year) x (0.001 LCF) = 0.00001 LCF/year, or a risk of LCF equal to 1 in 100,000 per year of operation.

Shielding. A protective barrier, usually a dense material that reduces the passage of radiation from radioactive materials to the surroundings by absorbing it.

Source. A radioactive material that produces radiation for experimental or industrial use.

Tau neutrino. Neutrinos are elementary particles, which exist in three different types or “flavors”. They are uncharged, non-ionizing and only rarely interact with ordinary matter.

Target horn. beamline equipment located in the Target Hall used to focus and tune the electron beam

Total Effective Dose Equivalent (TEDE). The sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures). TEDE is expressed in units of rem.

1. INTRODUCTION

The U.S. Department of Energy (DOE) is proposing to construct and operate the Long Baseline Neutrino Facility (LBNF) and the Deep Underground Neutrino Experiment (DUNE) facilities at Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois, and the Sanford Underground Research Facility (SURF or Sanford Lab) in Lead, South Dakota. The action is referred to throughout this document jointly as LBNF/DUNE. Under the Proposed Action, Fermilab would construct facilities that would extract a proton beam from Fermilab's existing particle accelerator, generate a high-intensity neutrino beam, and direct the beam at a detector with one or more modules constructed 800 miles away at SURF. The beam would be generated underground and would travel through the Earth at depths of up to approximately 20 miles (**Figure 1.2-1**). This Environmental Assessment (EA) provides an evaluation of the potential environmental impacts of the Proposed Action as required by the National Environmental Policy Act of 1969 (NEPA) (42 U.S. Code [U.S.C.] 4321 et seq.).

1.1 NATIONAL ENVIRONMENTAL POLICY ACT COMPLIANCE

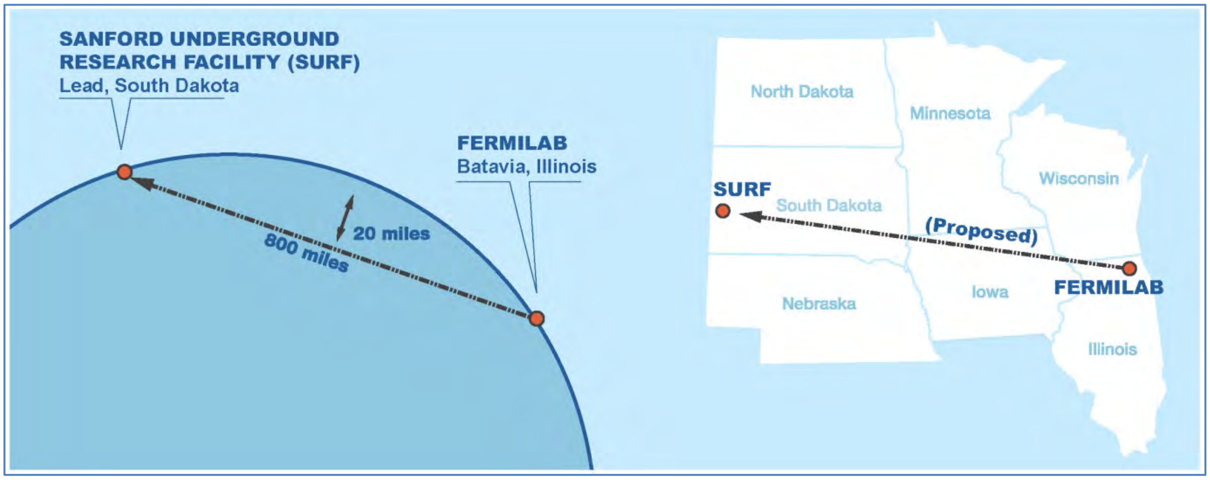
In accordance with NEPA, Council on Environmental Quality (CEQ) regulations at Title 40, Code of Federal Regulations (CFR) Part 1500-1508 and DOE NEPA implementing procedures at Title 10, CFR Part 1021, DOE has prepared this assessment of the direct, indirect, connected, and cumulative environmental impacts of LBNF/DUNE. Information contained in this EA will be used by DOE to determine if the Proposed Action would significantly affect human health and the environment. If the Proposed Action would have a significant environmental impact,, an Environmental Impact Statement (EIS) would be required to complete the NEPA process. If the Proposed Action would not result in significant environmental impacts, a Finding of No Significant Impact (FONSI) will be issued, thus completing the NEPA process.

1.2 COMPLIANCE WITH WETLAND AND FLOODPLAIN REVIEW

Under Executive Order (EO) 11988, Floodplain Management, and EO 11990, Protection of Wetlands, Federal agencies are required to consider the impact of proposed actions on wetlands and floodplains. DOE requirements for compliance with EO 11988 and 11990 are found in Title 10, CFR, Part 1022, "*Compliance with Floodplain/Wetlands Environmental Review Requirements*." A floodplain/wetlands assessment consists of a description of the proposed action, a discussion of its effects on the floodplain and wetlands, and consideration of the alternatives. The EOs require Federal agencies to implement floodplain and wetland requirements through existing procedures, such as those established to implement NEPA. Hence, a wetland assessment is included in this EA which supports the requirements of 10 CFR 1022.

If DOE determines that there is no reasonable alternative to implementing a proposed action in a floodplain or wetland, a brief statement of findings must be prepared. This statement of findings would include a description of the proposed action, an explanation indicating why it must be located in a floodplain or wetland, a list of alternatives considered, measures that would be taken to comply with state and local floodplain protection standards, and a description of the steps required to minimize adverse impacts on the floodplain or wetland.

Figure 1.2-1 Pathway of the LBNF/DUNE Neutrino Beam from Fermilab to SURF



1.3 BACKGROUND

DOE's Office of Science is the lead Federal entity responsible for energy and particle physics research. The challenge of particle physics is to discover, among other things, the composition of the Universe and how it works. Fermilab is one of DOE's national laboratories and is a leader in high-energy particle physics research. SURF is a collaborating partner in LBNF/DUNE and provides an existing underground physics research laboratory within Lead's former Homestake Mining Company (Homestake) gold mine. The mine was closed in 2003 and was donated to the State of South Dakota, which created the South Dakota Science and Technology Authority (SDSTA) to own and manage the laboratory. In 2006, the State of South Dakota committed $40 million to the Sanford Underground Research Facility and a private donor donated $70 million. Construction on the Davis Campus began in 2012.

Fermilab is an established National Laboratory that has designed, constructed, and operated proton accelerators and high-intensity neutrino beams for years, beginning with the Main Ring in 1972, followed by the Tevatron in 1983, as well as other facilities. The Tevatron closed in 2011 when the Large Hadron Collider (LHC) opened in Geneva, Switzerland. However, Fermilab has been operating the Neutrinos at Main Injector (NuMI) project since 2005 and recently completed construction of the NuMI Off-axis ve Appearance (NOvA) project. These projects have extensive underground and surface facilities including a large accelerator; the site's Main Injector (MI); and existing power and cooling water systems, and research laboratories. Appendix A-1 contains a fact sheet describing neutrino experiments at Fermilab. SURF has an extensive history of excavation and rock processing and disposal. SURF is located at the former Homestake gold mine, which has existing mining infrastructure to facilitate excavated rock processing and hauling, deep access shafts, and several underground caverns used for existing physics experiments. Construction of LBNF/DUNE at SURF would take advantage of this existing configuration.

DOE, Fermilab, and SURF conducted earlier stages of planning in conjunction with the LBNF/DUNE Science Collaboration. In January 2010, DOE granted Critical Decision-0 (i.e., Approval-Mission-Need, which also authorized the expenditure of funds for planning) for what was then termed the Long-Baseline Neutrino Experiment (LBNE, including the large, underground detector at SURF) and initiated environmental review of it as a major Federal action under NEPA. DOE and Fermilab planned for LBNE to consist of a beamline with a target, absorber, and near detector at Fermilab and an underground detector constructed between 620 and 930 miles away. After an extensive siting and technology evaluation, the LBNE team chose liquid argon (LAr) time projection chamber (LAr-TPC) and SURF respectively, as the most appropriate detector technology and location.

In December, 2012, DOE approved selection of the Fermilab and SURF sites for the proposed accelerator and detector facilities to support LBNE, allowing for expanded scope and underground siting of the detector in collaboration with international partners. This plan is consistent with the May, 2014 recommendation of the Particle Physics Project Prioritization Panel (P5), that the U.S. partner with the international neutrino physics community to develop a leading-edge facility for neutrino science and proton decay studies. This facility would be an internationally designed, coordinated and funded program, hosted at Fermilab, comprising the world's highest-intensity neutrino beam and advanced underground detectors designed to both exploit this beam and observe galactic neutrinos from supernovae. As a result, the Proposed Action was renamed Long Baseline Neutrino Facility and Deep Underground Neutrino Experiment (LBNF/DUNE).

A new international long baseline neutrino collaboration is forming that brings together a global neutrino research community to pursue an accelerator-based long-baseline neutrino experiment located at Fermilab and SURF. The collaboration would also be able to conduct related neutrino astrophysics and nucleon decay research. This international collaboration would be responsible for the design, construction and operation of the facility and also the experiment that will utilize the facility. This international collaboration is growing and new partners could affect portions of the planning, construction, and experimental research phases, and overall execution of the experiment. The range of environmental impacts considered in this EA would be bounding of these potential future experimental changes, should they occur.

1.4 STATEMENT OF PURPOSE AND NEED

DOE’s Office of Science is the Nation’s largest supporter of fundamental research in the physical sciences, which it pursues in partnership with national laboratories, universities, institutions, and other organizations with related missions. Fundamental research involves investigation and analysis focused on obtaining a better or fuller understanding of a subject, phenomenon, or a basic law of nature, not necessarily specific practical application of the results. One important research area within the physical sciences is Elementary Particle Physics, which has, as one of its goals, helping us to understand the physical nature of our Universe.

LBNF/DUNE would help to advance our understanding of the basic physics of the elementary particles called neutrinos. Neutrinos are elementary subatomic particles that have no electrical charge and are one of the most abundant particles in the Universe. In nature, they are produced in great quantities by sources such as our sun, from stellar explosions known as supernovas, and in smaller quantities on earth by man-made facilities, such as nuclear power plants. Neutrinos stream to the earth each day. The very small size of neutrinos means that they pass right through matter largely unimpeded, and only very rarely interact with other particles. In the lab, at facilities such as Fermilab, scientists can make neutrino beams for experimental purposes with particle accelerators. Appendix A-2 contains an article (Piergrossi 2013) describing what physicists know about neutrinos and the questions that could be answered by further research.

LBNF/DUNE would make use of an existing high-energy particle accelerator at Fermilab in Batavia, Illinois (the Near Site) to generate a beam of neutrinos and would utilize particle detectors to analyze the beam, one at Fermilab and another detector with one or more modules approximately 800 miles away at SURF (the Far Site). Although DOE has other neutrino experiments currently underway, where the neutrino source and detector are separated by 500 miles or less (see Appendix A-1), the longer baseline has been determined by scientists to be the optimal distance for this experiment and would enable scientists to gather important new information about neutrinos. The Far Site detector would be underground, to eliminate cosmic radiation that could interfere with the detector.

Neutrinos in flight naturally transform themselves quantum mechanically, by oscillating back and forth between three different states or "flavors" (muon neutrinos, electron neutrinos, and tau neutrinos). LBNF/DUNE would enable the most precise measurements yet of this neutrino oscillation phenomenon, which could potentially help physicists discover whether neutrinos violate the fundamental matter-antimatter symmetry of the Universe. If they do, then physicists would be a step closer to answering the puzzling question of why the Universe currently is filled preferentially with matter, while the antimatter that was created equally by the Big Bang has all but disappeared. So far, other sub-atomic particles known as quarks are the only elementary particles known to violate the fundamental symmetry between matter and antimatter. However, the observed violation of this symmetry in the physics of quarks is not sufficient to explain the observed abundance of matter over antimatter in the Universe.

Constructing LBNF/DUNE with a Near Site detector at Fermilab and with a Far Site detector deep underground would produce the best data for answering these questions. The Near Site detector would provide data on the quality of the beam as it leaves Fermilab and add to the precision of the measurements. The deep detector at the Far Site, shielded from cosmic radiation, would provide the most sensitive measurements of oscillations of the neutrinos sent from Fermilab. A deep detector would also enable sensitivity to proton decay and the capability for measuring electron neutrinos from a supernova should one occur in our galaxy during the Experiment's lifetime. The SURF site would provide the necessary long baseline (800 miles from accelerator to detector) and the capability to construct a large detector deep underground to shield the detector modules from interference by cosmic rays. For these reasons construction of a LAr detector deep underground (4,850 feet deep) at SURF would generate the most accurate data, and is recommended by the international collaboration.

As these questions are pursued by LBNF/DUNE, other experiments that would make use of the same detectors and/or laboratory infrastructure may provide additional opportunities for basic research in other areas of physics. In short, LBNF/DUNE and ancillary experiments would enable scientists potentially to transform our understanding of neutrinos and their role in shaping our Universe.

1.5 SUMMARY OF THE PROPOSED ACTION AND ALTERNATIVES

Under the Proposed Action, Fermilab would construct facilities that would generate a high-intensity neutrino beam that would be directed through the curvature of the earth toward detector modules constructed 800 miles away at SURF. The proposed facilities are summarized here and described in detail in Section 2. Proposed facilities at Fermilab, or the Near Site, would be constructed adjacent to its existing accelerator ring and would include beamline facilities to extract and focus the beam (by means of target horns and magnets). The primary structures would include a Primary Beam Enclosure, Target Hall, Absorber Hall, Decay Pipe, and Near Neutrino Detector (NND). Most of these facilities would be constructed underground or within an earthen embankment to shield the surrounding environment from beamline radiation. The facilities and work areas would be housed in a series of underground experimental halls and aboveground service buildings. The Proposed Action at SURF, or the Far Site, would include a large, underground LAr detector with one or more detector modules, and associated supporting facilities. Construction and operation of the proposed facilities together make up the Proposed Action. At both Fermilab and SURF, the Proposed Action would include implementation of Standard Environmental Protection Measures (SEPM), such as revegetation, erosion control, and traffic management.

In addition, Alternative A, consisting of other smaller, reasonably foreseeable experiments being considered at SURF was evaluated. These alternatives are not mutually exclusive and if approved by DOE, these experiments could be constructed in addition to the Proposed Action, or they could be constructed independently. As required by NEPA, the EA also evaluates the No Action Alternative.

2. DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

This section describes the U.S. Department of Energy's (DOE) Proposed Action for the Long-Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE). It also describes Alternative A, the No Action Alternative, and the rationale for not fully analyzing certain other alternatives.

Fermilab was selected as the proposed location for the neutrino beamline to originate because it is currently operating similar experiments and has much of the expertise and the existing infrastructure needed to support a new neutrino experiment. The proposed far detector site was selected by comparing candidate sites against LBNF/DUNE requirements, including capability for data collection in support of LBNF/DUNE's scientific objectives (Fermilab 2012a). Most importantly, the proposed far detector site met the following criteria, deemed necessary by the project managers, program managers and scientists:

- A baseline (i.e., the distance from the neutrino beam to the detector) of between 620 and 930 miles from Fermilab, which is a key factor in the experiment's sensitivity to neutrino oscillations.
- A sensitivity to proton decay and detection of supernova neutrinos.
- Directional compatibility with Fermilab facilities and the location of the MI.
- Rock with low background radioactivity and of sufficient strength to support construction of a large and deep cavern with shielding from cosmic rays and low background radioactivity.
- Supporting infrastructure sufficient to excavate a large, deep-rock cavern.
- Dedicated and reliable underground access that would not pose conflicting objectives (e.g., a mining objective versus a science objective).
- A site with robust ventilation and at least two means of access/egress.

A number of potentially suitable sites were considered in formulating the Proposed Action. Section 2.4 summarizes them. The site that most fully met the criteria identified above was the Sanford Underground Research Facility (SURF) in South Dakota.

The LBNF/DUNE team also considered several different technology and transportation schemes (e.g., proton source, the near and far detector type, and transportation methods and placement locations for the excavated rock).

The Proposed Action and alternatives are as follows:

- Proposed Action – the LBNF/DUNE includes construction and operation of a beamline facility and Near Neutrino Detector (NND) at Fermilab, and a Far Detector at SURF's 4,850-foot level (referred to in the EA as the 4850 Level). The Proposed Action includes multiple possible technology and transportation scenarios.
- Alternative A – additional, smaller physics experiments at SURF. The experiments in this alternative are not fully defined or funded but are considered "reasonably foreseeable".
- No Action – existing research programs at Fermilab and SURF including neutrino experiments would continue; however, LBNF/DUNE and/or additional reasonably foreseeable facilities and experiments would not be constructed or operated. The No Action Alternative would leave the

remainder of Fermilab's large physics research programs unchanged. Existing shorter-baseline neutrino experiments at Fermilab would continue to advance neutrino science, but the experiments conducted would be limited to shorter-baseline measurements and would not achieve the longer-baseline scientific objectives set out for LBNF/DUNE.

2.1 PROPOSED ACTION

The Proposed Action includes construction and operation of a neutrino experiment (i.e., the detectors) and supporting facilities at two separate geographical locations - the Near Site at Fermilab in Batavia, Illinois, and the Far Site at SURF in Lead, South Dakota.

Figure 2.1-1 depicts Fermilab as well as surrounding roads and geographical context. At Fermilab, the Proposed Action would be constructed adjacent to the Main Injector (MI) to the southwest of Wilson Hall. **Figure 2.1-2** depicts SURF and the surrounding area, including features of the former Homestake mine, the Open Cut, Mickelson Trail, and transportation infrastructure. The proposed Fermilab and SURF facilities and their construction and operation are described in detail below.

2.1.1 Near Site (Fermilab)

The proposed features of the LBNF/DUNE at Fermilab, referred to as the Near Site, are the following. For simplicity, the near site structure designations use LBNF as opposed to the LBNF/DUNE convention, although they are also part of the LBNF/DUNE Proposed Action.

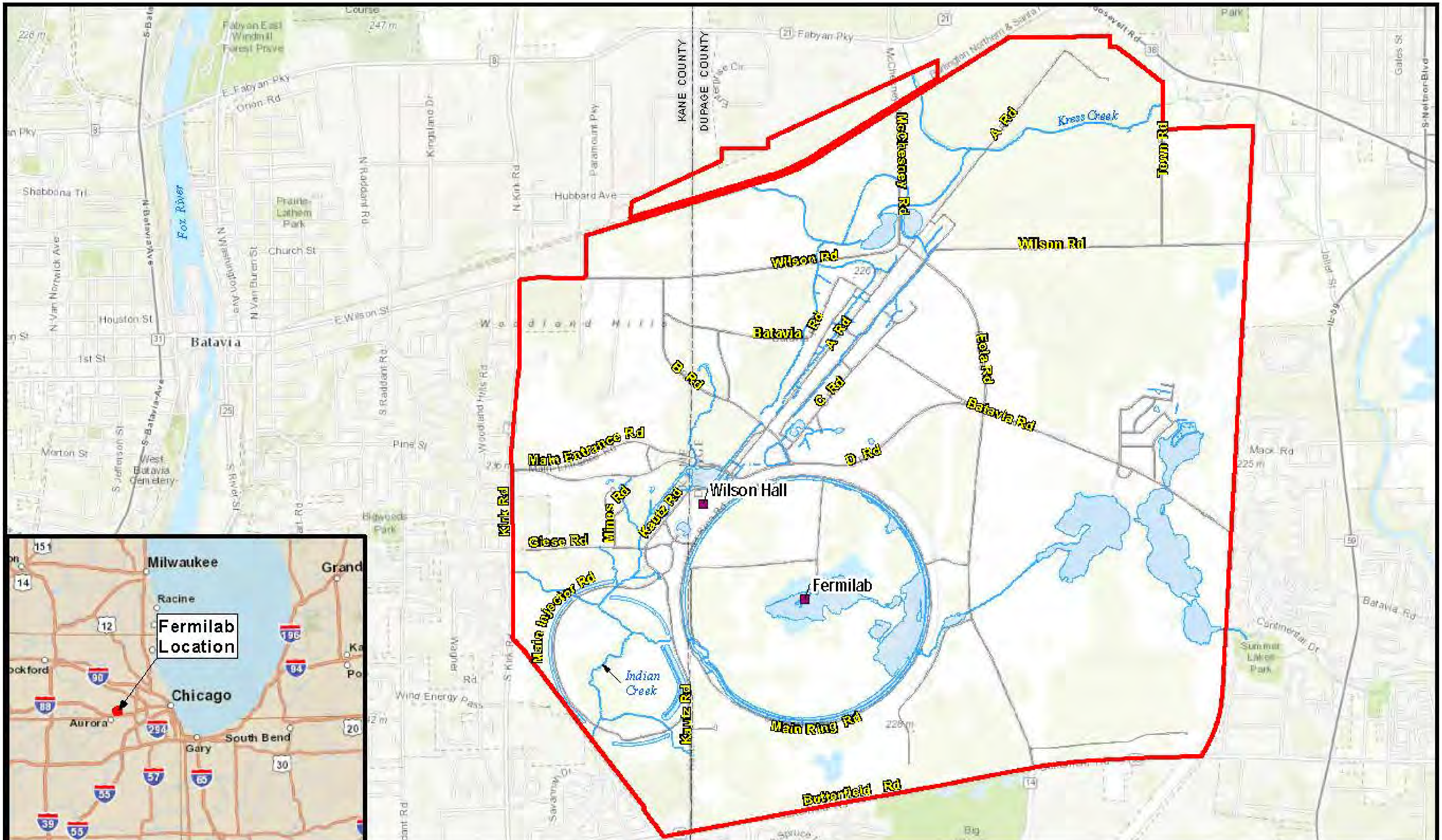
2.1.1.1 Proposed Facilities and Detectors

The Proposed Action for the Near Site includes the experimental equipment and enclosures required to extract a proton beam from the existing proton accelerator ring (the Main Injector at extraction point MI-10), and generate a neutrino beam. The experiment would collect information on the beam's properties using relatively small detectors at the Near Site (the muon detector and Near Neutrino Detector), and direct the beam toward the Far Site. Giese Road borders the site to the north, with Kautz Road to the east, Main Injector Road to the south, and Kirk Road to the west. **Figure 2.1-3** depicts a plan view of the proposed facilities, which are referred to throughout the EA using the Fermilab-designated building/station numbers (e.g., NND Service Building [LBNF-40]). These facilities are listed below from southeast to northwest and include the beamline facilities and service buildings. The latter, as currently constituted, include three surface buildings and a near-surface buried structure (the Target Hall Complex [LBNF-20]). Although the number of buildings could change as design proceeds, the scope would not. Each service building would be located generally above the underground facility enclosures and would provide access for equipment and personnel, as well as egress from the underground enclosures, and would have a total of approximately 60,000 square feet of interior space. The beam and all beam enclosures would be within an earthen embankment or below the existing grade level and shielded by combinations of soil, rock, steel and concrete. The Proposed Action, subject to design changes that do not affect the scope, includes:

- Primary Beam Enclosure:

  This area would house equipment and magnets that would extract the beam from the MI and transport it approximately 1,000 feet to the Target Hall. The below-grade section would house the connection to the MI and the proton beam would be directed to the Target Hall through a series of magnets. The approximately 800-foot-long Primary Beam Enclosure would extend to the Target Hall and would be protected by approximately 25 feet of earth shielding.

Absolute Scale = 1:48,000
1 inch = 4,000 feet



Legend

Fermilab Boundary
County Boundary
Facility
Stream
Road
Pond

Basemap:
World Topo Map and World Street Map, serviced by ESRI ArcGIS Online, accessed on 5/13/2015.

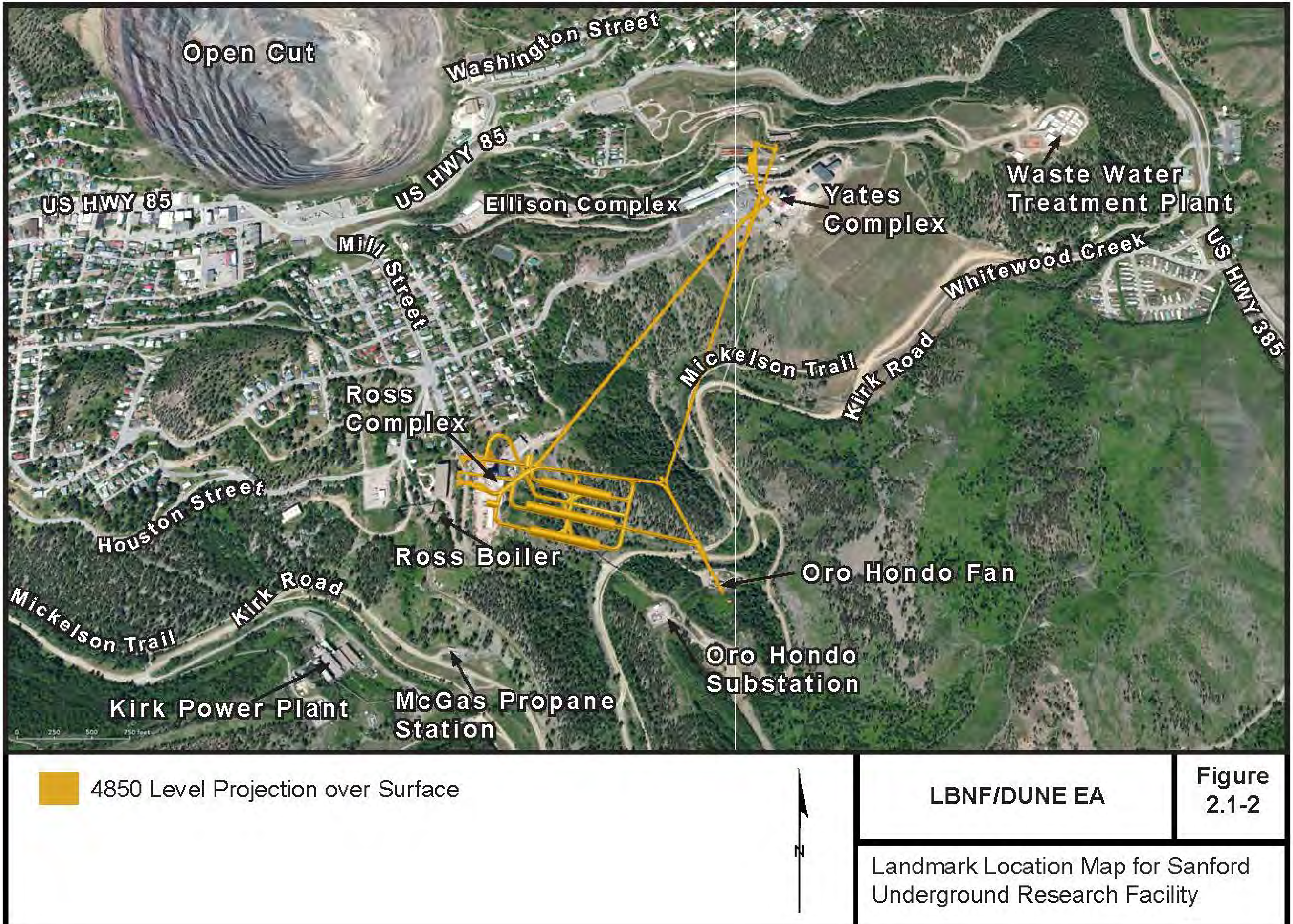
0 2,000 4,000 Feet

N

LBNF/DUNE EA

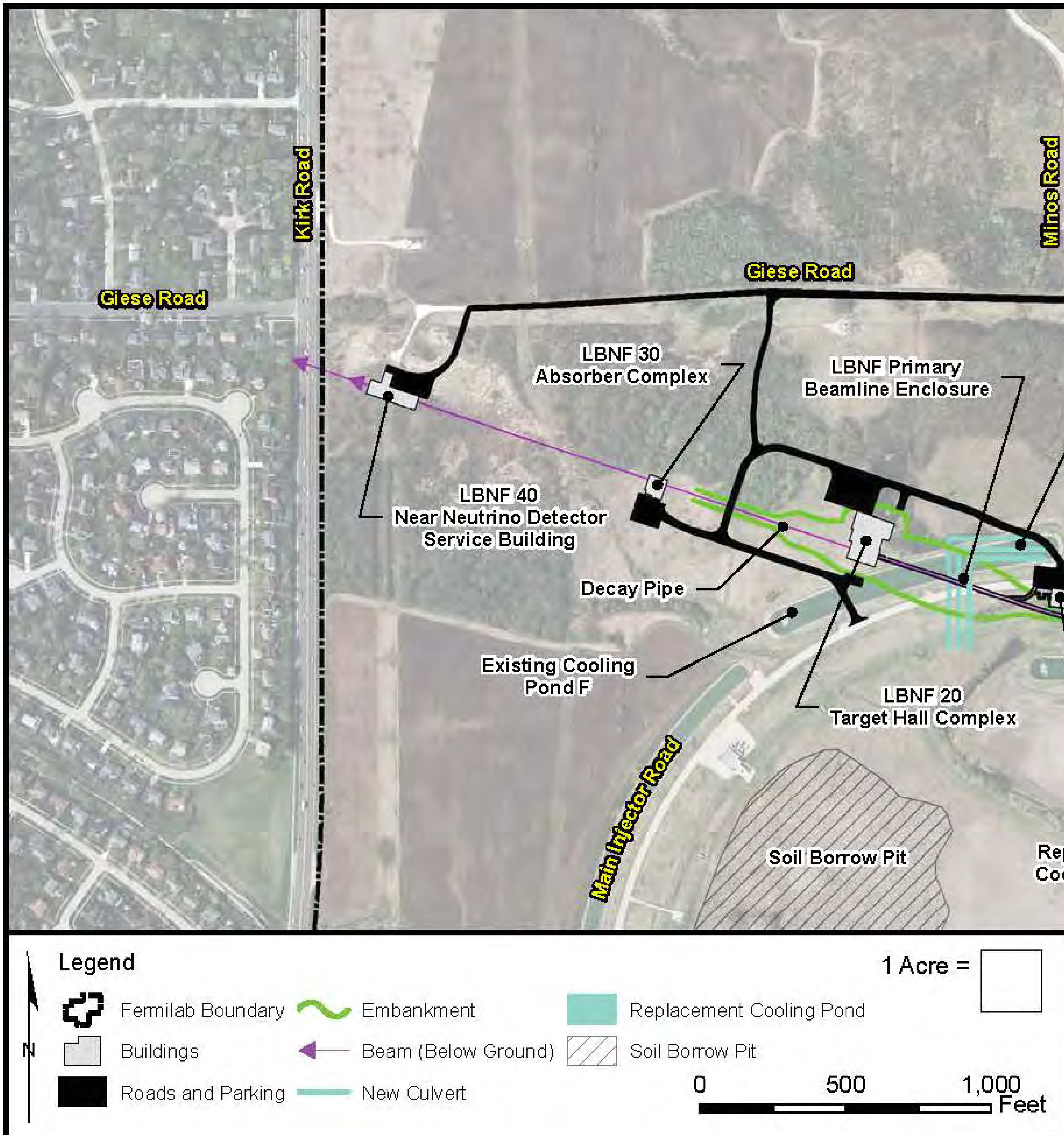
FIGURE 2.1-1

Fermilab Property and Surrounding Area



LBNF/DUNE EA	Figure 2.1-2
Landmark Location Map for Sanford Underground Research Facility	

Absolute Scale - 1:7,200
1 inch = 600 feet



LBNF/DUNE EA

FIGURE 2.1-3

Proposed Action Facilities Layout Fermilab

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- Primary Beam Service Building (LBNF-5)

  This at-grade service building would house the primary beam support equipment and utilities and would provide access for equipment and personnel to the subsurface Primary Beam Enclosure below.

- Target Hall Complex (LBNF-20)

  The Target Hall Complex would be located within an engineered fill embankment (see Construction section below) and would have approximately 30,000 square feet of floor space. It would house the Target Hall and support rooms for utilities, a truck bay and equipment staging area, and a restroom. These areas would provide the space needed to assemble, test, and operate the equipment. The Target Hall would house the target where collisions would produce pions and kaons (i.e., charged proton decay particles), and focusing horns to direct the path of the resulting charged particles. Beamline components would be shielded with steel shielding blocks and concrete that would be approximately 5.5 to 7 feet thick in some areas. The Target Hall would have a 50-ton overhead bridge crane for installing and removing target modules and horn components, and a hot handling cell for storage of irradiated or damaged components.

- Decay Pipe

  The Decay Pipe, where charged particles from the target would decay into neutrinos, would extend from the Target Hall to the Absorber Hall - a distance between 650 and 850 feet - at a downward slope of approximately 10 percent. This 13-foot-diameter steel pipe would be surrounded by approximately 18 feet of concrete shielding to protect the surrounding soil from radiation produced in the pipe. The shielding would be lined with a geosynthetic barrier system and equipped with a moisture interceptor system to prohibit groundwater from infiltrating into the Decay Pipe. The proposed liner system would include an outer geomembrane barrier layer, a geosynthetic clay liner (GCL) barrier, and a leak detection layer placed between the GCL and the inner geomembrane barrier layer.

- Absorber Hall

  The Absorber Hall would house the concrete and steel-shielded absorber and hadron monitor, the Muon Alcove, and support rooms. The absorber would remove the residual secondary particles (hadrons) and protons that did not interact with the target, and would be approximately 94 feet below existing grade. The Muon Alcove would house an array of muon detectors downstream of the absorber to provide information regarding the produced neutrino beam. This area would also support the beamline-measurement system (BLM), an array of muon detectors or monitors, and a Global Data Acquisition (GDAQ) system.

- Absorber Hall Service Building (LBNF-30)

  The Absorber Hall Service Building would support the assembly and operation of the Absorber Hall, Muon Alcove, and support rooms, which would be located approximately 94 feet below grade. The building would be located over an access/egress shaft and an equipment shaft, both constructed in an open cut excavation.

- NND and the NND Hall

  The NND would measure the characteristics of the beam before it leaves Fermilab. The NND Hall would be deeper than that of the Absorber Hall given the downward incline of the beamline. The NND would have two access shafts and would be located as far as practicable from the target (but within the boundary of Fermilab) to obtain the best experimental results, which places it approximately 1,800 feet from the target. The NND Hall would be located approximately 180 feet below the surface and approximately 125-150 feet east of Kirk Road at its closest point (**Figure 2.1-4**). This chamber would measure approximately 100 feet long by 55 feet wide by 50 feet high and would contain a comparatively small (20 ton) liquid argon (LAr) time projection chamber (LAr-TPC) detector. Although LAr-TPC is preferred, Fermilab is also evaluating other similar detector technology alternatives that would be accommodated by a similar-sized chamber, including scintillator tracker, fine-grained straw-tube tracker (FGT), and LAr membrane tracker. Potential impacts, if any, from these other, similar detectors would be equal to or less than those discussed regarding the LAr-TPC detector.

- NND Service Building (LBNF-40)

  The NND Service Building would house utilities and support assembly and operation in the below-grade NND Hall and support rooms. The building would be located over two access shafts that would provide access for people and equipment to the detector hall.

- Roads and Parking Areas

  The Proposed Action would include use of Kautz Road at Fermilab's southern boundary along Butterfield Road for construction access. It would also improve Giese Road and construct new local access roads to access the Primary Beam Service Building (LBNF-5), the Target Hall Service Building (LBNF-20), the Absorber Hall Service Building (LBNF-30), and the NND Service Building (LBNF-40). Each service building would have parking and staging areas for equipment laydown and soil stockpiling.

- Conventional Utilities

  Required utilities would include heating, ventilation, and air conditioning (HVAC); mechanical; plumbing; cooling water; and data and communications. Industrial and domestic water, sanitary sewer, and other utilities would be extended from existing services along Main Injector Road. Cooling water from the Industrial Cooling Water (ICW) system would be used to cool the beamline magnets and power supplies. HVAC units would be quiet units to the extent practicable and would be fitted with enclosures to minimize operational noise.

- Cooling Water

  The primary beamline, LBNF-20, and other facilities would cross the area now occupied by the existing MI Cooling Pond F (**Figure 2.1-3**). Therefore, the Proposed Action would require removing this pond and its associated infrastructure and surrounding banks, and filling the area to grade. The area of Cooling Pond F would be replaced with a new cooling pond within the infield of the MI, or Fermilab would construct on-site mechanical cooling units to achieve the same purpose.

- Power Source and Transmission

  Fermilab would use an existing proton beam to generate the neutrinos. The Proposed Action would require upgrades to Fermilab's pulsed (short-term) and conventional power systems, including extension and expansion of the existing 13.8 kV (kV) electric distribution facilities. The improvements would include electrical substation modifications, extension of existing 13.8 kilovolt distribution feeders (for pulsed power), minor changes to the Kautz Road substation to create new electrical feeders for conventional power, and relocation of on-site electrical facilities to accommodate LBNF/DUNE.

The LBNF/DUNE beamline would be designed for initial 1.2 megawatt (MW) operations and would have the potential to be upgraded to 2.3 megawatts (MW). As a conservative measure, LBNF/DUNE would be designed and constructed to accommodate an eventual increase in beam power so that a second large construction effort would not be required. Beamline elements that cannot economically or practicably be changed later, such as the absorber and shielding for the target and decay pipe, would be designed and constructed to accommodate a 2.3 MW beam. Elements that could be upgraded later, such as the target and horns, would be designed for the lower initial beam power. The analysis of operational impacts presented herein is based on the bounding (higher) beam power.

Figure 2.1-4 provides a cross-section view of the Near Site portion of the Proposed Action, including the sloped underground beamline and halls.

2.1.1.2 Construction

The following subsections describe construction of the Proposed Action at Fermilab. Construction would require an approximate average of 56 construction workers, with a peak worker population of approximately 200 during construction of the service buildings. Overall, construction and equipment installation would require several phases over a period of 7 years (currently planned 2017 through 2023). Refer to Section 2.6 for a summary of the estimated project schedule. Major components would include:

- Construction of a culvert to convey Indian Creek;
- Excavation of up to approximately 950,000 yd^3 of soil for Pond F replacement, borrow pit, and conventional site work;
- Construction of an approximately 240,000 CY^3 earthen embankment;
- Excavation of approximately 45,000 yd^3 of rock;
- Placing approximately 95,000 yd^3 of cast-in-place concrete;
- Open cut excavations of approximately 2,000 linear feet and 670,000 yd^3 volume;
- Construction of access shafts to the underground NND;
- Construction of LBNF-5, LBNF-20, LBNF-30, and LBNF-40, with a combined floor space area of approximately 60,000 square feet; and,
- Assembly and installation of beamline components, including horns, magnets, and detectors.

Culvert and Embankment - Construction of the Proposed Action would require excavation and placement of fill to create an earthen embankment for supporting and shielding the beamline. First a portion of Indian Creek would be directed to a new culvert under the embankment and over the MI tunnel.

The embankment would consist of engineered fill and would be approximately 950 feet long, 250 feet wide at the widest point, and 50 to 60 feet high (includes approximately 25 feet of soil shielding above the beamline). The edge of the proposed embankment appears as a green line on **Figure 2.1-3** and **Figure 2.1-4**. The fill would be obtained from the nearby borrow pit excavation, which would be allowed to fill with water after construction. Recent geotechnical investigations (AECOM 2013) show that these soils have the necessary properties to create the embankment. In addition to the embankment, **Figure 2.1-3** depicts the borrow site.

The soils below and within the embankment would consolidate (settle), particularly during the first year. Preliminary estimates suggest that 50 percent of the settlement would occur within 1 month, with 90 percent within 1 year and 100 percent within 2 years. Because the beam's alignment with the target and Decay Pipe is critical to the beamline performance and avoiding equipment damage, Fermilab would construct the embankment early in the construction schedule and allow the soils to settle for approximately 2 years before constructing the beamline enclosures. Because some settlement may continue after construction, grout would be used to fill the potential gap between the bottom of the structure and the embankment. Drilled shaft foundations would provide additional support for the beamline if needed, depending on the results of the geotechnical investigations and analyses. Finally, because consolidation of underlying soils could affect the MI, standard design measures such as structural protection and isolation systems (potentially including braced excavations, retaining wall systems, and/or slurry-filled cut-off trenches) would be used to minimize settlement effects on the MI and other existing facilities.

Excavation - The easternmost portion of the beamline, including part of the Primary Beam Enclosure and all of LBNF-20, would be constructed above the existing grade within the embankment. All facilities would be constructed using standard open cut excavation methods. The Absorber Hall would include excavation to 94 feet below grade and construction of a tall vertical concrete structure to the surface, then backfilling. All excavations would require dewatering during construction in response to rainfall events and groundwater infiltration. Excavated soil and rock would be stored on the construction site or at one of Fermilab's on-site stockpile areas until used as backfill as needed. Unused materials would remain permanently stored at the stockpiles.

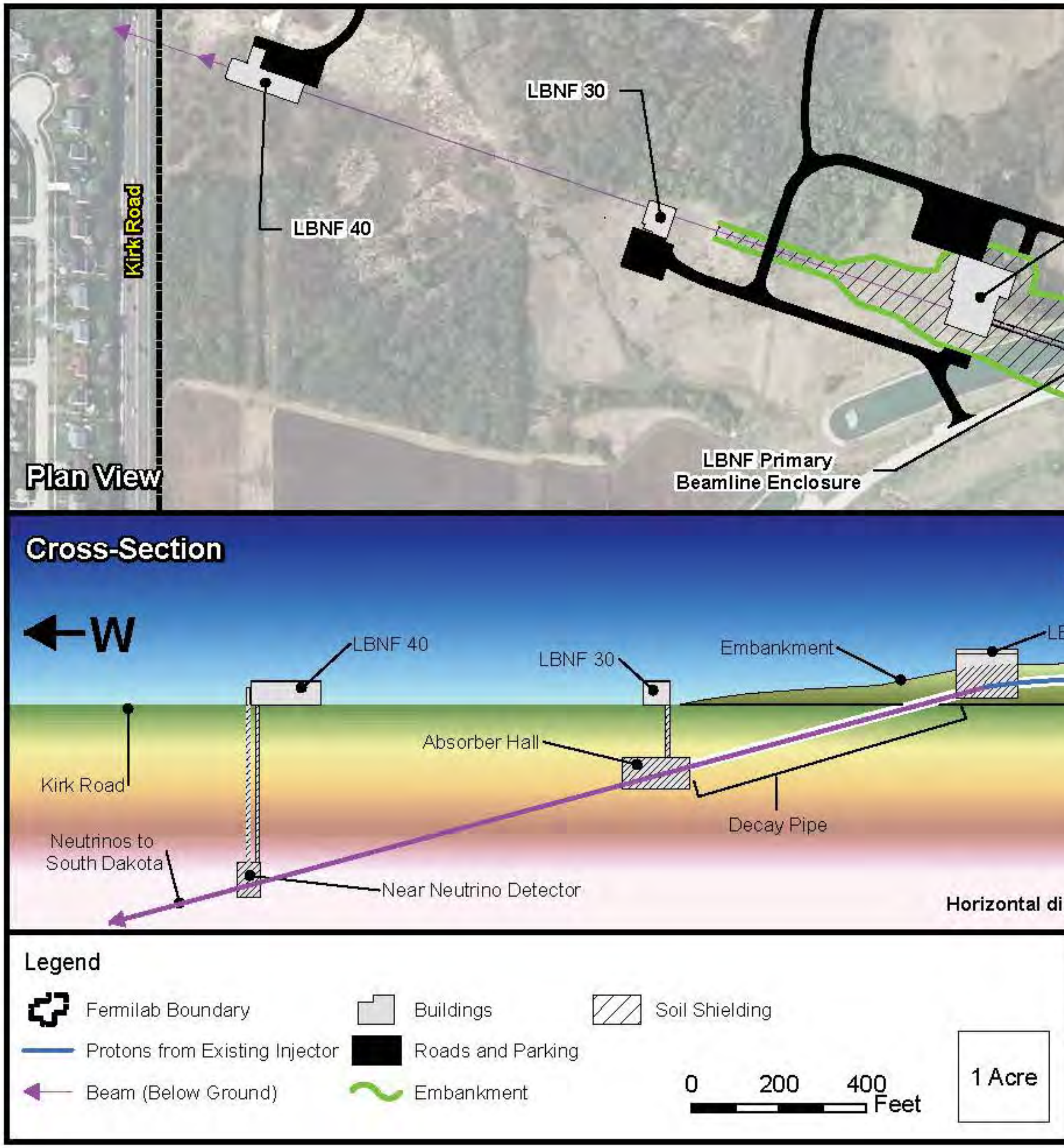
After construction of the embankment and the 2-year soil consolidation period, crews would construct the beamline facilities. Facilities would include cast-in-place concrete construction as well as pre-cast concrete enclosures. The Primary Beam Enclosure would be constructed on an approximately 15 percent incline through the embankment and then at a 10 percent decline to and through LBNF-20. The enclosure would be within the embankment and above the original grade for approximately 500 feet, where it would be covered with the soil shielding of the embankment. The apex of the embankment would be approximately 50 to 60 feet above existing grade, including approximately 25 feet of soil shielding over the beamline, as shown on **Figure 2.1-4**.

The Absorber Hall would be constructed approximately 94 feet below grade. Soil would be excavated to bedrock, and then approximately 25 to 30 feet of rock would be removed by drilling and blasting. For illustrative purposes only, **Figure 2.1-5** shows a similar excavation from a previous Fermilab project, the Liquid Argon Testing Facility (LArTF). Any excess soil and rock from the excavations would be transported to existing stockpiles on the Fermilab property. A geosynthetic barrier system would be placed between the surface of the excavation and the exterior of the Absorber Hall to minimize groundwater infiltration. The bedrock surface would be grouted to seal fractures and provide additional isolation from groundwater.

The NND would be constructed within an underground chamber excavated in rock with a supported crown and sidewalls. The chamber would be constructed from a vertical shaft connecting the surface with the underground space. Soil in the shaft would be excavated to bedrock followed by a drill-and-blast excavation through rock to the base of the proposed underground facility. **Figure 2.1-6** provides a conceptual view of the completed LBNF-40, shafts and NND Hall. Because the beamline facility would be constructed in the current location of Cooling Pond F, the existing Main Injector Road and utilities in this area would be relocated. Utilities would be extended to all LBNF/DUNE facilities in approximately 2,000 feet of trenches from the LBNF-20 and LBNF/DUNE 30 areas, including power, industrial water, domestic water, and communications.

Construction crews would also install supporting utilities including electrical, plumbing, HVAC, and safety systems, largely inside the enclosures, buildings, and underground halls. Construction parking would be temporary and located close to the final service building locations.

Absolute Scale - 1:4,800
1 inch = 400 feet



LBNF/DUNE EA

FIGURE 2.1-4

Proposed Action Facilities Cross-Section - Fermilab

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Figure 2.1-5 Previous Fermilab Excavation for LArTF Underground Experimental Hall

Beamline and NND Component Installation - The experimental equipment would be installed within the Extraction Enclosure, Primary Beam Enclosure, Target Hall, Absorber Hall, and NND Hall. This would include beamline and detector components such as the target, horn, magnets, and the detector. A crane would be used intermittently over a period of 2 to 4 months to lower the detector components into the underground NND Hall.

2.1.1.3 Operations

Fermilab would operate and maintain the beamline facilities in coordination with DOE and other partners over a planned operational life of approximately 20 years. During operations, researchers would optimize the beam for experimental purposes and monitor the NND and Far Site detector to observe particle interactions and to record the resulting signals. Fermilab would operate the beamline, and the DUNE Science Collaboration would operate the NND. Researchers would be located primarily at Fermilab and would remotely access, analyze, and interpret data. The Proposed Action would require approximately ten on-site workers at any one time over the 20 years of beamline operations. However, these workers would be transferred from existing Fermilab experiments such as NuMI and therefore, the Proposed Action would not substantially alter the number of Fermilab employees. Fermilab would monitor and maintain system components, including replacement of irradiated or damaged components; monitor groundwater tritium concentrations; maintain ventilation and cooling water systems; and monitor staff for health and safety.

After extraction from the MI, the primary proton beam would be bent upward by magnets into the embankment and then downward toward the target (**Figure 2.1-4**). Fermilab operators would again use magnets to focus the beam on the target. The primary beam would be tuned to reach the target with very low losses to ensure efficient production of neutrinos and minimal radiological activation of beamline components. The beamline horn would then focus the secondary beam into the Decay Pipe, in which particles produced from the target-beam interaction would be allowed to decay into secondary particles, predominantly into muon neutrinos and muons. The absorber would stop both the secondary particles and the protons that did not interact with the target, but not the neutrinos. The NND would measure the composition of the neutrino beam and thereby predict the rate of signal and background events expected at the Far Site, minimize uncertainties in neutrino oscillations, and maximize experimental results.

The resulting neutrino beam would then travel through the Earth (**Figure 1.2-1**) toward the Far Site detector at SURF, beginning with a diameter of approximately 13 feet and gradually spreading out to a diameter of approximately 50 miles before leaving the ground and travelling through the atmosphere into space. The beam would be used as needed over the operational period to accommodate planned experiments organized by the International Collaboration scientists. Over the experiment's lifetime, the target and focusing horns would require replacement. The Target Hall would be designed to accommodate safe, routine replacement of irradiated beamline components (e.g., horns, targets). Maintenance and repair would be completed in the managed and shielded environment of a hot handling room.

Prior to operations, the beamline and NND would be subject to cryogenic safety and oxygen deficiency hazard (ODH) analysis and an Accelerator Readiness Review (ARR) by an Environmental Safety and Health (ES&H) Review Panel as described in the Fermilab Environment, Safety, and Health (ES&H) Manual (Fermilab 2013a). The responsible operational Fermilab Division, Fermilab management, and DOE would then provide operational approval.

2.1.1.4 Future Decommissioning

The Proposed Action does not address future LBNF/DUNE decommissioning. The beamline facilities would be designed for the expected 20-year experimental operation. After operations, many of the facilities, including the surrounding shielding, would be radioactive from exposure to prompt radiation. Eventual demolition of the facility would require extensive precautions. DOE and Fermilab would likely delay decommissioning for approximately 10 years until radiological hazards from the original proton beamline are reduced to manageable levels through radioactive decay. Because decommissioning may not proceed for approximately 40 years from the present, the scope of this work has not been determined. For example, decommissioning could include the following:

- Repurposing the structures for a new experiment, including reusing the experimental components;
- Disassembling the experimental apparatus and beamline components for reuse at Fermilab or shipping to other DOE facilities or for sale as surplus equipment according to standard procedures for disposition of U.S. Government properties; or
- Mothballing (abandoning) the facilities in place with ongoing monitoring.

Ultimate decommissioning, however, would not occur for many years and is too speculative to evaluate future decommissioning impacts in this EA. Therefore, the environmental impacts of decommissioning would need to be evaluated as part of a future NEPA review process.

Absolute Scale - 1:4,800
1 inch = 400 feet

Legend

- Fermilab Boundary
- Beam (Below Ground)
- Embankment
- Buildings
- Roads and Parking

1 Acre

0 200 400 Feet

N

LBNF/DUNE EA

FIGURE 2.1-6

Proposed Action Near Detector Construction - Fermilab

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2.1.2 Far Site (SURF)

The Proposed Action includes construction of an underground detector at SURF. Two different detector technologies were considered: Water Cherenkov Detector (WCD) and LAr-TPC. The technology selected for evaluation was the LAr-TPC at the 4850 Level, based on the potential for clear measurement of neutrino oscillation, proton decay studies, and the potential for producing unique information on neutrinos generated by a galactic supernova, should one occur during the experiment's lifetime.

2.1.2.1 Far Site Facilities & Detectors

The proposed features of the LBNF/DUNE at SURF, referred to as the Far Site, are the following (**Figure 2.1-8**):

- An underground detector (the Far Site detector), consisting of four detector modules, would contain approximately 51-kiloton (kt) of LAr.
- Under the Proposed Action, the Far Site detector would be placed in one or more excavated caverns at the 4850 Level near the Ross Shaft as shown in yellow on **Figure 2.1-9**. Other surface features labelled on this figure are for reference purposes only and not proposed for the 4850 Level. Most of the construction of the Proposed Action and its supporting facilities at SURF would be completed underground. An excavation of up to approximately 460,000 yds^3 would be required to create underground caverns large enough to house the detector modules and supporting infrastructure. LBNF/DUNE is considering several technical alternatives for the detector configuration, including two mailbox-shaped detectors or a single cylindrical detector.

  The detector would consist of one or more cryostats, which are heavily insulated stainless steel-lined chambers commonly used to keep liquids at low temperatures. The LBNF/DUNE cryostats would be similar to those found on tanker ships that transport liquefied natural gas (LNG).

  The cryostats would be filled with LAr, which would be maintained at a temperature of 87 Kelvin (-303 ^{o}F), purified, and kept cool by a liquid nitrogen (LN) cryogenic refrigeration system and heat exchanger. This cold temperature would also be maintained by multiple containment and insulating layers including (from inside to outside) stainless steel, insulation, an aluminum secondary containment layer, and more insulation.

  Each cryostat would have a TPC detection system immersed in the LAr and connected to readout electronics. The cryostats would hold a total mass/volume of approximately 51 kt or 10.8 million gallons of LAr.
- Utilities

  Utilities would be routed to the underground detector modules through the previously refurbished Ross Shaft and would include electrical power, industrial water for process water and fire suppression, ventilation supply, fire detection and alarm systems, a sump pump drainage system (for conveying native infiltration water to the facility-wide discharge system), communications, cryogens, and security. Exhaust from the detector area would follow a dedicated, unoccupied path to the Oro Hondo Shaft, which provides ventilation for all underground spaces. This dedicated ventilation path would minimize an oxygen deficiency hazard (ODH) to underground workers.
- An aboveground Cryogen Support Building

  A new surface building would support the underground detector modules. This building would replace the existing Ross boiler building and its associated stack. The new structure would house day-tanks, compressors and associated electrical and mechanical equipment to support the surface delivery of LAr and LN and the transfer of these cryogens to the completed underground cryostats that would compose the detector. LAr would be delivered to the cryogen support building, offloaded, and then piped to the 4850 Level. Approximately 1,800 tanker truckloads of LAr would be delivered to the site over a period of 12 months. Initial filling of the cooling system would require an additional 8 tanker trucks of LN. Approximately 1-2 truckloads of LN per week would be needed to periodically refill the system throughout the life of the experiment..

- Transportation of excavated rock to the Gilt Edge Mine Superfund site in Deadwood, or transportation to and placement at the Open Cut in Lead

  The excavated rock would be hoisted to the surface and broken up by a crusher. It would then be conveyed to the Gilt Edge Mine Superfund site or the Open Cut. The Gilt Edge site is approximately 8 miles from Homestake. Gilt Edge is a highly disturbed former gold mine near Deadwood with large waste rock piles and acid rock drainage pits that are currently undergoing remediation. Excavated rock would be transported to this site and managed by USEPA as part of their remedial plans. Rock could also be transported approximately 4 miles to the north end of the Open Cut in Lead, either by truck or conveyor. The Open Cut is the former surface mining pit in Lead that is owned and managed by Homestake Mining Company. The Gilt Edge Mine Superfund site remedy is not part of the Proposed Action and thus the impacts of the remedial action are not part of this EA. For more information on the history of the site and details of the remedial action, see the USEPA Region 8 Gilt Edge Mine webpage at http://www2.epa.gov/region8/gilt-edge-mine.

2.1.2.2 Construction

The Far Site facilities would be constructed and installed over approximately 8 years (currently planned 2017 through 2024), beginning with surface buildings and excavation, followed by detector installation and filling. Construction would require a worker population averaging approximately 50, with a peak worker population of approximately 100 during underground construction.

Underground construction materials would be delivered to the Ross Shaft yard, conveyed down the Ross Shaft, and hauled by electric locomotive or rubber tired diesel equipment to the construction site. Much of the equipment, such as drills and loaders, would be brought down in pieces and reassembled on the 4850 Level. The cavern would be excavated using conventional drill-and-blast techniques. Excavated rock would be hauled to the Ross Hoist Skips, which were used by Homestake to bring ore to the surface.

The cavern crown and walls would be supported by rock bolts, cable bolts, mesh, and shotcrete, and would be sufficiently wide to safely accommodate access and equipment. The underground detector would be filled with LAr by off-loading LAr trucks at the surface support building, currently the site of the Ross Boiler Building. The LAr would be stored in exterior (outdoor) tanks prior to being gasified in this building and piped through the existing service tunnel to the Ross Shaft and then down to the 4850 Level to the detector's re-liquification and detector purification system.

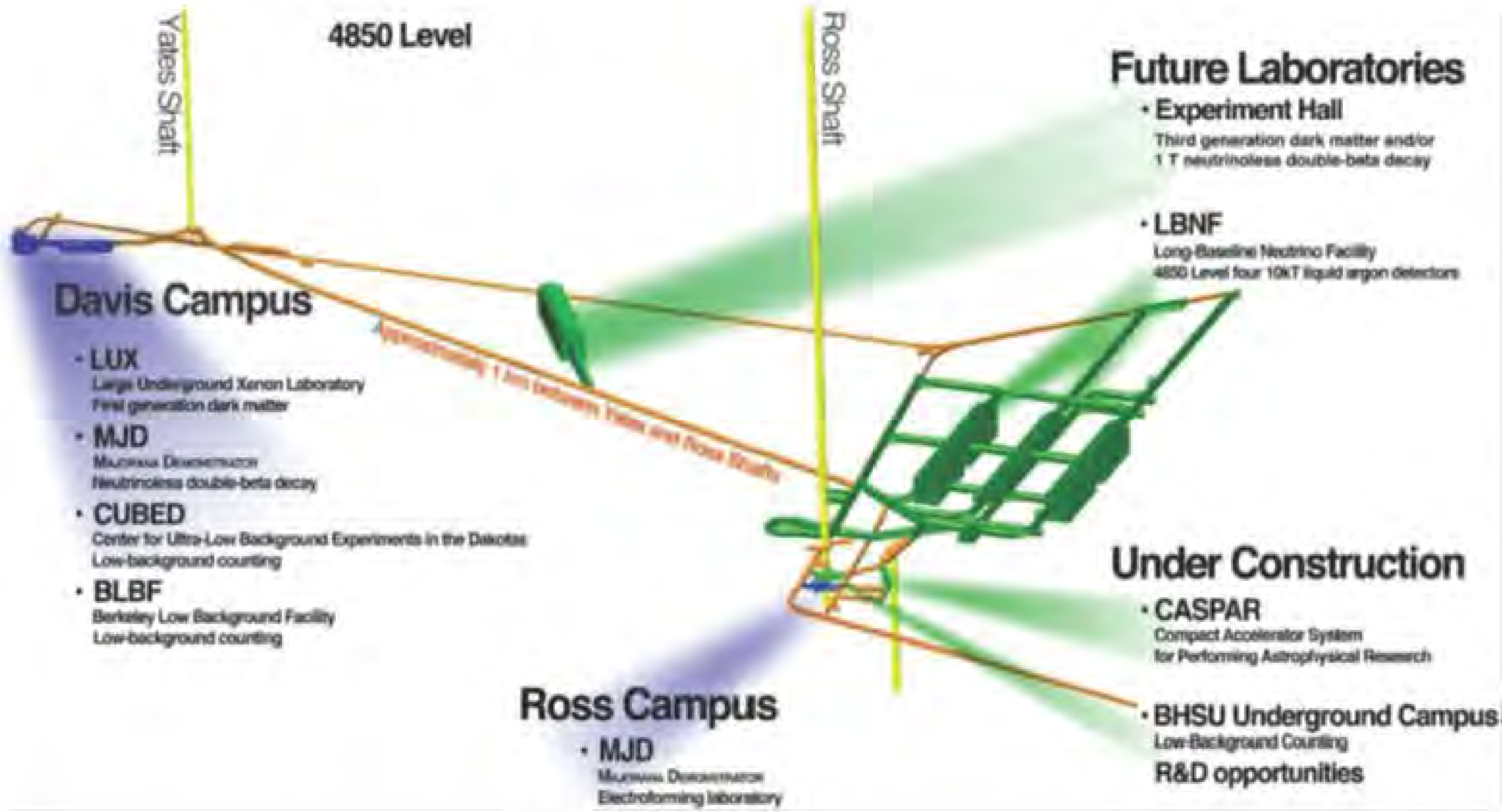
Two surface structures would be modified for the Proposed Action. The Ross Boiler building and stack would be demolished to provide space for the new cryogenic support building. Demolition would also include removal of three 10,000-gallon aboveground diesel storage tanks (currently unused and empty) that lie within concrete secondary containment. The Ross Boiler has not been used for many years and is in disrepair. A small portion (one room) of the Ross Dry building would be used as an additional control room for the detector.

4850 Level Projection Over Surface

LBNF/DUNE EA

Figure 2.1-7

Projection of Proposed Action Facilities and 4850 Level Over Surface



New construction areas associated with Proposed Action and Alternative A

LBNF/DUNE EA

Figure 2.1-8

Underground cutaway of Proposed Action and Alternative A on 4850 Level

Installation of the underground detector would require excavation and tunneling on the 4850 Level to create access drifts (horizontal tunnels) and cavern(s) to house the cryostats. The paragraphs below describe the various means available for conveying the excavated rock from the surface at the Ross Shaft to the placement site. Trucks would be the only method available to transport the rock to the Gilt Edge Superfund site. The conveyance technologies being considered for the Open Cut include trucking, pipe conveyor, and rail system.

Three potential means of rock conveyance are evaluated in the EA as part of the Proposed Action.

<u>Trucking</u> - Trucking the excavated rock would involve installation of a new overland conveyor to move rock downhill from the crusher southwest, approximately 1,300 feet, to Kirk Road (not to be confused with Kirk Road at the Near Site at Fermilab), where a highway truck load-out would be constructed. The truck load-out site would also have a re-fueling station including containment structures and a scale.

To transport the excavated rock to the Gilt Edge Superfund site, the trucks would be loaded as described above and would travel east on Kirk Road, south on Hwy 385, and east on Gilt Edge Road into the Gilt Edge Superfund site where the rock would be managed by the Gilt Edge Superfund remediation project (**Figure 2.1-9**). The final disposition of this rock is outside the scope of the Proposed Action.

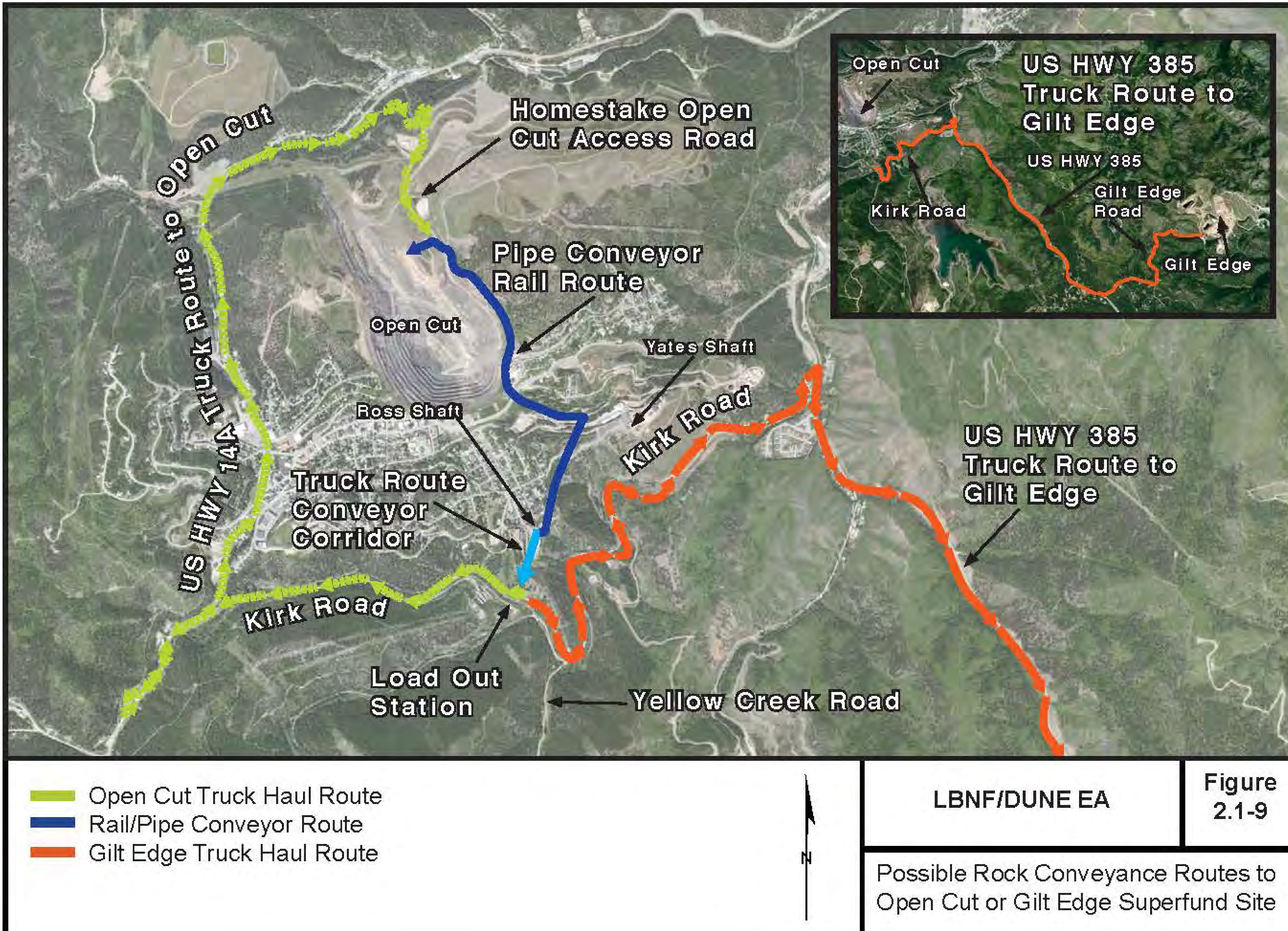
To transport rock to the Open Cut, the trucks would travel on public roads in the City of Lead and enter the Open Cut via Homestake's private access road. A bulldozer would spread the rock in the placement area. Noise and dust would be minimized as necessary with a dust suppression system and noise screens.

<u>Pipe Conveyor</u> – Due to the closer location than Gilt Edge, the pipe conveyor method could be a practicable way to transport rock from Homestake to the Open Cut. The pipe conveyor method would be nearly identical to that operated by Homestake between 1982 and 2002 and would follow the route of the old pipe conveyor over Hwy 85, along the east side of the Open Cut, and to the throat (north end) of the Open Cut (**Figure 2.1-9**). Rock would pass through the existing ore pass chutes from the crusher to the former ore bins above the Ross Tramway, 125 feet below the surface. The rock would be loaded into 10-ton capacity mine rail cars and then transported by locomotive through the existing 2,300-foot underground tramway. The cars would exit the tramway and discharge rock to a load-out bin. The rock would then be loaded onto an aboveground 2,300-foot, 18-inch diameter, "split pipe" conveyor, which would transport the rock to the Open Cut. It would operate as continuous loop and would be closed except for accepting or depositing rock at the Open Cut, where a bulldozer would spread the rock.

<u>Rail System</u> – The rail system conveyance method for rock would require constructing a railway to the Open Cut. Rock would be loaded into tramway ore bins as described for the pipe conveyor and then loaded into a series of small rail cars (3 tons each) forming a string 400 to 500 feet long. The rail cars would emerge from the tunnel, and turn northwest toward the Open Cut along the same corridor as the proposed pipe conveyor.

2.1.2.3 Operations

The DUNE Science Collaboration, through Fermilab, would operate and maintain the Far Site detector over the planned operational lifetime of approximately 20 years. During operations, the Far Site detector would be used to detect neutrinos originating from the Near Site. Operations would include maintaining the detector facility (including the refrigeration system and the LAr within the cryostats); monitoring the site security, fire, and life safety systems. The Proposed Action would add approximately 2 to 4 SURF workers for maintenance and approximately five on-site researchers.



LBNF/DUNE EA

Figure 2.1-9

Possible Rock Conveyance Routes to Open Cut or Gilt Edge Superfund Site

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Underground LAr management would include filtering the LAr to achieve high purity levels. The LAr would be collected via a manifold along the bottom of the cryostat and circulated for purification. The LAr would be maintained at 87 Kelvin (K) (*equals -186.15 degrees Celsius or -303.07 degrees Fahrenheit*) using LN refrigerators and nitrogen compressors. High-purity LAr stored in the cryostat would continuously evaporate. The argon vapor (boil-off gas) would be recovered, chilled, re-condensed, and returned to the cryostat. A closed system would be used to prevent losses. LN volume would be maintained by refilling the system with approximately 1-2 tanker-truck loads of LN per week. These trucks would travel on US 85 into Lead and on Mill Street and E. Summit Street to access the cryogen support building.

The Far Site detector would be subject to cryogenic safety and ODH analysis in addition to an experimental operational readiness review by an ES&H Review Panel with operational approval from DOE as required under applicable Federal regulations and from the responsible Fermilab Experimental Division Head and the South Dakota Science and Technology Authority (SDSTA).

2.1.2.4 Future Decommissioning

As described for the Near Site, the Proposed Action does not address decommissioning. At the end of the 20-year operational period, DOE would evaluate the potential environmental impacts of decommissioning in a future NEPA review process.

2.2 ALTERNATIVE A - REASONABLY FORESEEABLE ACTIVITIES AT SURF

Alternative A includes reasonably foreseeable future physics experiments also investigating fundamental particles that would be constructed and operated at SURF by DOE and its partners. These partners may include the National Science Foundation (NSF), international collaborators, or other private or public funding sources in partnership with universities, institutions, and other external organizations. These future experiments would not necessarily be dependent on the Proposed Action going forward. Undertaking these experiments, however, would require coordination among all the experimental partners. A decision to go forward with the Proposed Action or Alternative A would not be mutually exclusive. Alternative A physics experiments could proceed independently or in parallel or series with the Proposed Action.

In addition, these experiments would require rock excavation as described for the Proposed Action. Features of the excavation include:

- Excavation of a total of approximately 153,000 yd^3 (250,000 tons) of rock to create underground caverns for equipment and working space.
- The excavation and construction would occur after the excavation for the Proposed Action. The construction equipment and site resources necessary to construct and operate these experiments (e.g., shaft use) would be similar to LBNF/DUNE but smaller, both individually and in aggregate.

The potential environmental effects of future physics experiments are addressed in this EA, to the extent that they fall within the constraints outlined below:

- The experiments would be installed within the newly excavated underground caverns at SURF, and the excavated rock would be:
    - Disposed of within existing underground spaces, or,

    - Managed (hoisting, crushing, hauling, and removal) in the same manner as the LBNF/DUNE and transported to either the Gilt Edge Superfund site or the Open Cut.
- Underground placement sites would be dry and free of seepage, avoiding the potential for water quality impacts.
- Any additional infrastructure required outside the underground areas of SURF would be constructed within existing SURF facilities or within existing disturbed areas, thereby minimizing any potential adverse impacts on biological and cultural resources.
- Historic preservation review would proceed as described in the LBNF/DUNE Programmatic Agreement (PA). The PA is described in Section 3.3, Cultural Resources.
- The experiments would incorporate standard environmental protection measures (see Section 2.5 below) used by SURF to minimize environmental impacts.

2.3 NO ACTION ALTERNATIVE

NEPA requires consideration of the No Action Alternative as a baseline for comparison with other alternatives. Under the No Action Alternative, existing research programs at Fermilab and SURF, including neutrino experiments, would continue. However, neither LBNF/DUNE nor other reasonably foreseeable experiments described as Alternative A would be constructed or operated. Therefore, under the No Action Alternative, none of the adverse (or beneficial) impacts discussed in Section 3 would result. Moreover, the scientific goals of studying neutrino oscillations would not be achieved in the U.S. in the near future, and thus neither the purpose nor the need for LBNF/DUNE (see Purpose and Need statement in Section 1) would be fulfilled. At Fermilab and SURF, the No Action Alternative would leave the remainder of the large physics research programs unchanged. Existing shorter-baseline neutrino experiments, such as NO*v*A and Main Injector Neutrino Oscillation Search (MINOS), would continue to advance neutrino science, but would not achieve the longer-baseline scientific objectives set out for LBNF/DUNE.

2.4 ALTERNATIVES CONSIDERED BUT ELIMINATED

DOE considered several siting alternatives for the LBNF/DUNE Far Site.

DOE examined a number of far site alternatives identified by the NSF for the Deep Underground Science and Engineering Laboratory (DUSEL) project, which was cancelled. DUSEL's proposed neutrino element is what the basis became for the LBNF/DUNE. The sites evaluated for DUSEL are listed in **Table 2.4-1**.

Other than the Homestake Mine (now SURF), none of the sites listed above met the specified criteria for the Proposed Action. Criteria for selection are identified in Section 2.

Notably, two sites listed in Table 2.4-1 were subject to their own previous DOE NEPA Environmental Assessments and thus, substantial siting information was available for consideration in the Proposed Action. The Soudan Mine in Minnesota, home of the MINOS neutrino detector, was considered but did not meet the criterion for baseline length and Fermilab is already conducting shorter-baseline experiments such as NO*v*A. DOE's Waste Isolation Pilot Plant (WIPP) site also had an insufficient baseline length, was not sufficiently deep to address the cosmic radiation criterion, and the salt bed geological formation was not desirable.

Table 2.4-1 Alternative LBNF/DUNE Detector Sites Evaluated by DOE (Table 4-2 of LBNE Alternatives Analysis Report)

Site	Distance from Fermilab (km)	Depth (mwe)	Rock Type	Access	Condition
Cascades, Washington	2,700	5,900-6,800	Hard rock	Horizontal	New site
Henderson Mine, Colorado	1,470	3,100-6,000	Hard rock	Vertical	Commercial
Homestake Mine, South Dakota [now SURF]	1,290	4,200-6,000	Hard rock	Vertical	Closed mine; property donated to state
Kimballton Mine, Virginia	820	1,900	Limestone	Horizontal	Commercial mine
San Jacinto, California	2,600	4,000-6,000	Hard rock	Horizontal	New site
Soudan Mine, Minnesota	735	2,200	Hard rock	Vertical	Operating lab
SNOLAB, Ontario	770	5,890	Hard rock	Vertical	Commercial mine and Lab
Waste Isolation Pilot Plant, Carlsbad, New Mexico	1,700	1,800	Salt bed	Vertical	Operating DOE Laboratory

Notes:
Summary table adapted from Table 4-2, page 4-13 of LBNE-doc-5541.
The Homestake mine site is now SURF (a physics research facility) and not a "closed mine".
km = kilometer
Mwe = meters-water-equivalent
Source: LBNE 2012 (LBNE-doc-4382)

Other sites previously studied did not have the desired baseline length or were operating commercial facilities, which would require their purchase and thus an uncertain schedule. DOE also considered the privately owned Henderson Mine in Colorado; however, this location was eliminated based on technical feasibility (Fermilab 2012). As a result, these sites were eliminated from consideration.

Finally, DOE considered a less ambitious alternative at SURF that would have included all of the beamline components described above for the Proposed Action; however, it would not have included the NND and associated facilities at Fermilab, and at SURF would have included construction of a surface detector rather than the underground (4850 level) detector. This alternative was eliminated from detailed evaluation in the EA because it would not achieve the precision for oscillation measurements, nor any measurements for proton decay or supernova neutrinos. Moreover, this alternative would not satisfy the Purpose and Need statement.

2.5 STANDARD ENVIRONMENTAL PROTECTION MEASURES

Fermilab and SURF would implement standard environmental protection measures (SEPM) required by regulation, DOE directives, and site policies to minimize environmental effects of LBNF/DUNE construction and operation. These SEPMs would be employed as part of the Proposed Action or Alternative A to minimize environmental impacts and include commonly used methods. The Fermilab ES&H Manual (Fermilab 2013a) and SURF's Health and Safety Manual (SURF 2014) describe many of these measures. Several examples are listed below.

2.5.1 Biological, Cultural, and Geological Resources

Fermilab would pursue SEPMs to preserve on-site habitat and soil, including providing compensatory wetlands, protecting trees adjacent to construction areas, stockpiling and reusing topsoil, managing storm water, and restoring vegetation. All construction workers and managers would be required to become familiar with and apply U.S. Fish and Wildlife (USFWS) and State Historic Preservation Office (SHPO) requirements to protect biological and cultural resources that could be encountered during excavations and the relevant laws and reporting procedures. Training would also be provided to address permit conditions and SEPMs to protect migratory birds and bats, including avoiding vegetation removal at specific times of the year. For cultural resources, Fermilab workers would be familiarized with the Cultural Resources Management Plan (CRMP), which outlines a process for evaluating potential impacts of ground disturbance. SURF workers would be familiarized with the PA (**Appendix C-2**) developed for SURF for consideration of future actions pursuant to the National Historic Preservation Act (NHPA), Section 106, and concluded with the South Dakota SHPO.

2.5.2 Health and Safety

Fermilab and SURF would require the construction contractors to implement SEPMs such as preparing and implementing construction health and safety plans pursuant to the respective Fermilab and SURF Integrated Safety Management Systems (ISMS), DOE requirements (e.g., 10 CFR 851, Worker Safety and Health Program), Occupational Safety and Health Administration (OSHA) 29 CFR 1910 and 1926, and pertinent building codes (e.g., National Electrical Code). During operations, LBNF/DUNE would comply with operational SEPMs outlined in the Fermilab Radiological Control Manual and 10 CFR 835, Occupational Radiation Protection. LBNF/DUNE would be designed with sufficient shielding and operated such that worker and public radiation doses would comply with the Fermilab ES&H Manual, DOE standards, and Fermilab policy. Other SEPMs would include worker training, including cryogen safety training.

SEPMs specific to SURF due to work in the mine would require construction contractors to comply with Mining Safety and Health Administration (MSHA) regulations (30 CFR), SURF's cryogen safety policy, security and fire prevention plan, health and safety program, and project-specific truck safety requirements.

2.5.3 Air and Water Resources

Construction contractors would be required to minimize fugitive dust emissions and construction impacts on air and water quality. These SEPMs are outlined in Fermilab and SURF manuals and would include preparation of a Storm Water Pollution Prevention Plan (SWPPP) outlining appropriate stormwater best management practices (BMP) as well as spill prevention measures. BMPs would be tailored to the site and could include placing erosion control measures (e.g., silt fence, straw bales), preserving existing vegetation, covering stockpiled soil, sweeping access roads, and spraying disturbed areas with water. The contractor would also prepare a dewatering plan to ensure any discharge complies with National Pollutant Discharge Elimination System (NPDES) permit requirements. Fermilab would request a permit modification from the Illinois Environmental Protection Agency (IEPA) to allow pumped water discharges to the Indian Creek watershed. To address potential flood waters, Fermilab would implement SEPMs to provide any lost flood storage capacity according to Federal Emergency Management Act (FEMA) regulations.

During operations, Fermilab would use SEPMs to minimize the impacts of radiation on surface water and groundwater and would design and operate the beamline to comply with DOE and EPA water quality standards. Fermilab and SURF would minimize air emissions, comply with existing air permits, implement and maintain operational stormwater BMPs, and comply with NPDES permits. To protect groundwater quality, Fermilab would implement a groundwater monitoring plan, in accord with the Fermilab Groundwater Program, in the vicinity of the beamline structures to establish flow patterns and conduct groundwater quality sampling. The details of the plan (e.g., number of wells, installation details, or locations) have not yet been developed. Both Fermilab and SURF would incorporate existing Executive Orders (EO), which set goals for greenhouse gas (GHG) reduction and water conservation.

2.5.4 Noise and Vibration

The construction contractors would be required to implement SEPMs to minimize noise and vibration. Fermilab construction would normally be conducted during daytime hours. Fermilab would evaluate quiet equipment where practicable and add enclosures around ventilation systems. During rock excavation, the contractor would be required to communicate the schedule to residents at public meetings and by mail and to monitor the resulting vibration. Fermilab would also comply with LBNF/DUNE-specific requirements and local noise ordinances regulating construction and operational noise and vibration to minimize impacts to the surrounding communities.

SURF would implement SEPMs to limit noise including noise monitoring, limiting aboveground construction to the daytime, notifying residents regarding the blasting schedule, enclosing the crusher and Cryogen Support Building within a noise dampening fence, and implementing noise reduction features for the conveyor/railveyor (if selected). SURF would also require trucks outfitted with mufflers and would restrict trucks from using engine brakes in residential areas.

2.5.5 Transportation

The construction contractor would be required to implement traffic and transportation SEPMs outlined in Fermilab's ES&H Manual including preparing a construction traffic management plan, scheduling worker and delivery arrivals during off-peak commuter hours, and complying with the Federal Highway Administration's Manual on Uniform Traffic Control Devices. This manual provides specifications for signage, detours, speed limits, flaggers, and other traffic safety measures.

Traffic SEPMs at SURF would include implementing a traffic control plan, worker training, posting speed limits, regular inspection of construction vehicles, and signage.

2.5.6 Visual Resources

Because construction and the NND would be visible from Kirk Road, Fermilab would implement SEPMs to minimize visual impacts, including revegetation of the embankment, developing an LBNF/DUNE-specific architectural style for new buildings, and directing outdoor lighting downward. Visual resources at SURF are typically considered along with cultural and historic resources, since the Historic District in Lead includes much of the site.

2.5.7 Hazardous and Radioactive Materials

The construction contractors would be required to implement SEPMs for managing hazardous and radioactive waste pursuant to DOE Orders, DOE's Manual 435.1-1 for Radioactive Waste Management, and the FRCM and ES&H Manual. These measures would govern how the construction contractor would characterize, recycle, and manage any radiological or hazardous waste encountered during excavation and construction. For example, the contractor would be required to conduct radiological surveys of soil excavated near the MI. LBNF/DUNE would require compliance with SEPMs for management of operational waste, including managing pumped groundwater in on-site cooling water ponds. Materials exposed to radioactivity would be surveyed prior to removal by radiological control technicians and documented before release for disposal or reuse. Should components become activated as a result of a beam mis-steering accident, SEPMs would include storing the material underground in a shielded compartment until final disposal in compliance with DOE Orders.

SURF SEPMs for hazardous waste management would include contractor compliance with the site Emergency Response Plan, SWPPP, spill prevention measures, and Waste Management Plan.

2.6 CONSTRUCTION AND INSTALLATION PROPOSED ACTION SCHEDULE

Construction and equipment installation at Fermilab and SURF would require a total of approximately 7 years. This schedule is preliminary and subject to change. Start dates depend on completion of the NEPA process and receipt of all permits and approvals. Availability of funding could also impact the schedule. In the case of schedule slippage, the duration of individual work components and sequencing would not be expected to change substantially. As described below, many of the major components would be constructed concurrently.

Work at Fermilab	
Embankment	2018 – 2019
Enclosures (Target Hall, Absorber Hall, NND)	2020 – 2022
Beamline installation	2021 – 2024
NND installation	2023 – 2024
Operations	2024 – 2044
Decommissioning (not included in Proposed Action)	2044 – 2054
Work at SURF	
Site preparation and excavation	2017 – 2021
Buildings and infrastructure	2017 – 2021
Underground installation	2020 – 2023
Cryogenics construction and filling	2023 – 2024
Operations	2024 – 2044
Decommissioning (not included in Proposed Action)	2044 – 2054

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3. AFFECTED ENVIRONMENT AND ENVIRONMENTAL IMPACTS

This section describes the existing physical, biological, and socioeconomic features of the Fermilab and Sanford Underground Research Facility (SURF) areas and the potential environmental impacts of implementing the Proposed Action and alternatives. Potential impacts are analyzed by evaluating the type and magnitude of the effects on each resource. Specifically, the impacts are analyzed by evaluating the following factors and terms:

- Type - beneficial or adverse, direct or indirect
- Context - the geographic, biological, physical, and social context in which the effects would occur, whether site-specific, local, regional, national, or global
- Duration and frequency - short- or long-term
- Intensity - the severity of the impact, in whatever context(s) it occurs

Sections 3.1 through 3.16 describe and summarize the affected environment and provide analysis of the potential environmental impacts. The assessment is based on plans developed by Fermilab and SURF as described in the Long-Baseline Neutrino Experiment *NEPA Project Information Form* (Fermilab 2012b), the *LBNE Environmental Evaluation Notification Form* (Fermilab 2012c), and the description provided in Section 2. The impact analysis is intended to accommodate the full range of potential impacts from the Proposed Action and alternatives so that the range of impacts has been considered and minor changes in the design would not require additional analysis and would be covered by this Environmental Assessment (EA). The final design may differ slightly from that discussed in this EA, and all facility sizes and dimensions (e.g., sizes of excavation, square feet of facilities, volume or weight of excavated material) described are approximate. However, the nature, scope, and potential environmental impacts of the Proposed Action or alternatives (see Section 3, Affected Environment and Environmental Impacts) would not differ substantially from those identified in the EA. The impact analysis accommodates future reasonably foreseeable actions as part of an approach for SURF.

The impact assessment methodology used in Section 3 includes comparison of impacts with regulatory thresholds such as those contained in DOE regulations, U.S. Environmental Protection Agency (EPA) limits, and other guidelines and numerical criteria. These values are risk or technology based and were developed to evaluate, regulate, and control discharges and exposure risks and to evaluate potential impacts from construction and operation of industrial facilities.

3.1 LAND USE AND RECREATION

This section describes the land use for the Fermilab and SURF sites, the types of land uses present, land use context, including adjacent land uses and on-site research facilities, as well as adjacent and on-site recreational facilities and land uses, and the potential land use and recreational impacts of the Proposed Action and alternatives. The affected environment includes areas at Fermilab and SURF affected by construction and operations as well as adjacent areas where land use or recreation could be affected indirectly by visual or other impacts.

3.1.1 Fermilab

3.1.1.1 Affected Environment

Fermilab is located on 6,800 acres 38 miles west of downtown Chicago, Illinois. It straddles the boundary between eastern Kane and western DuPage Counties in an area of mixed residential, commercial, and agricultural land use. Adjacent municipalities include the Town of Warrenville (east), Batavia (west), West Chicago (north), and Aurora (south and southwest).

Land uses directly adjacent to the proposed construction area, west of Kirk Road and extending to the west and north, are residential (Single Family Low Density [R1-L]) (City of Batavia 2013). To the south and to the west of the Prairie Path are areas zoned General Commercial (GC) and Multi-Family Medium Density (R4). At the corner of Kirk Road and Giese Road, there is a parcel zoned Public Facilities and Institutional (PFI). To the north on Kirk Road, there are large areas zoned Light Industrial (LI) and General Industrial (GI). Land uses south of Butterfield Road in Aurora Township are primarily commercial.

Fermilab was commissioned by the U.S. Atomic Energy Commission, under a bill signed by President Lyndon B. Johnson in 1967 and has been a visible and continuing presence in the surrounding community since that time. Land uses surrounding the facility have developed and evolved over time, increasing in both diversity and intensity. By all measures, the changes in surrounding land use have progressed in harmony with operations at Fermilab. Land uses within the Fermilab property are primarily devoted to DOE-funded research facilities. However, Fermilab land is also used for agriculture and ecological research. Approximately 30 percent of the property is under license agreement for crop production. Fermilab supports recreational activities for the community including an interpretive nature trail and public areas for birding as well as various educational programs. Portions of Fermilab are devoted to restoration of native prairie as well as a bison herd. In 1989, Fermilab was designated a National Environmental Research Park (NERP). DOE established seven NERPs around the U.S. for environmental research. The preserve and research areas of Fermilab are not generally open to the public. In addition, the Illinois Prairie Path – a 62-mile-long trail used for hiking and biking – crosses the southwest corner of the Fermilab property.

Fermilab's primary mission and associated land use is the conduct of high-energy physics research experiments. For several decades, Fermilab hosted the Tevatron, which was the world's most powerful accelerator until 2011, when the Large Hadron Collider (LHC) in Switzerland came online. The Tevatron allowed scientists to examine the most basic building blocks of matter and the forces acting on them. Since the spring of 2005, Fermilab has been operating other neutrino experiments including the Neutrinos at Main Injector (NuMI) facility and the Main Injector Neutrino Oscillation Search (MINOS) experiment, and recently completed construction of the NuMI Off-axis ν_e Appearance (NOνA) project. Fermilab has extensive underground and surface facilities including a large accelerator complex, power and cooling water systems, research laboratories, and other facilities to support the Laboratory’s mission. The use and character of developed land comprising Fermilab is consistent with its primary mission as a high-energy research facility. While fulfilling this mission, Fermilab has maintained a balance with the environment by preserving and restoring natural habitats.

3.1.1.2 Environmental Impacts

Proposed Action

Construction

The Proposed Action would be constructed in an area bounded by Fermilab’s existing Main Injector (MI) to the south, Kirk Road to the west, Giese Road to the north, and Kautz Road to the east. This area has not been used in the past for recreation or ecological research or restoration. Construction of the Proposed Action, including soil borrow pits, temporary construction laydown areas, and soil stockpiling areas, would have very low adverse impacts on existing or future land uses at Fermilab in that LBNF/DUNE is entirely consistent with the mission of the facility to conduct state-of-the-art high-energy physics research. Construction of the Proposed Action would elevate Fermilab’s role as the National Laboratory for neutrino physics research.

Construction activities would have no or very low direct or indirect impacts on off-site land use. Construction would not change the character, use or intensity of land in the surrounding community. The construction workforce would commute to the site from surrounding areas and therefore, would not stimulate the need for new permanent housing, schools, medical facilities, mass transportation, or other community services that could otherwise influence land use. The Proposed Action would be visible intermittently from adjacent recreational areas, specifically the portion of the Illinois Prairie Path located approximately 2,500 feet to the southwest. Many facilities on the Fermilab site are presently visible from off-site and the Proposed Action would not substantially change views from surrounding land uses. Construction, which would be intermittently visible, would have very low temporary effects on off-site recreational users hiking and biking on the adjacent trail.

Operations

Operation of the Proposed Action would commit an additional area of Fermilab property to this activity. However, operations would not affect lands used for recreation, natural resource preservation and research, or NERP activities. Therefore, operation of the Proposed Action would have no on-site land use impacts.

Operation of the Proposed Action would have no or very low direct or indirect impacts on off-site land use. Operation would not change the character, use or intensity of land in the surrounding community. The operations workforce would be derived from existing staff and therefore would not stimulate the need for new permanent housing, schools, medical facilities, mass transportation, or other community services that could otherwise influence land use in the immediate area.

Recreational users of the Illinois Prairie Path, located approximately 2,500 feet to the southwest, would have views of the Proposed Action's embankment. However, these recreational users have views of existing Fermilab facilities, including Wilson Hall. Furthermore, the embankment would be vegetated per Standard Environmental Protection Measures (SEPM) and would not be in the direct view of recreational users. Trail users would not be exposed to the low operational noise levels associated with the Proposed Action. Therefore, adverse effects of Proposed Action operations on off-site recreational use of the Illinois Prairie Path would be very low. Operations would have very low impacts on adjacent, off-site, residential land uses along Kirk Road.

No Action

The No Action Alternative would have no adverse effects on on-site or off-site land uses, including adjacent residential and recreational land uses. Fermilab's high-energy physics mission would be unchanged, the current experiments would continue to run, and the lab would continue to pursue ecological research and natural resources restoration.

3.1.2 SURF

3.1.2.1 Affected Environment

The proposed construction area was mined and supported regional mining activity during the period 1876 to 2002. The current affected land use supports SURF activities or Homestake reclamation. The Homestake Mine was first developed in the Open Cut area as a surface mine. The Cities of Lead and Terraville developed at this time near the Open Cut to support mining and miners. The ore body plunged underground to the south, and as a result, mining activities and land use moved south with the construction of the Ellison Shaft and support buildings *circa* 1902 and then the Ross and Yates Shafts and their support structures *circa* 1939, and finally the expansion of the Open Cut in 1982. Numerous prospect pits and excavations were created to the south of the Ross Complex in an effort to find re-emergent gold-bearing rock.

The City of Lead continued to grow and develop with the expansion of the mine. Utilities such as water, electricity, and sewer were installed and operated by Homestake for use by the mine and the city. Hospitals, recreational facilities, libraries, and entertainment were provided by Homestake to help Lead become a cultural center. Lead experienced major infrastructure changes such as removal and construction of roads, utilities and residences to accommodate the shift to underground mining and the southern migration of the mine support facilities.

In 2002, the mine closed. Utilities, facilities, and land ownership and management were transferred to the City of Lead. Homestake sold tracts of land for residential and commercial use. However, many mining features remain and are used by the city to generate tourism revenue. The Open Cut is one such tourist attraction and is zoned 'Historical Interpretation for Geology and Mining.' The Yates hoist building, yard and shops continue to host thousands of visitors each year. SURF also draws over a thousand visitors annually for Neutrino Day. Finally, hundreds of scientists come to the site to conduct underground experiments.

Land use in the affected area supports current activities at SURF and Homestake. The Ross Complex buildings and land supports activities to rehabilitate the Ross Shaft. The Oro Hondo shaft is the main ventilation shaft exhausting underground air. The Oro Hondo substation is the major power distribution center for SURF. The Grizzly Gulch Dam, located one mile south, is a large tailing water dam maintained by Homestake that retains over 150 acre feet of water. A shallow buried pipeline delivers water from this dam to the SURF wastewater treatment plant (WWTP) for treatment.

The Ross Boiler building and stack were constructed in 1934 to convert water to steam to heat the mine site buildings and the Ross Shaft in the winter. The boiler was decommissioned in 2002 in a shift to electric and gas heat and is no longer in use. The land under and near the Ross Boiler is zoned 'Light Industrial.'

The land south of the Ross Complex is owned by SURF and is zoned Industrial. This land was previously disturbed *circa* 1933-34 during the construction of the Ross Shaft and Yard. During construction of the Ross Complex buildings, the Ross Yard was graded and material was pushed over the hillside, creating a slope of mixed soil and talus. McGas, a local propane distributor, and the Lawrence County Highway Department own land at the bottom of the slope on Kirk Road and use it as a small propane transfer station and truck turning area.

The Mickelson Trail is the major recreational feature in the area and is crossed by Kirk Road in two different locations. This trail is part of the former Chicago, Burlington and Quincy Railroad line that served both Lead and Deadwood. The multi-use trail is managed by South Dakota Game, Fish, and Parks and seasonally hosts hikers, joggers, bikers, and snowmobilers. The trail parallels Whitewood Creek and Kirk Road.

3.1.2.2 Environmental Impacts

Proposed Action

Construction

Construction of the Proposed Action would include demolition of the Ross Boiler to allow construction of a new cryogenic support building to convert liquid argon (LAr) to gaseous argon for transport underground. The land use would not require a zoning change. The boiler and stack would be replaced by a single building, 2 LAr storage tanks, and load-out area.

The conveyor that would transport excavated rock from the crusher to Kirk Road for trucking would be constructed on the south slope of the Ross Yard and would be visible from Kirk Road. Approximately 4 acres of this steep hillside would be cut and graded to accommodate the conveyor and truck load-out area. No fill would be required. The proposed truck load-out area and the conveyor corridor is zoned Industrial and would not change under the Proposed Action. However, the Proposed Action would require a building permit from the City of Lead. In addition, SURF would obtain easements from the Lawrence County Highway Department and McGas for use of this land adjacent to Kirk Road.

The excavated rock would be transported to the Gilt Edge Superfund site or the Open Cut. Under the Gilt Edge option, only transportation was considered since the Proposed action does not consider further excavated rock disposition at that site. This transportation would have no or very little impact on land use. Under the Open Cut rock transportation/placement option, the rail or pipe conveyor corridor would be the same as that formerly used by Homestake to transport ore from the underground to the Homestake mill. The former pipe conveyor has been removed and the corridor reclaimed. Although it crosses Lead's downtown, the land is currently unused. The corridor is zoned Industrial and owned by Homestake. SURF would secure the permission and right-of-way from Homestake needed to use the conveyor route for the rail or pipe conveyor system. If the Open Cut option were chosen, an additional method of transport would be using trucks to move excavated rock to the Open Cut.

There would be no or very low impact on land use associated with the Open Cut. The Open Cut and other lands adjacent to the Sanford Laboratory are owned by Homestake Mining Company of California (Homestake), which is in turn owned by the Barrick Gold Company. This land is currently appropriately zoned for rock conveyance and placement. Further, the land has previously been disturbed and used to move rock from the Open Cut to the Homestake Mill. Open Cut rock placement would have low impacts on recreation as installation of the rail or pipe conveyor would be near the City of Lead's tennis courts and Rod and Gun club. These facilities would remain and SEPMs implemented to reduce impacts on users. Placement of rock in the Open Cut would require a revision of Homestake's Mining Permit 332 (to place excavated rock in the Open Cut or East Waste Rock Facility) as well as an agreement between SURF and Homestake to manage the rock on Homestake property and transfer of ownership/right-of-way for the conveyor corridor to SURF.

Operations

There would be no change in land use associated with the operations. The operation would occur primarily underground, with periodic deliveries of LAr and liquid nitrogen (LN) to the surface buildings. LBNF/DUNE would be consistent with existing SURF land uses for physics experiments.

Alternative A

Construction

Alternative A would not require land use changes on SURF property or at the Gilt Edge Superfund site, if rock were transported to the surface. There would be minimal surface staging and warehousing of equipment for assembly underground. This may require the use of existing surface facilities or some minor rehabilitation of existing site surface buildings similar to that used during construction of the Large Underground Xenon (LUX) Surface Laboratory. However, no new surface structures would be constructed for these experiments.

Operation

Alternative A operational impacts would be similar to the Proposed Action. There would be no change in land use associated with the operations. The operation would occur primarily underground, with periodic deliveries of LAr and liquid nitrogen (LN) to the surface buildings. LBNF/DUNE would be consistent with existing SURF land uses for physics experiments.

No Action

The No Action Alternative would not affect current land use or recreation. SURF would continue to operate as an underground physics research facility. Recreational resources, such as the Mickelson Trail, would be unaffected.

3.2 BIOLOGICAL RESOURCES

This section addresses potential impacts on biological resources including regulated wetlands and aquatic habitat, terrestrial vegetation, protected species, wildlife, and fisheries. The affected environment includes areas directly affected by construction and operation of the Proposed Action, including excavation and fill areas as well as construction staging areas, soil borrow areas, ingress and egress routes, and potential indirect effects on adjacent habitat and downstream areas.

3.2.1 Fermilab

3.2.1.1 Affected Environment

Fermilab occupies lands that were historically farmed. Approximately 2,200 acres are currently licensed for crop production, and approximately 1,000 acres have been restored with native prairie vegetation. Other biological communities at Fermilab include forested uplands and wetlands, oak savannas, prairie remnants, and non-native grasslands. Fermilab supports a variety of wildlife including common bird and mammal species characteristic of open fields, forests, and forest-edge communities. Many bird species use the site during spring and fall migration. The following sections describe the existing biological resources in the area.

Wetlands and Aquatic Habitats

Indian Creek and adjacent wetlands occur in the area. A wetland delineation was conducted in 2010 (Planning Resources, Inc. 2010) to support planning, including areas between the existing MI cooling ponds and Giese Road. Wetlands in this area include persistent emergent palustrine wetlands, palustrine forested wetlands along the floodplain of Indian Creek, and palustrine scrub-shrub wetlands. Emergent wetlands were dominated mostly by reed canary grass (*Phalaris arundinacea*) and cattails (*Typha* sp.). Other dominant emergent species identified included black bent (*Agrostis gigantea*), Dudley's rush (*Juncus dudleyi*), and bald spikerush (*Eleocharis erythropoda*). Forested wetlands were mostly flatwood wetland intermingled with scrub shrub and emergent wetlands. Typical dominant forested wetland species include green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*) and swamp white oak (*Quercus bicolor*). Scrub shrub wetlands were dominated mostly by gray dogwood (*Cornus racemosa*). The location and quality of some of the wetlands were affected by previous disturbance, including construction of the MI and cooling ponds, access roads, and an electric transmission line. The 2010 wetland delineation identified more than 12 acres of potentially jurisdictional waters of the U.S., including wetlands and approximately 1,700 linear feet of Indian Creek.

Because several years passed and regulatory guidance had been updated since the 2010 survey, Fermilab conducted a field confirmation of the previously delineated wetland boundaries in July 2013. Fermilab expanded the scope to include approximately 41 acres within the circular area or "infield" formed by the MI, including an additional reach of Indian Creek and an unnamed tributary. This area consisted of a cultivated field, an old field meadow, and a restored prairie. Two of the three fields had no wetlands and consisted of a cornfield and restored prairie. Wetlands were identified along the floodplain of Indian Creek and its unnamed tributary, which included persistent emergent palustrine wetlands. Typical dominant species in the floodplain wetlands were reed canary grass, rice cut grass (*Leersia oryzoides*), black willow (*Salix nigra*), and soft stem bulrush (*Scheonoplectus tabernaemontani*). One emergent wetland was identified within the old field meadow. Dominant species included reed canary grass and unidentified sedge (*Carex* sp.). The 2013 boundary review also confirmed that hydrologic and vegetation conditions had not changed substantially from conditions documented in 2010.

The 2013 wetland delineation characterized an additional approximate 0.5 acres of wetland and identified an additional 1,384 linear feet of Indian Creek and one unnamed tributary within the area. A total of approximately 12.6 acres of wetlands and 3,084 linear feet of Indian Creek and unnamed tributaries were identified within the approximate 180-acre survey area. Fermilab and the U.S. Army Corps of Engineers (USACE) conducted pre-application meetings in 2013 and 2014 to review mapping of the on-site wetlands and waters.

The relative quality of area wetlands was evaluated by vegetative analysis using a calculated Floristic Quality Index (FQI) and a mean-C value. Wetlands with an FQI greater than or equal to 20 are considered a High Quality Aquatic Resource (HQAR). From the 2010 survey, approximately 1 acre of wetland was below the threshold for a HQAR; however; approximately 12 (11.79) acres were above the threshold and would likely be considered a HQAR by the USACE and Kane County. None of the additional wetlands identified within the 2013 survey obtained an FQI score commensurate with a HQAR. Additionally, the Kane County Advanced Identification (ADID) Study (Northeast Illinois Planning Commission 2004) identified and mapped wetland resources within the survey area: four potential wetland areas and Indian Creek would be considered ADID resources (

Figure 3.2-1). The Kane County Advanced Identification of Aquatic Resources (or ADID) study was a cooperative effort between federal, state, and local agencies to inventory, evaluate, and map high quality wetland and stream resources in the county. Although not a regulatory document, this information is intended to be used by federal, state and local governments to aid in zoning, permitting and land acquisition decisions. In addition the study can provide information to agencies, landowners, and private citizens interested in restoration or acquisition of aquatic sites.

Indian Creek is a perennial stream and a tributary to the Fox River. It currently flows through a large culvert above the MI tunnel. The creek ranges from approximately 5 to 12 feet wide and has a well-defined bed and bank. Currently, Fermilab discharges stormwater and cooling water to Indian Creek at 4 discharge points. The discharges comply with Fermilab's National Pollutant Discharge Elimination System (NPDES) permit.

Vegetation

The vegetation in the proposed construction area consists of a matrix of upland, wetland, and riparian habitats. Habitats include upland fields, reconstructed prairie, marsh, open water, and woodland. Upland fields are dominated by grasses such as tall fescue (*Festuca elatior*), quackgrass (*Agropyron repens*), Kentucky bluegrass (*Poa pratensis*), and reed canarygrass (*Phalaris arundinacea*). Grass fields are typically mowed to a summer height of approximately 6 inches.

Mesic woodlands in the area are dominated by swamp white oak (*Quercus bicolor*), bur oak (*Quercus macrocarpa*), American linden (*Tilia americana*), ash (*Fraxinus pennsylvanica*), and American elm (*Ulmus americana*). In wooded areas with sufficient sunlight, shrub species included bush honeysuckle (*Lonicera spp*), gray dogwood (*Cornus racemosa*), and common buckthorn (*Rhamnus cathartica*). Groundcover species included black snakeroot (*Sanicula gregaria*), enchanter's nightshade (*Cricaea luteiana canadensis*), woodland knotweed (*Polygonum virginianum*), hairy sweet cicely (*Osmorhiza claytonia*), and lopseed (*Phryma leptostachya*).

The U.S. Fish and Wildlife (USFWS) species list for Kane County identifies the Eastern prairie fringed orchid (*Plantanthera leucophaea*) as a federally listed threatened plant species with potential to occur in the area. This species occurs on silt loam or sand prairies and requires full sun for optimal growth and reproduction. Its preferred habitat includes wet prairies and bogs. It occurs within palustrine areas, such as freshwater wetlands, and can even occur in disturbed habitats, such as wet roadside ditches. The area provides marginal habitat; however, during the 2010 and 2013 wetland delineation field exercises, this species was not observed. Consultation under Section 7 of the Endangered Species Act will be conducted by FWS as part of the multi-agency review of the wetland permit application for the project being conducted by the U.S. Army Corps of Engineers USACE). As part of that process, three intensive searches for the orchid will be conducted on non-consecutive days in 2015 during the prime blooming period (June 28 through July 11). As part of the NEPA process for LBNF/DUNE, Fermilab has communicated with the FWS on the consultation process which will proceed in parallel with USACE wetlands permitting process (**Appendix B-1**).

Wildlife

The Fermilab area provides suitable habitat for birds and mammals. Common species expected to occur include avian species such as mallard (*Anas platyrhynchos*), American goldfinch (*Spinus tristis*), Northern flicker (*Colaptes auratus*), red-bellied woodpecker (*Melanerpes carolinus*), and wild turkey (*Meleagris gallopavo*) and terrestrial species such as white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), and striped skunk (*Mephitis mephitis*). Other representative bird species observed during the 2010 survey included Eastern wood pewee (*Contopus virens*), red winged blackbird (*Agelaius phoeniceus*), yellow-billed cuckoo (*Coccyzus americanus*), great blue heron (*Ardea herodias*), wood thrush (*Hylocichla mustelina*), red-eyed vireo (*Vireo olivaceus*), red-tailed hawk (*Buteo jamaicensis*), and downy woodpecker (*Picoides pubescens*).

Forested areas may provide summer roosting habitat for Indiana bat (*Myotis sodalis*), a federally endangered species, and northern long-eared bat (*Myotis septentrionalis*). In addition, the Illinois Natural Heritage Database identifies three special-status species with potential to occur, including:

1. **Black-crowned night heron** (*Nycticorax nycticorax*): a state-listed endangered species that occurs in Illinois from early April through late October. This species is a fairly common migrant but an uncommon summer resident. Nesting habitat for this species may occur where woody vegetation and trees overhang the wetlands and Indian Creek. This species would be expected to occur during the typical migratory period of early April through late October.
2. **Osprey** (*Pandion haliaetus*): an Illinois state-listed endangered species. This species nests and forages near large, open bodies of water. Nests are made from sticks and typically occur in larger trees or platforms or telephone poles with good vantage points for catching prey. Osprey show strong nest fidelity and may return to the same nest each year adding new material to existing nests. In Illinois, osprey nest between April and June. A pair of osprey and one chick were observed during the 2010 wetland delineation report field surveys (Planning Resources, Inc. 2010). The nest was constructed on a telephone pole located near South Indian Creek Road, approximately 1000 feet south of the Proposed Action.

Absolute Scale - 1:7,200
1 inch = 600 feet

Legend

ADID Wetland Type

- Natural Open Waters
- Wetland
- Artificial Pond
- High Habitat Value
- High Functional Value
- ADID Stream

0 300 600 1,200 Feet

N

LBNF/DUNE EA

FIGURE 3.2-1

Advanced Identification of Aquatic Resources Kane County, Illinois

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3. **Upland sandpiper** (*Bartramia longicauda*): an Illinois stated-listed endangered species. This species prefers open grassland habitats. Breeding for this species occurs in May, and nests are grass-lined depressions in the ground. Thus, the preferred habitat for this species does not occur at the site of the Proposed Action. However, the Upland sandpiper nests in the eastern portion of Fermilab, over a mile to the east of the Proposed Action.

Consultation with the IDNR in 2014 on these state listed species will also occur as part of the USACE wetland permit application process.

Fisheries

Indian Creek may provide habitat for small fish such as mottled sculpin (*Cottus bairdi*) and rainbow darter (*Etheostoma caeruleum).* Indian Creek is mapped as a High Habitat Value area by Kane County, and therefore would be expected to provide suitable habitat for native freshwater fish and stream invertebrates. Within the infield of the MI, Indian Creek is not incised and has developed a two-stage channel and abutting floodplain wetland (Section 3.5). Stream reaches in agricultural areas are channelized with steep banks that limit floodplain access. In areas with an intact woodland buffer, the channel is wider with gradually sloped banks. The dense canopy in these areas precludes herbaceous establishment, and some streambank incision has occurred.

3.2.1.2 Environmental Impacts

Proposed Action

Construction

<u>Wetlands and Aquatic Habitat</u>

This section of the EA documents the wetland assessment required by DOE (10 CFR 1022) and Executive Order (EO) 11990, Protection of Wetlands (Floodplain evaluation requirements are addressed in Section 3.5). The Proposed Action would directly affect wetlands and Indian Creek. Direct effects would result from placement of fill during construction of the embankment and beamline facilities. Construction would have permanent impacts on approximately 5.0 acres of wetland as well as Indian Creek. **Figure 3.2-2** provides an overlay of the proposed facilities, construction footprint, and wetlands, and quantifies wetland and stream impacts. The construction footprint accounts for construction access, staging areas, laydown areas, fill areas (the embankment), excavation areas (e.g., for the underground Absorber Hall and Near Neutrino Detector [NND]), and the soil borrow pit. The borrow pit would fill with water and become open water habitat.

Indian Creek would be intercepted north of Main Injector Road and diverted into a dual 12 foot by 4 foot box culvert that would convey the creek through the embankment and discharge to the existing Indian Creek channel south of the MI. This structure would not result in any interruption of base flow to Indian Creek upstream or downstream of the MI or Indian Creek Road and would be designed to pass the 100-year flood with no increase in upstream or downstream flood stage. An alternate design would utilize a dual 7 foot by 4 foot box culvert, which would result in an additional 20 acre-feet of upstream flood storage by allowing the flood stage upstream of the MI to rise by 0.9 feet. The final culvert configuration would be determined during final design.

Impacts on waters of the U.S., including wetlands, would be minimized to the extent practicable. The Proposed Action would take advantage of existing access roads (e.g., Main Injector Road), and construction staging, laydown, and soil borrow pits would be located in uplands. However, because of the location of the MI (i.e., Fermilab's proton source), the counterclockwise flow of protons in the MI, and the location/orientation of the proposed detector in South Dakota, the beamline must be located in an area that currently supports wetlands.

The Proposed Action would require USACE authorization under Clean Water Act (CWA) Section 404. Fermilab and DOE have submitted an individual permit application to the USACE Chicago District and a plan to provide compensatory wetlands by purchasing wetland credits from a local wetland bank. Fermilab and DOE would coordinate with the USACE to ensure that no net loss of waters of the U.S. occurs as a result of the Proposed Action. Fermilab would also initiate consultation with the USFWS under the Endangered Species Act to address potential impacts on threatened and endangered (T&E) species as an adjunct to the wetland permit process.

The impacted wetlands described above do not include Cooling Pond F. The cooling ponds are industrial in nature (i.e., part of a designed treatment process) in that they are actively used and maintained for the sole purpose of managing and treating industrial cooling water, are lined with riprap, and are included in Fermilab's NPDES permit. As such, they are not USACE jurisdictional waters and are not subject to the CWA Section 404 permitting process. The regulatory status of the ponds will be confirmed during the permitting process. The area of Cooling Pond F would be replaced with a new cooling pond within the infield of the MI. This wetland would not qualify as USACE jurisdictional water or wetland either, for the reasons stated above. Alternatively, Fermilab would construct on-site cooling towers.

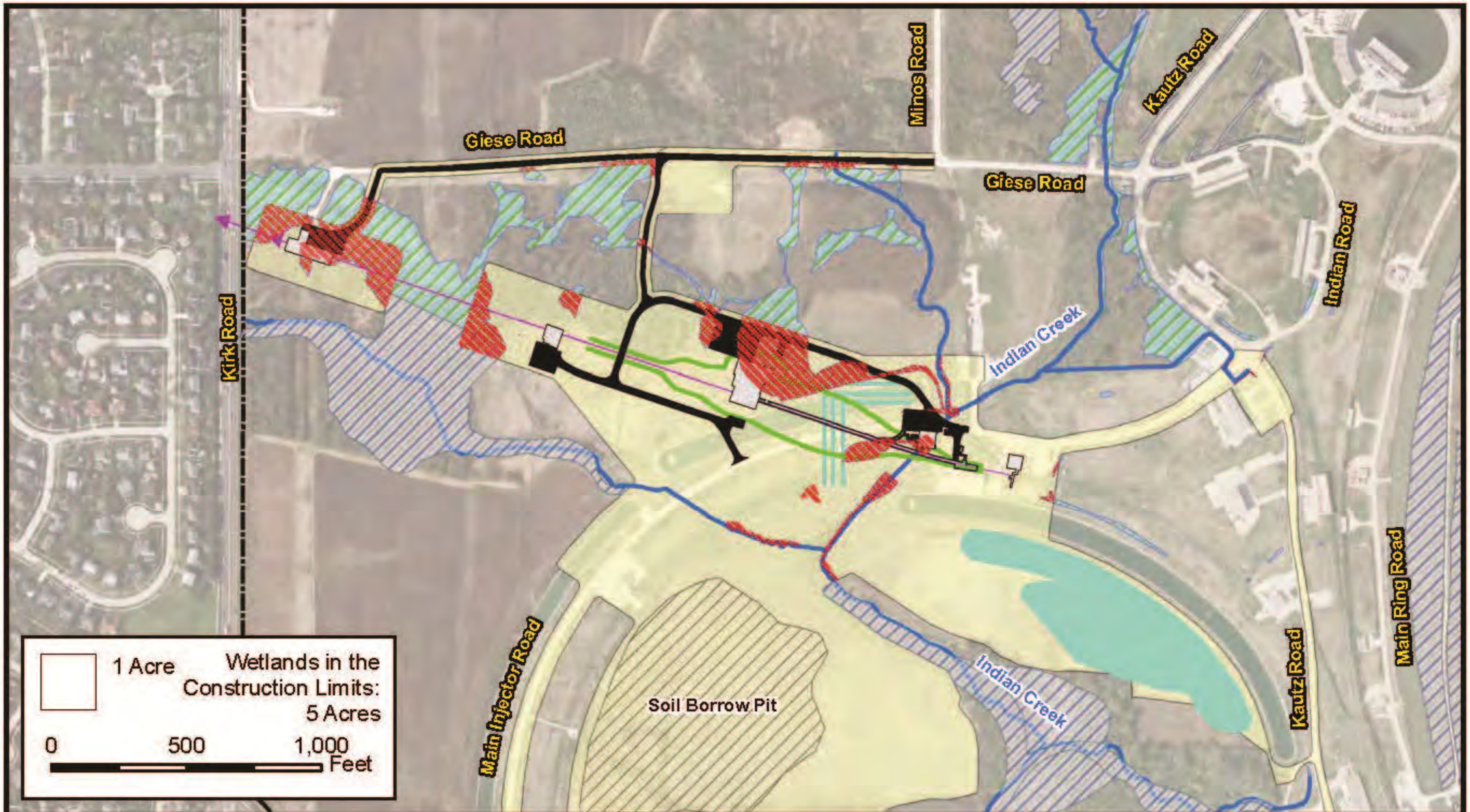
<u>Vegetation</u>

The Proposed Action would have both temporary and permanent effects on upland and wetland habitats at Fermilab. Areas temporarily disturbed during construction would be returned to pre-disturbance conditions to the extent feasible and would be reseeded with an appropriate native seed mix. Approximately 140 acres of upland habitat would be temporarily affected during construction. Because this area would include approximately 1.5 acres of woods, approximately 250 to 300 trees (greater than 3-inch diameter at breast height [DBH] at 15 feet on-center average) would be removed. Fermilab would minimize impacts on vegetation and trees using SEPMs, such as installing orange construction fencing around vegetated areas that would not be disturbed. Construction fencing would be placed at the drip-line of the tree canopy (minimum), but where practicable, the fencing would be placed a distance of two times the height of the tree from the base of the tree. No construction material staging would occur in these protected areas. High value trees in the 5 – 7 inch diameter range in the construction area would be evaluated for removal and transplantation to other sites at Fermilab.

<u>Wildlife</u>

Consultation under Section 7 of the ESA will be conducted as part of the wetland permit application review stated in Section 3.2.1 above. Habitat for common species would be impacted during construction. The area likely serves as a local pathway for movement of common wildlife species using the area for water or refuge. Construction could prevent common wildlife species from accessing areas to the south. However, this would be temporary because wildlife could use open areas to the east and west that are outside the construction boundary for local migration. For upland species, this would be a temporary impact, as vegetation would be restored as part of the SEPMs. To minimize impacts on aquatic species, Fermilab would re-establish adequate stream hydrology and vegetative cover as soon as feasible after construction.

Absolute Scale - 1:7,200
1 inch = 600 feet



Legend

Wetland Data

Data Source

- Delineated Data
- Fermilab Data
- Affected Wetlands
- Streams
- Embankment
- New Culvert
- Buildings
- Fermilab Boundary
- Roads and Parking
- Beam (Below Ground)
- Construction Limits
- Soil Borrow Pit
- Replacement Cooling Pond

N

LBNF/DUNE EA

FIGURE 3.2-2

Proposed Action Wetland Impacts - Fermilab

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Construction noise and the increase in human activity would likely deter common wildlife species from entering the construction boundary. Construction materials would be properly stored, and food and trash would be removed at the end of each workday to avoid attracting wildlife to the site.

Suitable foraging and breeding habitat for birds and raptors exists in the vicinity of the Proposed Action. Removal of vegetation, including scrub vegetation, wetland vegetation, and trees, would remove foraging and breeding habitat for common bird species. To ensure compliance with the Migratory Bird Treaty Act (MBTA), Fermilab would schedule removal of vegetation outside the typical nesting season (April through August) to the extent practicable. If nesting areas occur within approximately 250 feet of active construction, buffers would be placed until young have fledged. If raptor nests were present, buffers would be established at approximately 500 feet where feasible. Active nests would be monitored during construction to ensure that destruction of the site would be avoided.

Tree removal could affect summer roosting habitat for Indiana bat (*Myotis sodalis*), a federally endangered species, and northern long-eared bat (*Myotis septentrionalis*), if present. Accordingly, Fermilab and DOE will consult with USFWS. Construction would require tree removal and would result in a temporary increase in noise levels. Fermilab's SEPMs would minimize impacts on bats to the extent practicable by conducting the initial site preparation, including clearing of trees, outside of seasonal periods of bat activity. Prior to construction, a biologist would conduct an assessment to determine the presence of roosting bats in surrounding forested areas and would implement protective measures including establishing a buffer zone, and working with the contractor to minimize construction noise.

Fermilab and DOE would also consult with the Illinois Department of Natural Resources (IDNR) regarding state requirements for protected wildlife and plant species (**Appendix B-1**).

<u>Fisheries and Macroinvertebrates</u>

The Proposed Action would not affect any state or federally protected fish species or their habitats. Common fish species could be affected by construction of the Proposed Action and construction of the box culvert under the embankment. Fermilab would minimize these impacts by diverting flow around the culvert construction area. The Proposed Action would not affect any state or federally protected invertebrate species. Common invertebrate species could be affected during construction of the culvert in Indian Creek. Existing substrates are primarily unconsolidated sediments typical of a low gradient stream and are not a high quality substrate for macroinvertebrates. However, new sediments would be deposited from upstream areas and similarly, benthic macroinvertebrates from upstream and downstream areas would recolonize disturbed areas through drift or as part of their mobile adult life stages. Therefore, stream modification would have temporary low impacts on stream invertebrate species.

Water collected from dewatering excavations would be discharged to the Indian Creek watershed. This discharge would require a modification of Fermilab's existing NPDES permit. Impacts on surface water would be temporary and localized and would not result in long-term effects on fish or macroinvertebrates.

Operations

<u>Wetlands and Aquatic Habitat</u>

Daily operation of the Proposed Action would occur within the footprint of construction and would have very low effects on wetlands and aquatic habitat. Operations would not require additional excavation, wetland fill, or vegetation removal. Stormwater generated by additional impervious surfaces and any groundwater pumped from beneath the Absorber Hall and NND would be directed to the adjacent cooling pond in compliance with Fermilab's site-wide Storm Water Pollution Prevention Plan (SWPPP). The potential for impacts of chemical spills would be also be minimized by SEPMs, including Fermilab's existing Spill Prevention, Control, and Countermeasure (SPCC) Plan (Fermilab Environment, Safety, and Health [ES&H] Manual, chapter 8031). Therefore, impacts on these resources from operations would be low.

Vegetation

LBNF/DUNE operational impacts on grasslands and other vegetation would be low. Long-term maintenance and use of adjacent areas would continue, including mowing grassy areas and removing invasive species. Fermilab would also implement SEPMs, such as existing land use and maintenance programs to maintain vegetative cover on the embankment to minimize erosion.

Wildlife

Operation of the Proposed Action would not have direct impacts on wildlife. Operations would not affect wildlife movement pathways because most operations would occur within the footprint of the new facilities, primarily inside the new experimental facilities. Long-term maintenance and use of adjacent areas would continue according to existing land use and maintenance programs, including mowing and agriculture. Fermilab would maintain vegetative cover on the embankment to provide habitat continuity.

Operation of the beamline would result in prompt radiation and irradiation of beamline components. Radiation that is not contained by the shielding (i.e., during an unforeseen accident) could result in increased radiological exposure of site wildlife. Burrowing mammals (such as ground squirrels) or ground-nesting birds could receive the highest exposure should radiation escape into surrounding soils. Aquatic organisms in Indian Creek could similarly be exposed if an unforeseen and uncontrolled radiation release were to occur. Fermilab would have site safety and operational procedures in place to ensure that these unforeseen events would be avoided and releases, should they occur, would be managed promptly and effectively to avoid adverse biological impacts.

To minimize radiological exposure of ecological receptors, all beamline facilities would be shielded with soil or combinations of soil, steel and/or concrete. The Target Hall would have thick steel and concrete shielding. Similarly, the Decay Pipe would be shielded with concrete and a groundwater barrier to minimize concentrations of radionuclides in the surrounding soils and groundwater. The remaining radiation that could emerge above the surface presents a very small potential for radiation dose (Fermilab 2012c).

Fermilab has collected on-site data showing that radiation exposure of on-site biota is below DOE standards, and that the shielding used to minimize radiation doses of biological receptors is effective for existing physics experiments at Fermilab. Fermilab screened operations for effects on aquatic and terrestrial biota, following DOE's Technical Guidance (DOE-STD-1153-2002) and companion tool, the RAD-BCG calculator. In compliance with DOE Orders, Fermilab conducts extensive environmental monitoring of surface water as part of SEPMs, including for tritium concentrations in Indian Creek at the NPDES outfalls and the site boundary. Surface water concentrations in Indian Creek and site discharges are below DOE surface water standards. Fermilab has also conducted soil and groundwater monitoring showing that exposure to beamline radiation from existing Fermilab experiments does not pose a substantial risk to wildlife populations and that existing shielding and groundwater management programs contain effective design measures and SEPMs that maintain exposure at below DOE limits (DOE Order 458.1, Chg 2) (DOE 2002b). Therefore, exposure of plants and animals from soil or tritium in groundwater would be low.

Fisheries and Macroinvertebrates

Operation of the Proposed Action would have very low effects on fish and stream macroinvertebrates. Stormwater runoff would be managed through SEPMs, including Fermilab's existing site-wide SWPPP and existing wildlife and water quality monitoring programs, and compliance with water quality standards that support beneficial uses such as fish habitat.

No Action

Under the No Action Alternative, there would not be construction or operation of LBNF/DUNE facilities at Fermilab. Thus, no wetland or stream excavation or fill would be required, and the beamline would not be operated. Therefore, the No Action Alternative would have no additional incremental impacts on wetlands, vegetation, wildlife, or fisheries beyond the baseline of existing facility operations. Fermilab would continue to operate existing experimental facilities and manage its operations in accordance with DOE, state and Federal requirements.

3.2.2 SURF

3.2.2.1 Affected Environment

The Far Site area consists of urban, industrial, and forested areas. The forested areas typically occur on steep hillsides and are intermixed with talus and overburden left from mining and road construction activities. The urban and industrial areas, later referred to as modified/disturbed areas, occur on a flattened or moderate-sloped topography and are a mix of structures, roads, and disturbed, reclaimed, and re-purposed areas.

Wetlands and Aquatic Habitats

One 0.21 acre wetland was located on Homestake-owned land in a mined out area adjacent to the Open Cut. This palustrine emergent wetland (USFWS 1979) is the result of mining and the formation of a pit. Water collected in this pit drains underground and is ultimately treated by the existing Homestake waste water treatment plant (WWTP). A small area of vegetation has developed incidental to water collection and minor soil build-up and consists of bulrush (*Schoenoplectus tabernaemontani*), reed canary grass (*Phalaris arundinacea*), and broad leaf cattail (*Typha latifolia*).

Vegetation

The area is predominantly disturbed land that has been reclaimed. The disturbance has typically occurred multiple times and is the result of activity associated with the development of the 137 year-old Homestake mine. The land cover throughout the area is either forested or modified/disturbed. Within the forested areas, stands of ponderosa pine (*Pinus ponderosa)* and quaking aspen (*Populus tremuloides)* are present. Understory observed consists of smooth brome grass (*Bromus inermis)*, western thimble-berry and common tansy (*Tanacetum vulgare*). The modified/disturbed area hosts roads, structures, and open areas. The open areas are often re-vegetated with smooth brome, or are dominated by common tansy, a noxious plant.

Wildlife

Wildlife in the SURF area includes those known to occur in the northern Black Hills such as mule deer (*Odocoileus hemionus*), coyote (*Canis latrans*), jackrabbit (*Lepus townsendii*), red-tailed hawk (*Buteo jamaicensis*), mourning dove (*Zenaida macroura*), and a variety of songbirds, such as horned lark (*Eremophila alpestris*).

The USFWS South Dakota Ecological Services website identifies three special status birds and one special status bat with the potential to occur within Lawrence County. The whooping crane (*Grus americana*) is a federally endangered species with potential to occur within Lawrence County. There is only one self-sustaining wild population of the whooping crane in North America (USFWS 2014). The population nests in and near Wood Buffalo National Park (Alberta, Canada) and winters in coastal marshes in Texas. Whooping cranes utilize wetlands as a stopover habitat to feed and rest during their migrations. Lawrence County is within the migration corridor. However, the area near SURF does not contain the whooping crane's preferred habitat of marshes and open water. Further, the area is highly disturbed and no whooping cranes were observed during field reconnaissance.

The Red Knot (*Calidris canutus rufa*) is proposed as threatened and the northern long-eared bat (*Myotis septentrionalis*) is proposed as endangered by USFWS. (USFWS 2013). The Red Knot is a shorebird that migrates from the southern tip of South America to the Arctic and may utilize areas in South Dakota as stopover habitat during migration. However, there is no suitable habitat for Red Knot in the SURF area. The northern long-eared bat is abundant throughout the Black Hills (Tigner and Stukel, 2003). Summer roosting habitat occurs in old growth forests and may occur in forested areas around SURF. Winter hibernacula typically consist of caves or inactive mines. However, winter hibernacula were not identified during field reconnaissance. Sprague's pipit (*Anthus spragueii*) is a candidate species with potential to occur in Lawrence County. This species is endemic to North American grasslands and its migratory corridor includes South Dakota. There is no suitable nesting or breeding habitat for this species within the SURF area.

The Northern Black Hills provides habitat for several species of migratory birds. Species with the potential to occur within the proposed construction boundary include common species, such as red-tailed hawk (*Buteo jamaicensis*), killdeer (*Charadrius vocifero*), and mourning dove (*Zenaida macroura*). The SURF area contains limited habitat for migratory birds.

Although the bald eagle (*Haliaeetus leucocephalus*) and golden eagle (*Aquila chrysaetos*) have been delisted by USFWS, both species are protected under the Bald and Golden Eagle Protection Act and are present in the Black Hills. These species often use ponderosa pine forests near tall ridges and streams for nesting and roosting. These habitats are found in the area, and specifically in the forested area east of the Open Cut, and the forested area near Kirk Road that overlooks Whitewood Creek. No eagles or eagle-nests were observed during field reconnaissance.

Fisheries

Whitewood Creek parallels Kirk Road through the area. The portion of Whitewood Creek along Kirk Road is classified as a cold-water fishery (South Dakota Department of Environmental and Natural Resources [SDDENR] 2012). Whitewood Creek contains populations of common species, such as brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), long nose dace (*Rhinichthys cataractae*), and mountain sucker (*Catostomus platyrhynchus*) (GEI 2013).

3.2.2.2 Environmental Impacts

Proposed Action

Construction

The surface impacts for the Proposed Action include the replacement of the Ross boiler building with the Cryogen Support Building, and transport of the rock from SURF to the Gilt Edge Superfund site or the Open Cut.

Wetlands and Aquatic Habitat

The wetland adjacent to the Open Cut would not be disturbed by the construction of the pipe conveyor or the rail methods. Stormwater from the construction corridor would flow north and west away from the wetland. The construction stormwater permit and SWPPP would specify best management practices (BMP) (e.g., silt fences, detention ponds) to control erosion and protect aquatic habitat. Other SEPMs would include stabilization of disturbed or un-reclaimed upland areas on the hillside to minimize erosion.

Vegetation

Most of the construction would be completed underground. However, construction of facilities to move rock from the underground cavern to the placement site as well as the cryogenic support building would result in low impacts on vegetation. Construction of the cryogenic support building would temporarily affect 2 acres of vegetation that would be re-vegetated after construction.

Trucking the excavated rock to the Gilt Edge Superfund site or the Open Cut would disturb 4 acres of vegetation during conveyor and load-out station construction. The vegetation consists of ponderosa pine, thimble-berry, quaking aspen, and common tansy regrown in areas disturbed by mining.

Construction of the rail-conveyor to transport excavated rock to the Open Cut, if utilized, would disturb approximately 16 acres of vegetation. Six acres would be occupied by the conveyor and this impact would be permanent. Approximately 10 acres would be restored to pre-construction conditions after construction per SEPMs and the SWPPP.

Wildlife

The Proposed Action's surface construction is in and adjacent to Lead, a previously disturbed area. This location limits wildlife habitat and species to those that easily interface with human activity. There is no suitable habitat at or adjacent to SURF that would support whooping crane or Red Knot. Potential summer roosting habitat for the northern long-eared bat occurs in the area and migratory birds could potentially utilize the area for nesting. In order to minimize impacts, SURF would use SEPMs including clearing and grubbing outside of the migratory bird nesting and bat roosting season to the extent practicable. The loss of habitat for migratory birds would be relatively small as the proposed construction area is mostly disturbed and close to human activity and there is extensive bird habitat in the Northern Black Hills. Appropriate agencies would be notified if any Federal or state listed T&E species were encountered during construction.

Wildlife impacts on the trucking route to the Gilt Edge Superfund site would be similar to those in Lead as the established transportation routes would be located away from wildlife habitat.

No eagle nests or eagles were identified during the field reconnaissance including near the Open Cut. Although suitable habitat exists in the area, eagles have strong nest fidelity and typically return to the same nesting site year after year. Therefore, eagles would not likely nest at this location. If bald and golden eagle nests were found during construction within ½ mile, SURF would contact the USFWS and South Dakota Game Fish and Parks to determine the appropriate action. SURF's correspondence with the USFWS as informal consultation is provided in **Appendix B-2**.

Fisheries

The Proposed Action would not have a direct impact on fisheries. For construction at SURF, SEPMs including stormwater BMPs would be implemented to minimize impact on fisheries in Whitewood Creek.

Other elements of the Proposed Action in Lead, including placement of rock in the Open Cut, would not be constructed adjacent to waterways and would not affect fisheries.

Operation

Wetlands, Aquatic Habitat, Vegetation, Wildlife, and Fisheries

Operations would have no impact on wetlands, surface waters or associated biological communities since operational activities would be conducted primarily underground. Wildlife impacts would be very low as area wildlife are acclimated to human activity.

Alternative A

Construction and Operation

The construction and operation of Alternative A experiments would not impact biological resources as they would be constructed and operated underground. Any rock transported to either the Gilt Edge Superfund site or Open Cut would occur within previously disturbed areas. There is a possibility that excavated rock may remain underground and not require transport to either site. Thus, although the potential environmental impacts under Alternative A would be similar to the Proposed Action, they would be incrementally smaller.

No Action

Since there would be no construction or operation of the LBNF/DUNE detector and associated facilities, or Alternative A, there would be no impacts on biological resources under the No Action Alternative. Existing experiments at SURF would continue to operate and any impacts would be small.

3.3 CULTURAL RESOURCES

This section describes existing cultural, historical, and paleontological resources at Fermilab and SURF and the potential environmental impacts of the Proposed Action and alternatives, including excavation and grading. Cultural and historical resources include a broad range of objects, sites, buildings, structures and districts created or influenced by human use or occupation, or recognized in past or current cultural practice. Cultural and historical resources may include traditional resources, sacred sites, or traditional use areas that are important to a community's practices, beliefs, and cultural identity. Cultural resources may have archaeological, architectural, or traditional cultural significance. Architectural resources include standing buildings, bridges, dams, and other structures of historic significance.

DOE is coordinating its NEPA and National Historic Preservation Act (NHPA), Section 106 compliance for LBNF/DUNE. Section 106 is a Federal historic preservation process established by the NHPA (16 U.S. Code [U.S.C.] 470(f)). The NHPA also established the National Register of Historic Places (NRHP), the official list of the properties significant in terms of prehistory, history, architecture, or engineering. The NRHP is administered by the National Park Service, and properties listed in the NRHP may be privately or publicly owned. To meet the evaluation criteria for eligibility to the NRHP, a property should be 50 years of age or older, significant under one or more NRHP evaluation criteria (36 CFR Part 60.4), and retain historic integrity. Structures that are more recent may be eligible for listing in the NRHP if they are of exceptional importance or if they have the potential to gain significance in the future per special NRHP considerations. Properties may be of local, state, or Federal significance. Properties that are listed or eligible or that meet the NRHP evaluation criteria are historic properties according to the NHPA.

3.3.1 Fermilab

3.3.1.1 Affected Environment

Cultural Resources

The U.S. National Park Service (NPS) defines cultural resources as *"physical evidence or place of past human activity: site, object, landscape, structure; or a site, structure, landscape, object or natural feature of significance to a group of people traditionally associated with it".* The Fermilab Cultural Resource Management Plan (CRMP) (Fermilab 2015) summarizes the archaeological and architectural investigations completed at the facility from 1968 through 2014. It identifies and classifies known cultural and historical resources and outlines procedures for addressing cultural and historical resources that may be disturbed during construction. Fermilab cultural and historical records and reports are curated at Fermilab's Environment, Safety, and Health (ESH&Q) Section and at the Illinois State Museum.

Initial (Phase I) archaeological surveys have been completed for the entire Fermilab property (Fermilab 2015). Those surveys reported 108 prehistoric and historic archaeological sites. The majority of these sites (75) have been formally evaluated for their NRHP eligibility, and 5 sites are eligible to be included in the NRHP. Fermilab has also conducted surveys of all the historical standing buildings and structures on the property. In 1967, all these buildings and structures were evaluated for their potential historical significance. Subsequently, all but a few buildings and structures that were in relatively good condition were moved to the Fermilab Village for adaptive reuse, primarily as dormitories and laboratories.

Under the terms of the CRMP (Fermilab 2015), any undertaking on the facility that would result in ground disturbance must be re-evaluated for cultural and historical resources. This review is to be included in the NEPA assessment of all proposed undertakings. Reevaluation includes redefining the extent of the site and an eligibility evaluation based on current information and criteria. Section 106 requires that impacts on historic properties are avoided or that protective measures (e.g., documentation, recovery) are implemented. If any of the known resources within the area of the proposed undertaking are potentially eligible for the NRHP or have not been evaluated, Phase II evaluations must be completed.

The Area of Potential Effect (APE) for the current Proposed Action, or "undertaking" as defined by the National Historic Preservation Act, includes the embankment area, excavation areas, adjacent laydown areas and construction access areas, the soil borrow pit area and soil stockpiling areas. The APE does not include any sites that were listed on or determined eligible for the NRHP; however, two potentially eligible archaeological sites were present including the Tadpole Site and the Frog Site. In addition, three previous unevaluated farmstead locations were identified in adjacent areas, within the soil borrow pit area, as well as planned soil stockpiling areas.

Phase II resurvey and archaeological testing were completed for the two archaeological sites (Tolmie et al. 2013). The two sites were initially reported in 1968 and 1970. Several subsequent investigations in the area did not conclusively confirm the site locations. The Phase II investigations at the Tadpole Site began with systematic pedestrian survey. The Frog Site location was wooded and had poor surface visibility. Therefore, resurvey of the Frog Site began with shovel probe transects, with probes placed at 10 meter intervals. After resurvey at each site, approximately 200 square meters of surface sediments (soils) were removed to the base of the plow zone using a backhoe. Survey crews found both sites but reported an extremely low number of artifacts and no evidence of intact subsurface features and therefore concluded that neither site was eligible for the NRHP. The Illinois Historic Preservation Agency (IHPA; Haaker 2013) concurred and found that no historic properties would be affected by the proposed undertaking (LBNF/DUNE) (**Appendix C-1**).

The three farmstead locations were addressed as part of ongoing farmstead investigations being conducted by Midwest Archaeological Research Services, Inc. (MARS) (Bird 2013). All buildings at the sites have been razed or moved to other locations. MARS recently conducted a surface inventory and shovel testing at each location. Shovel tests at the Schwahn Farmstead site (11-K-1226) yielded a small number of artifacts and exhibited extensive disturbance. Investigations at the Williams Farmstead site (PS-71) yielded no artifacts or structural materials. Investigations at the John and Margaret Theis Farmstead site (11-Du-551) yielded foundations of one residence, a barn, and a silo, as well as an open stone well, which had subsequently been capped. Shovel probes at this site showed extensive disturbance. Therefore, Fermilab recommended to IHPA that these sites are not eligible for the NRHP and IHPA concurred that no historic properties would be affected (**Appendix C-1**).

Paleontological Resources

Pleistocene (defined as a period from approximately 2.6 million to 11,700 years ago) fossils have been recovered from sediments throughout Illinois. Taxa identified include Jefferson's ground sloth, American mastodon, woolly mammoth, stag-moose, Harlan's muskox, giant beaver, bison, and flat-headed peccary. Mastodon fossils are common in mire deposits of northeastern Illinois and stag-moose fossils are most frequently found in wetland deposits (Illinois Department of Natural Resources [IDNR] 2005). Mastodon fossils have been discovered in multiple locations near Fermilab, including a marsh lake near Batavia, a swamp near Aurora, a bog near Naperville, and on a farm near Wheaton (Anderson 1905). Recent mapping of surficial geology of the Batavia area indicates that the lake deposits of the Equality Formation are fossil-bearing (Curry 2001).

Unidentified invertebrate fossils were observed within cores retrieved from the Brandon Bridge Member of the Joliet Formation and the Kankakee Formation (GTC 2010). Fossils are recognized regionally within the Joliet and Kankakee Formations and most commonly produce invertebrate fossils such as tabulate coral (*Favosites* sp.) and orthocone nautiloids (Moshier and Greenberg 2011). These formations are exposed extensively in northeastern Illinois and southeastern Wisconsin. The Kankakee Formation also has produced halysitid and rugose corals, stromatoporoids, trilobites, and brachiopods including *Platymerella* sp. The upper Kankakee Formation commonly contains echinoderm (pelmatozoan) fossils. The Brandon Bridge Member of the Joliet Formation contains scarce macrofossils, but remains of trilobites, brachiopods, and orthoconic nautiloids are common. A soft-bodied biota was identified within the Brandon Bridge Member of the Joliet Formation in Wisconsin, but is not known to be present in Illinois (Mikulic et al. 1985).

3.3.1.2 Environmental Impacts

Proposed Action

Construction

Construction would require substantial excavation and fill to create the embankment and underground facilities. Excavations in the soil borrow and stockpile areas would affect areas occupied by three historic farmsteads. Fermilab recently completed additional investigations of these sites and recommended that these sites are not eligible for the NRHP (Bird 2013). IHPA concurred on a DOE determination that the three farmsteads are not eligible and that the Proposed Action would have no adverse effect on historic properties (Haaker 2013) (**Appendix C-1**).

In addition to known sites, undocumented and unanticipated cultural and historical resources, including human remains and fossils, could be encountered during construction. In the event of an unanticipated discovery, all ground disturbance including the movement of vehicles and equipment within 100 feet of the discovery would be stopped and the stop-work zone clearly marked. The discovery would be protected and an archaeologist or paleontologist would be notified and would inspect the discovery and implement the appropriate notifications and treatment procedures. Ground disturbance would not resume in the stop-work zone until authorized by DOE in consultation with the IHPA per the Fermilab CRMP.

Potential impacts on paleontological resources (if present) could occur during excavations to obtain embankment material and excavations for the Target Hall, Decay Pipe, Absorber Hall, and NND. These locations could contain marsh or bog deposits (Curry 2001; Soil Survey Staff [SSS] 2013). In similar deposits elsewhere in the state, Pleistocene mammal fossils such as mastodon and bison have been reported and could be encountered during construction based on fossil records for similar areas. The area around LBNF-40 has fewer wetland soil types and therefore would have a lower probability of containing vertebrate fossils. Bedrock excavations for the NND would not affect geologic units expected to contain scientifically important fossil resources. Nonetheless, Fermilab would follow a process based on approaches outlined in the CRMP.

Operation

Once constructed, operation of the Proposed Action would involve access to and use of support facilities and service buildings, maintenance, and landscaping. Because these activities would not require ground disturbance, operation of the Proposed Action would have no impact on cultural or paleontological resources.

No Action

Under the No Action Alternative, there would be no excavation, grading or other new ground disturbance in these areas; therefore, no impacts on historic properties or paleontological resources or other cultural resources would occur. Existing Fermilab experiments and research would continue and Fermilab would comply with the CRMP.

3.3.2 SURF

3.3.2.1 Affected Environment

Cultural Resources

SURF is within the Black Hills area of South Dakota, an area of historical, religious and cultural significance to American Indian tribes living within the Black Hills during the Protohistoric period. These tribes included the Arapaho, Cheyenne, Crow, Kiowa and Sioux (Sundstrom 1997). The treaty of 1868, between the Federal government and the Sioux, recognized the Black Hills as part of the great Sioux Reservation (or Nation) and an important sacred and culturally significant site. In 1874, gold was discovered in the Black Hills and resulted in an inflow of miners and prospectors. Lead and Deadwood were soon thriving encampments associated with development of mines in the Northern Black Hills. The Federal government seized the Black Hills in 1877 to protect these mining interests and miners despite the 1868 treaty. Consequentially, the Black Hills was diminished as a Native American Cultural site in terms of material objects and archeological sites as a result of mining and other development. However, the Black Hills remain a significant Native American sacred site (Sundstrom 1997).

Section 106 of NHPA requires Federal agencies to take into account the effects of its undertakings on any district, site, building, structure or object that is included in or eligible for inclusion in the NRHP. Cultural resource correspondence is contained in **Appendix C-2**. Most of the City of Lead has been included in an NRHP District ('District') because of its historical significance as a mining community. The District, along with a number of other features, are shown in **Figure 3.3-1**, and constitute the APE.

The District is significant for community planning and settlement, mining, and architecture from 1880 to 1948. It was nominated for inclusion into the NRHP, included properties on 48 to 50 blocks, primarily in the downtown commercial core and adjacent residential areas. A 1998 amendment to the District added properties on 28 blocks to the south and west of the original area and extended the District's period of significance to 1948. With these additions, the District includes most of Lead's public and commercial buildings as well as residential and mining architecture on the adjacent hillsides. It also includes a substantial portion of the Open Cut, the large open pit mine. The Homestake Mine, developed and operated by the Homestake Mining Company, was the largest and longest operating gold mine in the Northern Hemisphere. The City of Lead was constructed in conjunction with the mine, and grew to be South Dakota's second largest town in terms of population at the turn of the twentieth century.

Lead's topography contributes to its unique character and has influenced its historical development with unique architecture and landscape characteristics adapted to the steep hillsides and varied grades. Buildings are generally one-or two stories and constructed of frame or brick. The full range of Lead's architectural styles is represented within the District, which has 416 primary buildings and structures dating from the nineteenth century to 1948, additional secondary buildings and structures, the southern portion of the Open Cut, and a cemetery. Additional properties outside the district are individually listed in or are eligible for the NRHP.

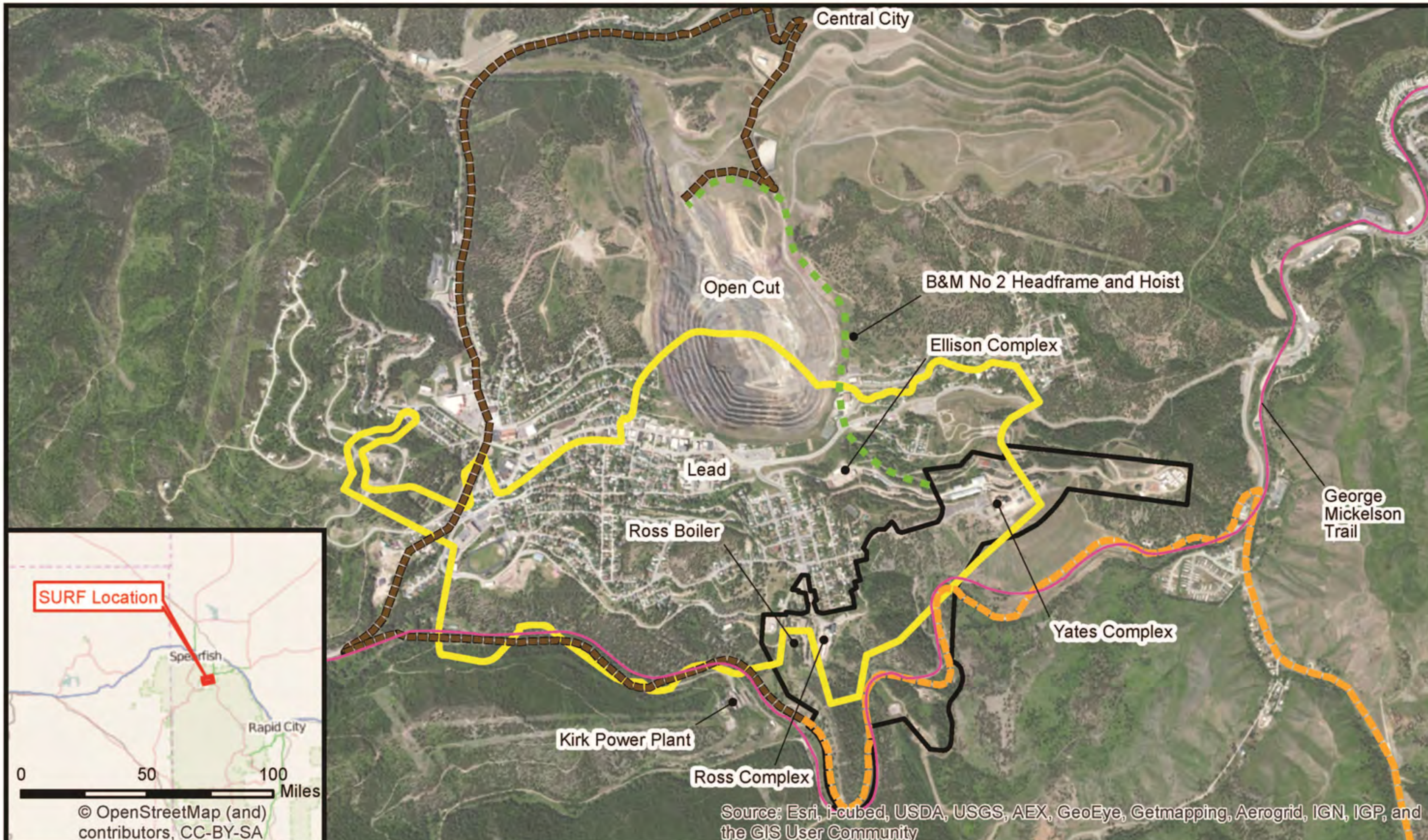
Many areas outside the boundaries of the District have not been systematically surveyed and evaluated for NRHP eligibility. SURF property includes the underground workings of the former Homestake Mine and selected surface facilities supporting the underground workings such as headframes, ventilation fans, crushers, offices, warehouses, hoists, electrical substations and other structures. Surface facilities are organized as support complexes around mine shafts. About half of the SURF property is outside the Historic District despite it being inside the City of Lead.

Three of the more important building complexes of the site are centered on the Ellison, Ross and Yates Shafts. The Ellison Complex was constructed during the period 1879-1932 and includes the Shaft, Headframe, Hoist Building, the Old High, the Construction Shop, the Ellison Boiler, the 1911 Electric Shop, the B&M No. 2 Shaft, Headframe and Hoist and Tramway. The Ellison Complex structures are within the Lead Historical District except the B&M No. 2 Headframe and Hoist.

The Ross Complex was constructed during the period 1932-1939 and is composed of the Ross Headframe/Crusher Building, Pipe Shop Building, Dry Building and Warehouse, which are within the boundaries of the Lead Historic District. The Ross Boiler Building, Hoist Building, and Substation are also part of the Ross Complex but outside of the Historic District's boundary. The buildings within the Ross Complex are NRHP eligible as they would be contributing resources to the Lead Historic District.

The Yates Complex was constructed during the period 1937-1945 and is composed of the Yates Shaft, the Yates Headframe, the Sawmill, Administration Building and Dry. These buildings are within the Lead Historic District. The Yates Hoist and Sawmill are also part of the Yates Complex but outside the Lead Historic District. These buildings are also NRHP eligible. In summary, many of SURF surface facilities that are not within the District would be considered contributing resources given the historical importance of the Homestake Mine.

Absolute Scale -1:25,000
1 inch = 2,083 feet



Legend

- George Mickelson Trail
- Proposed Action: Rail or Pipe Conveyor to Open Cut
- Proposed Action: Truck Haul Route to Open Cut
- Proposed Action: Truck Haul Route to Gilt Edge Superfund site
- Approximate Lead Historic District Boundary
- Approximate SURF Property Boundary

0 2,000 4,000 Feet

N

LBNF/DUNE EA

FIGURE 3.3-1

Proposed Action in Relation to the Lead Historic District

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A segment of the George S. Mickelson Trail is south of Lead and parallels Whitewood Creek and Kirk Road. The 110-mile trail is the former corridor of the Chicago, Burlington and Quincy Railroad constructed in 1890-91 and last operated by the Burlington Northern Railroad in 1983. A small segment of the trail is within the Lead Historic District as shown in **Figure 3.3-1**. The Mickelson Trail is a contributing resource to the Lead Historic District and is NRHP eligible.

The coal-fired Kirk Power Plant constructed in 1936, supplied electricity to the Homestake Mine. The plant, decommissioned in 1999, is located on Kirk Road approximately 2,000 feet southwest of the Ross Boiler and south of Kirk Road. The privately owned former coal-fired plant is not on the NRHP or within the District.

A Level I literature search was performed (HDR 2013a) and included examination of existing cultural resources records at the South Dakota State Historical Society Archaeological Research Center (SARC) and the South Dakota State Historic Preservation Office (SHPO). Records within a one-mile radius of the proposed construction were examined per SHPO guidelines and it was determined that twenty-two cultural resources surveys were conducted within the area between 1987 and 2013. The resources identified included the extensive Lead Historic District (District) which is listed in the NRHP (**Figure 3.3-1**); bridges; mining and industrial-related resources; a cemetery; archaeological lithic scatters and approximately 600 other resources, most of which had not been evaluated for NRHP eligibility. Most of the surveys conducted in the area were for architectural resources.

Cultural Resources Fieldwork

A Level III field survey was conducted in June 2013. This survey (HDR 2013b) meets the South Dakota Resource Survey Manual 2006 standards. The survey included transects within the Ross Boiler area, the Ross Yard south hillside down to Kirk Road, and the former Homestake pipe conveyor route.

The remains of a possible dugout-type feature and associated trash scatter, a prospect pit, concrete coal chute, cast iron water pipe and iron slag from the destruction of a foundry were identified north of the Ellison Complex and south of Highway 85.

3.3.2.2 Environmental Impacts

Proposed Action

Construction

Surface construction activities associated with the Proposed Action would be both inside and outside the District. The Ross Boiler and Stack would be demolished and replaced by the Cryogen Support Building. The Ross Boiler Building is a large red brick structure with a tall boiler stack. The boiler and stack sit below the elevation of Ross Hoist Building tucked into the hillside. The Ross Boiler and Stack demolition would be considered an adverse effect by the NHPA on the District as it would diminish the overall integrity of the Ross Complex. Construction of the Cryogen Support Building would result in visual effects on the Ross Complex.

The construction of the conveyor and truck load-out station would occur partially within the Lead Historic District. The Phase 1 Cultural Resource Survey (HDR 2013) identified buildings and cultural resources including the conveyor corridor and load-out station.

Trucks traveling from the Kirk Road Load-out station to the Gilt Edge Superfund site would use Kirk Road, Highway 385 and the Gilt Edge Road. Kirk Road crosses the Mickelson Trail in two places and the

District in one short section in this haul route. The District is located generally on the north side of Kirk Road and separated from view by a ridge occupied by the Yates and Ross Complexes. The houses and features along Kirk Road, Highway 385 and the Gilt Edge Road have not been evaluated for NRHP eligibility.

The Open Cut is a potential repository for the excavated rock resulting from the construction of the underground detector. Trucking rock to the Open Cut would require the use of the west end of Kirk Road, passing the Kirk Power Plant and one residence. Trucks would also use Highways 14A and 85 and pass by approximately 20 historic properties that contribute to the District, including 14 residential and commercial properties dating from 1900 to 1942, including Lead High School, the United Methodist Church, the Homestake Mansion, a former railroad roundhouse (now a restaurant), three residential properties and a Standard Oil gas station. The Open Cut is a contributing property of the District. However, the portion of the Open Cut that would be utilized for the rock repository is outside (north of) the District and outside SURF ownership boundary. The rock placement location in the Open Cut is visible from portions of the District.

Another possible means for transporting rock to the Open Cut would be a combination underground and surface rail-pipe conveyor. The surface portion of this conveyance lies both within and outside of the District. The route would pass through the Ellison Complex (within the District), cross over (or under) Highway 85 and the hillside southeast of the Open Cut, where it exits the District. The conveyor surface infrastructure would pass near seven structures including the 1911 Electric Building and B&M No. 2 Headframe.

The SHPO was contacted concerning Section 106 compliance because of the large size of the District, the geographical extent of the Proposed Action, and number of structures that would likely be contributing resources to the District that might have an adverse effect on the district. On September 9, 2013, SHPO met with SURF on-site and toured potentially affected areas inside and outside the District. The SHPO recommended development of a Programmatic Agreement (PA) per 36 CFR 800.14(b). The PA is a roadmap for Federal agencies to develop Section 106 compliance tailored to the specific needs of a complex project or program. The goal of Section 106 is to identify and to consider historic properties that might be affected and attempt to resolve any adverse effects through consultation. Accordingly, a initial draft of the PA was developed with the SHPO and shared with the Advisory Council on Historic Preservation (ACHP), 19 Tribes, the City of Lead, and the City of Deadwood. The final draft is being made available in this EA to all stakeholders for review (**Appendix C-2**). It addresses the Proposed Action (i.e., the Undertaking pursuant to Section 106) and Alternative A and provides a framework for consideration of future DOE and Federally funded actions at SURF. Required signatories to the PA would be DOE, SURF, and SHPO. The City of Lead, the City of Deadwood, ACHP, and 19 American Indian tribes would be invited signatories, should they decide to participate.

The Proposed Action would take place within the Black Hills region. Although it has not been designated as an historic property, the region is a traditional cultural resource for many tribes. However, the specific footprint of the Undertaking has already been significantly disturbed by past mining activities and other development. Redeployment of the Homestake mine via the Proposed Action, i.e., science projects like LBNF/DUNE, would begin the rehabilitation process in a way that would have multiple benefits; from educational programs for children to the possibility of scientific discovery important to members of tribal and non-tribal communities alike.

Potentially adverse effects to historic properties from construction would be addressed through implementation of the Section 106 PA. LBNF/DUNE would adaptively reuse historic mining resources where feasible. Historic properties would continue to be used and maintained, and there would be new vitality brought to the District. The public would benefit from new opportunities to appreciate the history of Lead.

Operation

Operations would have no or little affect on historic properties or traditional cultural resources. The PA would address any unforeseen new surface construction or modifications to SURF surface buildings through required annual meetings and other communication with the SHPO.

Alternative A

Construction and Operation

Alternative A would have little or no impact on historic properties or traditional cultural resources beyond those described for the Proposed Action. Alternative A would increase duration of some impacts because of the added excavation tonnage and transportation of excavated rock. However the intensity of the impact (number of truck hauls per day or daily use of the Rail/Pipe Conveyor) would not be greater than the Proposed Action. There would be no new disturbances other than those described, except where there could be minor use or modification of existing surface buildings at the Ross or Yates Complexes. Modification to a historical building is addressed in the PA and through yearly consultation with SHPO per the PA. The construction and operation of future experiments under Alternative A would be subject to the Section 106 and the PA. Any potential adverse effects from these specific, yet undetermined projects would be avoided or minimized through stipulations in the PA document.

No Action

The No Action Alternative would eliminate the Proposed Action and PA. Other experiments may be sited at SURF. Each experiment would be evaluated for its compliance with NEPA and NHPA. Modifications to any building at the SURF would be coordinated with SHPO. There would be no direct effect on historic properties or traditional cultural resources.

3.4 HEALTH AND SAFETY

This section describes the potential human health and safety impacts associated with the Proposed Action and alternatives. Health and safety impacts are evaluated in terms of the potential risk to both Fermilab and SURF workers and nearby residents. The following subsections provide an overview of existing human health and safety hazards and how these hazards and risks are minimized by engineering controls and existing safety and environmental health management programs. It then describes and assesses potential risks from construction and equipment installation hazards (excavation, use of heavy equipment, falls, exposure to high voltage, material handling, dust, fumes, noise, and the use of hazardous materials) as well as industrial and radiological hazards from operations. At Fermilab, the affected environment includes construction and operational areas, particularly within underground enclosures at Fermilab where workers would be exposed to components with residual radiation. It would also include adjacent Fermilab and off-site areas potentially exposed to radioactive air emissions. At SURF, the affected environment includes underground excavation areas and aboveground construction. The potential risk of traffic accidents is analyzed in Section 3.7, Transportation, and potential waste management impacts are addressed in Section 3.14, Waste Management.

3.4.1 Fermilab

3.4.1.1 Affected Environment

Fermilab has existing health and safety programs to protect workers and the public from hazards associated with construction and experimental activities. Fermilab's Integrated Environment, Safety, and Health (ES&H) Management Plan (IESHMS 2011) complies with DOE requirements (10 CFR 851, "Worker Safety and Health Program"). Fermilab is dual certified through the Occupational Health and Safety Advisory Service (OHSAS) 18001 and International Organization for Standardization (ISO) 14001 standards and provides an ongoing process that focuses on planning, implementing, evaluating, and improving environmental and safety performance and regulatory compliance. Elements of the Environmental Management System (EMS) are coordinated with Fermilab's Integrated Safety Management System (ISMS) to form a combined Environment, Safety, and Health (ES&H) Management System. Protection of workers against exposures to common industrial hazards is in accordance with regulations established by the Occupational Safety and Health Administration (OSHA).

Fermilab's overarching health and safety program is outlined in the Fermilab ES&H Manual (Fermilab 2013a). The Fermilab Radiation Control Manual (FRCM; Fermilab 2013b) outlines the radiological health and safety procedures in compliance with CFR Title 10, Part 835 (10 CFR 835), "Occupational Radiation Protection." The Fermilab ES&H Manual and FRCM contain numerous chapters relevant to LBNF/DUNE construction (e.g., excavation), installation, operation (e.g., accelerator operations, electrical safety, fire protection, emission control, radiation safety), and future decommissioning (e.g., facility decontamination and decommissioning), which is not addressed in this EA.

Fermilab imposes environmental, safety, and health requirements on construction subcontractors as SEPMs to ensure subcontractor programs conform to the principles of Fermilab's ISMS and comply with the Fermilab ES&H Manual, including 7010: ES&H Program for Construction and 9010: Traffic Safety (Appendix B, Safeguards for Construction and Maintenance Activities) and OSHA 1926 Construction Safety Standards. Excavations must be carried out in compliance with 29 CFR 1926.650 and Fermilab ES&H Manual section 7030, "Excavation."

Under OSHA regulations (29 CFR 1904), a work-related injury or illness is "recordable" if it results in days away from work, restricted work, or transfer to another job; medical treatment beyond first aid; loss of consciousness; or death. Total Recordable Cases (TRCs) are work-related injuries or illnesses serious enough to require medical treatment, a hospital visit, or prescription medication. The TRC Rate is a normalized expression of 100 employees working full-time for 50 weeks or 1 year (200,000 hours). The rate is calculated as the number of recordable cases divided by the hours worked, and then multiplied by 200,000.

If an injury prevents the employee from performing any or all of his or her duties, that is, they must be assigned "light duty" or cannot work at all, the injury is classified as a Days Away, Restricted, or Transferred (DART) case. DART cases are a subset of the TRCs. The DART rate is calculated in a manner similar to that of the TRC rate (number of DART cases per total worker hours multiplied by 200,000).

Fermilab subcontractors must comply with contractual performance measures regarding safety. Fermilab requires that construction contractors develop and implement LBNF/DUNE-specific health and safety plans and complete appropriate site-specific health and safety training. Under the Fermilab ES&H Manual, a hazard analysis (HA) process must be completed to evaluate the associated hazards and how the work can be performed safely. The HA includes identification of hazards, measures to reduce hazards, and expectations for all affected employees.

The U. S. Department of Labor, Bureau of Labor Statistics (BLS), Occupational Injury and Illness Data maintain statistics on the TRC and DART rates for the construction industry. Under Fermilab ES&H Manual section 7010, Fermilab contractors must show a 3-year safety record equal to or less than 85 percent of the most current BLS statistics for total construction.

Similar to other industrial settings, current activities at Fermilab typically result in some occupation-related injuries. However, the Fermilab safety record is substantially better than that of general industry. Currently, the Fermilab safety goal is a TRC rate of 0.65 (Valishev 2013). As of September 30, 2014, the TRC rate for the previous 365 days for all work activity was 1.01. For "Construction" activities alone the Fermilab TRC rate was 1.89 (Fermilab 2014). By comparison, for general industry in 2013, the total number of recordable cases of nonfatal occupational injuries/illnesses for all industries was 3.5 and for the "Construction" sector was 3.8 (BLS 2013). As of September 30, 2014, the DART rate for the previous 365 days at Fermilab was 0.39 (Fermilab 2014). This rate is substantially below the 2013 rate of 1.8 for all U.S. Workers. The rate of fatal work injuries for U.S. workers in 2012 was 3.2 per 100,000 full-time workers, down from the 2011 rate of 3.5 per 100,000 (BLS 2013). By comparison, Fermilab has never experienced a fatal injury.

Radiation Safety

At Fermilab, a policy consistent with integrated safety management (ISM) and in accordance with Title 10 Code of Federal Regulations Part 835 (10 CFR 835) (DOE 2007), occupational radiation protection requirements is to conduct activities in such a manner that worker and public safety, and protection of the environment are given the highest priority. Fermilab is committed, in all its activities, to maintain any safety, health, or environmental risks associated with ionizing radiation or radioactive materials at levels that are As Low As Reasonably Achievable (ALARA). Likewise, Fermilab management supports ALARA design considerations, work planning, and review of activities in support of the Fermilab ALARA program.

Ionizing radiation is currently produced at Fermilab during normal operations. The accelerated particles, or particle beams, produced in the accelerators are one source. In addition, some accelerator components become radioactive as a result of operations. Radioactive materials are carefully labeled and controlled by trained personnel.

The biological effects of radiation exposure vary depending on the type of radiation, the energy of the radiation, the portion of the body exposed, and the exposure duration. The biological effect of radiation is measured in units called rem, a relatively large unit. The biological effect of radiation is usually reported in millirem (1000 mrem = 1 rem). As shown in **Table 3.4-1**, data published by the National Council on Radiation Protection and Measurements shows that an average member of the U.S. population receives a total dose of ionizing radiation of 624 mrem (0.624 rem) per year from naturally occurring sources such as terrestrial and cosmic radiation, medical, commercial, and industrial sources (NCRP 2009).

Radiation exposure of Fermilab employees, scientific users and visitors is regulated by DOE 10 CFR 835 while such exposure to members of the public is subject to DOE Order 458.1 Change 2 (DOE 2011a). Radiological wastes are managed in compliance with DOE Order 435.1 (DOE 1999). These requirements are implemented at Fermilab through detailed written policies outlined in the FRCM (Fermilab 2013b). Terminology used to describe radiological doses (e.g., equivalent dose, effective dose, and total effective equivalent dose) are defined in 10 CFR 835.

Table 3.4-1 Comparison of Annual Average Doses Received by a U.S. Resident from All Sources

Source		Dose (millirem per year)[a]	Percent (%) of Total
Ubiquitous background	Radon and thoron	228	37
	Space	33	5
	Terrestrial	21	3
	Internal (body)	29	5
	Subtotal	**311**	**50**
Medical	Computed tomography	147	24
	Medical x-ray	76	12
	Nuclear medicine	77	12
	Subtotal	**300**	**48**
Consumer	Construction materials, smoking, air travel, mining, agriculture, fossil fuel combustion	13	2
Other	Occupational	0.5[b]	0.1
	Nuclear fuel cycle	0.005[c]	0.01
	Total	**624**	**100**

Notes:

a To convert millirem per year to millisieverts per year, divide by 100.

b Occupational dose is regulated separately from public dose and is provided here for informational purposes.

c Calculated using 153 person-sieverts per year from Table 6.1 of NCRP Report 160 using a 2006 U.S. population of 300 million.

Source: NCRP 2009

DOE standards limiting radiological doses to the public (who are not occupational workers at Fermilab) are addressed in DOE Order 458.1 (DOE 2011a) and supported by DOE-STD-1196-2100 (DOE 2011b). DOE limits the primary radiation dose for the public to 100 mrem in a year from activities conducted at Fermilab and other DOE facilities (Fermilab 2014). The amount of exposure members of the public receive during visits to Fermilab is never more than a very small fraction of this dose limit. Radiation dose to the maximally exposed member of the public from airborne radionuclide emissions during the past 20 years were estimated to be well below the EPA standard of 10 mrem per year and also much less than the EPA's continuous monitoring threshold of 0.1 mrem per year (see, for example, Report to the Director on the Fermilab Environment 2013).

3.4.1.2 Environmental Impacts

Proposed Action

This section describes the potential human health and safety impacts associated with the construction and operation of the Proposed Action. Federal, state, and local health and safety regulations would govern work activities. Additionally, industrial codes and standards would apply to the health and safety of workers and the public.

Construction

During construction, the primary potential health and safety risk would be work-related accidents and injuries typical of the construction industry. Workers would be subject to the typical hazards and occupational exposures faced at other industrial construction sites. Fermilab employees and subcontractors may encounter hazards associated with excavations; heavy equipment use; work in confined spaces (areas with limited egress); work at elevation/falls; electrical hazards; exposure to dust, fumes, and noise; wildfire risks; material handling, and handling hazardous materials. Hazardous materials used during construction may include paints, epoxies, oils, and lead for construction of shielding.

No new safety and health programs would be required because the established programs would be implemented. Task-specific Hazard Assessments (HA) would be completed to identify construction hazards and to avoid or minimize them by delineating and establishing construction boundaries and barriers; implementing established Fermilab safety programs and procedures, including engineering and administrative controls and use of appropriate personal protective equipment (PPE); health and safety training; and conducting routine inspections.

Subcontractors would perform the excavations and would be required to meet safety qualifications and comply with existing SEPMs, including Fermilab requirements. To minimize potential impacts on workers, the public, and the environment, construction activities would also conform to the applicable requirements of OSHA (29 CFR Parts 1910 and 1926) and DOE (10 CFR Parts 835 and 851), as well as the Fermilab ES&H Manual (Fermilab 2013a) and the FRCM (Fermilab 2013b). These regulations and site-specific plans require such measures as hazard communication, personal protective equipment, safety training, worker monitoring, hearing protection, fire protection, fall protection, and excavation safety.

Construction would require excavation, grading, and installation of experimental components (e.g., magnets) and construction of service buildings. Construction would require substantial earth-moving activities and would follow conventional practices for excavation and operation of heavy earth-moving equipment. Excavation-related effects would be limited to areas within Fermilab’s boundaries. Construction hazards would also include blasting and rock removal. Blasting would be conducted by an experienced and licensed subcontractor with Fermilab ES&H oversight.

Access to construction areas would be limited to construction workers, Fermilab, and DOE employees who would administer and monitor construction activities, particularly those personnel engaged in the administration or monitoring of construction. Areas accessible to workers would be routinely monitored, and appropriate signs posted. These controls and protective measures would be designed to adhere to applicable standards, which would reduce the probability of accidents. In addition, site security would minimize the risks of unauthorized people accessing the site.

Fire risk would be minimized through SEPMs by following the fire safety precautions required by the Fermilab ES&H Manual, as well as OSHA regulations and the National Fire Protection Association (NFPA) 241, “Standard for Safeguarding Construction, Alteration and Demolition Operations.” In addition, potential ignition sources would be controlled. For example, smoking would be limited to designated areas, and hot work (e.g., welding) would be controlled through the Fermilab burn permit program.

Facility access and egress would be designed and provided in accordance with applicable NFPA Life Safety Codes and Standards including NFPA 520: “Standard on Subterranean Spaces,” which requires adequate egress in the event of an emergency. Facility fire detection and suppression systems, as well as personnel occupancy requirements, would comply with NFPA 101: Life Safety Code. Fire alarm/fire suppression systems would also be designed in accordance with Fermilab engineering standards, which require a hard-wired, zoned, general evacuation fire alarm system.

Electrical hazards would be minimized through engineered controls such as isolation and insulation, combined with Fermilab SEPMs including policies, procedures, and training. Work performed on electrical systems would include controls such as Lockout/Tagout (LOTO) procedures. Electrical equipment would be designed, upgraded, installed, and operated in compliance with the National Electrical Code, NFPA 70; OSHA 29 CFR 1910, Subpart S, Electrical; and the Fermilab Electrical Safety Program as outlined in the Fermilab ES&H Manual (Fermilab 2013a).

Although the rate of incidents cannot be predicted, the potential LBNF/DUNE-related injuries can be estimated based on typical and reported injury, illness, and fatality rates. Based on an average daily workforce over the 7 years of construction of 56 workers, and assuming that each worker would be on the job 2,000 hours per year for 7 years, the Proposed Action would result in an approximate total of 784,000 worker hours. Based on the 2014 national recordable incident rate of 3.5 cases per 200,000 worker hours, an average of 14 work-related injuries and illnesses may occur during the 7-year construction period (approximately two per year). Based on the 2014 national fatality rates, no fatalities are likely over the 7 years of construction. Based on Fermilab's average incidence of 1.01 cases of recordable injuries/illnesses per 200,000 worker hours during 2014, construction would result in approximately 4 recordable work-related injuries or illnesses (fewer than 1 per year) and 1.5 DART cases for the 7 year period. The calculated results are an estimate and do not imply that a particular number of accidents, injuries, or fatalities would actually occur.

LBNF/DUNE construction would affect human health and safety in a manner similar to past and present high-energy physics experiments at Fermilab, including the NuMI and NO*ν*A (DOE 2008a) projects. Construction impacts on workers and the public would be minimized by implementing SEPMs, including established Fermilab health and safety procedures.

Radiation Safety

Construction workers for LBNF/DUNE would not work in radiation areas associated with existing Fermilab facilities and would receive radiation doses no higher than the public under the As Low As Reasonably Achievable (ALARA) program. Under ALARA, Fermilab takes every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical. Some excavation would occur in areas previously exposed to accelerator operations and cooling water, which contains very low levels of tritium (several times less than the drinking water standard set by the U.S. Environmental Protection Agency Primary Drinking Water Regulations; Radionuclide; Final Rule at 40 CFR 141 Subpart G). In addition, beamline construction would include removal of Cooling Pond F, which has been used to manage site stormwater and pumped groundwater, and to circulate cooling water to Fermilab experiments. Thus, excavation could result in minor radiation exposures. Soil excavation near the MI would be conducted in compliance with the procedures outlined in the FRCM (Fermilab 2013b), including monitoring of worker exposures and radiation safety oversight. Radiation exposure potential associated with the use of radiography sources or other licensed radioactive material would be managed by the subcontractor(s) in accordance with the applicable regulations and the terms of their license(s).

Operations

During operations, occupational hazards would be similar to those associated with research, educational, office, or light industrial workplaces and similar to those analyzed for the NO*ν*A project (DOE 2008a). For specific aspects of operations, Fermilab would prepare task-specific HAs or procedures to identify hazards. During operations, hazards would be minimized by engineering controls included in the design and operational planning, and SEPMs, as well as by implementation of established Fermilab protocols. Radiation exposures would be reduced to ALARA.

Potential hazards during operations would include use of heavy equipment (e.g., forklifts, cranes, and specialized lifting equipment for heavy components); work in confined spaces; work at elevation/falls; electrical hazards associated with exposures to high voltage (utilities); exposure to dust, fumes, and noise; wildfire risks; and handling of hazardous materials (oils, solvents). Use of lifting equipment would comply with established Fermilab standards and procedures. Rigging operations would be performed by properly trained and licensed operators using certified lifting equipment.

Some workers could be exposed to powerful magnets capable of pulling tools from hands and interfering with the performance of cardiac pacemakers, suture staples, aneurysm clips, artificial joints, and prostheses. Stray static magnetic fields would be measured and mapped, and appropriate warning signs would be posted.

Hazards associated with the handling of hazardous materials would be managed by implementing SEPMs, including established programs that comply with 10 CFR 851 and DOE orders. Under these requirements, site inventories would be completed for hazardous chemicals. Standard safety practices would include the use of protective equipment as appropriate, and spill prevention planning would be implemented, as outlined in the Fermilab ES&H Manual.

The Proposed Action would also use cryogens such as LAr for the NND and LN for the associated refrigeration system. Fermilab scientists use cryogens extensively for existing experiments. Personnel involved in handling cryogens would take cryogenic safety and oxygen deficiency hazard (ODH) training as required under Fermilab SEPMs, including the site's cryogen safety program. In addition, all piping and vessels for storing and conveying cryogens would be designed as per Fermilab ES&H Manual requirements.

Because no new positions would be created for operations, the Proposed Action would not result in an increase in worker hours relative to current conditions; therefore, there would be no incremental increase in potential injuries/illnesses. With implementation of established Fermilab health and safety standards and controls, health and safety impacts would be low.

Radiation Safety

Operation of the Proposed Action would expose LBNF/DUNE workers to low levels of radiation similar to those generated by existing Fermilab experiments. Under normal operations, worker exposures to radiation would be controlled by implementation of Fermilab's established safety procedures requiring that doses are kept ALARA and that limit doses to less than 1,500 mrem in a year. The primary operational health and safety risk would be the potential for the primary proton beam to partially penetrate the beamline shielding in a short term excursion that would be immediately terminated by numerous detection devices both to terminate the unplanned radiation exposure and to restore proper facility operation. Thus the beam radiation would be present only during beam operation and would cease instantly when the beam is off. Radiation exposure would be minimized by ALARA design measures as well as preparing and implementing operating plans and health and safety plans. ALARA design measures would consist principally of encasing the beamline in thick steel and concrete shielding.

The primary beamline would be constructed with shielding adequate to protect against radiation losses during routine operations as well as the unlikely event where control of the beam is accidentally lost. As described in Section 2, the beam enclosure would be constructed within the soil embankment and would be shielded by approximately 25 feet of embankment soil. The Target Hall would be shielded with steel plates, marble, borated polyethylene, and 5 to 7 feet of concrete. Similarly, the Decay Pipe would be shielded with 18 feet of concrete, and the absorber would be shielded with steel, aluminum, lead and concrete sufficient to absorb virtually all the radiation.

The Fermilab Radiation-Safety Interlock System would minimize the potential for accidents involving direct beam exposure. This system has successfully been in use for many years at Fermilab and would protect personnel from direct exposure to the beam, high voltage, and potentially resulting injury, radiation exposure, or death. This system would include access control interlocks, radiation detectors, exclusion area boundary gates, access keys and cores, an emergency shutdown system, an audio warning system, and an electrical safety system. Before enabling the beam, Fermilab operators would also conduct a walkthrough (Search and Secure) of the beam enclosure, as per facility-specific search and secure procedures, to ensure that the area is unoccupied. Shielding would minimize radiation exposure outside the enclosures and would minimize radioactive air emissions and activation of soil and groundwater in accordance with the FRCM (Fermilab 2014).

The beamline would have systems designed to contain radio-activated air and accidental spills of radio-activated water. Production of radionuclides in soil would be kept below the detection limit through the design of adequate shielding. The detection limits are 1 picoCurie per milliliter (pCi/ml) for tritium and 0.04 pCi/ml for sodium-22 (40 CFR Part 141.25). Transport of radionuclides would be minimized by geomembrane barriers at the Target Hall, Decay Pipeand Absorber Hall. Water from the Target Hall underdrain would be sampled regularly. Water would also be collected from within and outside the barrier system protecting the Decay Pipe and conveyed to separate sumps in the Absorber Hall. In addition, water collected inside the Absorber Hall would be collected in a third sump. Separate collection systems would allow Fermilab to monitor these systems independently before the collected water is pumped to the Industrial Cooling Water (ICW) ponds. In the unlikely event that this water were to exceed the regulatory limits for surface water, it would be treated as low level radioactive waste.

Shielding would keep residual radiation sufficiently low to allow maintenance personnel to access the target, horns, and other irradiated components. Beamline components, such as the target and focusing horn, would be subject to intense radiation during beam operation and would require regular replacement. To minimize worker exposure to activated components, the Target Hall would be equipped with a remote handling system and a shielded work/repair cell. This system would include remotely operated cranes, steel casks to transport radioactive components, and long-term storage space. This facility would be designed to maintain the radiation dose in the occupied space below 0.25 mrem per hour during beam operation. For areas where members of the public could access, shielding is designed to keep the dose rate below 0.05 mrem per hour.

The beamline would be monitored to identify areas experiencing beam losses. If excessive beam losses were detected, the system would turn the beam off. This system would also include monitoring of airborne radiation; radioactive gases generated from beamline operations. Closed-loop air cooling systems would chill and dehumidify the air as it circulates through beamline components and shielding in the Target Hall, Decay Pipe and the Absorber Hall. The air handling systems would be airtight and would retain the air to allow radioactive decay before discharge through the exhaust system. Fermilab's radioactive air emissions permit limits off-site exposure to radioactive air to less than 0.1 mrem in a year (40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities"). Fermilab stack-monitoring detectors are connected to the site-wide monitoring network. Fermilab uses the EPA-approved computer code CAP88-PC to calculate potential effective dose to individuals and to the population and to ensure compliance. When design parameters and expected radioactive components of air emissions are used in the CAP88-PC simulation, the expected offsite radioactive air releases from the Proposed Action are less than 25 percent of Fermilab's permit limit.

Many of the beamline components in the Target Hall and Absorber Hall would be cooled with water. Because the cooling water would be activated by exposure to radiation, this would be a recirculating closed-loop system, thus the water would be recirculated, depending on the component, for many months or many years until a purge is required. However, the system would be equipped with secondary containment and in the rare event of a leak, the water would be held until its radioactivity was below the levels that allow disposal as low-level radioactive waste. Radiological wastes would be handled in compliance with DOE Order 435.1 (DOE 1999). These requirements are implemented at Fermilab through detailed written policies outlined in the FRCM (Fermilab 2013b). With implementation of shielding and other design measures, as well as established Fermilab health and safety procedures, the Proposed Action would not result in substantial additional occupational radiation exposure relative to current conditions.

Workers conducting maintenance inside the beam enclosure would be subject to higher radiation levels with less frequent exposure. Beamline components would require maintenance and occasional replacement, requiring close work and handling of activated components. Workers would be exposed to a maximum of 50 mrem per hour while replacing or repairing beamline components. Per the FRCM, the maximum dose allowed for radiation workers is 100 mrem per week, which would limit this type of work to 2 hours per week. More stringent administrative controls apply to workers who receive over 350 mrem in a single calendar quarter. These individuals are placed on an Alert List to motivate more closely monitored radiation dose. Workers placed on this list must obtain special permission to accumulate additional dose in a calendar year.

Fermilab operations would adhere to existing radiation control programs and procedures of the FRCM (Fermilab 2014). As with existing Fermilab experiments, exposures would remain below the DOE regulatory dose equivalent annual limit of 5,000 mrem and the Fermilab administrative annual dose goal for radiation workers of 1,500 mrem. Based on relevant experience with the NuMI project at Fermilab (DOE 2008a), the average annual dose for workers would remain well below the Fermilab administrative dose goal of 1,500 mrem per year.

Collective radiation doses to occupational workers at Fermilab and other DOE facilities are routinely tabulated. This is the sum of the doses received by all occupational workers during a calendar year and is expressed in units of person-rem. Past and planned operations at Fermilab, including those that would occur with the Proposed Action typically result in an average collective dose of about 14 person-rem. (This is a five year average over the totals from calendar years 2010-2014.) Exposures to low levels of ionizing radiation may result in an increase in latent cancer fatalities (LCFs). Because the primary health concern with radiation is latent cancers, DOE uses a dose-to-risk conversion factor to estimate potential radiation impacts. The number of radiation-induced LCFs is estimated by multiplying the dose (person-rem) by health risk conversion factors (DOE 2004a) that relate the radiation dose to the potential number of LCFs. These factors are based on comprehensive studies of people historically exposed to large doses of radiation, such as survivors of atomic weapon detonations during World War II. The factor most commonly used in recent assessments is 0.0006 LCF per person-rem of exposure for workers and the public (Interagency Steering Committee on Radiation Standards [ISCORS] 2002). Based on a dose-to-risk conversion factor of 0.0006 fatal cancers per person-rem and the five year average of collective dose of about 14 person-rem, the estimated probability of a fatal cancer induced by radiation would be 0.0084 LCF (i.e., approximately one chance in 100 that there would be a single LCF among the approximately 1200 monitored workers). For comparison, the natural lifetime risk of fatal cancer in the U.S. population is approximately 0.2 (two chances in 10) (American Cancer Society 2013).

Fermilab has a long-standing policy of limiting off-site exposures resulting from Fermilab operations to less than 10 mrem in a calendar year. The five year average (2010-2014) off-site dose to the general public from penetrating radiation is 0.0288 mrem (Fermilab 2014). The same five year average offsite dose to the public from radioactive air is 0.01892 mrem. The average total annual offsite dose to the public over this five year period is 0.04772 mrem (Fermilab 2014). This total offsite dose to the public is a fraction of Fermilab administrative limit of 10 mrem per year (Fermilab 2014).

No Action

Under the No Action Alternative, there would be no new occupational or radiological health or safety impacts on workers or the public. Existing health and safety hazards would continue to be managed in accordance with established programs, policies, and procedures.

3.4.2 SURF

3.4.2.1 Affected Environment

Construction and operation of LBNF/DUNE would be managed directly by Fermilab under a lease agreement between DOE and SDSTA. All SURF spaces would be defined either as SURF common areas or as LBNF/DUNE areas in order to establish jurisdictional boundaries for Health and Safety issues among others. All aspects of the Health and Safety program at SURF within LBNF/DUNE jurisdictional areas, including incident reporting to DOE would be the responsibility of Fermilab. In that regard, Fermilab would follow DOE Order 851. The responsibility for Health and Safety in SURF common areas would fall to SURF, under OSHA and Mining Safety and Health Administration (MSHA) standards. During construction SURF would provide support relating to material handling, operation of the hoist and maintenance of easements and utilities.

SURF hosts a number of ongoing construction activities, including rehabilitation of the former Homestake mine shafts, tunnels, and surface facilities in order to provide a safe and usable space to conduct underground science. Construction on the surface is similar to other conventional construction environments. However, the underground construction work closely resembles modern mining practices. Rock excavation and movement is necessary to modify or make space for science and support activities. Drilling, bolting and securing rock in place is important to keep workers and researchers safe. Ensuring the safety and reliability of the shafts and shaft conveyances for safe access to the underground is vital to the SURF mission 'to enable compelling underground research in a safe work environment.' All of these activities require skilled, knowledgeable workers, well maintained equipment, and a highly effective safety culture.

SURF has an ISMS (Integrated Safety Management System, SURF 2014) program to help ensure worker, stakeholder, and community protection. In addition, ISMS articulates the requirements for operations including contractor and subcontractor work including electrical, excavation, blasting, and material handling. Safety management systems are used to systematically integrate safety into management and work practices so that all work is accomplished while protecting the public, the worker, and the environment. Administrative controls include but are not limited to programs, procedures, inspections, and reviews, which help to minimize the hazard. Programs are a broad based set of procedures that employees and contractors are required to know and follow to prevent accidents and include, among many others, lockout/tagout (LOTO), Hoisting and Rigging, Explosive Handling and Firing. These specific programs are industry standards that have been repeatedly tested to minimize hazard risk.

SURF ISMS requirements result from careful examination of the rules and regulations set forth in the Intergovernmental Agreement between the Bureau of Administration, Office of Risk Management of the State of South Dakota, and the South Dakota Science and Technology Authority (SDSTA). The Intergovernmental Agreement states, 'that 29 CFR 1926 (OSHA Construction Standards) and 29 CFR

1910 (OSHA Industry Standards) are considered the most applicable of the available standards for safety and health for most activities conducted in support of the development of the underground laboratory. In addition, MSHA 30 CFR (Mining Safety) standards would be employed as best practices for underground activities when OSHA standards do not sufficiently address a given hazard' (South Dakota Office of Risk Management 2011).

SURF recognizes that subcontractor safety and interface with the current operations and environment is critically important. SURF's commitment to safety and ISMS is formally extended to contractors, subcontractors, and their employees for whom SURF has ES&H responsibility. Contracts and subcontracts incorporate ES&H requirements, which then flow down to lower-tier subcontractors. Each subcontractor is responsible for ensuring compliance with applicable requirements that govern their work at SURF. Each subcontractor (unless escorted by an appropriately trained owner representative at all times) is required to develop an Environmental, Health and Safety Plan (EHSP) prior to conducting work on site. In accordance with the contracts requirements, the EHSP is subject to review and concurrence by SURF's Project Manager and the ES&H point of contact (POC) before the contractor is allowed to start work.

Table 3.4-2 compares incident rates for SURF, Heavy Construction, and the Metal Mining industry for the period 2013-2014. The SURF Total Recordable Incident (TRC) rate is higher than Heavy Construction and for Metal Mining given the fact that the SURF rate predominantly incorporates more commonplace recordable incidents such as insect bites and slip/trips. The SURF TRC rate has decreased over the past several years, due to the evolution of the ISMS and development of comprehensive JHA and Standard Operating Procedure (SOP) for all performed work. The higher TRC rate in 2013 (7.2) compared to 2014 (4.0) reflects a period of higher intensity maintenance work (e.g., building demolition).

Table 3.4-2 Summary Incident Rates for SURF, Heavy Construction and Metal Mining (2013-14)

	SURF 2013	SURF 2014	Heavy Construction[1]	Metal Mining[1]
Total Recordable Injury Rate (TRC)	7.2	4.0	3.2	2.6
Days Away, Restricted or Transferred (DART)	2.1	3.2	1.8	1.7

Notes:
1 Source: U.S Bureau of Labor Statistics 2014

SURF's EHS policies and programs are in place to identify, assess and reduce hazards, including for cryogen safety. The Cryogen Safety Policy requires cryogen reviews and assurances:

- The experimental team performs a safety review of the cryogen system design. The safety review considers ODH, freezing, and explosion hazards.
- The experimental cryogen system design is then reviewed by a panel of cryogen experts from SURF and other DOE institutions. Their recommendations are provided to the SURF Science Director who oversees implementation of the recommendations.
- The entire experiment, including cryogen safety, undergoes an EHS review by a panel of technical experts from SURF and other institutions. Recommendations as necessary are again made on systems, including cryogens, and implemented before an Experimental Authorization to Proceed is issued.

- Personnel working with cryogens must have formal training at their home institution and at SURF. This training is documented and followed by competency testing.
- Personnel working with cryogens must use proper personal protective equipment or PPE.
- Cryogen related SOPs and JHAs must be in place and approved in writing by SURF, the Experiment EHS coordinator and the Science Director.

Safety reviews and oversight are core requirements. For example, in rehabilitating the Ross Shaft, where hazards are present, there are regular safety reviews by multiple experts including workers to identify and reduce hazards. The project manager is responsible for safety and employs a team of EHS experts, shaft construction experts, a SURF EHS representative, and a project safety manager. Every worker reviews the SOPs, the hazards, and controls. Accordingly, every new or revised SOP and hazard evaluation is reviewed multiple times by multiple groups to assure safety.

3.4.2.2 Environmental Impacts

Proposed Action

Construction

The major safety concerns with the Proposed Action would primarily be the responsibility of Fermilab under the terms of the lease agreement. SURF would provide support for the construction as stated above. The work would include access, rock excavation (drilling, blasting, scaling, rock bolting), rock haulage, material handling, and use of powered equipment, hoisting and rigging. These hazards would be addressed by limiting access to the site and construction zones and adhering to both SURF and Fermilab ES&H and ISMs. Safety and health issues would be identified in the work planning and addressed by engineering, administrative controls, and the proper use of PPE. Work tasks would require JHAs or SOPs. Daily toolbox talks and work planning meetings would address risks to workers and the public and corresponding avoidance measures.

The construction of the Proposed Action would have the following estimated incidents per year corresponding to industry rates and the expected construction hours per year. For trucking the rock to the Gilt Edge Superfund site, the Proposed Action would result in an approximate total of 1,320,000 worker hours. Based on the industry incident rate for Heavy construction of 3.2, 21.2 work-related injuries and illnesses would be expected to occur during the 7-year construction period (approximately 3.0 per year). This estimate does not include transportation related injuries, which are presented in Section 3.7-2. Based on the industry DART rate of 1.8, construction would result in 11.9 DART cases (less than 2 per year). The calculated results are an estimate and do not imply that a particular number of accidents, injuries, or fatalities would actually occur. The rate of fatal work injuries for U.S. workers in 2012 was 3.2 per 100,000 full-time workers, down from the 2011 rate of 3.5 per 100,000 (BLS 2013). By comparison, neither Fermilab nor SURF has never experienced a fatal injury.

SURF would control site access, working under applicable Federal, State and local environment, safety and health standards (including OSHA 29 CFR 1926, 1910, and MSHA requirements as good management practices in the absence of OSHA requirements)) and under SDSTA's designated Authority Having Jurisdiction for Occupational Health and Safety. Activities taking place in common (not leased) areas would fall under both Fermilab and SURF ISMS standards.

The rehabilitated Ross Shaft and the existing Davis Campus area on the 4850 Level would be the principal route for worker access to the LBNF/DUNE detector construction site. The Davis Campus is in operation at the 4850 Level and currently hosts two physics projects: the LUX dark matter experiment and the Majorana Demonstrator neutrinoless double-beta decay experiment (**Figure 2.1-9**).

To alleviate the demand on the shaft and avoid logistical issues, engineering and administrative controls would be in place and administered by SURF to protect personnel near the Ross shaft on the 4850 Level and to alleviate the demand on the Ross shaft elevator. Examples include fixed schedules for blasting, establishing restricted access construction zones, and prohibiting walking under unsupported rock. Haulage equipment and track would be modernized, and an access drift would be created for workers going to the Davis Campus to circumvent the construction area. Material handling would be facilitated by increased speed of hoisting and lowering in the refurbished Ross shaft. New haulage equipment would meet modern safety standards for increased visibility, lower emissions, and fuel efficiency.

Rock removal and placement (conveyor to the Open Cut or trucking to the Gilt Edge Superfund site) would also be managed by Fermilab under the terms of the lease and governed by SURF and Fermilab work control standards. The underground travel route would be rock bolted and wire meshed to prevent rock fall. The rock crusher would be guarded and have controlled access. The Open Cut conveyor or trucking conveyor system would require fencing or enclosure to deter trespassing and limit public exposure to moving equipment. Stanchions supporting a conveyor system over or under roads would be protected by bollards to minimize accidental damage from cars and trucks.

Trucking the rock to either the Gilt Edge Superfund site or the Open Cut would include installation of a conveyor to transport excavated rock to the load-out station and transport by truck to the site. The conveyor for rock truck haul would be constructed on a steep hill and would require hill over-steepening to allow equipment to install concrete piers and footings. The steep slope would be fenced to prevent rock and other debris from falling onto Kirk Road. The selection of a subcontractor to truck rock to the Gilt Edge Superfund site or the Open Cut would consider contractor past incident rates and safety record. Controls would be considered to help prevent impacts including setting haul schedules, restrictions on Jake brake use, speed limits, additional traffic control signage, flaggers and dust control measures to maintain good visibility. This work would be completed by subcontractors managed by Fermilab.

During installation of the cryostats, cryogenic support equipment, and controls systems, workers would experience hazards typical to other detector installations. SURF/Fermilab employees, subcontractors, and LBNF/DUNE experimenters may encounter hazards associated with heavy equipment use; work in confined spaces (areas with limited egress); work at elevation/falls; electrical hazards associated with exposures to high voltage (utilities); exposure to dust, fumes, and noise; material handling, rigging, work off scaffolding, and handling hazardous materials. These hazards would be controlled by work practices addressed by the Contractor EHS controls that would meet both Fermi and SURFs standards.

Operations

The operation of the Proposed Action would require nine full-time employees which equates to 18,720 work hours per year. The current incident rate at SURF associated with experiments is 0 based on 36,000 hours for researches and, 8,348 hours for contractors. Using this incident rate of 0, it is estimated that the incident rate during operation of the Proposed Action would also be 0. This equates to no incidents over the operational period of 20 years. The principal safety concerns are access control, material handling, and slips, trips and falls. Access control would be achieved by adhering to the approval process for going underground. Sponsorship, training, guide accompaniment, and Trip Action Plans (TAP) must be in place before the Director of Underground Access would permit access. This is similar to procedures currently in place at SURF.

Material handling includes moving, handling and storing materials. These activities would be performed by SURF personnel to move equipment and supplies underground. SURF has and would continue to use its EHS program to reduce the risk of a material handling incident and to ensure worker and science safety. Material handling procedures would continue to be reviewed and training provided on a regular basis. Material handling equipment would continue to be inspected on regular basis. Employees would continue to be required to use necessary protective equipment and practice measures to help prevent injuries and equipment damage.

A large volume of LAr as well as a smaller volume of LN would be used during operations. Neither argon nor nitrogen is harmful to breathe at normal temperatures and both are naturally occurring in the atmosphere. However, their use as cryogens requires them to be in liquid form at extremely low temperatures. They can exist as liquids only well below normal ambient temperatures. Cryogens are hazardous because at their extremely cold temperature (the boiling points of N and Ar are -163 degrees C and -186 degrees C, respectively) they can quickly freeze tissue or modify the physical properties (including strength) on contact with other materials. Cryogens displace oxygen, creating ODH, which can result in asphyxiation. Cryogens are also potential explosion hazards because cryogens exposed to ambient air and pressure can expand up to 700 times their liquid volume, generating large pressures if contained.

Cryogen storage and handling systems would undergo careful design and review in accordance with current SURF and Fermilab policy and procedures. Staff working with cryogens would have the appropriate training and follow proper JHAs and SOPs designed to ensure cryogen safety. Special care would be taken in the design of the cryogen systems to ensure all of these factors were addressed. For example, an analysis would be performed to calculate the reduced oxygen levels from every probable failure point, and the ventilation system would be designed to ensure these levels remain safe. Redundant pressure relief systems would ensure containment vessels never exceed their design pressure. Special insulation would ensure all surfaces a person may contact remain at acceptable temperatures.

There would be no or only very, very low impacts from radiation at the Far Site. The LAr detector would not produce any radiation as the neutrino beam passes through it. Neutrinos are not radioactive and do not present a health concern to the public or researchers. Neutrinos naturally pass through our bodies constantly and in high numbers with no measurable impact. Radiation emitting devices associated with the Proposed Action are sealed source radioactive calibration devices that would be employed to help configure the detector. These small sources emit very low level radiation, which is not considered dangerous to the public or site workers. The sources are managed through Fermilab's and SURF's Radiation Safety Program, which provides for careful accounting, use, and storage of such instruments.

Fire safety is also an important operational consideration. A security and fire prevention plan would be developed in conjunction with SURF's Mine Rescue Manager, City of Lead Fire Chief, and the Lawrence County Emergency Manager and Lawrence County Sheriff.

The same cryogen hazards as described in the Proposed Action would be applicable to Alternative A. Locating the detector at surface provides the opportunity for easier ventilation control for ODH.

Alternative A

Construction

The construction of Alternative A experiments would be similar to construction of the Proposed Action in terms of rock excavation, crushing, rock haul and cavern outfitting. A total of 440,000 work hours is expected for the construction of Alternative A, based on the proportional volume of rock excavation relative to the Proposed Action, The expected number of incidents associated with Alternative A, assuming SURF's incident rate of 7.2 would be 15.8.

Construction of Alternative A experiments would adhere to the same Health and Safety provisions established for the Proposed Action. SOPs and JHAs would be well established from the Proposed Action construction. There would also be a list of lessons learned from near misses and incidents associated with the Proposed Action. These lessons learned would further identify likely causes of incident and controls would be in place to prevent similar accidents.

Operations

Conservatively and for the purpose of incident analysis, the operation of Alternative A could employ up to 4-6 scientists and 1 maintenance person for up to 20 years. Based on this scenario, this would equate to approximately 500,000 work hours. Using a SURF incident rate of 0, it is estimated that there would be 0 incidents associated with the experiments over the 20-year life of Alternative A.

Operation of the proposed underground experiments would follow SURF ISMS requirements and would not be expected to use or produce substantial amounts of hazardous materials, thus minimizing impacts on the public.

No Action

Under the No Action Alternative, existing health and safety hazards would continue to be addressed by ongoing implementation of established engineering and administrative controls. The No Action Alternative does not relieve SURF of the ISMS principals, training, and JHA responsibilities it currently conducts.

3.5 HYDROLOGY AND WATER QUALITY

This section describes existing hydrologic and water quality conditions at Fermilab and SURF and evaluates potential environmental impacts from construction and operations of the Proposed Action and alternatives on surface and groundwater hydrology and water quality. The affected environment includes adjacent surface waters, areas susceptible to flooding, and groundwater potentially affected by runoff and spills. At Fermilab, it also includes groundwater potentially affected by formation of radionuclides. The hydrology evaluation presented below is in support of DOE's requirement to complete a floodplain assessment as required by 10 CFR 1022 and related Executive Orders (EO) and DOE Orders.

3.5.1 Fermilab

3.5.1.1 Affected Environment

Surface Water Hydrology

Fermilab is located between two river systems – the Fox River and the West Branch of the DuPage River, which both flow north-to-south. The Fox River flows into the Illinois River near Ottawa, Illinois. The West Branch of the DuPage River flows along the DuPage-Cook County line to its confluence with the East Branch DuPage River near Naperville and then into the Illinois River near Joliet, Illinois.

Three creeks drain the Fermilab property, including Kress Creek, Ferry Creek, and Indian Creek. Kress Creek crosses the northeast corner of Fermilab, flowing east to the West Branch of the DuPage. Ferry Creek flows southeast to the West Branch of the DuPage. Several Ferry Creek tributaries were dammed to create on-site cooling water ponds (DUSAF Pond, AE Sea, Sea of Evanescence, and Lake Law). Indian

Creek flows to the south along the western edge of Fermilab and off-site at the lab's southwest corner and then to the Fox River at Aurora, Illinois.

Low-lying areas adjacent to Indian Creek in the infield of the MI, as well as to the north including Cooling Pond F and adjacent Indian Creek tributaries, are in the currently-mapped 100-year floodplain (**Figure 3.5-1**) (Federal Emergency Management Agency [FEMA] 2009). The 100-year flood has a 1 percent chance of occurring in any given year. FEMA has not determined base flood (100 year) elevations for this area; however, given the lack of topographic relief, the presence of agricultural fields and restored prairie, previous grading needed for construction of the MI and surrounding cooling ponds, and the precise elevation controls needed for operation of the MI, flooding in this area would likely be very shallow.

Stormwater and cooling water are discharged in accordance with an NPDES permit (IL0026123). The six outfalls identified in the permit are monitored for tritium, pH, and flow. In addition, the outfalls to Indian Creek and Kress Creek are monitored for total residual chlorine. Four of the site's six outfalls discharge to Indian Creek, although several of these discharges have little or no flow. Regulatory limits have been established for all these parameters with the exception of tritium for which there is no regulatory limit in Illinois. Since tritium was added to the permit in 2008, the highest reported concentration has been 3.7 pCi/ml and 13 out of 20 (65 percent) reported values have been below the analytical detection limit of 1.0 pCi/ml.

Surface Water Quality

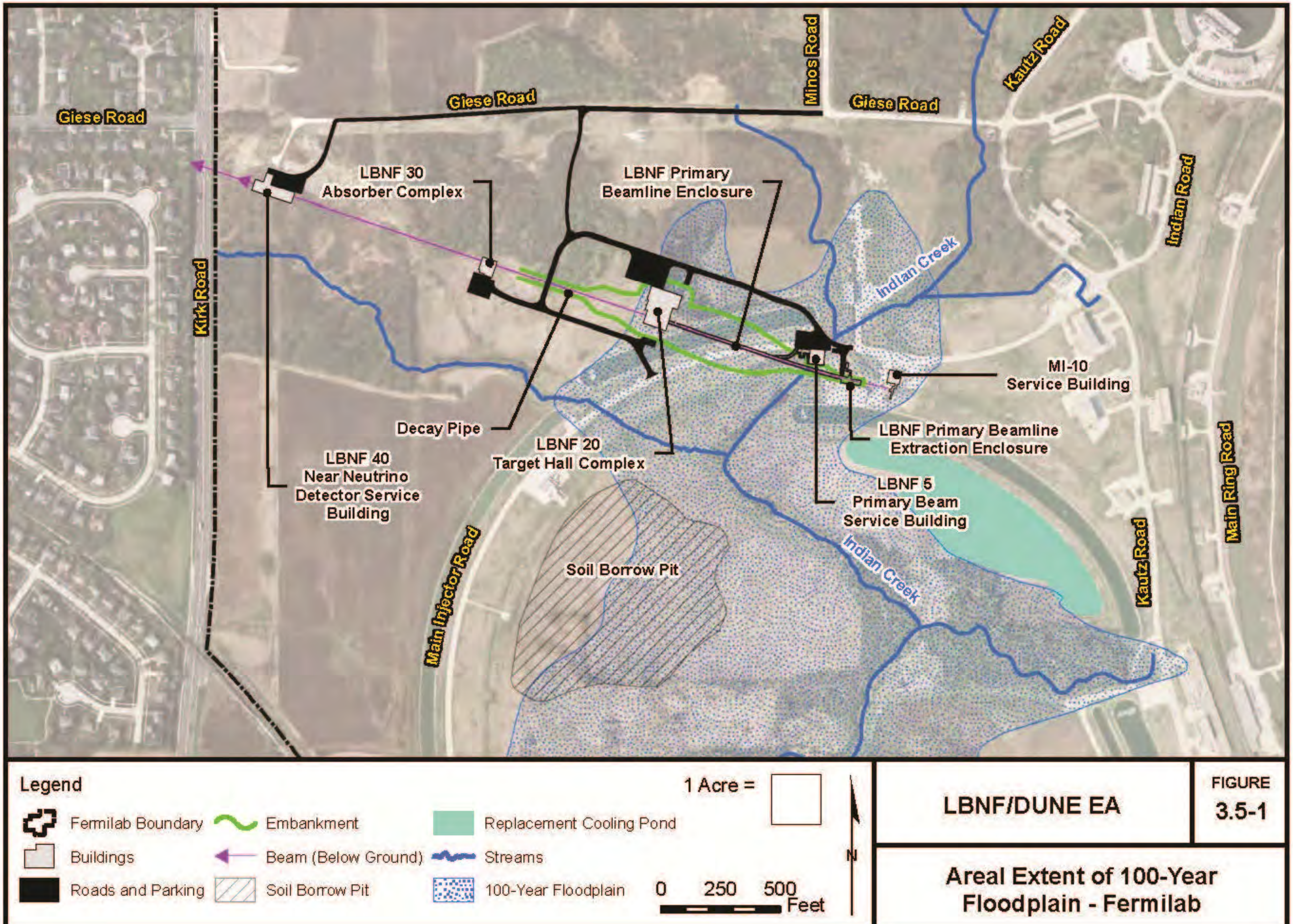
Fermilab implements an Environmental Monitoring Program to provide data on Fermilab's impacts on the surrounding environment, including surface water. Fermilab has numerous on-site sumps that collect water from buildings and beneath beamline tunnels in the Tevatron, MI, and other experimental areas. These waters typically contain low concentrations of radionuclides. However, tritium concentrations in the ICW ponds are typically well below DOE surface water standards for tritium (1,900 pCi/ml) as defined in 10 CFR 835 (DOE Order 458.1) (DOE 2011a) and DOE-STD-1196-2011 (DOE 2011b). Fermilab also measures other radionuclides in the ponds. For example, sodium-22 concentrations are typically below the analytical detection limit of 0.01 pCi/ml, which is well below the DOE Derived Concentration Technical Standard of 10 pCi/ml (DOE 2011b).

The Illinois EPA (IEPA) 303(d) report lists Indian Creek as an impaired water; however, no nonpoint source or other watershed studies (e.g., Total Maximum Daily Load [TMDL]) are currently planned. Chloride and fecal coliform attributed to urban runoff, storm sewer discharge, and sewer overflows currently exceed water quality standards (IEPA 2013). The USEPA defines an impaired waterbody as one where required pollution controls are not sufficient to attain or maintain applicable water quality standards.

Groundwater Hydrology

Groundwater at Fermilab and the proposed LBNF/DUNE area is found in three main aquifers: the glacial drift aquifer and the shallow and deep bedrock aquifers. Within the glacial drift aquifer, groundwater is intermittently present within discontinuous silt, sand, and gravel lenses. This groundwater is considered Class II water by IEPA and is not subject to the stricter standards for Class I ground water. The IEPA publishes groundwater quality standards (35 IAC, Part 620) and defines Class I groundwater as a non-degradable resource, which is to be highly protected. Water residing in or near the Silurian dolomite bedrock aquifer, the upper surface of which is 60 to 100 feet below ground surface (bgs) at Fermilab, as well as water in the overlying Quaternary Batestown Member, is classified as Class I groundwater according to criteria published by the IEPA (35 IAC 620.210) (IEPA 1998; Fermilab 2012e). Water in the Quaternary deposits overlying the Batestown has been demonstrated to be Class II water (35 IAC, Part 620) requiring less stringent standards.

Absolute Scale - 1:7,200
1 inch = 600 feet



LBNF/DUNE EA

FIGURE
3.5-1

Areal Extent of 100-Year Floodplain - Fermilab

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As described in Section 3.10, Geology and Soils, the glacial drift units are 60 to 100 feet thick. Groundwater flow in these deposits is generally downward and slow. The average water table fluctuates seasonally between 5 and 15 feet below ground surface (bgs), with a minimum depth of approximately 2 feet adjacent to Cooling Pond F. The upper portions of the Silurian bedrock are approximately 150 feet thick and have low primary porosity, but contain secondary porosity in the form of joints and fractures. This zone of high secondary porosity is referred to here as the shallow bedrock aquifer and is composed primarily of the Upper Bedrock Aquifer per Illinois State Water Survey terminology. The shale-dominated Brainard Formation provides lower confinement of the shallow bedrock aquifer.

Groundwater Quality

Fermilab conducts groundwater sampling pursuant to the Fermilab Ground Water Protection Management Plan (Fermilab 2008b) to identify migration of radiological or chemical contamination from beamlines or other experimental areas. Fermilab groundwater is affected by radiation when the shielding around high-intensity beam loss areas or around the beam targets becomes radioactive (i.e., “activated”). Radionuclides formed by this process can leach into groundwater. Of the leachable radionuclides produced by Fermilab operations, tritium (H-3) and sodium-22 are the only radionuclides produced in volumes that could affect water quality and that warrant long-term monitoring under Fermilab’s Environmental Monitoring Program.

Low levels of H-3 (less than 80 pCi/ml in non-regulated, Class II groundwater) have historically been detected in source-specific wells screened in the glacial tills beneath local experimental areas. The shallow depth, local source and extremely low migration rates of water through the glacial till make the probability of tritium reaching regulated groundwater extremely low. The tritium in these groundwater units has ample time to undergo radioactive decay to levels below detection limits before reaching any Class I waters.

Groundwater from the lower aquifers migrates inward into the NuMI tunnel, where it is collected and injected into the ICW system to be used for cooling. This water contains low levels of tritium (from 5 – 75 pCi/ml). This system ensures that Class I groundwater in the area of the NuMI tunnel remains free of tritium contamination.

The groundwater within the lower glacial deposits, Batestown Member, and Henry Formation deposits can be hydraulically connected to the bedrock and can be classified as Class I groundwater. Groundwater within the upper glacial deposits is Class II groundwater. The DOE Derived Concentration Technical Standard (DOE-STD-1196-2011) and the Illinois Class I groundwater standard for tritium is 20 pCi/ml. To date, no detectable levels of radionuclides have been found in the Class I water of the upper aquifer, including in 2014 when 28 samples were all below detection limits (Fermilab personal comm. 2014).

Recharge of the Class II groundwater in the glacial deposits beneath the area proposed for construction and operation is through infiltration of precipitation and percolation from surface waters at a very slow rate. The various confining layers effectively insulate the Class I bedrock aquifers from potential surficial radionuclide and chemical contamination due to dilution and radioactive decay during the long periods required for water to percolate downward. Measured vertical migration rates range from 0.12 to 0.036 foot per year. Recharge rates to the bedrock aquifer from the glacial deposits range from approximately 0.3 to 4.8 inches/year, with a median rate of 2.9 inches/year.

3.5.1.2 Environmental Impacts

Proposed Action

Construction

Surface Water Hydrology

During construction of the Proposed Action, potential impacts on surface water hydrology would be low. Construction of the embankment would have direct impacts on surface flows and would require modifications of Indian Creek. Indian Creek crosses the area of the proposed embankment at LBNF-5. Construction would require the excavation of approximately 240,000 yd^3 of soil for the structure, creating a large "borrow pit" located in upland area within MI, which would modify surface water flows in the area. The creek currently flows through a series of culverts through the vicinity of the MI-10 and -12 complex and over the MI just south of the proposed location of LBNF-5. The Proposed Action would include construction of a dual box culvert of approximately 500 feet long that would convey the creek beneath the embankment and discharge to the existing Indian Creek channel south of the MI. This structure would be designed to pass the 100-year flood with no increase in upstream or downstream flood stage. An alternative design would allow some flood storage upstream of the culvert. These modifications would be incorporated into a CWA Section 404 permit from the USACE (Section 3.2, Biological Resources) and IDNR floodplain review.

Structures associated with the Proposed Action, including the Primary Beam Enclosure, embankment, and Target Hall, would be constructed partially within the currently-mapped 100-year floodplain. Therefore, Fermilab and DOE must comply with EO 11988—Floodplain Management (May 24, 1977) and 10 CFR 1022, which require Federal agencies to evaluate the potential effects of its actions on floodplains.

Based on existing FEMA Flood Hazard Boundary Maps (**Figure 3.5-1**), the Proposed Action would be located in a base floodplain. The Primary Beam Enclosure, embankment, and Target Hall would cross floodplain areas adjacent to Indian Creek. The area does not support occupied structures, and the upstream portion of the Indian Creek watershed is small; therefore, the potential for flood hazards on the Fermilab property would be low. Construction in the Indian Creek floodplain would reduce flood storage capacity when flood flows exceed the hydraulic capacity of downstream reaches of Indian Creek. However, the floodplain encompasses large flat areas including the infield of the MI and wetland areas to the north. This area is historically farmland and accommodates a circular series of large cooling ponds.

The area supports restored prairie habitat and has very limited topographic relief. Although FEMA has not determined flood elevations in this area, floodwaters in this area would be very shallow, as floodwaters would spread over a large area. Further, the Proposed Action would not encroach on downstream reaches of Indian Creek in FEMA floodway Zone AE (high flood risk area, which allows floodwaters to recede. To better define the floodplain and potential floodplain impacts, Fermilab will request a determination of the floodplain elevation as part of its Section 404 application. The flood mapping states that the stream channel downstream of the MI must be kept free of encroachment to allow the 100-year flood to recede.

Floodplain Management EO 11988 (42 F.R. 26951) requires Federal agencies to comply with flood protection standards, including construction of Federal structures and facilities in accordance with the standards and criteria promulgated under the National Flood Insurance Program as appropriate for the type of structure or facility. Facilities in the floodplain must have accepted flood-proofing and other flood protection measures. As required under this EO, pending a new floodplain determination, Fermilab would elevate LBNF/DUNE's structures above the base flood level and would not fill surrounding lands beyond that necessary for construction and operation of LBNF/DUNE. Facilities below flood elevations, such as storage areas for activated components, would be equipped with watertight structures (e.g., flooring), redundant sump systems, and backup power generation to ensure that these areas would not be inundated by floodwaters.

During design, pending a new floodplain determination, lost flood storage capacity would be delineated and compensatory floodplain storage volume provided according to standard Fermilab procedures, and FEMA and IDNR regulations. By maintaining the drainage's surface hydrology (flow directions), as well as SEPMs that would provide adequate stormwater retention for added impervious surfaces and compensatory flood storage capacity, the Proposed Action would have low impacts on floodwaters.

<u>Surface Water Quality</u>

The Proposed Action could have potential impacts on surface water quality during excavation of borrow areas, construction of the embankment, and other ground-disturbing activities. Impacts to surface water quality would be low. Multiple ground-disturbing activities would occur under the Proposed Action; including excavation; grading; stockpiling of excavated soil and rock from the Absorber Hall excavation; and construction of surface features such as service buildings, parking lots, staging areas, and access roads. Construction of the embankment would expose soils to rain and wind erosion during the placement and compaction of the soil prior to revegetation. Trenching, grading, and stockpiling activities would, if not properly addressed, result in exposing bare soil that could be eroded by wind and rainfall and ultimately transported to Indian Creek. The resulting sedimentation could degrade water quality, and channel siltation could affect hydraulic capacity and habitat quality. Work in wetlands and Indian Creek would require a CWA Section 404/401 Joint Individual Permit and Water Quality Certification.

Potential impacts on water quality would include increased turbidity in Indian Creek, surface waters created by the borrow pit, and downstream waterways. Minor increases in turbidity and sediment load would not be expected to influence the inclusion of Indian Creek on the IEPA 303(d) impaired water bodies list. Fermilab would be required to apply for a construction stormwater general permit (ILR10). Stormwater would be managed according to Fermilab's existing Storm Water Pollution Prevention Plan (SWPPP) as well as an LBNF/DUNE-specific SWPPP in accordance with the general permit, IEPA regulations and Fermilab ES&H Manual section 8012, Sedimentation and Erosion Control Planning. Stormwater BMPs would be used to control erosion, minimize degradation of water quality, and comply with local stormwater regulations.

Groundwater pumped for dewatering would be treated to remove suspended solids and to ensure compliance with water quality standards and discharged within the Indian Creek watershed. This discharge would require a modification of Fermilab's existing NPDES permit. Increased discharge rate and flow velocity within Indian Creek would be expected during this phase of construction.

Implementation of the SWPPP would include installation and maintenance of proper soil erosion barriers around all disturbed soil and rock stockpile areas as specified in the Illinois Urban Manual (National Resource Conservation Service [NRCS] 2002a). The SWPPP would require a combination of BMPs such as silt fences, hay bales, and other measures such as excavated temporary waterways to direct stormwater away from wetlands and sensitive resources and to detain water long enough for the sediment to settle prior to flowing into surface water. Containment measures would be used around the embankment to protect slopes and to prevent transport of eroded soil into surface waters during storm events. Fermilab would develop and implement a site-specific monitoring plan for sampling runoff and receiving waters during wet weather to ensure compliance with water quality standards. Fermilab would minimize impacts on water quality by implementing its existing stormwater management program and site-wide SWPPP, preparing and implementing an LBNF/DUNE-specific SWPPP, and employing the same methods used to control erosion during the recent construction of the NuMI and NO*v*A projects.

Construction could also generate minor amounts of oily debris, cement truck washout, paint waste, paint solvent, and minor petroleum contaminated soils typically resulting from equipment hydraulic line breaks or leaks. Pollution prevention regulations (40 CFR 112) require facilities that store more than 1,320 gallons of oil on-site to have an SPCC plan. The SPCC plan would provide details regarding the site oil inventory, work procedures, and SEPMs specific to release prevention and countermeasures. Accordingly, fueling and fuel storage could have potential impacts on water quality and would be managed according to Fermilab's SPCC plan. The Fermilab ES&H Manual (8031) also addresses SPCC requirements and secondary containment requirements. Finally, the construction SWPPP would also outline further SEPMs, including pollution prevention BMPs that would focus on the proper storage and use of hazardous materials.

Groundwater Hydrology

Construction of the Decay Pipe, Absorber Hall, and NND would require excavations to depths below groundwater elevations. Construction within these excavations would require groundwater pumping throughout construction, which would result in some localized groundwater drawdown but no substantial changes in flow direction, elevation, or quantity. The drawdown and increased flow would be localized and temporary during construction. To minimize groundwater flows into the excavation site, construction crews would seal the bedrock with shotcrete, sealing fractures and reducing the volume of groundwater entering the excavation. Impacts to groundwater hydrology would be low.

Groundwater Quality

During construction of the Decay Pipe, Absorber Hall, and NND, the related excavation would require dewatering to keep the excavation dry for construction workers and equipment. Groundwater would be collected in a sump at the base of the excavation and pumped continuously to the surface, where it would be treated to reduce turbidity and subsequently discharged to the ICW ponds and/or the Indian Creek watershed. The treatment and discharge would require a modification to Fermilab's existing NPDES permit. Impacts on groundwater quality during excavation of facilities below the water table would be minimized by grouting the bedrock at the base of excavations to minimize groundwater inflow. Groundwater contamination would also be minimized by the SPCC and SWPPP BMPs designed to minimize releases of oil, fuel, solvents, and other construction materials. Impacts to groundwater quality would be low.

Operations

Surface Water Hydrology

Stormwater runoff from the service buildings, adjacent loading and parking areas, and other impervious surfaces would be retained such that the increase in impervious surfaces would not result in an increase in peak stormwater flows. The Proposed Action would comply with existing stormwater regulations and SEPMs that would allow percolation of stormwater in detention basins or similar BMPs. Collected stormwater would be directed to the cooling ponds and recycled through the permitted ICW system. Therefore, operation of the Proposed Action would have no impact on flooding.

Surface Water Quality

Operations would have low effects on surface water quality. Operational stormwater BMPs would be used to protect water quality in Indian Creek and surface waters created by allowing the borrow pit to fill with water. Pumped groundwater would be collected and discharged to the ICW ponds or into the Indian

Creek watershed. For the NOνA project, Fermilab determined that, even under drought conditions when radionuclides would be most concentrated (Martens 2007), neither tritium nor sodium-22 concentrations would exceed surface water quality standards. Calculations showed that under drought conditions, tritium concentrations would be approximately 25 to 50 pCi/ml (DOE limit of 1,900 pCi/ml) and that sodium-22 concentrations would be below detection limits (0.3 pCi/ml; DOE limit of 10 pCi/ml). Therefore, cooling water discharges to Indian Creek would have low impacts on water quality. Furthermore, even in the event of a 500-year flood, ICW discharges to Indian Creek would be covered by Fermilab's NPDES permit. In 2005, tritium was detected for the first time at the Indian Creek outfall location at the southwest corner of the lab. Since that time, Fermilab has instituted additional measures to reduce these tritium concentrations, including routing tritiated groundwater from MINOS to the ICW system and cooling towers and reducing tritium production from NuMI by dehumidifying the air in the tunnels and evaporating it into the air. In addition, Fermilab monitors water quality in Indian Creek (Fermilab 2012e).

Vehicle use by maintenance workers and researchers during Proposed Action operations could result in increases in oil and fuel use and increased concentrations of oil and fuel in stormwater runoff from parking lots and roadways if not maintained. However, runoff from all parking lots, access roads, and loading areas would be managed through SEPMs, including BMPs required by the site-wide and LBNF/DUNE-specific SWPPPs. In addition, pollution prevention (source reduction) SEPMs would be applied to all aspects of the Proposed Action operation as outlined in the Fermilab ES&H Manual, including recycling and proper disposal. Impacts to surface water quality would be low.

Groundwater Hydrology

Operation of the Proposed Action would have limited and localized impacts on groundwater flow. The beamline's underground enclosures would operate in the glacial drift aquifer and surface of the upper bedrock aquifer. Groundwater collection and pumping would have a localized impact on groundwater flows around the Decay Pipe, Absorber Hall, and NND, and localized drawdown. Impacts to groundwater hydrology would be low.

Groundwater Quality

As described in Section 2.1, and like previous Fermilab experiments such as NOνA (DOE 2008a), the Proposed Action would be designed to minimize water quality impacts during operations. Impacts to groundwater quality would be low. Construction of the Primary Beamline Enclosure and Target Hall within the embankment (i.e., above the ground surface) would reduce the depth of the other excavations, which would minimize exposure of groundwater to radiation generated by the proton beam. To minimize activation of adjacent soil and groundwater, the Decay Pipe would be shielded with 18 feet of cast-in-place concrete. Similar to the design for the NOνA project, the Proposed Action would be designed to maintain groundwater radionuclide concentrations at below DOE surface water standards and EPA drinking water standards. Furthermore, the groundwater near the LBNF/DUNE shielding would be part of the glacial drift aquifer, which is subject to institutional controls on the Fermilab property, and not available for consumption as part of a Class 1 groundwater resource. In addition, as described below, site groundwater has very slow seepage velocities, and drinking water wells are located at a substantial distance from the Fermilab boundary.

Local public drinking water supplies are not derived from this shallow groundwater but rather from the deep aquifer at a minimum of 700 feet below ground level. Private wells are generally in the shallow bedrock aquifer at 200 feet (Martin 2009). The closest municipal water supply well is located approximately 1.4 miles west of Booster Ring Road. Some private wells have tapped groundwater at depths from 25 to 100 feet bgs (IEPA 1998, 2000). These drinking water wells are protected by wellhead protection regulations under the Illinois Groundwater Protection Act (IGPA), which provides for well setbacks, land use regulation, groundwater quality standards, and detailed assessment of threatened community wells and their aquifers, as necessary.

Groundwater quality would be protected by installing a geosynthetic barrier system around the Decay Pipe and Absorber Hall as well as a moisture interceptor system. The geosynthetic barrier system would consist of a geomembrane, a geosynthetic clay liner (GCL), and a leak detection system to reduce groundwater infiltration. The interceptor system provides a redundant, secondary system should the geosynthetic barrier system be compromised. These measures isolate groundwater from the source of activation, thereby severely limiting the potential for radionuclide production.

As described above, the Absorber Hall and Decay Pipe excavation into bedrock would be grouted to minimize exposure of groundwater. A sump would direct groundwater to the Indian Creek watershed or the ICW ponds. These ponds are underlain by naturally occurring clay, further minimizing migration of radionuclides to the groundwater. Groundwater that seeps through to groundwater in the glacial deposits would be unlikely to migrate off-site. Downward flow is a major component of the flow direction within the upper Quaternary deposits. Vertical seepage velocities range from 0.12 to 0.036 foot per year, whereas horizontal seepage velocities range from 0.0006 to 0.14 foot per year (Fermilab 2008b). In addition to the redundant interceptor system and bedrock grouting, Fermilab would evaluate the installation of a monitoring well program adjacent to these structures to allow sampling of each of the shallow bedrock zones. The number of monitoring wells and their specific locations has yet to be determined, but would be based on the Fermilab Groundwater Monitoring Plan.

Operation of vehicles and maintenance activities could affect groundwater quality without protective measures in place. However, operation of the Proposed Action would only require chemical use indoors and in small quantities and impacts on groundwater would be minimized through SEPMS and by implementing the SPCC and SWPPP, which both contain operational BMPs. Impacts to groundwater quality would be low.

No Action

Under the No Action Alternative, no additional impacts on surface water or groundwater hydrology or water quality would occur because Fermilab would not conduct excavation or construction. No impervious surfaces would be added to the site, and no additional stormwater would be generated. Further, the No Action Alternative would not involve operation of a new beamline; therefore, there would be no potential to produce radionuclide contamination within groundwater adjacent to the beamline shielding. Hydrology and water quality impacts from current construction and operations would continue, and Fermilab would continue to address those impacts through existing water quality controls and flood abatement measures.

3.5.2 SURF

3.5.2.1 Affected Environment

Surface Water

SURF is located within the Whitewood Creek watershed, a perennial mountain stream consisting of generally steep banks with cobble and gravel substrates, which flows into the Belle Fourche River within the greater Missouri River basin. Whitewood Creek drains an estimated area of 56.7 square miles, and has an average annual stream flow of 28.2 cubic feet per second (cfs) (United States Geological Service [USGS] 2013).

The SURF site is characterized by a continental climate of dry summers and wet winters and springs. The average annual precipitation is 27.4 inches (from SURF database years 1909-2011) and generally reflects the area's orographic effect of increasing precipitation with increasing altitude (Carter et al. 2002).

Surface water flows are strongly influenced by the low primary permeability crystalline metamorphic rocks in and above the proposed construction area (Davis et al. 2003, Carter et al. 2002). Precipitation does not readily seep into the rocks, but rather evaporates or runs off into streams. Supporting this observation are hydrographs of Whitewood Creek, which typically show sharp spikes and declines correlated with precipitation events (Carter et al. 2002).

Mining wastes and raw sewage were discharged into Whitewood Creek from early 1875 until 1977 (Williamson and Hayes, 2000). In 1972 the Federal Pollution Control Act was passed and resulted in several activities to clean up Whitewood Creek which included construction by Homestake of a tailings dam in 1977 for mine waste collection and a wastewater treatment plant in 1978. Homestake later rehabilitated the Whitewood Creek tailing sites in 1986, 2001 (Red-X placer site) and 2002 (Wasp Mine tailing). The Cities of Lead and Deadwood constructed a publicly owned treatment works (POTW) in 1979.

Whitewood Creek is classified as a Marginal Cold Water Fishery downstream of its confluence with Gold Run Creek. The temperature limit associated with this stream classification is 75^{o}F. Whitewood Creek upstream of Gold Run Creek confluence is classified as a Cold Water Fishery and has a water quality temperature standard maximum of 65^{o} F. This portion of Whitewood Creek is on the state's 303(d) impaired waterbody list for exceeding the water temperature standard (SDDENR 2014). Three other streams in the Northern Black Hills are also on the 303(d) list for temperature impairment, which suggests that temperature impacts may not be limited to Whitewood Creek and are possibly related to low flow and land development (Williamson and Hayes 2000).

SURF continues to treat and discharge water collected from the former underground mine and Homestake's tailing dam to remove ammonia and heavy metals prior to discharge to Gold Run and Whitewood Creek in compliance with NPDES permit requirements. SURF conducts regular water quality monitoring and annual bioassessments (GEI 2012, 2013, 2014). Water quality data from Whitewood Creek are collected regularly by the State of South Dakota and SURF above and below the confluence of Gold Run Creek. The SURF data reveal that surface water meets water quality standards, including the temperature limit of 75^{o} F for protection of a marginal cold-water fishery, specified for this portion of Whitewood Creek.

The hydrology of the Black Hills is determined by the geology. The sedimentary units surrounding the older crystalline core rocks are considered the primary water-bearing units in the Black Hills region and are not present in the affected area. As a result, the hydrology in the affected area is controlled by rock fractures and along the shallow alluvium-bedrock contact where surface water percolates through porous soil and encounters hard and compact crystalline rock. The hydraulic conductivity and average porosity of the crystalline core is estimated to be 10^{-7} cm/s (Zhan and Duex 2010) and 0.01 percent (Rahn and Roggenthen 2002), respectively. The low permeability of the crystalline rocks affects regional hydrology by limiting deep infiltration and lateral groundwater movement into surrounding streams (Zahn 2003).

Local water well data support the presence of two groundwater regimes - shallow and fracture controlled. Drinking water has not been affected by mining activities and meets groundwater standards (Homestake Mining Company, 2013). The source water for these wells is shallow groundwater consisting primarily of infiltrated storm water. The closest surface water well is 0.5 mile south of the Ross Shaft and 0.5 mile west and up-gradient of the proposed construction area.

The rock contains man-made openings (e.g., shafts and tunnels) and fractures that allows surface water in collected in the Open Cut and ground water traveling along fractures to move to the saturated underground water pool at the SURF's 5600 Level. The underground water is not artesian and as a result there is no upward force causing underground water to mix with perched or shallow water. Water pumped from the underground has created a cone of depression in which groundwater surrounding mined-out areas flows inward and downward to the underground pool. The pool water is treated through SURF's water treatment plant.

The Homestake Mine and SURF have been dewatering the underground mine for more than 100 years. Approximately 1200 million tons of excavated rock and tailings have been backfilled into various underground openings (Zahn 2002). Different rock formations have been included in this backfill including the Poorman, Ellison, Homestake, and Tertiary rhyolite. In many instances, these backfilled areas have been flooded and re-flooded with groundwater coincident with precipitation events and mining activities such as washing walls, pumping of sumps, and other activities. During this time, underground water quality has not deteriorated. The assessment of the water quality during the closure of the Homestake Mine concluded that the "mine water is generally good and that there are no indications of acid mine drainage" and "mine (underground) water contains small concentrations of arsenic, sulfate, and TDS that are above state groundwater standards" (Nelson, 2003). The term "good" in this context indicates that the water would meet discharge standards with minimal treatment.

Table 3.5-1 lists water groundwater standards and representative SURF underground water concentrations before and after water treatment. Groundwater in the underground is pumped, treated and discharged through a permitted outfall.

Table 3.5-1 A Comparison of Groundwater Standards and Representative Sanford Underground Water Untreated Before Discharge

Parameter	Groundwater Standard[1] (mg/L)	Representative Underground Pool Water Concentration *before* WWTP Treatment (mg/L)	Representative Discharge Concentration *after* WWTP Treatment (mg/L)
Arsenic	0.01	0.032	0.014
Cadmium	0.005	<0.001	<0.001
Chromium	0.01	<0.001	<0.001
Copper	1.0	0.006	<0.005
Iron	0.3	10.0	<0.01
Lead	0.015	<0.001	<0.001
Mercury	0.002	<0.0002	<0.0002
Nickel	none	0.007	0.006
Selenium	0.05	<0.005	<0.005
Silver	0.1	<0.001	<0.001
Zinc	none	<0.050	<0.050
pH	6.5-8.5	7.8	8.1
Ammonia	Seasonal	10.0	<0.02

Notes:

1 When the *ambient* pH or concentration of any water contaminant exceeds the standard specified, the ambient pH or concentration is the allowable limit.

Due to the presence of iron and ammonia, the underground pool water quality does not meet surface water quality standards for color, arsenic, and nitrogen-ammonia. The water must be treated before discharge to surface water. In general, pool water quality has improved (lower iron and ammonia) since 2008 when pumping the pool water was resumed after 5 years of no pumping. The improvement resulted from lower residence times for wall-rock equilibrium, the mineralogy of the wetted rock, and the relative increase in surface water input to overall pool volume (Logsdon 2003).

Floodplain Analysis

Whitewood Creek is identified as Zone A floodplain on the Lawrence County Flood Insurance Rate Map (FIRM). An additional detailed hydraulic analysis of Whitewood Creek was performed in order more accurately to define the 100-year floodplain boundary (HDR 2013). The affected area receives drainage from 23.6 square miles. The direction of flow is from the geographic southwest to northeast and has an average channel slope of 131.7 ft/mi which was determined using USGS topographic maps. The 100-year flow was determined to be 3,266 cubic feet per second (cfs).

3.5.2.2 Environmental Impacts

Proposed Action

Construction

Construction of the Proposed Action would involve several activities that have the potential to affect groundwater or surface water quality. These activities include rock excavation activities on the 4850 Level, transporting the rock to the Gilt Edge Superfund site or Open Cut. However, the potential impacts on surface water and groundwater quality would be low for the reasons described below.

The underground detector cavern would be constructed in the Poorman Formation. This formation was tunneled through many times to access Homestake ore over the past 100 years. Excavated rock from the tunneling has been backfilled into the mine in both wet and dry areas. Previous backfilling of waste has not adversely affected the groundwater quality or its treatability (i.e., the Poorman rock excavation and backfill into the mine has not introduced incremental contamination to underground water).

SURF recently conducted a geochemical assessment of the rock planned to be excavated for the Proposed Action (**Appendix D**). This report concludes that the excavated rock would neutralize acid mine drainage and would only minimally leach metals or other contaminants. This report and the historical evidence suggest that rock placement at the Open Cut would not adversely affect groundwater or surface water quality.

Groundwater on the 4850 level could be impacted by dust, rinsing of shotcrete equipment, oils and greases, and drilling fluids. These potential impacts would be minimized as water generated during construction would be treated at SURF’s waste water treatment plant. In addition, all products and chemicals used underground would be reviewed in advance of construction by SURF’s environmental department to determine if they would affect the water treatment process in the event of a spill. Chemicals and products that could compromise the water treatment process would either not be allowed on-site or, SEPMs would be specified. For instance, if petroleum-contaminated water could mix with underground (or pool) water and affect the treatment plant, petroleum-absorbing booms and pads would be installed in the underground pumping stations’ rock sumps to soak up floating petroleum products. This measure was employed successfully during mining operations when petroleum was routinely used underground.

The lime contained within the shotcrete that would be used to coat the cavern walls could also affect underground water quality. The regular wash-down of the shotcrete equipment increases the alkalinity and pH of the water, which in turn drains to the underground pool. To minimize pH effects, wash water would be diverted to sumps and neutralized. Because the pH of the water would be below 12.5, the process would not be considered treatment under the Resource Conservation and Recovery Act (RCRA) and the resultant solids would not be considered a hazardous waste. However, SURF would be required to obtain a new Underground Injection Control (UIC) permit by Rule from EPA and the State.

Trucking the excavated rock to the Gilt Edge Superfund site (or the Open Cut) could affect surface water should the trucks experience hydraulic fluid or oil leaks. SURF SEPMs would require trucks to carry and maintain spill response equipment, perform pre-shift inspections, and maintain equipment. Rock spills would be cleaned up immediately and loaded onto trucks bound for the rock placement area. All vehicles would also be subject to routine maintenance and inspection in order to minimize the potential for incidental leaks during trucking.

Construction of the underground detector would have low impact on groundwater and surface water quality. Contaminant loading from the rock would be minimized by SEPMs as well as design measures, including water collection and treatment at the Gilt Edge or SURF waste water treatment plants.

Operations

The operation of the Proposed Action has the potential for a low impact on groundwater and surface water quality. Condensate from the mine air interacting with the cold detector would be less than 5 gpm and would be collected in a sump and discharged to mine water after initial monitoring to ensure that condensate water quality is of better quality than mine water. If the condensate water were found to be of lower quality than the mine water, an EPA underground injection control (UIC) permit by Rule would need to be obtained. In general, the small amount of condensate water added to the mine water (in the billions of gallons) would not adversely affect or measurably alter existing mine water quality.

Sanitary waste would be collected in a tank and brought to the surface for treatment at the Lead-Deadwood Sanitary WWTP. This is the current procedure for sanitary wastes produced by existing underground experiment users. No floodplains would be impacted by the operation of the Proposed Action.

Alternative A

Construction

The construction of future experiments, including the possible excavation of a 153,000 yd^3 experiment hall, would take place in the Poorman Formation and would have low impacts to surface water or groundwater. The geochemical report (Geochimica and SRK Consulting 2015) on the Poorman Formation rock highlight the very limited ability of this rock to leach metals or create acid mine drainage. Consequently, if Alternative A excavation rock is transported to the Open Cut, water would not require additional treatment and waste water treatment plant processes would not be affected.

Stormwater controls and other SEPM's to protect surface water and ground during the construction activity would be implemented as outlined in the Proposed Action.

Operations

The operation of these experiments would not adversely impact groundwater or surface water. A small amount of ground water is expected to interact with shotcrete surfaces. As in construction, this water may need to be treated to reduce the pH. In addition, the experiments would employ a small amount of pure water using small reverse osmosis (RO) water treatment equipment. Brine from RO units would be discharged to the underground. Quality of RO brine from existing experiments is similar to the quality of surface water and is discharged to the underground in accordance with the EPA's UIC Permit by Rule. No measurable impact on groundwater or surface water would result from brine discharge to groundwater.

No Action

The No Action Alternative would essentially leave groundwater and surface water as they currently exist. No incremental impact on surface water or groundwater would result from the No Action Alternative. SURF would continue to operate underground experiments and collect and treat groundwater in the underground pool in the SURF waste water treatment plant and discharge effluent to Whitewater Creek.

3.6 NOISE AND VIBRATION

This section evaluates potential noise and vibration effects of the Proposed Action and Alternative A, including construction of the embankment and beamline facilities at Fermilab and the Far Site detector at SURF. The affected environment includes areas at Fermilab and SURF that would be subject to noise or vibration that exceeds ambient levels, including areas near the proposed NND construction at Fermilab and adjacent to excavated rock trucking routes near SURF in Lead and Deadwood.

3.6.1 Fermilab

3.6.1.1 Affected Environment

Existing Noise Conditions

The proposed construction site is located on an isolated portion of the western side of the Fermilab property. Existing noise sources on the western side of the Fermilab property include vehicular traffic from Kirk Road to the west as well as Butterfield Road to the south. Ambient noise varies depending on the time of day, weather, and proximity to noise-attenuating features such as trees and topographical changes. Existing Fermilab operations contribute little to existing noise levels. The land uses adjacent to Fermilab include residential communities to the west, south, and east, and industrial facilities to the north and south.

The noise receptors in the area are single-family residences located west of Kirk Road and near the southwest corner of Fermilab property to the west of the Illinois Prairie Path (e.g., Savannah Drive). The neighborhood at the southwest corner of Fermilab is approximately 4,550 feet south of Giese Road.

Kirk Road is a four-lane road with substantial existing automobile and truck traffic. To document the current ambient noise conditions at the site and areas adjacent to Kirk Road, noise levels along Kirk Road were measured using noise monitoring equipment placed approximately 250 feet east of Kirk Road (and approximately 150 feet south of the Giese Road and Kirk Road intersection) (**Figure 3.6-1**). The existing noise levels at this location ranged from 56.2 to 62.2 dBA (decibels, A-weighting) Leq (equivalent sound level) during the day (7:00 a.m. to 9:00 p.m.) and 50.7 to 60.5 dBA Leq at night (9:00 p.m. to 7:00 a.m.). This noise level is typical for a commercial area with vehicular traffic (**Appendix E-1**). The higher daytime noise levels can be attributed to Kirk Road traffic. To confirm these measurements, individual daytime "spot" noise measurements were made at three off-site locations (**Figure 3.6-1**). Ambient noise levels adjacent to Kirk Road ranged from 62.4 dBA Leq near Pine Street to 67.5 dBA Leq near Giese Road. **Appendix E** presents the methods used to collect these data and detailed results as well as general information on noise and typical noise levels associated with common noise sources.

Regulatory Setting

This section provides a summary of applicable regulatory criteria and guidance for noise and vibration during and after construction with a focus on state and local criteria.

Noise Standards

Federal Standards

EPA published noise guidelines to protect public health and welfare with an adequate margin of safety (EPA 1974). These criteria were intended as a guideline for instances where no local, county, or state standard existed. The EPA set guidelines of Ldn 45 dBA indoors and 55 dBA outdoors for residential areas. The day-night average sound level (Ldn) is the average noise level over a 24-hour period.

Sound has two physical properties, pressure variation and loudness. Pressure variation is measured in the number of pressure changes (cycles) per second and is referred to as frequency, measured in Hertz or Hz. The higher the frequency (Hertz), the higher-pitched the sound. Sound loudness is typically characterized by both sound pressure and sound pressure variation.

The following are examples of noise and associated loudness measured in dB:

- Country Park 30 dB
- Whispered speech 45 dB
- Speech normal 60-65 dB (at 3 ft.)
- Busy Road Traffic 70 dB (at 80 feet from source)
- Washing Machine 75 dB
- Hair dryer 90 dB
- Hand Drill 98 dB
- Snowmobile or Motorcycle 100 dB

The frequency of pressure contributes a correction to decibel readings. The human ear can hear sounds within a frequency range of 20 Hz to 20,000 Hz. Sounds are most easily heard within a frequency range of 2,500 to 3,000 Hz. An 'A-weighting' scale applies a weight to dB levels depending on frequency. This correction to the Decibel scale is strongest at the lower and higher levels of sound pressure. Sound loudness is expressed in the following sections as dBA or decibels corrected (A-weighting) for frequency response.

State Standards

The State of Illinois Administrative Code Title 35, Subtitle H, Chapter I, Part 901, Sound Emission Standards and Limitations for Property Line-Noise-Sources includes noise limits specific to source and receptor land uses (residential [Class A], commercial/retail [Class B] and agricultural/industrial [Class C]) (State of Illinois 2006). Given the on-site and adjoining land uses, the most restrictive noise limitations (source: Class C, receptor Class A) would be applicable to the Proposed Action. **Table 3.6-1** summarizes the applicable requirements, which are defined by octave band. An octave is a range of frequencies whose upper frequency limit is twice that of its lower frequency limit. For example, the 1000 Hertz octave band contains noise energy at all frequencies from 707 to 1414 Hertz. A Hertz (Hz) is the unit of frequency or pitch of a sound. One hertz equals one cycle per second (1 kHz = 1000 Hz, 2 kHz = 2000 Hz etc.) **Appendix E** provides further technical information and definition of noise terms.

Absolute Scale - 1:12,000
1 inch = 1,000 feet

Legend

- Fermilab Boundary
- Buildings
- Roads and Parking
- Beam (Below Ground)
- Construction Limits
- Noise Monitor Locations

Absolute Frame

1 Acre =

0 500 1,000 Feet

N

LBNF/DUNE EA

FIGURE 3.6-1

Noise Monitoring Locations - Fermilab

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Section 901.107 (regulatory exceptions) indicates that the Leq levels presented in **Table 3.6-1** do not apply to construction activities insofar as construction noise is typically intermittent and transient.

Table 3.6-1 Illinois Noise Regulation – Sound Pressure Levels (dBA) Emitted to Class A (Residential) from Class C (Industrial)

Scenario	Octave Band Center Frequency (Hertz)								
	31.5	63	125	250	500	1000	2000	4000	8000
Daytime Limit (Leq) (7:00am to 10:00pm)	75	74	69	64	58	52	47	43	40
Nighttime Limit (Leq) (10:00pm to 7:00am)	69	67	62	54	47	41	36	32	32

Notes:
Hertz - unit of frequency defined as one cycle per second.
Source: State of Illinois 2006

Local

Kane County's general nuisance noise ordinance prohibits loud and unnecessary noise. Construction that can be heard from a distance of 100 feet or more from the source is prohibited between 9:00 p.m. and 6:00 a.m. on weekdays, and between 9:00 p.m. and 8:00 a.m. on Saturdays and Sundays (Kane County 2008).

The City of Batavia City Code Chapter 4, Section 4-4-5, limits noise sources on industrial properties (City of Batavia 2005). Noise generated may not exceed the levels listed in **Table 3.6-2** at receiving (receptor) properties.

Table 3.6-2 City of Batavia Maximum Permissible Effective Source Noise Levels at Residential Property

Industrial Property To:	Daytime Hours (7:00am to 9:00pm)	Nighttime Hours (9:00pm to 7:00am)
Residential property	60 dBA	50 dBA

Chapter 4, Section 4-4-4, Permitted Hours for Construction Activity, prohibits outdoor construction within 1,000 feet of any residential lot on weekdays and Saturdays between 9:00 p.m. and 7:00 a.m. and between 9:00 p.m. and 8:00 a.m. on Sundays.

Vibration Standards

Vibrations caused by construction activities are transmitted via waves in the ground. The energy associated with ground-borne waves generally dissipates with distance from the vibration source. Vibration is an oscillatory motion that can be described in terms of the displacement, velocity, or acceleration. Peak Particle Velocity (PPV) is defined as the maximum instantaneous positive or negative peak of the vibration signal. PPV is used to assess the potential for damage to buildings and structures and is expressed in inches per second (in/sec); vibration for evaluating human response can also be expressed using PPV. Vibrations of 0.13 in/sec PPV are distinctly perceptible. The potential for structural damage exists at PPVs of 2.0 to 2.5 or higher.

The Federal Transit Administration (FTA) vibration guidelines state that a vibration level of 65 velocity in decibels (VdB) is the threshold of perceptibility for humans and vibration that exceeds 80 VdB may cause annoying effects on humans. The threshold for potential cosmetic damage to extremely fragile buildings is 90 VdB. **Table 3.6-3** summarizes FTA's construction vibration damage criteria (DOT FTA 2006).

Table 3.6-3 FTA Construction Damage Criteria

Building Category	PPV* (in/sec)	VdB (Approximate Lv**)
I. Reinforced concrete, steel, or timber (no plaster)	0.5	102
II. Engineered concrete and masonry (no plaster)	0.3	98
III. Non-engineered timber and masonry buildings	0.2	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

Notes:
* Peak Particle Velocity
** Root mean square (RMS) velocity in decibels (VdB) re 1 micro-inch/second
Source: DOT FTA 2006

3.6.1.2 Environmental Impacts

This section evaluates the potential direct effects of construction and operational noise and vibration on the environment. The direct effects of noise may include general annoyance, interference with speech, and sleep disturbances.

Proposed Action

Construction

Construction of the Proposed Action would require the use of heavy earth-moving equipment, excavators, loaders, and haul trucks and would normally occur during the daytime hours from 7:00 a.m. to 9:00 p.m. Noise-producing activities would include on-site excavation, transport, and placement of excavated material to create the embankment; transport of construction materials; construction of service buildings; assembly of beamline components; and site preparation and restoration.

Construction noise was evaluated for the following construction phases:

- Construction of the embankment and borrow pit excavation;
- Excavation and foundation installation for the Primary Beam Enclosure and Target Hall, including the installation of foundation shafts;
- Excavation in rock for the Absorber Hall, Decay Pipe, and the NND;
- Service building construction for the Primary Beam Enclosure, Target Hall, Absorber, and the NND.

The Proposed Action would include construction of the NND Hall and LBNF-40 approximately 125-150 feet east of Kirk Road and 780 feet west of LBNF-30 (**Figure 2.1-1**) NND construction would include a deep mechanical soil excavation within a shaft (approximately 70 feet) followed by blasting of bedrock at depths below 70 feet. NND construction would also require construction of access shafts, equipment installation (within buildings), and site restoration. As construction of the NND underground facility progresses, the source of noise would be located progressively deeper inside the shaft and less audible with time.

Construction noise levels for the Proposed Action were estimated using a predictive noise model (CadnaA - Computer Aided Noise Abatement). Noise values for construction equipment were derived from literature sources (e.g., Federal Highway Administration Construction Noise Handbook [FHWA 2009]). The loudest equipment typically emits noise levels between 73 and 85 dBA at 50 feet, with utilization factors of 20 to 40 percent (i.e., the percent of time the equipment would be used per day). Noise emissions from blasting would be 94 dBA at 50 feet from the noise source.

Table 3.6-4 and **Figure 3.6-2** present modeled noise levels for construction of the Proposed Action at adjacent residential receptors. The short-term ambient noise measurement locations were used to represent adjacent residential receptors. According to the model, construction noise levels would range from approximately 70.9 dBA at the closest receptors west of Kirk Road where construction noise levels would be similar to an urban area, to 39.8 dBA at receptors to the southwest near Savannah Road. These values represent a reasonable worst-case analysis because they are based on the initial construction period when most equipment would be at or near the surface. The model results shown in **Table 3.6-5** and **Figure 3.6-2** represent the contribution of LBNF/DUNE noise only and do not account for existing community noise sources such as roadways, aircraft overflight, or residential/commercial noise. The contribution of ambient noise is discussed separately below. **Appendix E-1** describes the model, input data, assumptions including construction equipment, and model results.

Table 3.6-4 Proposed Action Construction Noise Levels Compared to Ambient Noise Levels

Sensitive Receptor	Receptor Location	Construction Noise Impacts (dBA Leq)				
		Construction of Embankment	Excavation, Foundations, Primary Beam Enclosure, Target Hall, and Drilled Pilings	Excavation of Absorber Hall and NND Shafts and Underground Enclosures	Service Building Construction (4 Buildings)	Increase in Noise Levels Over Existing Ambient Noise (dB)[1]
1	Residential (Kirk Road near Pine Street)	44.5	47.5	52.5	48.6	0.4
2	Residential and Recreational (Kirk Road near Prairie Path)	51.5	52.4	56.2	51.8	0.4
3	Residential (Kirk Road near Giese Road)	50.9	56.0	65.6	64.4	2.2
4	Residential (Kirk Road directly west of the Proposed Action	51.1	56.7	70.9	69.4	5.0[2]
5	Residential (near Savannah Road)	43.0	43.3	45.0	39.8	---

Notes:
dBA = A-weighted decibels
1 Increase based on the highest calculated construction noise level.
2 Ambient noise level based on data collected at monitoring location 3

Table 3.6-5 Proposed Action Operations Noise Levels Compared to Ambient Noise Levels

Receptor	Receptor Location	Measured Daytime Noise Level (dBA Leq)	Calculated Noise Level (dBA Leq)	Combined Noise Level (dBA Leq)	Operational Noise Level Increase Over Existing Ambient Noise (dB)
1	Residential (near Pine Street)	62.4	28.2	62.4	0.0
2	Residential and Recreational (near Prairie Path)	66.8	31.5	66.8	0.0
3	Residential (near Giese Road)	67.5	35.0	67.5	0.0
4	Residential (Kirk Road directly west of the Proposed Action	67.5*	42.8	67.5	0.0
5	Residential (near Savannah Road)	N/A	21.8	N/A	N/A

Notes:
dBA = A-weighted decibels
* Ambient noise level based on data collected at monitoring location 3.

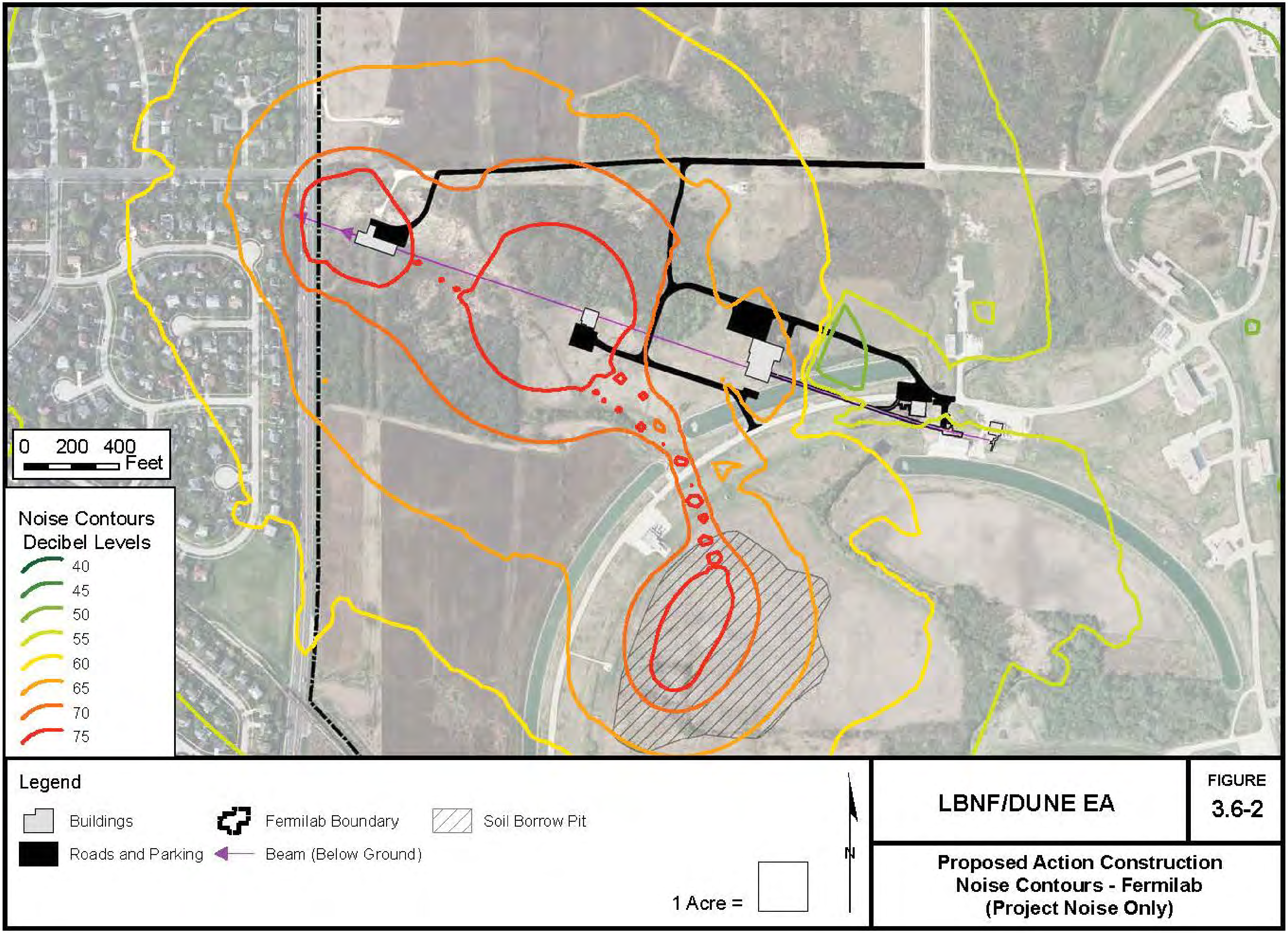
The impact assessment was conducted by comparing the predicted construction noise level with existing noise levels in the area, or ambient noise levels. In general, a change (in this case, increase) of 3 dB is just noticeable, a change of 5 dB is clearly noticeable, and a change of 10 dB is perceived as a doubling of the noise level. Traffic on Kirk Road generates substantial ambient noise. Because the existing ambient noise levels at adjacent receptors range from 62.4 to 67.5 dBA Leq noise contributions from construction of the Proposed Action (**Table 3.6-5**), would increase noise levels by approximately 5 decibels directly west of Kirk Road and less than 3 decibels at other locations. Noise levels would diminish rapidly at distance because much of the construction of the underground facilities would be conducted within excavations that would attenuate much of the sound. In addition, construction would normally be completed during the day and within the day, during which activities (and their associated noise levels) would be exempt from the City of Batavia's noise code.

Construction would also generate ground-borne vibration from use of heavy equipment and blasting. Potential sources would include excavators and compactors, drilling support pilings, and blasting for removal of bedrock for the Absorber Hall and NND Hall. The construction contractor would drill holes in the bedrock and set charges ("drill and shoot"), resulting in two to four blasts per day followed by removal of rock and drilling of new holes.

Excavation equipment would result in vibration levels of approximately 57.5 VdB at the nearest residential receptor west of Kirk Road. This vibration level is well below thresholds for annoyance and structural damage.

The Proposed Action would also incorporate blasting with approximately four events per day over several months for excavation at the NND, Decay Pipe, and Absorber sites. Blasting would result in vibration levels of approximately 82.5 VdB at the nearest residential receptor west of Kirk Road. The vibration levels from blasting would be below the 90 VdB threshold for potential cosmetic damage to extremely sensitive structures but would exceed the 80 VdB threshold and could be noticeable for the nearest residents. Accordingly, Fermilab would incorporate several measures to prepare residents before blasting begins through notification. Fermilab would communicate with local residents regarding the construction schedule through public meetings and announcements, and would announce the start of blasting and progress toward completion. In addition, the construction contractor would monitor to determine whether vibration exceeds expected levels and use those data to adjust the drilling depth and size of the charges.

Absolute Scale - 1:7,200
1 inch = 600 feet



LBNF/DUNE EA

FIGURE 3.6-2

Proposed Action Construction Noise Contours - Fermilab (Project Noise Only)

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Operations

The primary noise sources during Proposed Action operations would be from outdoor equipment including transformer and chiller units, HVAC units, and ventilation of the service buildings. The Proposed Action would include an outside chiller unit and 5,000 cfm HVAC unit at LBNF-40 located approximately 150 feet from Kirk Road. LBNF-30 would be located approximately 990 feet from Kirk Road and would have two chiller units, two transformer units, and a 2,400 cubic feet per minute (cfm) HVAC unit. LBNF-20 would be located approximately 1,830 feet from Kirk Road and would have three chiller units and three rooftop HVAC units (50,000 cfm, 35,000 cfm, and 4,000 cfm). LBNF-5 would be approximately 2,530 feet from Kirk Road and would have three transformer units, three outside air fans, one rooftop ventilation fan, and one 15,000 cfm rooftop HVAC unit.

Table 3.6-5 and **Figure 3.6-3** present modeled operational noise levels (LBNF/DUNE only) for residential receptors. The highest predicted operational noise level would be 42.8 dBA Leq, which is below measured nighttime ambient noise levels of approximately 50 to 60 dBA and below the City of Batavia's nighttime noise threshold limit of 50 dBA Leq. However, the corresponding octave band noise level of 36.8 dB at 2,000 Hz (**Table 3.6-6**) at the nearest residential receptor west of Kirk Road would exceed the State of Illinois nighttime octave band noise threshold limit of 36 dB at 2,000 Hz by 0.8 dB. A potential increase of 0.8 dB within a single octave band would be barely noticeable, if at all, to a receptor along Kirk Road. Noise level increases ranging from 0-3 dB are regarded to have no appreciable effect on receptors and typically are barely perceptible to the human ear; increases from 3-6 dB may have potential for a noticeable to intrusive noise impact in cases where the most sensitive of receptors are present; sound pressure increases of more than 6 dB may be intrusive and require a closer analysis of impact potential depending on the character of surrounding land use and receptors; sound pressure increases approaching 10 dB result in a perceived doubling of noise and are intrusive to very noticeable. A potential noise increase in this case of 0.8 dB is well below the threshold for a perceptible or nuisance effect. Nonetheless, following existing SEPMs, Fermilab would seek to reduce noise from outdoor mechanical equipment (e.g., dampers) which could include installing quieter equipment or adding an enclosure during final design.

Table 3.6-6 Proposed Action Operational Octave Band Noise Levels at the Residential Receptors

Receptor	Sound Pressure Level (dB) Octave Band Center Frequency (Hertz)									Leq (dBA)
	31.5	63	125	250	500	1000	2000	4000	8000	
1	14.0	28.6	29.2	26.9	26.1	25.3	14.2	0.0	0.0	28.2
2	16.4	31.2	32.7	29.8	29.0	28.6	19.0	0.0	0.0	31.5
3	28.8	36.0	34.5	31.5	31.3	32.6	25.3	6.8	0.0	35.0
4	28.4	40.9	38.4	35.4	38.7	39.0	36.8	27.7	8.6	42.8
5	5.3	25.0	26.0	23.2	21.2	16.6	2.3	0.0	0.0	21.8

Notes:
dBA = A-weighted decibels

No Action

Under the No Action Alternative, there would be no construction or operational noise or vibration impacts. Ongoing activities associated with current Fermilab construction activities, and ongoing operation and maintenance of existing experimental facilities would continue, as would existing ambient noise sources such as Kirk Road.

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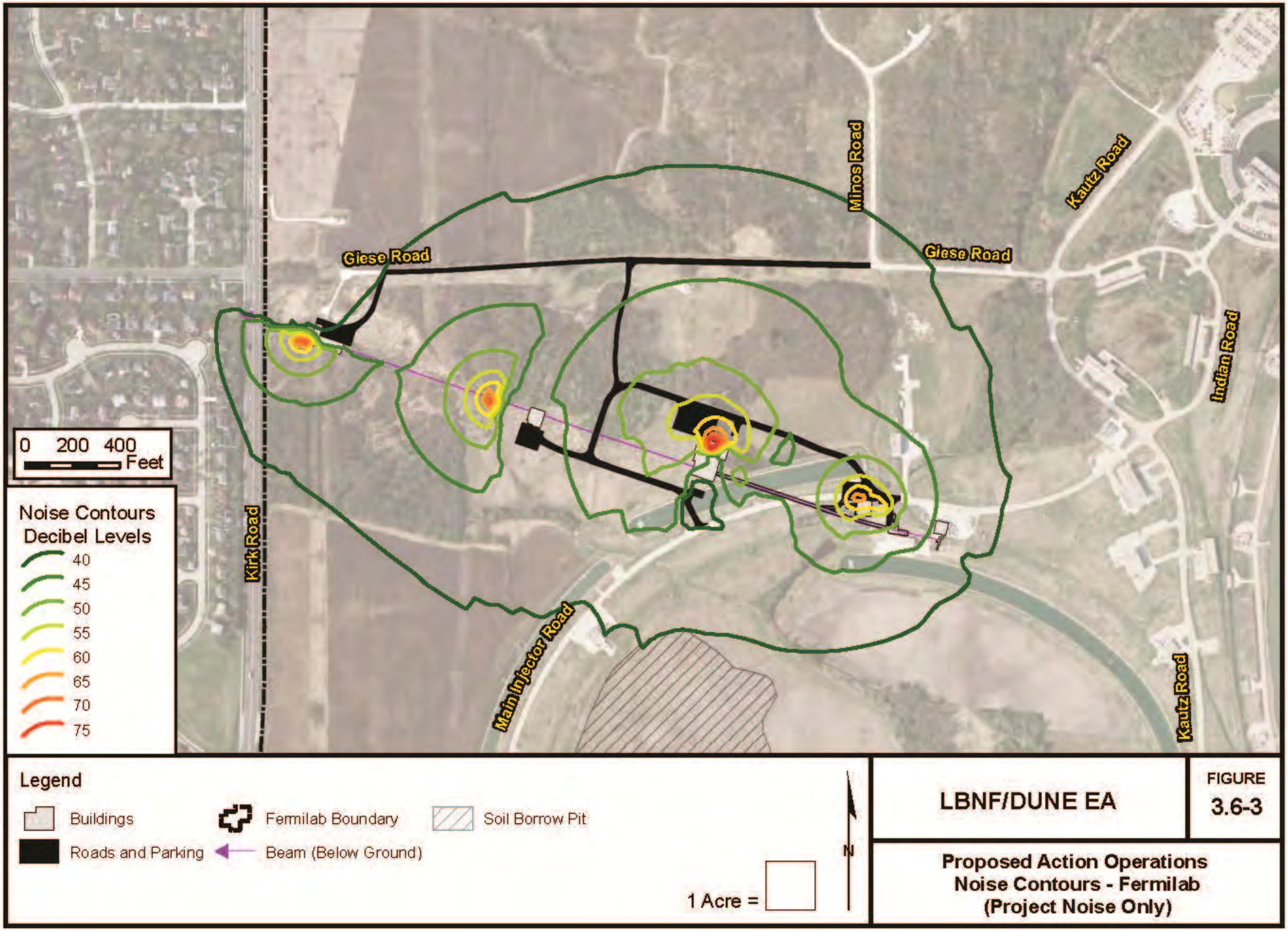
Absolute Scale - 1:7,200
1 inch = 600 feet



LBNF/DUNE EA

FIGURE 3.6-3

Proposed Action Operations Noise Contours - Fermilab (Project Noise Only)

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3.6.2 SURF

3.6.2.1 Affected Environment

The north and east sides of the City of Lead and the area south and adjacent to the SURF site on Kirk Road were evaluated for potential noise impacts resulting from the Proposed Action. Existing noise and vibration in these areas are primarily associated with traffic. Lesser amounts of ambient noise are associated with residential and business activities. Existing construction noise occurs primarily during the summer months. Traffic noise also increases during summer months due to tourism. Winter months are generally quieter, but are often interrupted by winter activities such as snowmobiling and snow removal.

Noise and vibration associated with mining activities occurred in the Lead area from 1876 through 2002. Examples of the noise and ground-borne vibration sources were mining in the Open Cut area (blasting, hauling, conveying, crushing); ventilation of the underground mine by large surface exhaust fans; rock processing noise at the mills (hauling, loading, dumping, milling, grinding, crushing, classifying, refining, sluicing, pumping); and facility support noise (such as boiler operation, construction, employee traffic, and material handling). Thus, the area is not historically a pristine or sensitive environment from a noise or vibration perspective.

SURF currently contributes to the noise in the area. There is shipping and receiving truck traffic, equipment operation (e.g., 2 forklifts, small compressor usage, and 2 bobcats), employee and researcher traffic, snow removal activities, surface construction, and operation underground ventilation fan(s). These noise sources are intermittent throughout the day and year except for the continuous operation of the Oro Hondo fan. SURF recently modified the pitch of the fan blades and added a silencer to the fan. Noise measured at 50 feet from the Oro Hondo Fan is now 53.4 dBA.

Noise Guidelines

Federal, state, and local governments have established day-night noise standards and guidelines to protect receptors from excessive or nuisance noise levels. There are no applicable State of South Dakota or local noise standards. The City of Lead has a general ordinance for noise which states, "(the City) will protect, preserve and promote the health, safety, welfare, peace, quiet and tranquility of the citizens of the city and persons or visitors frequenting the city through the reduction, control and prevention of noise which is disruptive and constitutes an annoyance to the citizens and persons" (City of Lead, 2014). In addition, there is a specific City noise ordinance which states, "a person may not operate any jack hammers or heavy equipment within 600 feet of a residence, church, hospital, hotel or motel between 7:00 p.m. and 6:00 a.m. (Lead City Ordinances Chapter IX, 93.21 (B)).

Vibration Guidelines

As described above in section 3.6.1.1, vibration levels exceeding 80 VdB may cause annoyance to humans, and the threshold for structural damage is 90 VdB.

3.6.2.2 Environmental Impacts

Proposed Action

Construction

Construction for the Proposed Action would occur both on the surface and underground. Construction activities on the surface would be the important generators of noise and ground-borne vibration. Noise occurring underground (e.g. shaft, tramway, and the 4850 Level) would not be heard by surface receptors.

Similarly, ground-borne vibration from subsurface activities would not be felt by surface receptors. Subsurface mining and shaft work have occurred at this level for 70-years with no noise or vibration effects at the surface. The absence of surface noise impacts was confirmed during the more recent Davis Campus construction in 2008-2010 and LBNF/DUNE geotechnical drilling conducted in 2014. Therefore, the quantitative analysis of construction-generated noise and vibration that follows focuses solely on surface activities.

Construction alternatives for the far site include possible noise impacts over a number of separate locations, depending on the specific activity and the alternative(s) ultimately chosen. A range of sites in the Lead-Deadwood area were monitored to establish ambient (background) noise levels. The sites were selected to represent those areas that would be most susceptible to project-related construction noise. The sites monitored for ambient noise levels are indicated on the area map in **Figure 3.6-4**.

Potential receptors that would be impacted due to construction activities are shown in **Figure 3.6-5, Figure 3.6-6** and **Figure 3.6-7**. The CadnaA (Computer Aided Noise Abatement) noise model was employed to predict future construction noise levels based on the type of equipment, equipment usage rates, equipment noise values, and topography. **Table 3.6-7** presents a summary of the modeling results intended to be representative of changes in noise levels from the Proposed Action. More detailed and comprehensive data, including noise contour maps by construction activity, are presented in **Appendix E**. In this table, "Receptors Affected" are only those receptors (indicated in **Figure 3.6-5, Figure 3.6-6** and **Figure 3.6-7**) that would experience an increase in noise due to a construction activity. The "Maximum Difference" column on the right of the table indicates the largest difference between ambient (background) and modeled construction noise levels, and indicates the receptor(s) that would experience that change. Vibration was estimated using source levels and equations from the FTA Transit Noise and Vibration Impact Assessment manual (FTA 2006).

<u>Ross Boiler Demolition</u>

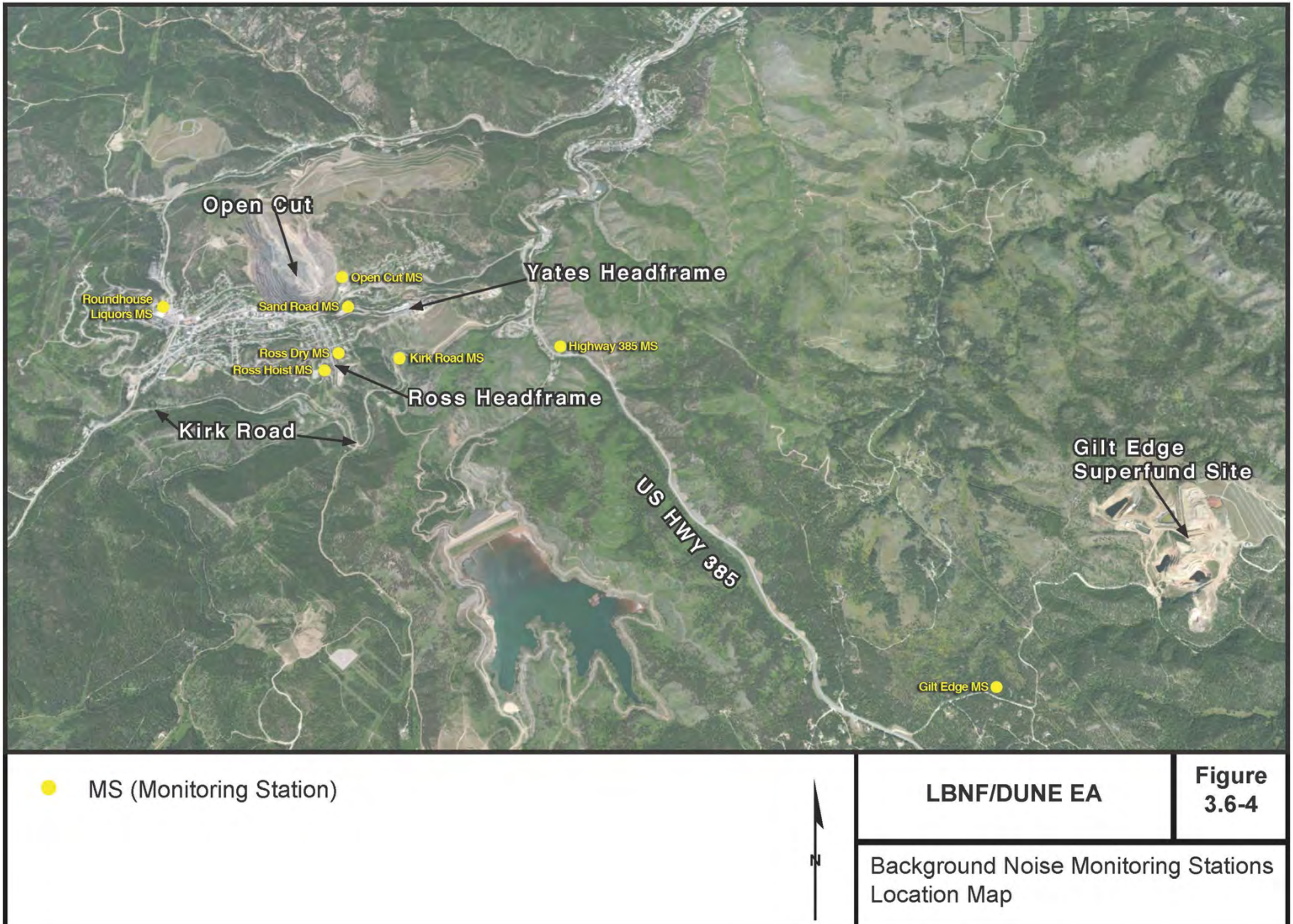
The demolition and rubble removal of the Ross Boiler and Stack would result in incremental Leq noise to Receptors 3 – 9 of 1 – 4 dBA (4 dBA above background). Receptors 5 and 6 would experience the greatest impact of 4 dBA (**Table 3.6-7**). The impact is short-term because rubble would be loaded into trucks during weekday, daylight hours (7am to 5pm) over a period of approximately 18 days.

The Ross Boiler stack would likely be imploded. The small amounts of explosives used to raze the boiler stack and the episodic nature of the event was not modeled because of its overall small contribution to noise and GBV impacts. Residents would be provided the demolition plan before demolition and asked to provide comments and input to help minimize impacts.

The closest receptor to the Ross Boiler demolition is located approximately 365 feet away. Estimated GBV levels at this distance are 60 VdB, below the 80 VdB level estimated to cause annoyance in humans.

<u>Cryogenic Support Building Construction</u>

Noise associated with the construction of the Cryogenic Support Building would impact Receptors 1 and 3 through 9. The incremental noise above background at these receptors would range from 1- 9 dBA and primarily depends on the building phase (such as foundation, construction, and utilities) and the distance to a receptor. The total noise experienced at receptors during construction would range from 50 to a maximum of 66 dBA. The maximum increase in noise level of 9 dBA over the existing background would occur at Receptor 6. Construction of the cryogenic building would take place on weekdays, 7am to 5pm over a period of approximately 9 months.



LBNF/DUNE EA

Figure 3.6-4

Background Noise Monitoring Stations Location Map

Absolute Scale - 1:19,415
1 inch = 1,618 feet

Legend

- Noise Receptor Locations
- Proposed Action Study Area

0 1,000 2,000 Feet

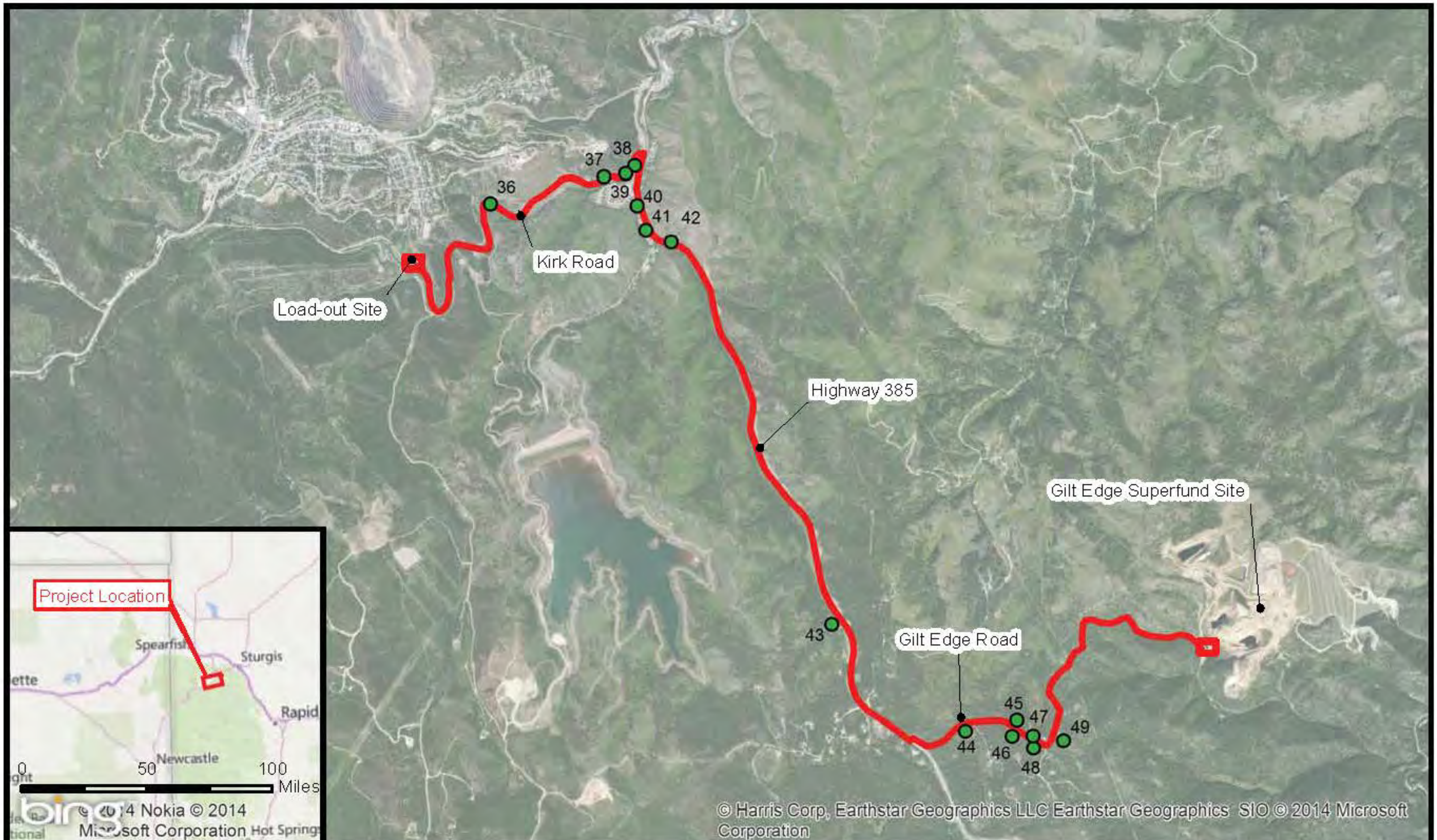
N

LBNF/DUNE EA

FIGURE 3.6-5

Proposed Action Noise Receptors for Construction and Operation at Ross Boiler, Trucking Conveyor, Truck Load-out, Cryogen Support Building, Crusher, and Conveyor

Absolute Scale - 1:50,000
1 inch = 4,167 feet



Legend

Noise Receptor Locations

Gilt Edge Road Haul Route

0 2,500 5,000 Feet

N

LBNF/DUNE EA

FIGURE 3.6-6

Proposed Action Noise Receptors for Truck Haul to the Gilt Edge Superfund Site

Absolute Scale - 1:25,000
1 inch = 2,083 feet

Legend

Noise Receptor Locations

Open Cut Haul Route

0 1,000 2,000 Feet

N

LBNF/DUNE EA

FIGURE 3.6-7

Proposed Action Noise Receptors for the Truck Haul to the Open Cut

Table 3.6-7 Incremental and Absolute Noise Levels Associated with Representative LBNF/DUNE Surface Construction Activities at the Far Site

Activity	Receptors Potentially Affected	Background Noise Range (L_{eq} dBA)[1]	Maximum Modeled Noise (Leq dBA) above Background (Receptors Affected)	Maximum Difference between Modeled Noise (Leq dBA) and Background (Receptors Affected)
Ross Boiler Demolition[2]	3 - 9	42 - 57	61 (5,6)	4 (5,6)
Cryogen Building Construction[3]	1, 3-9	49 - 57	65 (6,7)	9 (5,6)
Conveyor and Truck Load-out Construction[4]	1 – 9, 34	49 - 57	63 (1)	10 (9)
Crushing, Conveying and Truck Load-out operation (Daytime)[5]	2, 7, 8, & 9	46 - 52	58 (7)	5 (9)
Crushing, Conveying and Truck Load-out Operation (Nighttime)[6]	2 - 9	42 - 55	57 (2)	10 (9)
Gilt Edge Truck Haul[7]	36 - 49	43 -59	61 (36,40,41)	12 (47)
Open Cut Truck Haul[8]	50 - 59	60 (all receptors)	64 (53)	4 (53)
Rail System Construction[9]	8 - 33	49 - 54	70 (21)	16 (21, 27))
Crushing and Rail System Operation (Daytime)[10]	7 - 33	49 - 54	59 (21)	5 (21)
Crushing and Rail System Operation (Nighttime)[11]	3- 33	49 - 54	58 (21)	13 (21, 27)

Notes:

* L_{eq} is a measure of overall noise over a specific period of time. All values in this table are calculated over the hours from 7 am to 10 pm, with the exception of the crushing activity (including conveying to the truck load out bin), which would be conducted 24 hours a day. More detailed information related to specific activities and receptors is included in Appendix E

1 From Table E-2.3
2 From Table E-2.4
3 From Tables E-2.4
4 From Tables E-2.4 and E-2.7
5 From Table E-2.8b
6 From Table E-2.8a
7 From Table E-2.9
8 From Table E-2.10
9 From Tables E-2.4 and E-2.6
10 From Table E-2.8b
11 From Table E-2.8a

Minor surface blasting would be necessary to install footings for the conveyances and the cryogenic building. Blasting would likely generate small levels of GBV. Minimal amounts of explosives would be placed in drilled holes and detonated with millisecond delays to improve to reduce noise and vibration of the blasting process. Local residents and other affected members of the public would be notified at a minimum 12 hours in advance of such activity. Nearby Receptors (3 through 9) would be inspected by qualified personnel before and after blasting to document any possible effects. Blasting would be scheduled to occur during 8 am to 5 pm on weekdays. The closest receptor to the Cryogenic Building construction activities is located approximately 365 feet away. Estimated GBV levels at this distance are 62 VdB, below the level estimated to cause annoyance in humans.

Conveyor and Truck Load-out Construction (including site preparation)

Noise associated with the construction of the conveyor and truck load-out station would impact Receptors 1 through 9 and 34 by increasing noise from 1- 10 dBA. The maximum increase in noise would occur at Receptor 9 during site preparation. The Truck Load-out construction would cause a 63 dBA noise level at Receptor 1 (near Kirk Road) which is 8 dBA over background at this site. Receptor 9, overlooking the Ross Headframe and Ross Crusher building, would experience the highest increase of noise over background of 10 dBA over a background noise level of 49 dBA.

The conveyor construction and truck load-out would occur on the south side of the Ross Yard above Kirk Canyon. This construction on the south-facing hill would limit noise impacts on Lead residents. Construction of the Truck Conveyor and Load-out would occur on weekdays, 7am to 5pm, for approximately 9 months.

Receptor 9 is located approximately 290 feet from the Ross Crusher and is the closest receptor to the truck conveyor. Estimated GBV levels at this distance are 66 VdB, below the level estimated to cause annoyance in humans.

Rock Crushing, Conveying, and Truck Load-out (during Underground Cavern Excavation)

Crushing and conveying the rock via conveyor to the truck load-out station would cause increased noise over background to Receptors 1- 9. The rock crushing operation is the only construction activity that is proposed to operate on a 24 hour basis. During daylight hours (7am - 10pm) Receptors 2, 7, 8, and 9 would experience noise increases of 1 – 5 dBA. During nighttime operation (10pm to 7 am) Receptors 2 - 9 would experience noise increases of 1 – 10 dBA. The maximum increase of 10 dBA would impact Receptor 9. Receptors near the crusher and conveyor (Receptors 1-9) would experience overall noise levels of 47 to 58 dBA, approximately the level equivalent of normal conversation at 3 feet.

Rock from the crusher would be conveyed to the Load-out station. The noise increase over background at Receptor 2 would be 1 dBA during daylight hours and the increase at Receptors 1 and 2 would be 1 and 2 dBA respectively during nighttime hours. The resulting total noise level at Receptor 2 would be 57 dBA.

The closest receptor to the Ross Crusher operation activities is located approximately 230 feet away (Receptor 9). The sound level adjacent to a typical primary jaw crusher can range from 88 to 105 dBA. In lieu of specific data for the crusher to be used on-site during construction, a worse-case source levels for an impact pile driver was used to estimate GBV levels at this distance. The estimated GBV at 230 feet from an impact pile driver is 75 VdB, below the level estimated to cause annoyance in humans.

Trucking Rock to Gilt Edge Superfund Site

Trucking rock to the Gilt Edge Superfund site would increase noise levels to Receptors 36-49. The maximum increase of 12 dBA would be to Receptor 47 on Gilt Edge Road. This Receptor is 80 feet from the roadway's center line and would have a maximum noise level of 55 dBA. A truck generating this noise would pass by a receptor on Gilt Edge Road a maximum of once every 24 minutes with an average frequency well below that.

The background Leq daytime noise level measured on Kirk Road was 56 dBA. The modeled increase in noise associated with the truck haul would be 1-3 dBA, or 57-60 dBA. The frequency of truck traffic would increase similar to the frequency on Gilt Edge Road.

GBV would be the same as background since the size of trucks scheduled for the rock haul are similar to trucks currently using these roadways.

Trucking Rock to the Open Cut

Trucking the rock to the Open Cut would increase noise levels to Receptors 50 to 59 along Highway 14A/85. The measured background noise on Highway 14A/85 100 feet from the highway center line is between 51 and 67 dBA and is primarily due to truck traffic using this road. Noise associated with trucking rock to the Open Cut would increase noise levels slightly. The maximum expected increase would be to receptor 53 of 4 dBA.

GVB would be the same as background since the size of trucks scheduled for the rock haul are similar to trucks currently using these roadways.

Rail System Construction and Operation

Another mode of conveying rock to the Open Cut would be the Rail/Pipe Conveyor. The Rail System is evaluated in this section in lieu of the Pipe Conveyor as it would have a greater noise impact during construction and operation. The Rail System construction would affect noise levels at Receptors 8-33 located near or on Washington Street, Sand Street, and Park Avenue. The maximum increase in noise level over the ambient would be 16 dBA for Receptor s 21 and 27. The maximum total (combined) noise level would be 70 dBA at receptor 21. Construction of the rail system would take 9 months overall, and would occur on weekdays from 7am to 9pm. However, a given receptor would not experience the maximum construction noise at one time, due to the linear nature of the construction.

The closest receptor would be 110 feet from the Rail System construction. Estimated GBV levels at this distance would be 78 VdB, below the level estimated to cause annoyance in humans.

Noise associated with the operation of the rail system would increase the noise level above background by for receptors 3-33 with most of the noise originating from electric drive units and car movement. During daytime operation the Rail System would increase noise levels 1 – 5 dBA on Receptors 7 – 33 with the greatest impact (5 dBA) on Receptor 21. During night time operation Receptors 3 – 33 would experience increased noise of 1 – 13 dBA. Receptors 21 and 27 would experience the maximum noise impact of 13 dBA or 58 dBA and 53 dBA respectively.

Estimated ground-borne vibration for the rail system would be very low. The closest receptor to the rail system activities is located approximately 110 feet away. Estimated GBV levels at this distance are 57 VdB, below the level estimated to cause annoyance in humans.

The incremental impact noise during construction would be minimized by operating equipment where possible during daylight hours and not during weekends. The construction duration would also be minimized to prevent prolonged noise impacts. The construction contractor(s) would be required to comply with LBNF/DUNE-specific requirements regulating construction noise and vibration during construction beyond those identified above. These specifications include:

- Use properly maintained and operated equipment;
- Avoid the use of engine brakes in-town;
- Locate stationary construction equipment as far as practicable from noise sensitive sites.

Operation

The noise and vibration associated with construction of the detector, surface support facilities and rock movement/disposal would cease prior to operational activities. There would be very little surface noise during operations except for delivery of supplies and commuting employees/scientists. Operation of the underground detector and facilities would add approximately 2-5 SURF employees for maintenance and approximately 5 on-site researchers over a 20-year period. This increase in personnel would be similar to current levels in terms of frequency and intensity at sensitive receptor locations.

Long-term operational noise would be introduced from the compressors installed inside the Cryogen Support Building. 5 receptors (residences) occur within 500-feet of the proposed location of the Cryogen Support Building. Large Screw-type compressors generate 88 dBA within 5 feet of the air intake. The closest receptor, 250 feet away, would experience a noise level of 52 dBA. This noise is 7 dBA above the Leq (10pm-7am) background and 5 below the Leq (7am-10pm) background. The Cryogen Support Building would require noise dampening or mufflers to be installed on the compressors if they were to be operated at night. Maintenance would occur intermittently and likely be detectable at receptor locations. However, the impacts would be low given the intermittent nature of maintenance and distances to the receptors.

Alternative A

Construction

Noise and GVB from Alternative A experiments would be associated with the operation of the Ross Crusher and the conveyance method to either the Gilt Edge Superfund site or the Open Cut. The noise impact intensity would be identical to the Proposed Action as the crushing and hauling rate would be the same. However, it is estimated that the construction of Alternative A would extend the duration of these impacts for 168 days beyond the 500 days expected for the Proposed Action. This rock would be managed in the same manner as the Proposed Action. There would be no new surface disturbance. There would be additional activity associated with truck deliveries to outfit the experiments. The increased traffic noise would be during daylight hours and similar in intensity to current truck traffic noise.

Operations

The noise and vibration associated with Alternative A experiments' operation would not result in a measurable increase in noise and vibration. Operational impacts would occur underground and many of the systems would be in place to support the various experiments. Noise and ground-borne vibration from equipment operated underground would not affect surface receptors. Additional researchers and maintenance personnel would be minimal due to the small scale of these experiments. Negligible increases in traffic noise and quantity associated with these experiments would be very low.

No Action

Under the No Action Alternative, the LBNF/DUNE or Alternative A would not be constructed or operated. Thus, there would be no increases in noise levels or vibration effects on sensitive receptors. SURF would continue to operate existing underground experiments as well as surface facilities such as the administration building, access shafts, and WWTP.

3.7 TRANSPORTATION

This section describes the existing transportation infrastructure and traffic volumes, LBNF/DUNE-related traffic, and potential effects on public roadways, including the potential for travel delays or traffic accidents near Fermilab and SURF. It quantifies potential impacts on public travel and identifies methods to minimize traffic impacts. The affected environment for Fermilab and SURF consists of on-site and off-site roadways that would be used for transportation by workers and to transport materials to and from the construction sites.

3.7.1 Fermilab

3.7.1.1 Affected Environment

Fermilab is located approximately 38 miles west of downtown Chicago, Illinois. **Figure 3.7-1** depicts the roadways near and adjacent to Fermilab. Interstate 88 (I-88) is a multi-lane, high-volume route running east-west and located south of the site. State Highway 59 (IL 59) is a principal four- to six-lane north-south arterial located to the east. Kirk Road forms the western boundary of the Fermilab property and becomes Farnsworth Avenue south of Butterfield Road. This four-lane arterial connects to I-88 to the south and IL 38 (Roosevelt Road) to the north. Butterfield Road is a four-lane arterial that runs east-west along the southern boundary of the Fermilab property. At peak periods, commuter traffic is often heavy on all primary routes to and from Fermilab (DOE 2008a).

The roads within Fermilab are operated as private roads. Employees and visitors may access Fermilab via one of three gated entrances. The primary access for both employees and visitors is the Main Entrance, located on Pine Street, which is accessed from Kirk Road. The second entrance is East Gate on Batavia Road. Batavia Road is a public access, paved road that is used primarily for travel within the Laboratory. Public access is limited to designated recreational and educational areas within the main campus. A third entrance at West Wilson Street. and Kirk Road is open during limited hours, primarily for heavy truck deliveries. Other potential entrances exist at Kautz Road and Eola Road. These entrances are normally gated and locked.

The current workforce at Fermilab is approximately 1,970 full- and part-time employees, along with 1,500 visiting scientists (Users). The number of Users fluctuates because experimenters typically stay at Fermilab for a few weeks and then return to their home institutions. Approximately half of Fermilab's employees are located in Wilson Hall. Users work at various experimental facilities across the Site and are not localized in any one area.

Fermilab has approximately 35,000 visitors annually (Walton 2013). During the Tevatron era, there were approximately 50,000 annual visitors (DOE 1999); therefore, the number of visitors has declined over recent years. Many visitors come to see the bison herd, train dogs, and walk the nature trails. Visitors also go to Wilson Hall to attend cultural activities, take self-guided tours, attend middle school and high school group tours, participate in activities at Fermilab's science education center, and conduct business with the Laboratory.

Fermilab operates a network of roadways within the site, primarily around the central experimental campus, Wilson Hall, and the accelerator rings.

<u>Traffic Volume</u>

Table 3.7-1 shows the 2010 annual average daily traffic (AADT) (or 2011/2012 AADT if available) for the primary public travel routes near Fermilab. The existing roadways meet the current needs of area

traffic. Based on the Comprehensive Road Improvement Plans for DuPage and Kane Counties (DuPage County 2010; Kane County 2012), no intersection deficiencies were noted for the roadways in the immediate vicinity of Fermilab.

Table 3.7-1 2010 Annual Average Daily Traffic in the Fermilab Area

Roadway	Location	Existing AADT	Existing Truck AADT
Kirk Rd (CR 77)	South of Pine St; North of Mesa Ln	36,100	Not Counted
Kirk Rd (CR 77)	North of Pine St; South of E Wilson St	30,200	Not Counted
North Farnsworth Ave (CR 77)	South of Butterfield; North of Biltner Rd	31,500	Not Counted
Butterfield Rd (IL 56)	Between Packford Ln and DuPage Pkwy	14,900*	1,150*
Butterfield Rd (IL 56)	Between Beverly Dr & Ginger Woods Pkwy	16, 700*	1,100*
IL 59	North of Butterfield Rd	32,600*	3,550*
IL 59	South of Butterfield Rd	29,700**	2,300**
Eola Rd (CR 14)	Between Ferry Rd and Butterfield Rd	12,800**	Not Counted
East Roosevelt Rd (IL 38)	Between Fabyan Pkwy and McChesney Rd	26,400**	1,800
I- 88	Between Eola Rd & IL 59	107,200*	6,700*

Notes:
AADT = Annual Average Daily Traffic; * 2011 AADT; ** 2012 AADT
Source: IDOT 2013

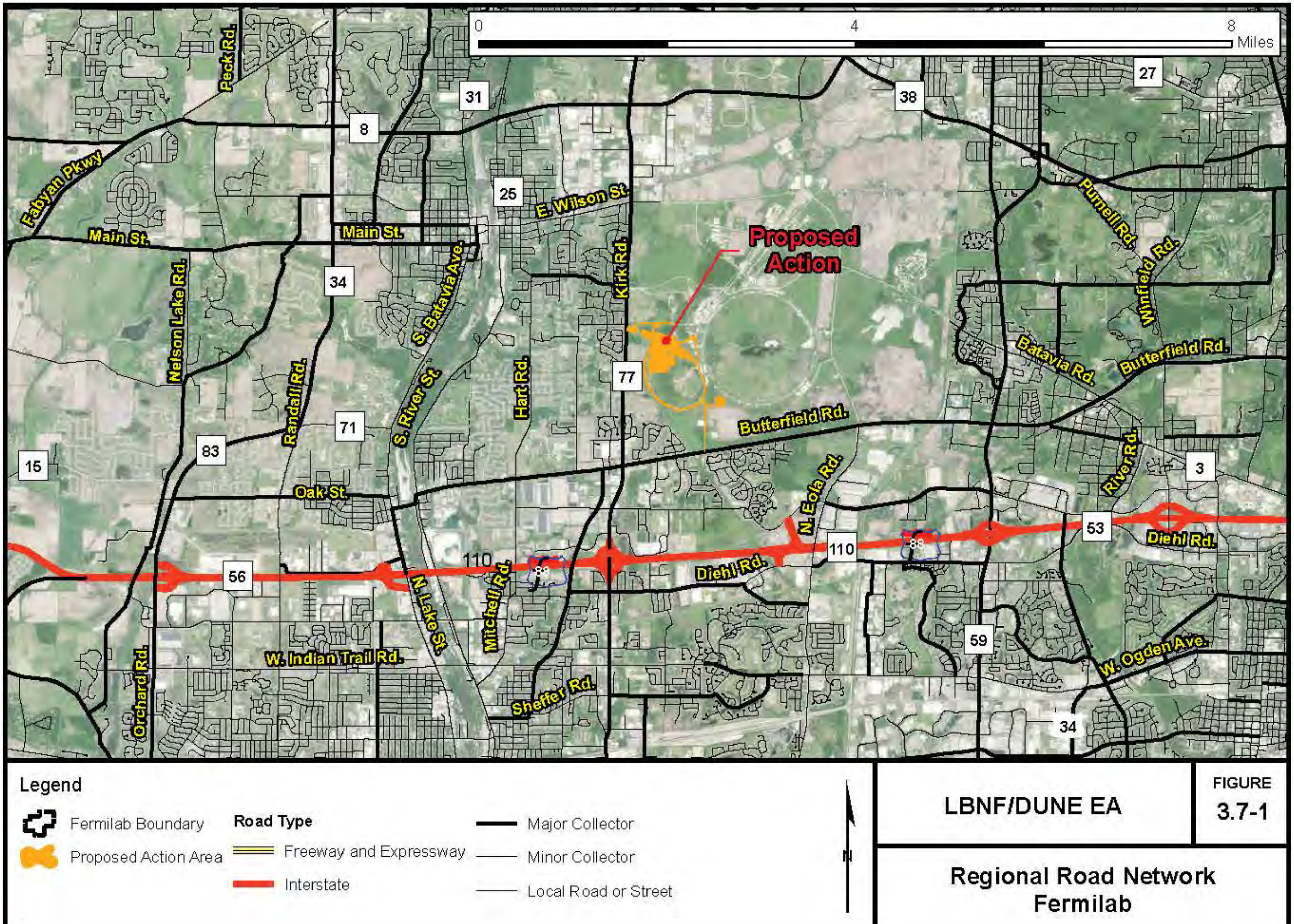
Traffic Accidents

Based on the Illinois Department of Transportation (IDOT) 2011 Illinois Crash Facts and Statistics, there were a total of 281,788 motor vehicle crashes in the State of Illinois, resulting in a total of 84,172 injuries (IDOT 2011). Based on the 103 billion (103,369,436,684) total vehicle miles driven by all motor vehicles in 2011, the crash and injury rates were 2.73×10^{-06} and 8.14×10^{-07}, respectively (IDOT 2011). The 2011 vehicle crashes resulted in 918 fatalities; therefore, the death rate was 0.89 per hundred million vehicle miles traveled or 8.88×10^{-09} (IDOT 2011). These are statewide statistics for all motor vehicles and do not account for the differences in accident rates for commuter vehicles relative to the rates for delivery trucks or tractor trailers.

To reduce the risk to motorists, bicyclists, and pedestrians, Fermilab has adopted, as a minimum, the applicable portions of the State of Illinois Vehicle Code and the *Rules of the Road* publication into its Work Smart Standards as SEPMs. As of 2010, Fermilab no longer allows drivers to use cell phones, including hands-free devices, while driving on site (Fermilab 2010). All Fermilab employees are required to take the online *Traffic Safety Awareness* training course per site SEPMs.

Fermilab traffic control protocols comply with the Fermilab ES&H Manual, including section 9010: Traffic Safety, including Appendix B, Safeguards for Construction and Maintenance Activities. An on-site security force enforces traffic safety rules, issues citations, and responds to traffic accidents and emergencies. Construction work, road repairs, and road closures must follow the Federal Highway Administration's Manual on Uniform Traffic Control Devices (FHWA 2009), which provides standards for measures such as signage, traffic controls, worker safety, and flaggers. It would also comply with Fermilab's ES&H Manual section 2060: Work Planning and Hazard Analysis. This policy requires review and revision of traffic safety measures as needed to respond to new or increasing traffic impacts. To minimize potential traffic impacts, Fermilab implements a traffic safety program as an SEPM.

Absolute Scale - 1:96,000
1 inch = 8,000 feet



LBNF/DUNE EA	FIGURE 3.7-1
Regional Road Network Fermilab	

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This program is formalized in the Fermilab ES&H Manual, section 9010. The following safeguards are required SEPMs during construction or maintenance activities that may affect the flow of traffic:

- Signs shall be posted indicating road work in progress. Reflective signs and/or flashing lights are required for night visibility.
- Traffic cones shall be set up to divert traffic safely away from or through the work area.
- A flag person shall be assigned to the area if the work is to be performed in any area where driver visibility is obstructed (e.g., by heavy equipment). The flag person shall wear a hard hat, an orange reflective vest, and use an orange flag or hand-held stop/slow sign to direct traffic. In some circumstances, two flag persons may be necessary.
- Fire and security crews shall be notified in advance so they are aware of the temporary road conditions.

For impaired roadways (totally blocked):

- Fire and security crews shall be notified at least 3 days in advance so that appropriate notifications and emergency arrangements can be made.
- “Road Closed” and “Detour” signs shall be posted. Reflective signs and/or flashing lights are required for night visibility.
- The area shall be fully barricaded to prevent inadvertent access.

3.7.1.2 Environmental Impacts

Proposed Action

Construction

The construction workforce would average approximately 56 workers, with a peak workforce of approximately 200 during construction of the service buildings and beamline. Construction vehicles, including workers, would use the Kautz Road entrance off Butterfield Road (**Figure 3.7-2**). Points of origin for transport of construction-related materials and commuting workers would vary; however, many construction-related vehicles would likely travel primarily on Butterfield Road, Kirk Road, and I-88.

On-site roadways that would be directly affected by construction would include Giese Road, which borders the Proposed Action to the north, Kautz Road to the east, and Main Injector Road to the south. Under the Proposed Action, Giese Road would be extended and local roads would be constructed to access the new service buildings (e.g., LBNF-40). Each of the new service buildings would have parking and staging areas for equipment laydown and soil stockpiling. Construction parking would be temporary, while operations parking would be permanent.

<u>Traffic Volume</u>

During construction of the Proposed Action, traffic volumes would increase slightly on the public roadways near Fermilab. Construction-related vehicular traffic on public roads would include commuting construction workers and trucks delivering construction materials and supplies. Construction-related traffic would be intermittent and would vary over the construction period depending on the activities conducted. The Proposed Action would not require rail or marine transport of construction materials or components.

On average, under the Proposed Action, daily commuting of 56 construction workers (112 round trips per day) would result in an increase in the number of vehicles of less than 1 percent relative to the existing traffic volumes on the surrounding roads. The increased volume of traffic on public roadways would be limited to the 7-year active construction period. The additional LBNF/DUNE-related traffic would result in very few traffic delays because there would be a minimal increase in the number of vehicles traveling on public roadways. Traffic effects would be minimized by scheduling the arrival and departure of construction-related workers to avoid peak commute hours. Workers would typically arrive before the morning commute peak period and avoid the evening commute peak.

During embankment construction, traffic volumes would increase on Kautz Road, Giese Road, and Main Injector Road within the Fermilab property. The contractor would transport heavy excavation equipment (e.g., front-end loaders) and haul trucks (dump trucks) to the site, prepare and grade the site, and construct access roads. Within the Fermilab property, trucks would transport excavated rock and soils, as well as borrow materials. During the initial construction, approximately 50,016 on-site truck trips (141 round trip truck trips per day for 17 months) would be required for construction of the embankment and transport of engineered fill obtained from on-site borrow sites. Excavated soil would either be stored at the construction site for use as backfill or transported to existing soil stockpiling areas within the Fermilab property. The truck trips for embankment construction would not result in noticeable traffic effects because travel would be limited to on-site roads within the Fermilab property, which are not accessible to the public.

The vehicles and equipment used for excavation/embankment construction activities would only travel within the Fermilab property and would not result in increases in off-site traffic. After flatbed trucks arrive to deliver the excavation equipment, construction traffic would consist primarily of commuting workers. The majority of heavy equipment movement for this phase would occur within the Fermilab property, with trucks moving between the borrow area and the embankment construction site. After construction of the final embankment, minimal activity would occur during the 2-year soil consolidation period.

Periodically, on-site roadways would require temporary closure; however, these closures would be limited to roads within Fermilab and directly adjacent to the construction area - primarily Giese Road and Main Injector Road. The truck trips for embankment construction would not result in noticeable off-site traffic effects because travel would be limited to on-site roads within Fermilab, which are not accessible for routine use by the public.

Construction of the Target Hall, Absorber Hall, NND and service buildings would be completed in approximately 5 years. Over this period, approximately 643 truck trips would be required for delivery of materials for the beamline construction. In addition, approximately 13,220 truck trips to Fermilab would be required for transport of service building and beamline materials and components. These deliveries (13,220 + 643 trucks over 17 months) would require an average of 39 trucks per day (78 round trip truck trips).

The Proposed Action would not require frequent closure of public roads; however, construction of the NND would require a large crane to lower heavy components through the access shaft. The crane would arrive (and depart) on a large flatbed truck that would be wider than a single lane and would require an escort and flaggers for wide turns and for entering the site.

Absolute Scale - 1:24,000
1 Inch = 2,000 feet

Legend

Road Type

Major Collector

Local Road or Street

Soil Borrow Pit

Fermilab Boundary

Construction Limits

1 Acre =

0 0.25 0.5 Miles

N

LBNF/DUNE EA

FIGURE 3.7-2

Construction Entrance and Access Roads - Fermilab

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The Proposed Action would result in a minor increase in the AADT on public roadways in the vicinity of Fermilab. **Table 3.7-2** shows the estimated LBNF/DUNE-related vehicles and the percentage increase in AADT under the Proposed Action for the primary public travel routes near Fermilab relative to existing AADT (**Figure 3.7-1**). The estimated number of LBNF/DUNE-related vehicles is based on the peak number of vehicles (200 commuter vehicles and 39 truck deliveries per day). The traffic associated with the peak construction workforce (400 round trips per day for commuter vehicles and 78 round trips per day for truck deliveries) would cause an increase in the number of vehicles on public roadways in the vicinity of Fermilab. These vehicles would travel various routes, and no single stretch of road would experience all the worker and truck traffic. Therefore, the estimated percent traffic increases presented in **Table 3.7-2** are very conservative because they assume that all 478 construction vehicles would travel the same route each day. Even with this assumption, no road would experience an average daily traffic increase of greater than 4.2 percent. Therefore, impacts on public travel would be low.

Table 3.7-2 Proposed Action Projected AADT and Traffic Increase with LBNF/DUNE-Related Construction Vehicles

Roadway	Location	LBNF/DUNE-Related Vehicles*	Total Projected AADT	Percent Increase
Kirk Rd (CR 77)	South of Pine St; North of Mesa Ln	478	36,578	1.32
Kirk Rd (CR 77)	North of Pine St; South of E Wilson St	478	17,178	2.86
North Farnsworth Ave (CR 77)	South of Butterfield; North of Biltner Rd	478	15,378	3.21
Butterfield Rd (IL 56)	Between Packford Ln and DuPage Pkwy	478	26,878	1.81
Butterfield Rd (IL 56)	Between Beverly Dr and Ginger Woods Pkwy	478	13,278	3.73
IL 59	North of Butterfield Rd	478	33,078	1.47
IL 59	South of Butterfield Rd	478	30,178	1.61
Eola Rd (CR 14)	Between Ferry Rd and Butterfield Rd	478	30,678	1.58
East Roosevelt Rd (IL 38)	Between Fabyan Pkwy & McChesney Rd	478	31,978	1.52
I-88	Between Eola Rd and IL 59	478	107,678	0.45

Note:
* Assumes peak number of LBNF/DUNE-related vehicles (400 commuter vehicles and 78 truck deliveries roundtrip per day) and that all LBNF/DUNE-related vehicles travel on the listed road.
Source: IDOT 2013

Traffic impacts on regional roadways would be low because these truck trips would in all but one case represent an increase of less than four percent relative to the current truck AADT on local public roadways. (Traffic could increase by approximately 3.7 percent on a portion of Butterfield Road, assuming all truck traffic uses Butterfield Road.) To minimize traffic impacts, the construction contractor and Fermilab would prepare and implement a construction traffic management plan. Construction vehicles and workers would be required to enter Fermilab via Kautz Road at the Butterfield Road entrance. To minimize traffic delays resulting from vehicles turning left from Butterfield Road into Fermilab, the traffic control plan would outline the truck routes and constrain trucks from making left turns against oncoming traffic wherever feasible. Because land uses adjacent to Butterfield Road are primarily commercial, existing automobile traffic in this area is limited. The traffic control plan would establish LBNF/DUNE-specific traffic management measures such as arrival and departure times. Construction traffic typically would occur outside the normal commute peak periods. Traffic effects would be minimized by scheduling the arrival and departures of construction-related trucks and heavy haul deliveries to avoid peak commute hours to the extent practicable. With implementation of these measures, Fermilab would minimize off-site construction traffic impacts from the Proposed Action.

Construction of the Proposed Action would cause an increase in the number of vehicles traveling on Giese Road, Kautz Road and Main Injector Road within the Fermilab property. LBNF/DUNE activities would primarily occur in areas away from the roads commonly driven by employees and visitors. The LBNF/DUNE-related traffic would represent a small increase in the number of vehicles relative to the 2,500 vehicles (employees and visitors) currently traveling to Fermilab daily.

On-site traffic impacts would be minimized by following site traffic control procedures, including employing flaggers and posted detours, which would minimize effects on traffic flow and the potential for accidents. Access to the construction areas would be limited to construction workers and Fermilab personnel engaged in the administration or monitoring of construction activities. Other controls would be implemented as needed to address potential traffic impacts, including minimizing construction vehicle movement on-site during peak rush hours and placing construction staging areas in locations that would minimize construction vehicle traffic on routes traveled by visitors. Overall, public travel impacts on Fermilab private roadways would be minimized by implementing the traffic control measures outlined in the Fermilab ES&H Manual, section 9010: Traffic Safety.

Traffic Accidents

The Proposed Action would result in the potential for traffic accidents roughly proportional to the number of LBNF/DUNE-related vehicles miles. Although the rate of traffic accidents cannot be definitively predicted, the incremental increase can be estimated based on the historical rates. Numerical estimates of potential accidents were calculated using the number of vehicle miles that would be driven during construction and applying the accident rates per vehicle mile from the IDOT Illinois Crash Facts & Statistics (IDOT 2011). The calculated result is an estimate of risk and does not imply that a particular number of accidents, injuries, or fatalities would actually happen.

To determine the number of vehicle miles associated with construction under the Proposed Action, a conservative average commute distance of 76 miles per round trip was used to estimate the distance traveled by workers driving to and from Fermilab. This distance is based on a one-way distance of 38 miles between Chicago and Batavia.

Table 3.7-2 provides an estimate of the average daily traffic (number of vehicles) traveling on local roads during peak construction; however, the total vehicle miles over the 7-year construction period were used to estimate the potential number of accidents. Under the Proposed Action, construction would result in approximately 7,448,000 vehicle miles for workers traveled over the 7-year construction period. This estimate assumes one 76-mile round trip per day for 56 workers over 7 years. In addition, approximately 1,053,588 vehicle miles would be generated by 13,863 truck trips travelling one 76-mile round trip each for 17 months during embankment construction. Based on IDOT-published accident rates (Section 3.12.1.1), the Proposed Action may potentially result in 23 accidents, 7 injuries, and zero (0.075) fatalities. These estimates are approximations based on the available statewide statistics for all motor vehicles, and do not account for the differences in accident rates for commuter vehicles relative to the rates for delivery trucks or tractor trailers, local factors such as traffic safety devices, weather conditions, police enforcement of safety regulations, or shared use of roads and parking areas with pedestrians and bicyclists.

The truck trips for excavated material would all occur on roads within the Fermilab property, which are closed to the public, and over very short distances. Trucks would transport excavated material from the soil borrow pit to the embankment site and from excavations to temporary soil stockpile site. Although this activity would require numerous truck trips (approximately 50,016 on-site truck trips) for construction of the embankment and beamline enclosure, the distance traveled would be low (less than 1.5 miles to the soil stockpiling area); therefore, the activity would result in approximately 75,039 vehicle-miles total, with 0 (0.21) accidents. There would be a very low risk of accidents, injuries, or fatalities because the construction area would not be accessible to the public.

LBNF/DUNE-related trucks traveling within the Fermilab property would adhere to the traffic safety policy contained in the Fermilab ES&H Manual (9010: Traffic Safety). For construction, this policy requires signage and/or flashing lights, traffic cones, and flaggers to direct trucks where visibility is obstructed. Trucks would also be required to adhere to on-site speed limits. Further, the contractor would establish one-way transport routes where practicable. On-site roads closed for construction would be barricaded and marked to prevent inadvertent access. Traffic management would be incorporated into the construction contract. (On-site traffic safety is also addressed in Section 3.4, Health and Safety).

Construction of the Proposed Action would not involve transport of substantial volumes of hazardous materials or any radioactive materials or wastes. Transported hazardous materials would include those required for construction such as lubricants and solvents. Risks from routine transport of small volumes of hazardous materials and waste are evaluated in Section 3.14, Waste Management.

Operations

Under the Proposed Action, no permanent new positions would be added at Fermilab; however, approximately 10 additional researchers could be present on-site at any one given time. Potential impacts on traffic volume and accidents are presented below.

<u>Traffic Volume</u>

During operation of the Proposed Action, the 10 additional researchers would not result in a noticeable increase in traffic volume relative to current operations. Assuming this increase in personnel increases local traffic by an average of approximately 10 vehicles per day, the impact on nearby roads would be less than 0.1 percent, a very low increase in traffic. Impacts on public travel would be low because the construction-related vehicles would result in a very slight increase in traffic volume relative to current conditions.

Operations would slightly increase parking demand. Under the Proposed Action, additional parking areas would be constructed near the two new service buildings; therefore, the increased parking demand would not exceed the supply. The increased parking demand would likely not affect parking in other experimental areas or at Wilson Hall.

<u>Traffic Accidents</u>

Under the Proposed Action, operations would result in 1,875,000 vehicle miles traveled over the 20-year experiment life. Whereas construction workers may come from Chicago and suburbs, most of the operations staff would seek housing closer to Fermilab; therefore, this estimate assumes one 25-mile round trip per day for 10 workers. Based on IDOT-published total accident rates for all motor vehicles, the total vehicle miles traveled for operations under the Proposed Action has the potential to result in 3 traffic accidents, 1 injury, and zero (0.01) fatalities.

No Action

Under the No Action Alternative, the existing research programs at Fermilab would continue; however, LBNF/DUNE would not be constructed or operated. Under the No Action Alternative, the traffic impacts associated with LBNF/DUNE construction and operation would not occur, and there would be no incremental increase in impacts on traffic volumes or accident rates. Public travel on Kirk Road, Butterfield Road, I-88, and other nearby travel routes, as well as the on-site roads within the Fermilab property, would increase over the term of the experiment relative to regional changes in population and development.

3.7.2 SURF

3.7.2.1 Affected Environment

The SURF area and the City of Lead are accessed by State Highways 85, 385 and 14A. These paved two- and three-lane state-maintained roads host commercial, tourist, and residential traffic. Kirk Road, Yellow Creek, and Gilt Edge Road are gravel county roads used primarily by local residents and provide commercial access to a local landfill and the Gilt Edge Superfund site. Houston Street, Washington Street and Mill Street are city maintained and are used by residents and businesses and to access the SURF property. The access road to the Open Cut is a gated, gravel road owned and maintained by Homestake. These roads are shown on **Figure 2.1-9**.

Traffic Volume

Table 3.7-3 shows the 2012 annual average daily traffic (AADT) for the highways and roads listed above.

Table 3.7-3 Annual Average Daily Traffic for the SURF Area

Roadway	Location	Existing AADT	Existing Truck AADT
US 85[1]	Mill Street in Lead	3,992	407
US 14[1]	Dixon Road in Lead (north of JCT US85)	4,446	355
US 85/14[1]	Kirk Road (south of JCT US85)	3,683	427
Highway 85[1]	Between Lead and 385	3,492	233
Highway 385[2]	Between Pluma and Gilt Edge Road	3,068	865
Kirk Road[2]	US 85 to US385	311	122
Gilt Edge Road[2]	385 to Gilt Edge Mine	137	10[3]
Yellow Creek Road[2]	From Kirk Road to Tri-Cities Landfill	167	12[3]
Houston Street[2]	West of SURF	90	6[3]
Mill Street[2]	North and west of SURF	1,484	50[3]
Washington Street[2]	North of Surf	932	32[3]

Notes:
AADT = Annual Average Daily Traffic
1 South Dakota Department of Transportation, 2012
2 South Dakota Department of Transportation, 2014
3 Estimated by the South Dakota Department of Transportation, 2014

Traffic Accidents

The total vehicle miles travelled on Lawrence County roads in 2013 was 254,824,999 miles (South Dakota Department of Transportation [SD DOT] 2014). During this period, there were 596 accidents, 161 injuries, and 5 fatalities. Given this number of incidents and the miles traveled, the accident rate was 2.39 accidents, 0.63 injuries, and 0.020 fatalities per million miles traveled (SD Department of Public Safety, 2014; SD DOT 2014).

3.7.2.2 Environmental Impacts

Proposed Action

Construction

Traffic Volume

Construction for the Proposed Action would increase traffic on affected roadways. The impact analysis assumes that the construction activities would occur in a sequential order and with no overlap, with the exception of excavation and outfitting the detector cavern, which would overlap with rock transport to either the Gilt Edge Superfund site or the Open Cut.

Ross Boiler Demolition – Approximately 800 tons of rubble would result from the demolition of the Ross Boiler Building and Stack. Approximately half of the rubble would be transported on Houston Street to Highways 85 and14A, onto Kirk Road, onto Yellow Creek Road to the Tri-Cities Landfill. The other half would be transported via Mill Street, Highways 85 and Interstate 90 to the Rapid City Landfill as it would contain asbestos. The Rapid City Landfill would be the closest landfill permitted for asbestos disposal. Approximately 5 employees would work to remove the rubble and Asbestos Containing Material (ACM) over 10 work days. Two loads of rubble per day would be trucked to the Tri-Cities Landfill and two loads of ACM would be trucked to the Rapid City Landfill.

Cryogen Support Building – Construction of the Cryogen Support Building would require 180 workdays. The estimated number of truck deliveries would average 2 truckloads per day with a maximum of 10 truckloads per day. The trucks would travel an average distance (one way) of 125 miles. (This assumes that 80 percent of the deliveries would originate in Rapid City, SD and 20 percent would originate in Denver, CO.) There would be an average of 10 workers per day and a maximum of 15 workers per day over the approximately 180-day work period.

Truck Conveyor and Truck Load-Out – Truck Conveyor and Truck Load-out construction would occur over 180 workdays. There would be an average of 10 employees per day, with a peak of approximately 15. There would be an average of 2 equipment and supply deliveries per day, with a peak of approximately 10 loads per day.

The Rail/Pipe Conveyor – The construction of the Rail/Pipe Conveyor would occur over 250 work days. There would be an average of 15 employees per day, with a peak of approximately 20. The average number of equipment and supply deliveries per day would be 2 with a peak of 15.

Detector Cavern - The construction of the detector cavern would occur over 60 months (1,250 days) and require an average of 50 and a maximum of 100 workers per day. There would be an average of 2 truck trips per day to deliver equipment and supplies. In addition, tanker trucks would be needed to deliver LAr and LN to fill the detector and refrigeration systems. Approximately 1,800 tanker truckloads of LAr would be delivered to the site over a period of 12 months. The average number of deliveries per day would be 7 – 8. The primary access for these deliveries would be from Route 85 to Mill Street to the Ross shaft.

Rock Hauling – Construction would include conveying 460,000 yd^3 of rock from the underground excavation to either the Gilt Edge Superfund Site or the Open Cut. Each truck would haul 20 tons of rock (approximately 12 yd^3). This activity would occur over two years and operate on weekdays during the period from 7 a.m. to 6 p.m. The average daily truck haul rate would be 75 round trips per day, with an approximate peak of 150 trips per day. There would be an average of 10 employees per day loading and hauling the rock, with a peak of 15 employees per day. The distance from the load-out to the Gilt Edge Superfund site is 7.4 miles; the distance to the Open Cut is 4.1 miles.

For the alternate pipe/rail conveyance to the Open Cut, construction traffic would result from construction of the pipe/rail conveyor; however, once constructed, the conveyor would transport rock with minimal impact on public roads and would avoid using trucks to haul rock through the north and west sides of Lead on their way to the Open Cut. The construction of the rail system or pipe conveyor would involve crossing Highway 85. There would be short-term disturbances of traffic on Highway 85 to complete the construction. In addition, much of the construction work for the conveyor would occur near Washington Street, increasing traffic and detours near this roadway for approximately 9 months. Only periodic maintenance of the conveyor would be required, including approximately 2-3 inspections per day.

Table 3.7-4 shows the percent increase in daily roadway usage for each construction activity and disposal alternative as well as the total miles for the activity over the two-year (500 days) period.

During construction of the Proposed Action, traffic volumes would increase on the public roadways near SURF. The traffic associated with the peak construction workforce would include employee commutes and truck trips on various routes, and no single stretch of road would experience all the worker and truck traffic. On most roadways (**Table 3.7-4**), impacts on public travel would be low because LBNF/DUNE traffic would result in a slight increase in traffic volume relative to current conditions. The traffic increase would be greater on Kirk Road between the Truck Load-out and Highway 385, on Gilt Edge Road, and on Open Cut Road. Based on an average of 75 round trips per day, with a peak of 150 round trips, traffic would increase by approximately 96 percent on Kirk Road and 146 percent on Gilt Edge Road. However, based on the history of the Lead area being a mining area, these increases would have low impact to transportation in the community in this context. During construction, workers would travel to and from the site via Highways 14, 85, and 385, as well as on roads throughout Lead to the Ross Shaft. Worker commute traffic would result in minor traffic disruptions during shift changes over a 24-hour workday.

Table 3.7-4 Proposed Action Construction Activity- Incremental Roadway AADT, Percent Traffic Increase, and Total Roadway Miles

Location	Number of Additional Trips (per day)	Baseline AADT	Percent Increase
Ross Boiler Demolition (20 days)			
Houston St. Between SURF an Hwy 85	4	90	4
On Highway 85 between Houston Street and Kirk Rd	4	3,683	0.1
Kirk Rd. From Hwy. 85/14A to Yellow Creek Rd	4	311	1.3
Yellow Creek Rd From Kirk Road To Tri-Cities Landfill	4	167	2.4
Mill Street	4	1,484	<0.01
Hwy 85 to Rapid City Landfill	4	4,446	<0.01
Employee commute[1]	10		
Total Road Miles Associated with Ross Boiler Demolition = 10,700 miles			
Cryogen Support Building (180 days)			
Mill Street From SURF site to Highway 85[2]	20	1,484	1.3
Highway 85 from Lead to I-90[2]	20	4,446	0.4
Employee commute[1]	30		
Total Road Miles Associated with the Cryogen Support Building Construction = 147,600 miles			
Truck Conveyor and Load-out Station (180 days)			

Table 3.7-4 Proposed Action Construction Activity- Incremental Roadway AADT, Percent Traffic Increase, and Total Roadway Miles

Location	Number of Additional Trips (per day)	Baseline AADT	Percent Increase
Kirk Road from Hwy 385 to Hwy 85/14A[2]	20	311	6.4
Employee Commute[1]	30		
Total Road Miles Associated with the Truck Conveyor and Load-Out Construction = 147,600 miles			
Rail/Pipe Conveyor Construction (250 days)			
Washington Street[2]	30	932	3.2
Highway 85/14A[2]	30	4,446	0.7
Employee Commute[1]	40		
Total Road Miles Associated Rail/Pipe Conveyor Construction = 245,000			
Detector Cavern Excavation and Outfitting (60 months)			
Mill Street[2]	61.5	932	6.9
Highway 85/14A[2]	61.5	4,446	1.3
Employee commute[1]	200		
Total Road Miles Associated with the Detector Cavern = 2,859,000			
Gilt Edge Superfund Site Truck Haul (24 Months)			
Kirk Road Between Truck Load-out and Highway 385	300	311	96
Highway 385 from Kirk Road to Gilt Edge Road	300	3,068	9.8
Gilt Edge Road	300	137	146
Employee commute[1]	30		
Total Road Miles Associated with the Gilt Edge Superfund Site Rock Haul = 784,000			
Open Cut Truck Haul (24 months)			
Kirk Road Between Truck Load-out and Highway 85/14a	300	311	96
Highway 14A/85 to Open Cut Access Road	300	3,683	8
Employee commute[1]	30		
Total Road Miles Associated with the Open Cut Site Rock Haul = 541,500 miles			

Notes:
1 Assumes the average distance of a one-way employee commute would be 16 miles.
2 Assumes truck deliveries. A one-way truck delivery would be 125 miles.

Traffic impacts would be reduced by implementing a traffic control plan, training personnel on the plan's components, posting speed limits, regular inspections of construction vehicles, employing highly visible signage, and holding contract drivers accountable for vehicle safety. Important elements of the traffic control plan would be to widen Highway 385 at the Gilt Edge Road turn off, post caution signs at major intersections such as the intersection of Highway 385 and Kirk Road, limit delivery trucks using Highway 85 in downtown Lead, provide dust control on Kirk Road and Gilt Edge Road to maintain visibility, improve Kirk Road grade and banking along sharp turns, haul only during daylight hours, and limit hauling during the Sturgis Motorcycle Rally and Mickelson Trail usage events.

<u>Traffic Accidents</u>

Incremental predicted accidents for the construction of the Proposed Action at SURF were calculated using existing SD DOT accident, injury and fatality rates, which are expressed in million miles traveled, multiplied by the number of million vehicle miles for three scenarios that correspond to the rock conveyance method to either the Gilt Edge Superfund site or the Open Cut.

Table 3.7-5 provides the total driving miles required for the Proposed Action with transportation of rock to the Gilt Edge Superfund site and the Open Cut (truck and conveyor), the incident rate per million miles, and the potential incremental impact on accidents, injuries, and fatalities associated with the Proposed Action. Based on SD DOT-published total accident rates for all motor vehicles, the total vehicle miles traveled for the Proposed Action with the transport of rock to the Gilt Edge Superfund site has the potential to result in 9.3 traffic accidents, 2.5 injuries, and zero (<0.1) fatalities.

Table 3.7-5 Accidents, Injuries, and Fatalities – Proposed Action Construction

	Total Miles Driven	Rate per million miles	Potential Incremental Increase in Accidents, Injuries and Fatalities
Proposed Action with Rock Placement at the Gilt Edge Superfund Site			
Accidents	3,948,900	2.39	9.4
Injuries	3,948,900	0.63	2.5
Fatalities	3,948,900	0.02	<0.1
Proposed Action with Rock Placement at the Open Cut (Trucking)			
Accidents	3,706,400	2.39	8.9
Injuries	3,706,400	0.63	2.3
Fatalities	3,706,400	0.02	<0.1
Proposed Action with Rock Placement at the Open Cut (Conveyor)			
Accidents	3,262,300	2.39	7.8
Injuries	3,262,300	0.63	2.1
Fatalities	3,262,300	0.02	<0.1

Operation

Traffic Volume

The Proposed Action would add approximately 4 SURF employees for maintenance and approximately five on-site researchers at any one time. This would result in a total of 9 commutes per day one-way or 18 round trips on local roads with an average commute distance of 16 miles. Operations would also result in additional traffic from trucks delivering LN and LAr to refill the cryostats and refrigeration system. This traffic would use US 85, US 14, and roadways throughout Lead to access the detector site. Approximately 1 truck per day would deliver LN and miscellaneous supplies over a period of 20 years. **Table 3.7-6** shows the percent increase in daily roadway usage during the 20-year operational period.

Table 3.7-6 Proposed Action Operations- Incremental Roadway AADT, Percent Traffic Increase, and Total Roadway Miles (over 20 years)

Location	Number of Trips (per day)	Baseline AADT	Percent Increase	Total Miles for Activity[1]
Highway 85/14A/I-90	1	311	<0.01	1,543,000
Mill Street	1	1,484	<0.01	
Employee commute	18			2,102,400

Notes:

1 Assumes the average distance of a truck trip would be 125 miles (one way) and an average distance of an employee commute would be 16 miles (one way).

During operation of the Proposed Action, the LBNF/DUNE-related vehicles would result in a very slight increase in traffic volume relative to current conditions. The additional 4 LBNF/DUNE-related workers would not result in a noticeable increase in traffic volume.

Traffic Accidents

During operations, LBNF/DUNE-related traffic would be comprised of approximately 1 trip per day at 211 miles per trip (two-way) for the delivery of needed supplies and 9 commuter (researchers and maintenance) trips per day at 16 miles per trip (one way) would result in a total of 3,645,401 vehicle miles driven over 20 years. **Table 3.7-7** shows the incremental impact of the Proposed Action on accidents, injuries and fatalities over 20 years. Based on SD DOT-published total accident rates for all motor vehicles and the total vehicle miles traveled, operation of the Proposed Action has the potential to result in 9 traffic accidents, 3 injuries, and zero (<0.1) fatalities.

Table 3.7-7 Incremental Accidents, Injuries and fatalities associated with Operation of the Proposed Action

	Total Miles Driven	Rate per million miles	Potential Incremental Increase in Accidents, Injuries and Fatalities
Accidents	3,645,401	2.39	8.7
Injuries	3,645,401	0.63	2.3
Fatalities	3,645,401	0.02	0.07

Alternative A

Construction

Traffic Volume

Should underground placement of the rock not be a viable option, excavation and off-site, above-ground transportation of 153,000 yd^3 of rock would require approximately 168 days assuming an average of 75 truckloads per day and a peak of approximately 150 loads per day. The rock haul activity would require an average of 10 employees and a peak of approximately 15 employees. If all of the excavated rock were transported to the Gilt Edge mine or transported and placed at the Open Cut, scaling of impacts from the Proposed Action (i.e., 153,000 yd^3 vs. 460,000 yd^3) would suggest that construction impacts from Alternative A could be up to approximately one-third that of the proposed action. In the event that underground placement of the rock is a viable option, the incremental impact of this alternative compared to the Proposed Action would be small.

Traffic Accidents

The total miles driven (vehicle miles) associated with the Gilt Edge Superfund site haul for Alternative A experiments would be 240,260 miles (including employee commute miles). The total for the Open Cut would be 157,000 miles. **Table 3.7-8** shows the incremental accidents, injuries and fatalities associated with the construction of Alternative A considering a rock haul to the Gilt Edge Superfund site or Open Cut.

Table 3.7-8 Incremental Accidents, Injuries and fatalities associated with Construction of the Alternative A Using the Gilt Edge Truck Haul Route

	Total Miles Driven	Rate per million miles	Potential Incremental Increase in Accidents, Injuries and Fatalities
Gilt Edge Superfund Site			
Accidents	1,214,000	2.39	2.9
Injuries	1,214,000	0.63	0.8
Fatalities	1,214,000	0.02	0.02

Table 3.7-8 Incremental Accidents, Injuries and fatalities associated with Construction of the Alternative A Using the Gilt Edge Truck Haul Route

	Total Miles Driven	Rate per million miles	Potential Incremental Increase in Accidents, Injuries and Fatalities
Open Cut			
Accidents	1,132,000	2.39	2.7
Injuries	1,132,000	0.63	0.7
Fatalities	1,132,000	0.02	0.02

Operation

The operation of Alternative A experiments would require a limited number of employees because of their limited size and scope. Staff commutes would be minimized by remote monitoring and employing local scientists from local colleges to perform maintenance and upkeep. There would be a minimum of deliveries of cryogens and supplies. The Rail/Pipe Conveyor would result in extremely low incremental road miles including a small number of vehicle miles to perform routine maintenance. Impacts on public travel would be low during operations because the AADT on public roads near SURF would remain comparable to current conditions.

No Action

The No Action Alternative would not involve construction or operation and related traffic impacts and potential accidents. Existing experiments at SURF would continue to utilize area roadways and traffic patterns from local and regional changes in population and development would continue at rates similar to current conditions.

3.8 AIR QUALITY

This section evaluates the potential air quality impacts from construction and operation at both Fermilab and SURF. The affected environment for air quality standards at Fermilab includes DuPage and Kane counties. For SURF, the affected environment is the State of South Dakota, which has adopted EPA's National Ambient Air Quality Standards (NAAQS). Greenhouse gas emissions have very small if any localized impacts; therefore, the affected environment in this EA for GHG emissions is the global atmosphere.

3.8.1 Fermilab

3.8.1.1 Affected Environment

The ambient air quality of an area is generally characterized in terms of whether it complies with NAAQS and State Ambient Air Quality Standards (SAAQS), where applicable. The Clean Air Act (42 U.S.C. 7401 et seq.) requires the U.S. Environmental Protection Agency (EPA) to set national standards for emissions that are considered harmful to public health and the environment (criteria pollutants). The NAAQS establishes standards to protect the public health and welfare for the following "criteria" pollutants:

- Sulfur dioxide (SO_2)
- Ozone (O_3)

- Nitrogen dioxide (NO_2)
- Particulate matter whose particles are less than or equal to (≤) 10 microns [µm] (PM_{10})
- Particulate matter whose particles are ≤ 2.5 µm ($PM_{2.5}$)
- Carbon monoxide (CO)
- Lead

In Northeastern Illinois, DuPage and Kane Counties have been designated as a marginal non-attainment area for the 8-hour ozone standard (2008 standard) and a proposed non-attainment area for the annual $PM_{2.5}$ standard (2012 standard) (**Table 3.8-1**).

Table 3.8-1 Air Quality Standards Attainment Status for the DuPage and Kane County Areas

Parameter		State Standard		Federal Standard	
O_3	1-Hour	--		--	
	8-Hour	0.075 ppm		0.075 ppm	Non-attainment
CO	1-Hour	35 ppm ($40\ mg/m^3$)		35 ppm ($40\ mg/m^3$)	Unclassifiable/Attainment
	8-Hour	9.0 ppm ($10\ mg/m^3$)		9.0 ppm ($10\ mg/m^3$)	Unclassifiable/Attainment
NO_2	1-Hour	--		0.100 ppm	Unclassifiable/Attainment
	Annual Arithmetic Mean	0.053 ppm ($100\ \mu g/m^3$)		0.053 ppm ($100\ \mu g/m^3$)	Attainment
SO_2	1-Hour	--		75 ppb	Attainment
	3-Hour	30 ppb		0.5 ppm	Attainment
	24-Hour	0.14 ppm ($365\ \mu g/m^3$)		--	Attainment
PM_{10}	24-Hour	$150\ \mu g/m^3$		$150\ \mu g/m^3$	Unclassifiable
$PM_{2.5}$	24-Hour	$35\ \mu g/m^3$		$35\ \mu g/m^3$	Unclassifiable/Attainment
	Annual Arithmetic Mean	$15\ \mu g/m^3$		$12\ \mu g/m^3$	Attainment[1]
Lead	Rolling 3-Month Avg	$0.15\ \mu g/m^3$		$0.15\ \mu g/m^3$	Attainment

Notes:

1 Area was proposed Non-attainment Area for PM2.5 annual standard (2012 standard) in 2013.

2 no standard available

3 $\mu g/m^3$ = micrograms per cubic meter
ppm = parts per million
mg/m^3 = milligrams per cubic meter

Sources: EPA 2011; 35 IAC 243 Subpart B

Fermilab qualifies as a small emission source under the requirements of the Registration of Small Sources (ROSS) program per 35 IAC 201.175. The facility registered under ROSS in September 2012.

Potential emissions from facility processes include PM, CO, nitrogen oxides (NO_X), SO_2, volatile organic material (VOM), and Hazardous Air Pollutants (HAP) in quantities below major source thresholds. **Table 3.8-2** summarizes the estimated actual emissions of Criteria Air Pollutants (CAP) from the Fermilab site (existing emissions during 2013 operations), including carbon dioxide equivalent (CO_2e, an expression of the climate warming potential of GHGs in terms of equivalent amount of CO_2).

Tritium and other short-lived radionuclides are produced as a normal by-product of facility operations. The airborne radionuclides produced at Fermilab (e.g., in the NuMI facility) are released into the atmosphere through vent stacks to the surface of the Fermilab site. Atmospheric emissions are limited by minimizing the ventilation of the tunnels during beam operations. Ventilation is maximized for personnel access; however, air emissions are still limited by allowing sufficient time for decay after beam shutdown and before accessing. Air from the ventilation stacks is monitored for radionuclide emissions.

Table 3.8-2 Estimated Release of Criteria Air Pollutants at Fermilab in Tons per Year for 2013

Emission Unit	Actual Pollutant Emissions (tons per year)								
	PM	**PM_{10}**	**$PM_{2.5}$**	**CO**	**NO_x**	**SO_2**	**VOM**	**GHG (as CO_2e)**	**HAP**
Continental Boiler	0.01	0.01	0.01	0.06	0.07	0.0004	0.004	86.93	0.001
Cleaver Brooks Boiler	0.11	0.11	0.11	1.19	0.45	0.01	0.08	1710.14	0.03
Gasohol UST	-	-	-	-	-	-	0.02	-	Neg.
Computing Center Generator	0.02	0.02	0.02	0.17	0.65	0.03	0.02	33.54	0.00
Main Injector Particle Production (MIPP) Experiment	-	-	-	-	-	-	0.00	-	-
Cavity Processing Facility – Buffer Chemical Processing	0.00	0.00	0.00	-	0.00	-	-	-	0.00
Cavity Processing Facility – Electropolishing	-	-	-	-	-	-	-	-	0.00
Debonding Oven	0.02	0.02	0.02	0.002	0.003	0.00	0.0002	3.32	0.0001
Clean Air Act Permit Program Insignificant Activities (Not included in comparison to ROSS thresholds)	0.22	0.22	0.22	1.99	3.47	0.12	2.29	1112.32	0.02
Total	**0.37**	**0.37**	**0.37**	**3.42**	**4.65**	**0.16**	**2.41**	**2946.25**	**0.05**

Notes:
1 CY 2013 Annual emissions data, Site Environmental Report, Fermi Research Alliance, LLC. January 14, 2014.
2 CO_2e: The total global warming potential of all GHG emissions in terms of carbon dioxide.

The annual radioactivity of typical releases from Fermilab (site-wide) and the highest estimated dose rate at the site boundary from these releases are well below both the regulatory limits for the annual release of radionuclides (2,000 Curies/year, National Emission Standards for Hazardous Air Pollutants [NESHAP] requirement) and the maximum dose at the site boundary (10 mrem/year, 40 CFR 61).

<u>Conformity</u>

EPA promulgated the General Conformity Rule in November 1993 to implement the conformity provision of Title I, Section 176 (c) (1) of the Federal Clean Air Act. The General Conformity regulations apply to any Federal action to ensure attainment of the NAAQS and ensure that actions do not cause or contribute to new violations of the NAAQS. Each state must prepare and submit a State Implementation Plan (SIP) describing how the state will achieve the Federal standards by specified dates, depending on the severity of the air quality within the state or air basin. This provision requires that the Federal government not engage, support, or provide financial assistance to licensing, permitting, or approving any activity not conforming to an approved SIP.

A conformity analysis is required if the generation of air emissions would exceed conformity threshold levels for pollutants designated as nonattainment or maintenance for the NAAQS. The *de minimis* levels for conformity of each criteria pollutant in non-attainment in this air basin are presented in **Table 3.8-3**.

Table 3.8-3 General Conformity *de minimis* Level

Pollutant	*de minimis* Level (tons/year)
O_3 (NO_x)*	100
O_3 (VOC)*	100
PM_{10}/$PM_{2.5}$**	100

Notes:

* O_3 is a gas formed when volatile organic compounds (VOCs) and NO_x undergo photochemical reactions in the presence of sunlight. For this analysis, these two precursors were evaluated as surrogates for O_3. The *de minimis* values for non-attainment areas were used.

** No *de minimis* values have been established for $PM_{2.5}$. As a surrogate, the *de minimis* level for PM_{10} in a moderate non-attainment and maintenance area was used.

Greenhouse Gases

GHGs contribute to the greenhouse effect, which is the process by which terrestrial radiation is absorbed by gases in the atmosphere, warming the Earth's surface and atmosphere. According to the Intergovernmental Panel on Climate Change (IPCC), the atmospheric concentrations of the GHGs carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have all increased since 1750 due to human activity. In 2011, the concentrations of these gases were 391 ppm, 1803 ppb, and 324 ppb, and exceeded pre-industrial levels by approximately 40 percent, 150 percent, and 20 percent, respectively (IPCC 2013). In addition, the concentrations of these gases now substantially exceed the highest concentrations recorded in air samples taken from polar ice formed during the past 800,000 years. The mean rates of increase in atmospheric concentrations over the past century are, with very high confidence, unprecedented in the last 22,000 years (IPCC 2013). Concentrations of GHGs other than CO_2 are reported in units of metric tons of CO_2 equivalent, where impacts from each GHG are converted to equivalent impacts of CO_2.

The Federal government has taken a number of steps to reduce GHG emissions, conserve energy, reduce demand, and promote development of renewable energy sources and technologies. EO 13693, Planning for Federal Sustainability in the Next Decade (EPA 2015), requires Federal agencies to set goals in the areas of energy efficiency, acquisition, renewable energy, toxics reductions, recycling, renewable energy, sustainable buildings, electronics stewardships, fleets, and water conservation. The goal of EO 13693 is (in part) to reduce agency GHG emissions by 40% over the next decade. This EO requires that DOE address agency GHG reduction targets, reductions in petroleum, potable water use, solid waste generation, recycling, and other targets. By implementing these EOs, the Federal government as a whole has reduced GHG emissions.

The CEQ has published draft guidance on the inclusion of a GHG evaluation for NEPA (CEQ 2014). Federal agencies are advised to consider opportunities to reduce GHG emissions caused by proposed Federal actions and adapt their actions to climate change impacts. Further, the guidance states that actions having annual direct emissions greater than 25,000 metric tons of CO2-equivalent warrant description under NEPA for activities resulting in direct GHG emissions.

Both Fermilab and SURF have developed site-specific plans to comply with these EOs. Fermilab's SSP addresses these goals, and the Proposed Action and Alternative A would be consistent for construction and operation. In addition, SURF has developed a sustainability plan. In this way, both sites involved in LBNF/DUNE operate in a manner consistent with EOs and have reduced GHG emissions, as is described in Section 3.12, Sustainability.

3.8.1.2 Environmental Impacts

Proposed Action

Construction

Construction activities would produce particulate emissions from earth-moving activities and from fugitive emissions generated by traffic on paved and unpaved areas. Construction activities would also produce criteria pollutant emissions from combustion of fuel used in construction equipment, supply delivery trucks, and passenger vehicles. Construction activities associated with the Proposed Action would occur over a period of approximately 7 years and would include construction of the enclosures, service buildings, beamline, and utilities.

Construction activities would also include the removal of an existing cooling pond, construction of a new cooling pond, and construction or upgrade of local access roads to the service buildings. Particulate emissions would result from supply truck deliveries, earth moving for soil stockpiling and earthwork, and use of construction equipment in disturbed areas. Specific activities that would contribute to fugitive particulate air emissions would include excavation, stockpiling, and placement of approximately 950,000 yd^3 of soil (borrow and topsoil), excavation of rock, construction of the earthen embankment, and subsequent excavation within the embankment after settling to construct the beamline.

The information and assumptions used to calculate construction emissions, including construction activities and the approximate types and quantity of construction equipment that would be used for each type of construction activity are documented in **Appendix F-1**. Although construction activities would be performed during a 5-day workweek, emissions were calculated assuming six days per week to account for any potential weekend construction that may occur. Emissions from construction were estimated using EPA’s AP-42 emission factors or as otherwise noted in **Appendix F**.

Table 3.8-4 presents the resulting emissions calculations for each year of construction. Construction activities would generate emissions for area attainment and non-attainment pollutants. However, air emissions would be temporary and would not lead to long-term impacts on air quality. Proposed Action construction emissions when compared with the *de minimis* thresholds for the conformity regulations would not exceed the general conformity *de minimis* threshold (100 tons) for non-attainment pollutants (Ozone precursors: NO_x, VOC, and $PM_{10}/PM_{2.5}$) for the years encompassing heavy construction (2017 – 2023). Internal installation activities would continue for approximately 3-4 years subsequent to the heavy construction phase, which would require use of passenger vehicles for worker commutes. Emissions during this phase of construction would be very low. Diesel equipment would also emit small quantities of HAPs. Emissions from architectural coatings and other chemicals used in the building process would also be very low.

Air pollution emissions from excavation, soil stockpiling, and embankment construction activities would be minimized by using SEPMs including erosion and dust control BMPs such as water sprays and surfactants, minimization of disturbed soil area, soil stabilization and revegetation, and administrative controls such as sequencing and scheduling. Emissions from other construction activities, such as vehicle traffic and equipment operation, would be minimized by the dust control practices listed above, where applicable, and by proper maintenance of equipment and use of low-sulfur diesel fuels. Projected annual air emissions would not require additional air permitting.

Table 3.8-4 Estimated Construction and Operations Emissions for the Proposed Action – Fermilab

Year	Emissions (short tons/year)						CO_2e Emissions (metric tons/year)		
	CO	NO_X	PM_{10}	$PM_{2.5}$	SO_2	VOC	Direct	Indirect	Total
Proposed Action Construction									
2017	43.28	89.84	38.99	13.53	28.62	7.52	17,013	2,304	19,318
2018	42.81	90.50	42.36	14.40	28.71	7.52	17,195	2,310	19,505
2019	38.12	83.73	19.42	11.13	26.64	6.81	15,945	1,932	17,877
2020	40.68	87.92	26.01	12.23	27.96	7.25	16,757	2,315	19,072
2021	40.44	88.88	23.92	11.76	28.39	7.26	16,931	2,319	19,250
2022	39.77	88.51	23.88	11.73	28.30	7.19	16,879	2,312	19,191
2023	38.31	85.93	22.57	11.28	27.53	6.96	16,378	2,273	18,651
Max Proposed Action Construction Emissions	43.28	90.50	42.36	14.40	28.71	7.52	17,195	2,319	19,505
Proposed Action Operational Period									
Worker Vehicle Fuel	0.196	0.0168	0.0053	0.00351	0.000591	0.0247	0	55	55
Electricity Generation	--	--	--	--	--	--	0	54,046	54,046
Space Heating	0.580	0.487	0.0441	0.0441	0.00348	0.0319	635	0	635
2024 - 2044	0.776	0.504	0.0494	0.0476	0.00407	0.0566	635	54,101	54,736

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In addition to criteria pollutants, **Table 3.8-4** presents the total CO_2 emissions for both the construction and operation period at Fermilab. CO_2 emissions result from the combustion of fuel used to operate construction, passenger, and supply vehicles, and construction equipment and is considered a greenhouse gas (GHG). Direct GHGs emissions are defined as emissions from sources owned or controlled by the reporting entity and include emissions from all construction activities. Indirect GHG emissions are emissions that are a consequence of the activities of the reporting entity, but occur at sources owned or controlled by another entity and include emissions generated by commuting workers and purchased electricity for operations. While estimated GHG direct emissions were below 25,000 metric tons CO_2-equivalent per year at Fermilab, the addition of Fermilab and SURF GHG emissions would be higher than the draft guideline. Both direct and indirect potential GHG emissions were quantified for construction and operations at Fermilab and SURF and are presented in **Table 3.8-8**.

Operations

Criteria pollutants and GHG emissions would be generated during operations by natural gas combustion for space and water heating, and from fuel combustion for researcher commuting. The small increase in continuous emissions of criteria pollutants and GHGs would result from natural gas for heating of 60,000 square feet of floor space. Because of the small increase in staff, emissions related to water heating were assumed to be negligible. **Table 3.8-4** shows the criteria pollutant and GHG emissions. The increase in criteria pollutant emissions for increased researchers during facility operations would be less than 1 ton per year of any criteria pollutant, therefore conforming to the State's SIP. GHG emissions from worker commutes are also included in **Table 3.8-4**.

Purchased electricity needed to operate the facility is estimated at 9 MW and would be required for operation of the beam, lighting, and equipment. Electricity consumption would result in an indirect increase in criteria pollutants that would occur at the energy generation facility. The procedure for evaluation of GHG emissions includes indirect emissions; therefore, GHG emissions from purchased power are included in **Table 3.8-4**.

Proposed Action emissions from both operations and construction activities would be below the de minimis thresholds for the conformity regulations and would not exceed the general conformity de minimis threshold (100 tons) for non-attainment pollutants (Ozone precursors: NOx, VOC, and PM_{10}/$PM_{2.5}$).

The potential release of hazardous air emissions from the operation of the Proposed Action and existing operations could include radionuclides. Under normal conditions, some of the radionuclides produced by the operation of the Fermilab accelerator could become airborne in the form of radioactive gasses and tritiated water vapor and enter the atmosphere through three mechanisms: 1) ventilation of air from the underground facility; 2) evaporation of tritiated water; and 3) evaporation from the Fermilab ponds. Radionuclide emissions during operations would be controlled and monitored to ensure that radionuclide emissions from all sources were well below DOE requirements, Fermilab discharge permit limits, EPA dose limits, and site-specific Fermilab policy (Section 3.4, Health and Safety).

No Action

Under the No Action Alternative, the existing research programs at Fermilab would remain unchanged, and the LBNF/DUNE would not be constructed or operated. Therefore, air pollutant emissions would be unchanged. The No Action Alternative would not be expected to have any additional impacts on the NAAQS.

3.8.2 SURF

3.8.2.1 Affected Environment

Air Quality

South Dakota has adopted EPA's NAAQS which are shown as the Federal Standard values in **Table 3.8-1**. South Dakota enjoys overall good air quality and does not contain any non-attainment areas. The closest state air quality monitoring station is near Black Hawk, South Dakota, approximately 25 miles to the southeast. This monitor measures ambient ozone and PM_{10} (SDDENR 2013).

SURF generates air emissions from the operation of a soda ash silo/baghouse, emergency generators, stationary sources, and equipment associated with the operation of the Majorana Demonstrator experiment. SURF has been coordinating with South Dakota Department of Environment and Natural Resources (SDDENR) concerning its air emissions and does not require an air quality permit; however, SURF must meet Federal requirements and is considered an area source (SDSTA 2013). SURF does not generate any radionuclide air emissions. SURF currently generates emissions of less than 25 tons per year of any criteria pollutant, and less than 10 tons per year of HAPs either in total or individually. **Table 3.8-5** provides SURF's current annual emissions.

Table 3.8-5 Actual and Potential Air Emissions at SURF in Tons Per Year for 2012

Description	TSP	$PM_{10}/PM_{2.5}$	SO_2	NO_x	CO	VOC
2012 Potential Emissions	8	6	1	9	2	2
2012 Actual Emissions	0.01	0.01	0.00	0.03	0.22	0.73
Total Emissions	7	5	1	9	2	3

Notes:
TSP=Total Suspended Particulates
Source: SDSTA 2013

Section 3.8.1.1 provided the requirements for states regarding EPA's General Conformity Rule, with *de minimis* levels of each criteria pollutant being 100 tons per year. However, the conformity requirement only applies to non-attainment areas, and South Dakota lacks any non-attainment areas. Consequently, no further discussion of conformity is included regarding SURF air emissions analysis.

Naturally occurring radon gas is emitted from the underground rock, and SURF has a venting system to exhaust the gas to the surface.

3.8.2.2 Environmental Impacts

Proposed Action

Construction

The primary potential air quality impacts from construction of the Proposed Action would be from exhaust emissions of criteria pollutants from diesel-powered construction equipment and gasoline-powered personal vehicles, and fugitive dust emissions from earth-disturbing construction activities. Sources of fugitive dust would include grading, excavating, blasting, vehicles traveling on unpaved roads, construction equipment, and transport of rock. Construction activities associated with the Proposed Action would occur over a period of approximately 8 years and would include constructing the detector excavation and underground infrastructure, service buildings, and utilities as well as installing and commissioning the detector.

Exhaust emissions were estimated by applying pollutant-specific emission factors to the various types and sizes of engines that would be utilized for construction. Emission factors for on-road vehicles such as pickup trucks, dump trucks, concrete mixer trucks, and personal vehicles were obtained from EPA's MOBILE6.2 model using an assumed speed of either 15 or 30 miles per hour, depending on the type of vehicle. Emission factors for off-road vehicles, such as front-end loaders, cranes, graders, and scrapers were obtained from EPA's NONROAD model (Version 2008.1.0). A load factor was also obtained from NONROAD and applied to the emission estimates to reflect typical activity levels of certain types of equipment over the course of a workday. **Appendix F-2** summarizes the individual types of equipment and associated emission factors and operating variables assumed as part of the emission estimates for exhaust emissions.

The estimate of construction-related fugitive dust was based on the application of emission factors (tons per acre per month) to the estimated amount of disturbed area and excavated material, and estimated duration of construction activity. The total area that would be disturbed by the surface construction of the Proposed Action would be approximately 21 acres, including building, parking, conveyance route (assuming either the pipe conveyor or rail line), and equipment staging. Emissions for the Proposed Action were calculated assuming truck transport of rock to the Gilt Edge Superfund Site and the Open Cut. Particulate matter from crushing, loading, and transport of the rock were estimated along with vehicular emissions from transport assuming the material would be transported to the Gilt Edge Superfund Site, which is approximately 7.4 miles from Lead and provides a conservative estimate of emissions. Emissions generated from construction of the pipe conveyor or rail system were not estimated because they would be generated over a shorter timeframe and would be very low compared to the overall emissions generated by the truck hauling activities and other emission sources. The emissions for truck hauling provide a conservative estimate of emissions that would be greater than either of the conveyor methods.

Fugitive dust resulting from vehicle traffic on paved and non-paved roads was estimated using EPA's AP-42 equations that are based on vehicle miles travelled (VMT) and characteristics of the road surface. Dust emissions from vehicular traffic would be minimized by the application of water or surfactants to the unpaved roads during construction.

Construction activities would utilize diesel-powered equipment that would generate CO, SO_2, NO_2, particulates, VOC, CO_2, and minor amounts of HAPs (such as formaldehyde, naphthalene, toluene, benzene, and xylene). Based on AP-42 emission factors for diesel-fired engines, the HAP emissions from construction equipment are typically three to four orders of magnitude lower than the amounts of criteria pollutants emitted.

In addition to ground-disturbing activities, supplies and components would be transported to SURF for laboratory outfitting and assembly of the detector. Emissions associated with this component transport and minor surface assembly would be intermittent and temporary, and would not exceed air quality standards but would incrementally increase overall emissions. Trucks would be traveling on paved roads and off-loading in the Ross Yard a short distance from the Ross Shaft.

Table 3.8-6 summarizes criteria pollutant and CO_2e emission estimates associated with the construction of the Proposed Action and incorporating rock transportation to the Gilt Edge Superfund Site. The emissions estimates include demolition of the Ross Boiler, the construction of the cryogen support building, the construction of the Truck Conveyor and Load-out, truck deliveries of equipment, supplies, LAr and LN, and construction employee commuting. The emissions associated with the Proposed Action Gilt Edge truck haul are greater than the other methods described (truck haul to Open Cut, Rail/Pipe Conveyor to the Open Cut). See **Appendix F-2** for back-up calculations.

Table 3.8-6 Summary of Estimated Potential Construction Emissions for the Proposed Action (Gilt Edge Road Haul Route)

Construction Year[1]	Emissions (short tons/year)						CO_2e Emissions (metric tons)
	CO	NO_X	PM_{10}	$PM_{2.5}$	SO_2	VOC	
Proposed Action Construction							
2017	0.41	0.98	3.72	0.69	0.005	0.17	451
2018	7.06	10.4	10.6	3.09	0.04	1.71	4,649
2019	4.41	10.4	252	28.1	0.04	1.61	4,704
2020	5.65	8.62	179	20.1	0.03	1.35	3,714
2021	3.54	6.09	11.3	3.02	0.02	0.90	2,431
2022	2.88	1.22	9.72	2.42	0.007	0.27	478
2023	3.66	0.70	1.57	0.41	0.006	0.26	374
Total	**27.6**	**38.4**	**468**	**58**	**0.148**	**6.27**	**16801**

Notes:

1 See Appendix F-1 for backup calculations

The emissions estimates from construction activities would be temporary and would not lead to long-term impacts on air quality. Emissions would not exceed NAAQS standards for an attainment area. Further, the impact would be minimized by requiring Tier 3 and 4 engines on underground equipment, requiring equipment that uses low-sulfur fuel, and using water and a surfactant on roads to minimize dust.

The Proposed Action would require an air quality construction permit for the Ross Crusher and associated rock transfer points. The Ross Crusher was a previously permitted emission source under Homestake's Air Quality Permit. South Dakota air quality regulations would require a minor source permit and a source construction permit because the crusher's Potential to Emit would exceed 25 tons per year of particulate matter ($PM_{2.5}$) before installation of air pollution control equipment.

Operation

Operation of the Proposed Action would comply with all air quality permit requirements. Direct sources (combustion emissions) and indirect sources (such as emissions from water use, wastewater handling, natural gas use, and electricity consumption) would result in air emissions. Emissions associated with operation of the detector site would be low and indistinguishable from current or other future measurable emissions. **Table 3.8-7** shows expected air emissions during operation of the Proposed Action based on the assumption that there would be an average of one truck delivery per day and 9 worker vehicles over a 20 year period.

Table 3.8-7 Summary of Estimated Potential Operations Emissions for Proposed Action

Operation Year	Emissions*						
	CO	NO_x	PM_{10}	$PM_{2.5}$	SO_2	VOC	CO_2e
2024-2044	0.10	0.37	32.2	7.91	0.02	0.10	18.9

Notes:

* All emissions are in tons, except for CO_2e, which is in metric tons.

Greenhouse Gases

Table 3.8-8 lists the total CO_2-equivalent emissions for the Proposed Action. The total GHG emissions for LBNF/DUNE would exceed 25,000 tons and considered together with regional, national, and global emissions, would contribute a small amount to cumulative GHG emissions and global climate change.

Table 3.8-8 Total Annual Direct GHG Emissions as CO_2e Metric Tons (Combined Fermilab and SURF Construction and Operations)

Year	Fermilab	SURF	Total
Construction			
2017	19,318	451	18,466
2018	19,505	4,649	25,910
2019	17,877	4,704	25,132
2020	19,072	3,714	18,881
2021	19,250	2,431	20,012
2022	19,191	478	18,858
2023	18,651	374	16,378
2024-2044	54,736	19	54,755
Total	**187,600**	**16,820**	**204,420**

Alternative A

Construction

Alternative A experiments would result in emissions related to trucking excavated rock to the Gilt Edge Superfund Site or to the Open Cut. The emissions associated with trucking the rock to the Gilt Edge Superfund Site would be higher than those to the Open Cut. Emissions would include those related to underground equipment operation, crushing rock, transferring rock, conveying rock, experiment outfitting (truck deliveries), and employee commuting. These emissions sources are very similar to the Proposed Action less the construction activities associated with cryogen support building and the rock conveyance (Truck Conveyor, Truck Load-out, or the Rail/Pipe Conveyor). The expected incremental emissions associated with Alternative A experiments are shown in **Table 3.8-9**.

Table 3.8-9 Emissions Associated with Construction of Alternative A Assuming Rock Transport to the Gilt Edge Superfund Site

	Emissions (tons per year)						
Construction Year[1, 2]	**CO**	**NO_x**	**PM_{10}**	**$PM_{2.5}$**	**SO_x**	**VOC**	**CO_2 (MT)**
2020-2021	6.21	13.2	155	116	1.86	2.85	8,624

Notes:

1 The cavern construction period would occur the nine months directly following the excavation of the LBNF/DUNE Cavern in 2020 (i.e. six months in 2020 and three months in 2021. Following the cavern construction there would be nine months of cavern outfitting.

2 See Appendix F-2 for backup calculations

Operation

The emissions associated with the operation of Alternative A experiments would be due to truck deliveries and staffing of the experiments. The experiments are not expected to be large; hence the truck deliveries and staffing would be less than 1 truck load of supplies and up to 3-4 experimenters per day. The experiment(s) would be conducted over 20 years.

No Action

Under the No Action Alternative, there would be no construction or operation of LBNF/DUNE or Alternative A experiments. Existing research programs at SURF would be unchanged and would continue without LBNF/DUNE. Air emissions at SURF would be unchanged from current levels.

3.9 VISUAL RESOURCES

This section describes the visual setting at Fermilab and SURF and evaluates the potential visual impacts of the Proposed Action and alternatives. The affected environment includes on- and off-site areas from which the proposed facilities would be visible to residents and motorists.

3.9.1 Fermilab

3.9.1.1 Affected Environment

Fermilab is located on the boundary between eastern Kane and western DuPage counties in an area of mixed residential, commercial, and agricultural land use. The predominant adjacent public roadway is Kirk Road, which is located between Fermilab's western boundary and residential communities to the west. The characteristic landscape within and around the proposed construction area is predominantly natural and rural in character, with Fermilab experimental facilities mixed in, including roadways connecting the facilities, the MI, and a number of cooling ponds.

Fermilab is located on a flat landscape between the Fox and DuPage Rivers. The existing landscape does not contain unique landforms, and the vegetation patterns of wetlands, forested wetlands, agricultural lands, and grasslands are common to the region. Natural areas include wetlands and Indian Creek. Recreational areas on-site include an interpretive nature trail, and the Illinois Prairie Path – a 62-mile-long trail used for hiking and biking - is located just to the south. The western portion of Fermilab is primarily composed of experimental facilities devoted to high-energy physics research, which have been present since Fermilab was established in the 1960s. Several of Fermilab's facilities are visible in the area including the main entrance at Kirk Road and Pine Street, the MI, and Fermilab's main office building, Wilson Hall. This 16-story office building is a highly visible landmark at Fermilab and is the most dominant visual element in the landscape, particularly from Kirk Road.

3.9.1.2 Environmental Impacts

Proposed Action

Construction

Construction would be visible from Kirk Road and from several locations on the Fermilab property. Construction equipment, such as front-end loaders and dump trucks, would be visible from Kirk Road as they prepare and grade the site preparation, remove Cooling Pond F, and place fill for construction of the embankment. As the embankment is filled, graded, and compacted, its southern side would be visible from Kirk Road. During construction, the embankment would contrast with surrounding areas; however, this impact would be temporary, and the surface of the embankment would be restored and revegetated.

The embankment would blend in with the existing landscape as vegetation re-establishes as shown in **Figure 3.9-1**.

The Primary Beam Enclosure and Target Hall would be constructed within the embankment, and the Absorber Hall and NND Hall would be constructed underground under LBNF-30 and LBNF-40, respectively. Prior to construction of these facilities, the contractor would excavate spaces within the embankment, a pit for the Absorber Hall, and two shafts for the NND Hall. Soils generated by these excavations would be stored on the construction site and would be temporarily visible during construction from Kirk Road or they would be moved to longer-term soil stockpiling areas on the Fermilab site. Soils would be covered by the SWPPP and would be protected with soil erosion and dust control BMPs. Excavated soils would also be placed in a soil stockpiling area south of the MI adjacent to Butterfield Road.

The construction area would be visible from portions of the stretch of Kirk Road that extends from Butterfield Road to the area of Fermilab's main entrance at Pine Street. Construction would be visible to people driving north on Kirk Road as they look to the northeast. The embankment would not be in the direct view of motorists driving south on Kirk Road. Construction would not be visible from other public roads or recreation areas because the construction area would be separated from the surrounding areas by trees or developments.

Construction of the NND would be visible from Kirk Road near the intersection of Giese Road for people driving both north and south, but would not be visible from other public roads or recreation areas. Construction would require removal of trees and operation of construction equipment, including a large crane over a period of 2 to 4 months to lower heavy components down the shafts to the NND Hall.

Construction would require removal of trees, operation of construction equipment, and the presence of construction offices. Short-term, localized effects on the visual character of the landscape would result from removal of vegetation, including trees, and exposure of soils of contrasting color and texture during excavation, grading, and building the embankment. These effects would occur intermittently over the construction period as soil is excavated and stockpiled, and the area restored. Construction would not occur at night, and therefore would not require overnight lighting other than security lighting.

Overall, the visual impacts of the Proposed Action would be low and minimized by the distance of the embankment from Kirk Road, the temporary nature of construction, the visual shielding provided by existing vegetation and developments, and design measures that would reduce the visual impact of LBNF-40.

Operations

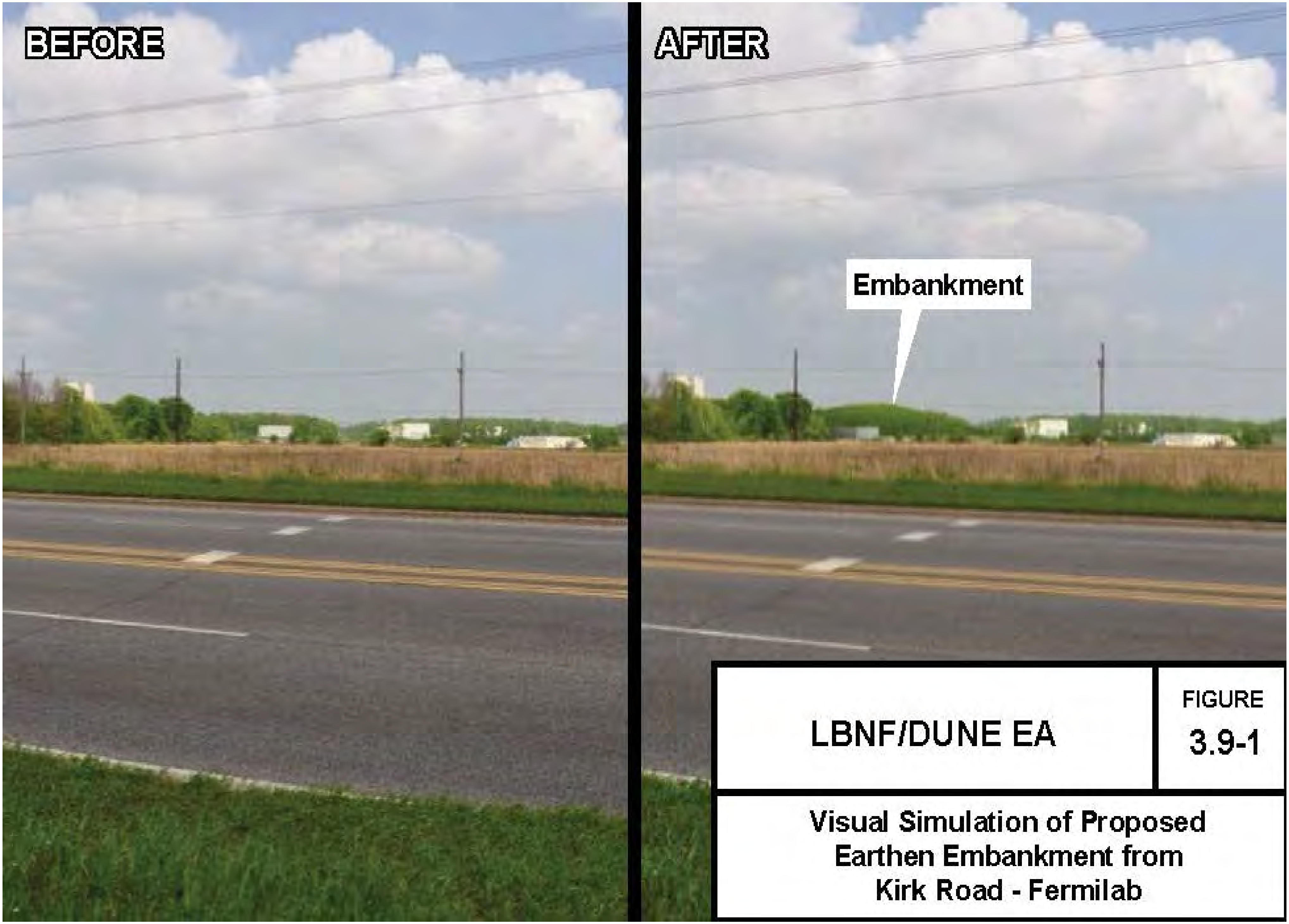
The visual effects of Proposed Action operations would result from the completed embankment as well as LBNF-40 and LBNF-30. **Figure 3.9-1** depicts existing views of the Proposed Action from Kirk Road and a computer-generated simulation of the completed vegetated embankment as it would be viewed from the same location looking to the northeast from Kirk Road. The embankment would be approximately 50 to 60 feet high, 950 feet long and approximately 250 feet wide at its widest point. However, the rendering shows that the embankment would be set in the distance, and that revegetation would reduce contrast with adjacent grassy areas, trees, agricultural fields, and restored prairie. In addition, the embankment would be constructed near existing Fermilab buildings with Wilson Hall in the background.

The embankment would also be visible to people biking or hiking on the Illinois Prairie Path. However, similar to views for motorists on Kirk Road, the Proposed Action would be visible for only a short stretch of the path. Although there is little intercepting terrain between Kirk Road and the embankment, views from the path would include other man-made features, including Kirk Road (for areas west of Kirk Road). LBNF/DUNE would not be visible from Fermilab recreation areas, such as the nature trail. In addition, as described above, most of the facilities would be hidden underground or within the earthen embankment and would be unseen by public viewers. Portions of the embankment may be visible to some residents to the west and southwest; however, Kirk Road would constitute a substantial intervening feature. The Proposed Action would not be visible from on-site recreation areas, such as the nature trail and bison herd.

Figure 3.9-2 provides a conceptual rendering of LBNF-40 (Near Neutrino Detector Service Building), simulating how it may be viewed from Kirk Road (Note: LBNF-40 may be rotated 90 degrees). LBNF-40 would be approximately 100 feet long, 50 feet wide, and 50 feet high and would be located approximately 125-150 feet east of Kirk Road and clearly visible to motorists. LBNF-40 would also be visible from the visitor’s entrance to the lab, located approximately 0.35 miles to the north. The building’s appearance would be similar to that of other Fermilab facilities, including the nearby MINOS service building and the commercial and industrial developments in the area. Generally, the building would be of braced-frame, steel, and concrete construction with prefinished metal siding. Fermilab would develop an LBNF/DUNE-specific architectural style during final design to minimize the visual effects of the new buildings on the surrounding environment.

The primary viewers would be motorists on Kirk Road, who would be able to see the building for a relatively short period. Motorists driving north-to-south would see LBNF-40 for longer; however, oncoming traffic would create an intervening feature. Residents to the west of Kirk Road would be less likely to see LBNF-40 given these homes general face the west and the presence of a fence and full-grown trees directly west of Kirk Road.

LBNF-40 would not be visible to people biking or hiking on the Illinois Prairie Path. It would be visible to some residents to the west; however, Kirk Road would constitute a substantial intervening feature. The Proposed Action would not be visible from on-site recreation areas such as the nature trail.



LBNF/DUNE EA

FIGURE 3.9-1

Visual Simulation of Proposed Earthen Embankment from Kirk Road - Fermilab

LBNF/DUNE EA	FIGURE 3.9-2

Proposed Action - Visual Simulation of Near Neutrino Detector Service Building - Fermilab

3.9.2 SURF

3.9.2.1 Affected Environment

SURF is located in the Northern Black Hills, which are characterized by steep-to-rounded, tree-covered hills and incised streams, such as Whitewood Creek. However, closer to the City of Lead, the predominant visual features are man-made and the result of 135 years of mining activity. Current and past mine support buildings, excavated rock disposal sites, excavations, tailing facilities, road cuts, rail haulage routes, and utilities are present and suggest the area's mining heritage.

The City of Lead developed around the mining activity. Main Street (U.S. Highway 85) through Lead features many historic buildings and landmarks, such as the Historic Homestake Opera House and the former Homestake Mill site. These visual resources all were constructed to support mining activities. The dominant visual feature of Main Street, and of Lead itself, is a former mining area called the Open Cut. This large pit is approximately 500 feet wide and 1,000 feet deep, with nearly vertical rock walls on the north and south sides. Reclaimed grassy waste rock areas are also visible from Main Street. The Homestake Visitor Center is located on the south edge of the Open Cut and is both a tourist attraction and an educational landmark for visiting geology students.

There are parks on both sides of lower (north) Main Street. The city park north of Main Street has a picnic shelter with tables, a large grassy area, and tennis courts. Gold Run Park on the south side of Main Street exhibits mining equipment. Both areas were reclaimed after past mining-related activities.

The Mill Street-East Summit Street neighborhoods are mostly single-family homes, built by miners on streets laid out in a roughly rectangular street grid on the steep hillside south of Main Street/U.S. Highway 85. There are also light industrial facilities in this area, including shops used by Lead residents. SURF's 186-acre surface campus is at the top of the hillside, on a ridge that extends from SURF's water treatment plant in the east to the Ross Shaft hoist room in the west. SURF's surface property also extends south, down to Kirk Road. Near the Oro Hondo Shaft (used to exhaust air from the underground), the SURF property extends to the south of Kirk Road.

Many of the visual resources in Lead, particularly on Main Street and in the neighborhood near North Mill Street include industrial buildings associated with milling and refining gold ore. Early mining surface structures were concentrated in this area because of its proximity to the main underground ore body. These structures included mills, headframe buildings for shafts, hoist buildings, support buildings, and railroad trestles. More recently, development of the Open Cut again changed the landscape in Lead near Mill Street. Homestake purchased homes in this area in 1985 to expand and develop the Open Cut. In 1992, a second Open Cut expansion resulted in the relocation of U.S. Highway 85 to the south, the removal of 23 structures, the construction of the Manuel Brothers Park, the relocation of the Homestake Visitors Center, and the relocation of the Sweatman Art Memorial. In 1987, Homestake built a 6,300-foot pipe conveyor to transport 350 tons per hour of crushed rock from the Open Cut across Highway 85 and past various residences to the Homestake Mill. The pipe conveyor was decommissioned and removed in 2002.

Hillsides in the affected area have slopes of natural talus or scree and grassy slopes that are both natural and engineered. For example, one of Homestake's reclaimed waste rock areas is a dominant visual feature of the Kirk Road valley. This terraced, grassy slope is on the north side of the road near the intersection of Kirk with US 385. This reclaimed slope is visible from U.S. Highway 385 and from local homes. Other treeless, grassy slopes, mostly at the top of the south side of the valley, are the result of the 2002 Grizzly Gulch fire. Power lines owned by Black Hills Power cross the Kirk Road valley about midway between the east and west ends of the valley. In the bottom of the valley, a riparian area along Whitewood Creek includes hardwoods, Ponderosa pines, Black Hills spruce, grasses, sedges, rushes, and forbs. Whitewood Creek and Mickelson Trail wind along the bottom of the Kirk Road valley for approximately 2 miles. Mickelson Trail is a gravel trail engineered for mountain bikes and pedestrians as well as snowmobilers and cross-country skiers in winter. The trail is frequently used by local residents and attracts tourists year-round.

Kirk Road is a gravel road owned and maintained by Lawrence County. The road runs the length of the valley from U.S. Highway 385 on the northeast to U.S. Highway 85 on the southwest, and the visual resources along the road vary. Two viaducts span over the road. The easternmost viaduct, located about 2 miles from U.S. Highway 85, carries an old Homestake pipeline that is no longer in use. This pipeline and an associated steel stairway ascend the north side of the valley to the SURF surface campus. The stairs and pipe are visible from the road. The westernmost viaduct, located about 2 miles from U.S. Highway 85, supports a new pipeline that carries water from Homestake's Grizzly Gulch Dam Impoundment to the SURF wastewater treatment plant. This pipeline enters an adit (tunnel) at the 300 Level.

A number of former Homestake structures, now occupied or owned by SURF, are visible at several locations along Kirk Road. These include two adits with locked or sealed entrances that provide access to the underground 300 Level, exhaust fans, the Yates and Ross headframes and hoist rooms, the SURF administrative office building, and the education and outreach building. These buildings dominate the viewshed that includes the northeast end of Kirk Road.

A Black Hills Power electrical substation on the south side of the valley about 2 miles west of U.S. Highway 385 is visible from several locations along Kirk Road. The long-closed, now privately owned Kirk Power Plant, also on the south side of the valley, is about 1.5 miles from U.S. 85. The power plant is visible from several locations along Kirk Road.

Residents and users of Kirk Road are familiar with construction in the Kirk Road valley, as the Yates waste rock pile was reclaimed in 2003. The Yates waste rock pile reclamation included blasting a new 500-foot stream channel and moving similar 500-foot sections of Kirk Road and the Mickelson Trail.

3.9.2.2 Environmental Impacts

Proposed Action

Construction

Visual impacts associated with construction of the Proposed Action would include the construction of a cryogen support building and a conveyor to move excavated rock from the crusher to Kirk Road for eventual loading onto trucks and transportation to either the Gilt Edge Superfund Site or the Open Cut. The construction of a new cryogen support building would be partially visible from Kirk Road and from several Lead residences located more than 1 mile away. The new building would be smaller and have a lower profile than the existing Ross Boiler and stack, and therefore would be less conspicuous. The Cryogen Support Building would not obstruct views as it would be far removed from most houses and tucked inside a hill. The conveyor would lie on the north side of Kirk Road and extend diagonally downhill to the loadout station. The conveyor and loadout station would be visible from portions of Kirk Road and two houses along Kirk Road. The loadout station is across Kirk Road from the abandoned Kirk Power Plant and the Mickelson Trail Kirk Trailhead parking lot.

An One method of transport that could be chosen, would be a conveyor or rail line to move excavated rock to the Open Cut.. Transportation of the excavated rock to the Gilt Edge Superfund site would have low visual impacts because the roads already exist and are used.

The construction of a pipe conveyor or rail system to convey rock from the Ross Shaft to the Open Cut area would be partially visible throughout the City of Lead. However, visual impact created by the conveyances would be minimized by their low profile and occurrence in currently disturbed areas. In addition, a significant portion of the rail or conveyor route would be underground using the existing tramway to move the excavated rock to the north where it daylights and then follows the Open Cut pipe conveyor corridor. The rail or pipe conveyor would be fenced and housed in a range of possible structures to limit noise and improve safety. The visual impact of the rail system would be similar to that of previous conveyors and railroad trestles that operated for much of the past 135 years. Refer to the PA in Appendix C-2 for applicable conditions.

Rock placed in the Open Cut would be placed on previously excavated rock and would be a small amount relative to the 150 million yds^3 removed during mining operations. The visual impact resulting from the use of equipment to place the rock would be minimized by its short-term nature and the historic mining context of the area.

Operation

Operation of the underground detector would not be visible to the public, and hence there would be no visual impact. Impacts from additional traffic and parking to accommodate the detector staffing would be low.

Alternative A

Construction

Potential future experiments underground may require additional excavation of rock. These excavations would require rock placement in underground openings with no visual impacts or transport of the rock to the surface and transportation to either the Gilt Edge Superfund site or the Open Cut as described in the description of the Proposed Action in Section 2 of the EA. Rock disposed of underground would have no visual impacts. Rock transported to either the Gilt Edge Superfund site or Open Cut would have low visual impacts because these areas are both highly disturbed former mine sites. Alternative A experiments could require repurposing existing surface buildings; however, this impact would be temporary and low.

Operation

Visual impacts during operation of potential future experiments could include traffic related to delivery of equipment and material and traffic and parking related to staffing of the proposed experiments. These deliveries would not affect visual resources.

No Action

Under the No Action Alternative, the LBNF/DUNE Far Site facilities would not be constructed or operated at SURF, and there would be no visual impact. Existing SURF facilities that can be seen on Kirk Road, and from Lead, would remain and other SURF activities would continue to operate, including the ventilation systems, stormwater management, substation maintenance, and security monitoring of the various portals to the underground spaces.

3.10 GEOLOGY AND SOILS

This section describes the existing geological and soils environment, including surface conditions and subsurface bedrock. It then describes the potential environmental impacts of the Proposed Action, including the excavations required in soils and rock to construct the proposed facilities, Alternative A, and the No Action Alternative. The affected environment for geology and soils impacts includes areas that would be excavated, graded, or filled as well as adjacent areas potentially subject to erosion and sedimentation.

3.10.1 Fermilab

3.10.1.1 Affected Environment

Geology

Fermilab is situated between the Marengo and Valparaiso Morainic Systems, in the Bloomington Ridged Plain of the Great Lakes Section of the Central Lowland Province (Natural Resources Conservation Service [NRCS] 2003). The regional topography was formed by a series of glacial advances and retreats, primarily during the Woodfordian Substage (22,000 to 12,500 years before present [B.P.]) of the Wisconsinan Glaciation. The area has nearly all the features associated with glaciated areas including kames, kame terraces, eskers, and a large number of glacial lakes, many of which are now drained. Fermilab's topography is predominantly flat with local topographic relief of generally less than 50 feet. Ponds have formed in the small depressions. Surface elevations at the proposed construction area range from approximately 740 to 760 feet above mean sea level (MSL). Surficial topographic features are composed of glacial tills, glacial outwash sands and gravels, and glacial lake deposits (NRCS 2003).

Fermilab's surface consists of silts and clays and alluvial deposits to depths of up to 20 feet bgs (Curry 2001; NRCS 2003; GTC 2010). These deposits are generally unconsolidated and overlie overconsolidated subglacial till deposits. This deposit is the Yorkville Till Member of the Lemont Formation (SCS 1979a; Curry 2001) and is approximately 55 to 80 feet thick, and consists of coarser sediments (sand to boulder) within a clay-dominated matrix (GTC 2010). A sand and gravel glacial outwash deposit known as the Henry Formation is discontinuously present at the base of the till.

Glacial deposits at Fermilab unconformably overlie early Silurian (443 to 417 million years ago [Ma]) bedrock. Bedrock outcrop exposures in the Fermilab area are rare, except in quarries (e.g., North Aurora and Elmhurst) and river bluffs. The closest bedrock outcrop is approximately 1.2 miles to the west along the Fox River (Curry 2001).

Soils

Other than the presence of chert, soils in the Fermilab area are generally uninfluenced by underlying bedrock composition (SCS 1979a; SCS 1979b). Soils are generally silty loams formed on outwash materials and till with scattered patches of muck formed on herbaceous organic deposits. Soil associations, as defined by the NRCS, include Drummer-Mundelein-Barrington, deep soils formed on glacial outwash with silty or loamy subsoil; Markham-Ashkum, deep soils formed on glacial till with clayey and silty subsoils; and Fox-Wauconda-Sawmill, deep soils formed in glacial outwash and stream alluvium (SCS 1979b).

Soil limitations were assessed using the updated Kane County soil survey (NRCS 2003), as well as interpreted soil properties (Soil Survey Staff [SSS] 2013). Due to the high clay content of site soils (generally 20 to 40 percent) and moist soil conditions resulting from a shallow water table (generally less than 3 feet), the risk of wind erosion is low to moderate when the vegetative cover is removed. Site soils are moderately susceptible to water erosion; however, this risk is minimized by flat topography. Most soils in the Fermilab site are NRCS-classified Prime Farmland or Prime Farmland if drained.

Seismic

Fermilab is located in a region of the central mid-continent that is tectonically stable and has very low seismic risk. The closest known earthquake zones capable of producing substantial ground motion are located several hundred miles to the south. The Fermilab area does not have known active faults. In 2008, the United States Geological Survey (USGS) produced updated seismic hazard maps for the conterminous United States, including peak ground acceleration (PGA) and spectral accelerations for a range of return periods and exceedance probabilities (Peterson et al. 2008). The predicted PGA value for the Fermilab area for a seismic event with a return period of approximately 2,500 years or less (2 percent probability of occurring in 50 years) would be approximately 0.06g (with *g* equal to acceleration due to gravity) (Peterson et al. 2008). The predicted PGA would create strong ground shaking corresponding to less than 2.0 on the Richter Scale, which likely would not be felt at Fermilab (Wald et al. 1999).

3.10.1.2 Environmental Impacts

Proposed Action

Construction

The Proposed Action would affect soils during excavation and placement of soils for the embankment, and excavations for the Absorber Hall, Decay Pipe, and NND. Environmental impacts would include removal of soil and soil functions, soil compaction adjacent to excavation and stockpile areas from frequent vehicle traffic, potential increased erosion, and loss of soil productivity during stockpiling.

The Proposed Action would involve excavation and disturbance of approximately 950,000 yd^3 of surface soils and bedrock. A total of approximately 15 acres of soils would be disturbed at the borrow location for embankment material. The top layers of soil excavated from this area would be moved to a soil stockpiling area at the southwest corner of Fermilab. Because this soil disturbance would be long-term and the borrow area would not be backfilled and would be allowed to fill with water, the impact on soil productivity in these areas would be long-term. Similarly, the approximate 4 acres (approximately 250 feet by 1,000 feet) of soils covered by the embankment would be permanently covered with fill.

Three acres of soils (approximately 200 feet by 600 feet) would be disturbed during excavations for the Absorber Hall, with approximately 50,000 yd^3 of soil and 4,000 yd^3 of bedrock removed. The final volume of the embankment would be approximately 240,000 $yd^{3.}$ Construction of the NND would involve the excavation of an additional 3 acres of soil, with approximately 27,000 yd^3 of soil and 30,000 yd^3 of bedrock removed. Construction of the Decay Pipe would require excavation of approximately 670,000 yd^3 of soil and rock, approximately half of which would be placed in temporary stockpiles and used as backfill after construction, and thus the impacts on these soils would be temporary. The excess material, having a volume of approximately 300,000 yd^3, would be permanently stockpiled at the southern boundary of Fermilab near Butterfield Road.

Although construction would require permanent excavation of bedrock, excavation would not result in the loss of substantial geological resources or data. No existing points of geologic interest, such as quarries or natural bedrock exposures, would be disturbed during construction.

The Proposed Action would have temporary and permanent impacts on areas designated as farmland. The entire proposed construction area is designated as Prime Farmland. In accordance with the Farmland Protection Policy Act, Fermilab designed LBNF/DUNE to minimize excavation and related impacts on farmland. However, a total of 20 acres of Prime Farmland or Prime Farmland if drained would be removed from productivity, as well as temporary effects on approximately 80 acres that would be used for construction staging, parking, soil handling, and equipment laydown. Because these areas are not currently being cultivated, the loss of soil functions would not represent a direct impact on farming operations. Other short-term impacts on soils would include increased risk of erosion. As described in Section 2, embankment soils would be thoroughly compacted and stabilized to prevent settling, shifting, and erosion. Soil excavation and grading would present an increased risk of sedimentation in Indian Creek. The construction contractor would comply with SEPMs as well as the NPDES permit and would develop and implement a SWPPP. SEPMs to minimize soil erosion would include diverting runoff from exposed soil surfaces, re-vegetating disturbed areas, and implementing other measures to collect and filter runoff (e.g., sediment/silt fences).

Fermilab would apply to the Illinois Environmental Protection Agency (IEPA) to be included in the statewide general stormwater discharge permit (IL10) by preparing a Notice of Intent (NOI). The Proposed Action would require preparation of a SWPPP that would conform to "Illinois Urban Manual" standards (NRCS 2002a). The SWPPP would describe the construction activity; soil disturbance; and required erosion and sediment controls, stabilization practices, structural controls, post-construction stormwater management, and wastewater treatment requirements. It would also propose a maintenance plan and required BMP inspections and reporting. The certified SWPPP would be available on-site for inspection by the IEPA, NRCS, and the local community (Fermilab 2008a). All SWPPPs are also available online at the IEPA web site.

Operation

The Proposed Action would have little or no direct impacts on geology or soils. Ongoing grounds maintenance includes mowing, and soil erosion would be addressed through the existing site-wide SWPPP. Operations would not require excavation or grading. The vegetation on the embankment would be maintained to minimize soil erosion per SEPMs.

No Action

The No Action Alternative would not involve excavation or grading; therefore, no impacts on soils or geological resources would result. Existing experiments and ongoing construction would continue and would comply with Fermilab SEPMs and permit conditions. Existing soil resources at Fermilab would be maintained through existing SEPMs and site restoration activities.

3.10.2 SURF

3.10.2.1 Affected Environment

Geology

The regional geology of the SURF area is within the eroded core of an Early Tertiary dome that lies within the northern end of the larger Black Hills uplift (Dewitt et al. 1986; Bachman and Caddey 1990). The uplift, through erosion, has exposed Proterozoic rocks (approximately 1.8 to 2.4 billion years old) flanked on the edge of the Black Hills by younger Cambrian-aged (560 to 480 million years old) rocks.

The local geology of the affected area occurs within the Homestake Mine District, which is a northwest-trending, 5-mile long, 2-mile wide surface area comprising one of the largest gold deposits in the world.

times, in an effort to find and extract gold ore and to support associated gold mining activities. The Homestake Mine contains more than 350 miles of underground openings. Some excavations created large openings, up to 100 by 150 by 450 feet (Mitchell 2013). Excavations, in all, resulted in hundreds of millions of cubic-yards of excavated rock. The district was continually moving rock, processing rock, and creating and modifying underground and surface support facilities.

The formations occurring in underground areas of the Proposed Action include (from oldest to youngest) the Poorman, the Homestake, and Ellison. The Upper Poorman, which would host the proposed LBNF/DUNE underground cavern, is a biotite-sericite-chlorite phyllite with localized graphite and phyrrhotite mineralization. (Rogers 1990; Nobel and Harder 1948; Bachman and Caddey 1990). The Poorman rock is not as well characterized geologically as the Homestake or Ellison Formations, as it did not contain gold. However, many hundreds of thousands of yards of Poorman were excavated and typically backfilled underground to access Homestake ore.

The USGS seismic hazard probability database, which uses known fault sequences and historical earthquake data, shows that the probability of an earthquake having a magnitude of greater than 5.0 (Richter Scale) over the next 30 years within 30 miles of the affected area is 0 percent according to the USGS 2009 Probabilistic Seismic Hazard Analysis (PSHA) model.

Soils

Soils in the area have been disturbed by past mining activities. Each of these areas has a history of multiple activities. The Ross Yard was developed by successive episodes of moving soil and rock over the edge of its disturbance area. Soils at the Gilt Edge Superfund site include only those at the surface of the access road and stockpiling area, all of which are heavily disturbed by past industrial uses and current remedial activity. The Open Cut pit contains no soil as it was removed in the late 1800's commensurate with the development of the Open Cut.

3.10.2.2 Environmental Impacts

Proposed Action

Construction

The Proposed Action would require the excavation of 460,000 cubic yards of rock consisting of the Upper Poorman Formation and minor intruded Tertiary Rhyolite. Underground cavern excavations would undergo geotechnical evaluation and would be rock bolted to ensure their stability. This impact would be permanent but would occur nearly a mile underground.

Construction of the Proposed Action would have very low effects on soils as much of the SURF area has already been graded and developed or otherwise disturbed in the past by mining activity, including at the Gilt Edge Superfund site and the Open Cut. The conveyance corridor to the Open Cut (if selected) would be disturbed during installation of the conveyance system. The construction contractor would follow SURF SEPMs to minimize erosion by wind or storm water. For example, soil stockpiles would be contoured, moated, seeded, and identified with the words 'Top Soil Stockpile' per the SURF SWPPP. Soils would be preserved and reused to the extent practicable.

Operation

Operation of the detector would occur primarily underground and would have very low impacts on geology and soils. Activities such as maintenance and deliveries of supplies and cryogens would occur in paved areas. Potential impacts from underground rock excavation on groundwater and surface water are addressed in Section 3.5, Hydrology and Water Quality.

Alternative A

Construction

The construction of future underground experiments, like the Proposed Action, would occur nearly a mile underground and geological impacts would be very low. Underground caverns for Alternative A experiments would require excavation of approximately 153,000 yd^3 of additional rock. The caverns would undergo geotechnical evaluation and would be rock bolted to ensure their stability. Similarly, soil impacts would be low and limited to potential erosion near the truck load-out station. SURF would follow SEPMs to minimize erosion during transport of excavated rock. Alternatively, should the rock disposed of underground, it would be placed in dry underground spaces to minimize interaction with groundwater. The incremental impact of underground rock placement compared to the Proposed Action would be small.

Operation

Operation of future experiments would occur primarily underground and would have very low impacts on geology and soils. Activities such as maintenance and deliveries of supplies and cryogens would occur in paved areas.

No Action

The No Action Alternative would have no impacts on geology and soils as there would be no construction or operation and no disturbance of rock or soils would occur. Existing SURF experiments would continue to operate in compliance with the SURF SWPPP.

3.11 SOCIOECONOMICS AND ENVIRONMENTAL JUSTICE

This section provides baseline data on population, ethnicity, employment, income, housing, and the local economy near Fermilab and SURF and evaluates the potential socioeconomic impacts of the Proposed Action and alternatives, including the potential for adverse human health or environmental impacts that could disproportionately affect a minority or low-income population. This analysis complies with EO 121898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, as well as DOE's Environmental Justice Strategy (DOE 2007). This EO directs each federal agency, as defined in the Order, to "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States." The affected environment includes the municipalities and communities (including Tribal in the case of SURF) surrounding Fermilab and SURF that could potentially be affected by economic factors, such as an influx of workers and increased demand for housing.

3.11.1 Fermilab

3.11.1.1 Affected Environment

Fermilab is located in eastern Kane County and western DuPage County, west of the greater Chicago metropolitan area. The area covered by this analysis includes the entirety of Kane and DuPage Counties, and communities located adjacent to Fermilab as shown in **Table 3.11-1**.

Table 3.11-1 Population and Demographics of the Area

Municipality Name	Total Population	White (%)	Black or African American (%)	American Indian / Alaskan Native (%)	Asian (%)	Native Hawaiian or Other Pacific Islander (%)	Some Other Race	Two or More Races (%)	Hispanic (%)
United States	308,745,538	72.4	12.6	0.9	4.8	0.2	6.2	2.9	16.3
State of Illinois	12,540,650	71.5	14.5	0.3	4.6	0	5.8	2.3	13.4
DuPage County	916,924	77.9	4.6	0.3	10.1	0	4.9	2.2	13.3
Kane County	515,269	74.6	5.7	0.6	3.5	0	13	2.6	30.7
Aurora (City)	197,899	59.7	10.7	0.5	6.7	0	19.1	3.3	41.3
Batavia (City)	26,045	91.9	2.4	0.2	1.8	0	2	1.6	6.8
Carol Stream (Village)	39,711	70.7	6.1	0.3	14.6	0	5.5	2.7	14.2
Geneva (City)	21,495	94.8	0.5	0.1	2.2	0	1.2	1.3	4.9
Montgomery	18,438	75.3	8.3	0.4	3.4	0	8.5	1.9	22.8
Naperville (City)	141,853	76.5	4.7	0.1	14.9	0	1.5	2.3	5.3
North Aurora (Village)	16,760	81.3	5.2	0.2	4.9	0	5.5	2.9	15
Oswego	30,335	85.6	5.2	0.2	3.4	0	3.2	1.2	10.3
St. Charles (City)	32,974	88.8	2.5	0.2	3.2	0.1	3.6	1.6	10.2
Warrenville (City)	13,140	82.2	3.9	0.6	3.7	0	7.3	2.2	20.9
Wayne (Village)	2,431	93.9	0.9	0.1	3.4	0.2	0.5	1.1	3.7
West Chicago (City)	27,086	67.6	2.5	0.6	5.9	0.1	20.6	2.7	51.1
Wheaton (City)	52,894	87.3	4.5	0.2	5.1	0	4.9	2	4.9
Winfield (Village)	9,080	91.6	1.5	0.1	3.4	0	13	1.9	5.4

Source: Census Bureau, 2011a

Population, Race, and Ethnicity

As shown in **Table 3.11-1**, the demographics of DuPage County are similar to the state as a whole; the percentage of the population of Kane County that identifies as Hispanic is larger than in DuPage County or the State.

Minority Populations

Only one of the communities in the area exhibited a minority group that accounted for more than 50 percent of the population of the city: West Chicago (population 27,086; 13,837 identifying as Hispanic or Latino). Several other surrounding cities also have selected minority populations that are larger than County, State, and national averages; however, none of those populations exceeded 50 percent. When minority populations are considered collectively, Aurora and West Chicago have minority populations between approximately 9% and 16% greater than the Kane County/DuPage County average.

Income

Median household income and per capita income data are presented in **Table 3.11-2**; these data were obtained from the Census Bureau's 2007-2011 American Community Survey (Census 2012a). The median household incomes are higher than those for the State of Illinois and the U.S. Generally, per capita income is higher than those for the State of Illinois and the U.S.; the exceptions are the Cities of Aurora and West Chicago.

Table 3.11-2 Median and Per Capita Household Incomes in the Area

Locality	Median Household Income	Per Capita Income
United States	$52,762	$27,915
State of Illinois	$56,576	$29,376
DuPage County	$77,598	$38,405
Kane County	$69,496	$29,864
Aurora (City)	$62,358	$26,400
Batavia (City)	$88,529	$38,679
Carol Stream (Village)	$72,757	$29,578
Geneva (City)	$95,467	$42,995
Montgomery	$73,406	$25,913
Naperville (City)	$105,585	$46,108
North Aurora (Village)	$82,355	$34,710
Oswego	$96,819	$34,046
St. Charles (City)	$77,011	$39,974
Warrenville (City)	$72,876	$32,640
Wayne (Village)	$149,375	$68,480
West Chicago (City)	$63,377	$25,436
Wheaton (City)	$84,980	$42,179
Winfield (Village)	$94,129	$43,571

Source: Census Bureau 2012a

Housing

The estimated median home value in DuPage County is reported at $309,800, and $241,600 in Kane County (Census Bureau 2012b); these are higher than the state and national medians, which are $188,500 and $186,200, respectively. Home values are also above the state and national median values. Housing is available in both counties, with housing unit vacancy rates ranging from 6 to 8 percent, and a rental property vacancy rate of approximately 6 percent.

Industrial Sectors

The economies of DuPage and Kane Counties are generally typical of suburbs of large cities. The percentage of workers employed in select industrial sectors is provided in **Table 3.11-3**. Similar to other suburban areas in the region, the professional, scientific, and technical services; educational, health care, social services, and retail industrial sectors play large roles in the local economy. Manufacturing also accounts for a large number of jobs. Combined, these sectors account for nearly 60 percent of the jobs in each County.

Fermilab employs approximately 1,970 staff. Additionally, approximately 1,500 scientists at institutions around the world are involved in experiments at Fermilab. Many of these individuals associated with Fermilab visit the area for short periods and usually seek accommodations off-site in the local area. Fermilab has an annual budget of approximately $451 million for 2014. Other large employers in DuPage County include McDonald's Corporation, Dover Corporation, Molex, OfficeMax, Navistar International, DeVry Incorporated, Havi Group L.P., EmployCo USA, Tandem HR, Duchossois Group, and Hearthside Food Solutions LLC. Kane County's largest employers include Caterpillar, Inc., First USA Bank, Grand Victoria Casino, Sherman Hospital, Jewel/Osco Stores, Inc., and many others.

Table 3.11-3 Workforce Percentages by Industry Type

Industry	Illinois	Kane County	DuPage County
Civilian employed population 16 and over	6,043,771	245,198	470,591
Agriculture, forestry, fishing, hunting, and mining	1.1%	0.6%	0.2%
Construction	5.7%	6.7%	5.2%
Manufacturing	12.8%	17.1%	12.7%
Wholesale trade	3.3%	4.2%	4.6%
Retail trade	10.9%	11.7%	10.8%
Transportation and warehousing and utilities	5.9%	5.0%	5.3%
Information	2.2%	2.4%	2.6%
Finance, insurance, real estate, rental, and leasing	7.7%	7.5%	9.7%
Professional, scientific, management and admin.	11.0%	12.7%	13.6%
Educational services, health care, and social assistance	22.1%	18.4%	20.1%
Arts, entertainment, recreation, accommodations, and food service	8.7%	7.6%	8.1%
Other services except public administration	4.8%	3.8%	4.7%
Public administration	3.9%	2.3%	2.3%

Source: Census Bureau 2012a

Low Income Populations

In 2010, 13.8 percent of Illinois' population was living below the poverty line; in DuPage and Kane Counties, only 6.9 and 11 percent, respectively, of the population were below the poverty line. Incomes in the area are higher than the poverty threshold (Census 2011b).

In 2010, the poverty rates for students attending school districts in the area ranged from 3.9 to 28.3 percent, with an average of 12.7 percent. For comparison, the statewide average poverty rate among school districts was 19.5 percent. Two districts within the area of study exhibited a greater number of students below the poverty level than the statewide rate: the Aurora East Unit School District 131 and the West Chicago School District 33 (Census 2011b).

3.11.1.2 Environmental Impacts

Proposed Action

Socioeconomics

Construction

The Proposed Action would have very low, if any, impacts on the population or demographics of the Fermilab area. Construction would require an average of approximately 56 workers and a peak of approximately 200 construction workers per day. A large, experienced construction labor pool would be available given the proximity of metropolitan Chicago, and thus construction employment needs would easily be met with local resources (Census Bureau 2014). Given the size of the locally-available labor pool, the Proposed Action would be unlikely to result in worker in-migration that could have a substantial effect on population or demographics. Therefore, in-migration of workers would be minimal, and there would be very low impacts on land use, population, demographics, or the local housing market.

The Fermilab portion of the Proposed Action has a total estimated cost of $415.7 million for the excavations, utilities, and surface and subsurface buildings, with a construction period of seven years. Annual construction spending would peak at $81 million. Based on economic multipliers developed for utility expenditures in the State of Illinois (Development Strategies 2011), the peak construction expenditure of $81 million would generate an additional approximate $117 million in regional economic activity. The average direct construction employment (56) would generate approximately 50 indirect or induced jobs in the local area, for a total of 106 jobs. The average construction worker for scientific research facilities near Chicago earns $47,700 (BLS 2014), resulting in approximately $2.6 million in annual construction wages on average and $9.5 million for the peak year (200 workers). (Many of the construction jobs would likely represent existing jobs that would remain filled rather than new jobs: for example, construction workers generally move from one project to another.) Based on the average per capita income in DuPage County of $38,405, earnings of indirect workers would average approximately $1.9 million annually. The Proposed Action also entails the development and installation of technical systems at a cost of approximately $170 million; these systems would either be fabricated outside the area and then assembled and installed by existing Fermilab staff, or fabricated, assembled, and installed by existing Fermilab staff. In either case, no additional economic benefit would be realized in the Fermilab area from the development and installation of technical systems.

Construction spending in Illinois has been depressed in recent years and is projected to remain depressed with only slow to stagnant growth through the start of construction (Commerce Department 2013). The relatively small construction cost and few numbers of workers would not increase the costs of labor or materials in the region, and thus would not result in adverse economic impacts. Construction of the Proposed Action would generate a short-term, beneficial economic impact in the area.

Operation

Operation of the Proposed Action would have low impacts on the local or regional economy. No additional new permanent positions would be created at Fermilab. Therefore, there would be no direct or induced economic effects generated from the earning and spending of new employees or on the local housing market. Some sectors of the local economy would experience a small, beneficial effect resulting from spending by researchers visiting the site, primarily in the areas immediately surrounding Fermilab. Economic impacts from operation of the Proposed Action would be small and beneficial, and would represent a continuation of existing economic benefits generated from operations at Fermilab.

<u>Environmental Justice</u>

Construction

LBNF/DUNE construction would not disproportionately impact minority and low income communities. In accordance with DOE's Environmental Justice Strategy (DOE 2008b), DOE's NEPA process would provide residents, including the minority populations, with access to information regarding the selected alternative. Potential impacts of LBNF/DUNE (e.g., increased traffic during construction, noise during construction) are low and would be borne equally by both minority and non-minority municipalities. Most impacts would occur along the Kirk Road corridor in Batavia, which is the closest off-site location to the Proposed Action. Batavia is neither a low income nor a disproportionately minority municipality. Hence there is no environmental justice concern.

Operations

LBNF/DUNE operations would not disproportionately impact minority and low income communities. In accordance with DOE's Environmental Justice Strategy (DOE 2008b), DOE's NEPA process would provide residents, including the minority populations, with access to information regarding the selected alternative. Potential impacts of LBNF/DUNE (e.g., increased traffic, noise during operation construction) are very low and would be borne equally by both minority and non-minority municipalities. Most impacts would occur along the Kirk Road corridor in Batavia, which is the closest off-site location to the Proposed Action. Batavia is neither a low income nor a disproportionately minority municipality. Hence there is no environmental justice concern.

No Action

Selection of the No Action Alternative would result in no socioeconomic impacts, no impact on the existing population or demographics, no impacts on the housing market, and no disproportionate impacts on minority populations and low-income populations. Under the No Action Alternative, Fermilab would continue to construct and operate existing experiments.

3.11.2 SURF

3.11.2.1 Affected Environment

The Proposed Action would be located 0.5 mile south of the City of Lead in Lawrence County, South Dakota on SURF property, a state owned facility operated by SDSTA under contract from the Lawrence Berkeley National Laboratory and DOE.

Lead is adjacent to, and southwest of Deadwood, South Dakota. The two Cities are commonly grouped, as they developed concurrently with mining activity that flourished between 1874 and 2002. Deadwood is currently a popular tourist destination due to its colorful history and casinos. Lead attracts tourists and outdoor enthusiasts as it is close to two ski areas; numerous Forest Service hiking, biking, and snowmobile trails; and several historic and educational facilities. The area covered by this analysis includes the communities of Lead and Deadwood.

Population, Race, and Ethnicity

The population and ethnicity of residents within the area are shown in **Table 3.11-4**. Data are also provided for South Dakota and the United States for comparison.

The data from **Table 3.11-4** indicate that the area contains fewer minorities as a percent of population than South Dakota and the United States. Whites dominate the population. The distribution of minorities in Lawrence County, Lead, and Deadwood is fairly uniform with no identified geographic concentrations of minorities. In general, minorities (with the exception of those identifying as American Indian and Alaska Native) are under-represented when compared to United States percentages.

Table 3.11-4 Population and Ethnicity of Residents

	Population	White (%)	American Indian & Alaska Natives (%)	Asian (%)	Black African Origin (%)	Two or More Races (%)	Hawaiian (%)	Other Races (%)	Hispanic (%)
United States	308,745,538	72.4	0.9	4.8	2.6	2.9	0.2	6.2	16.3
South Dakota	814,180	85.9	8.8	0.9	0.7	2.1	0.0	0.9	3.1
Lawrence County	24,097	94.1	2.2	0.7	0.9	2.0	0.1	2.0	3.1
Lead	3,124	94.6	2.0	0.4	0.3	2.3	0.0	0.4	2.9
Deadwood	1,270	94.9	1.8	0.5	0.2	2.0	0.0	0.6	3.4

Notes:
Those identifying as Hispanic may be of any race. Therefore, the data above may sum to greater than 100%.
Source: US Census, 2012, 2013 2011a

The American Indian population in South Dakota is considerably higher (8.8 percent) than in the United States (0.9 percent). The nearest of numerous American Indian reservations to SURF is the Pine Ridge reservation located approximately 63 miles southeast. However, Lawrence County, including Lead and Deadwood have low American Indian populations when compared with South Dakota overall.

Income

The median and per capita income in the area is shown in **Table 3.11-5**. The lower per capita income in Lead is, in part, reflective of its seasonal tourism economy coupled with the lack of industry and associated higher paying jobs.

Table 3.11-5 Median Household and Per Capita Income

Locality	Median Household Income	Per Capita Income
United States	$52,762	$27,915
State of South Dakota	$48,010	$24,925
Lawrence County	$45,137	$26,994
Lead	$40,875	$20,142
Deadwood	$38,452	$26,662

Source: Census Bureau 2012b

Table 3.11-6 presents information on the percentage of families whose income is below the poverty level. These data indicate that a higher percentage of families and individuals in Lead have incomes that are below the poverty line than the South Dakota average; however, this percentage is lower than the 2013 national average of 15.4 percent for the same period (Census Bureau 2014b). Although there are no specific geographic concentrations of low income populations in the project area, Lead's low income population is slightly higher than, but similar to South Dakota's and 1.9% higher than Lawrence County.

Table 3.11-6 Percentage of Families and People Whose Income is Below the Poverty Level

	United States	South Dakota %	Lawrence County %	Lead %	Deadwood %
All families	15.4	8.8	7.3	9.2	7.3
All people over the age of 18	14.3	12.4	14.0	14.0	10.4

Notes:
The poverty threshold for a single person is $11,490 or less. Add $4,020 for each additional person in a family.
Source: Census 2014b

Housing

Housing market data are presented in **Table 3.11-7**. The lower incomes seen in Lead are reflected in the lower median value of housing in the city. Vacancy rates are higher in both Lead and Deadwood than in Lawrence County or the state (Census Bureau 2012b).

Table 3.11-7 Median House Price and Selected Vacancy Rates

	South Dakota	Lawrence County	Lead	Deadwood
Median Value, Owner Occupied Units	$129,800	$166,00	$94,400	$127,900
Vacant Housing Units	11.9%	15.7%	23.5%	22.2%
Rental Vacancy Rate	6.3%	8.1%	19%	3.6%

Source: US Census Bureau 2012b

Industry and Employment

The percentage of workers employed in major industrial sectors is shown in **Table 3.11-8**. The data indicate that the largest industrial sectors in the Lead-Deadwood area are entertainment, tourism, health services, and education.

Table 3.11-8 Work Force Percentages by Industry Type

Industry	South Dakota	Lawrence County	Lead	Deadwood
Civilian employed population 16 and over	413,552	12,763	1,615	630
Agriculture, forestry, fishing, hunting, and mining	7.1%	5.3%	5.3%	2.7%
Construction	6.3%	9.7%	6.3%	4.3%
Manufacturing	10.0%	4.7%	2.3%	1.6%
Wholesale trade	2.7%	0.8%	0.0%	2.7%
Retail trade	11.6%	9.8%	9.0%	5.4%
Transportation and warehousing and utilities	4.3%	4.0%	3.4%	3.2%
Information	1.9%	2.9%	3.2%	3.5%
Finance, insurance, real estate, rental, and leasing	7.6%	5.9%	3.3%	2.4%
Professional, scientific, management and admin.	6.0%	6.3%	4.4%	5.9%
Educational services, health care, and social assistance	23.7%	21.2%	20.4%	13.3%
Arts, entertainment, recreation, accommodations, and food service	9.1%	19.2%	32.4%	42.9%
Other services except public administration	4.5%	5.1%	6.1%	4.9%
Public administration	5.3%	5.2%	3.7%	7.3%

Source: Census Bureau 2012a

The annual unemployment rates in South Dakota and Lawrence County in 2013 were 3.8 and 3.9 percent, respectively (BLS 2014). Looking over the past five years, the average unemployment rates in South Dakota, Lawrence County, Deadwood, and Lead were 4.9, 4.3, 1.5, and 3.5 percent, respectively. The unemployment rates in Lead and Deadwood are lower than that for the state, and considerably lower than the national rate of 9.3 percent (BLS 2014).

3.11.2.2 Environmental Impacts

Proposed Action

Socioeconomics

Construction

The construction of the underground detector would involve a labor force of approximately 50 workers per day, with a high of 100 workers per day during peak construction activity. The 2007 U.S. Economic Census Data (Census Bureau 2014) indicate that there were 3,128 construction firms in South Dakota employing 20,601 workers. This number includes 208 industrial and commercial construction contractors employing 3,074 workers. Given the large numbers of construction workers and former mine workers in the state and the SURF area, workers from the SURF area or South Dakota as a whole could contribute substantially to this demand. However, the low unemployment rates in the area, the length of the construction period, and the mix of skills necessary during construction may result in workers being recruited or hired from outside the area. The relocation of a small number of construction workers to the area would result in a small, and temporary, increase in the population. Given the number of vacant housing units available in the area, the Proposed Action would have very low impacts on the local housing market.

Construction would represent a beneficial economic impact in the area. The creation of new construction positions and the purchase of materials would result in direct, indirect, and induced effects throughout the local economy from the creation of additional employment positions to increases in income and spending. The SURF portion of the Proposed Action has a total estimated cost of approximately $563 million for the excavation and buildings, with a construction period of seven years. Annual construction spending would peak at $104 million. Based on economic multiplier approach presented above, peak construction spending could generate approximately $150 million in regional economic activity. The average direct construction employment (50) would generate approximately 45 indirect or induced jobs in the local area, for a total of 95 jobs. Assuming the construction workers earn the national average salary for construction workers of $35,020 (BLS 2014), construction would result in approximately $1.75 million in annual construction wages on average and $3.5 million for the peak year (100 workers). Based on the average per capita income in Lawrence County of $26,994, earnings of indirect workers would average approximately $1.2 million annually.

The Proposed Action would also entail the development and installation of technical systems at a cost of approximately $257 million; these systems would either be fabricated outside the area and then assembled and installed by a specialized contractor. Therefore, installation of these systems would result in less economic benefit when compared with the excavation phase.

Operation

During operation, the detector would be staffed by up to nine employees. Given the specialized nature of detector operation, these employees would likely be hired from outside the SURF area. The relocation of these employees (and potentially family members) to the area would not result in substantial increases to the population of the area, to the demographics of the area, and to the availability of housing in the area. The creation of these new operations positions would also not result in a substantial increase in area incomes. Given the small number of operations positions, no substantial indirect or induced beneficial economic impacts would result.

Environmental Justice

Construction

Construction of the Proposed Action would result in both direct and indirect beneficial economic effects. The Lead area has a slightly higher percentage of low-income people and a lower percentage of minority populations than the State as a whole. As described for Fermilab, DOE would implement its Environmental Justice Strategy to provide residents with information (DOE 2008b). Impacts (e.g., increased traffic) would be borne uniformly by the area's (defined as the Cities of Lead and Deadwood) entire population, which does not contain disproportionately high levels of minority or low-income residents compared to the Lawrence County. Although median household and per capita income are collectively less in Lead and Deadwood than in Lawrence County or the State of South Dakota, the population below the poverty level in Lead and Deadwood is similar to that of the County and the State. Hence there would be no environmental justice-related impact.

Operation

Operation of the Proposed Action would result in both direct and indirect beneficial economic effects. The Lead area has a slightly higher percentage of low-income people than the state as a whole, and low minority populations. As described for Fermilab, DOE would implement its Environmental Justice

Strategy to provide residents with information (DOE 2008b). Impacts (e.g., slightly increased traffic) would be borne uniformly by the area's (defined as the Cities of Lead and Deadwood) entire population, which does not contain disproportionately high levels of minority or low-income residents compared to the Lawrence County. Although median household and per capita income are collectively less in Lead and Deadwood than in Lawrence County or the State of South Dakota, the population below the poverty level in Lead and Deadwood is similar to that of the County and the State. Hence there would be no environmental justice-related impact.

Alternative A

Socioeconomics

Construction

In terms of scope and size, individual Alternative A experiments would be small relative to the Proposed Action and would have low impacts on the labor force, the population, or the housing market. Residents and local businesses would benefit economically from Alternative A construction as it would create jobs and increase income. Alternative A would stimulate the economy through the sale of primary goods and services as well as secondary purchases.

Operation

Alternative A operations would be staffed by experienced and trained researchers. The model for staffing would be similar to current SURF science activities, with students and researchers repeatedly visiting the site for short periods (ranging from 1 week to 2 months in duration). During operations, the visiting students and researchers would have a small, short-term beneficial economic impact resulting from spending on lodging, meals, and incidentals.

Operation of Alternative A, like the Proposed Action, would provide several benefits for students, teachers, and residents of Lead. Additional experiments would help continue educational opportunities, such as internships, for South Dakota students, including Tribal students. Science experiments associated with Alternative A would also promote interest in science.

Environmental Justice

Construction and Operations

Similar to the Proposed Action, construction and operation of Alternative A would not have disproportionately high human health or environmental effects on minority populations and low-income populations. Hence there would be no environmental justice-related impact.

No Action

The No Action Alternative would not involve construction or operation of LBNF/DUNE at SURF. SURF would continue to operate existing physics experiments in their current locations. So the socio-economics of the community would not change. Based on the lack of disproportionately high minority and low-income populations, there would be no environmental justice-related impact.

3.12 SUSTAINABILITY

This section evaluates the consistency of the Proposed Action and alternatives with Federal and site-specific sustainability policies and practices. The affected environment is the compliance environment at

Fermilab and SURF as well as air, energy, water, and other limited resources needed for LBNF/DUNE. An important part of the Sustainability program in the Federal government and DOE is the reduction of greenhouse gas (GHG) emissions. Those emissions, the impact of the Proposed Action and Alternative A, and approaches to emission reduction are discussed in Section 3.8 of this Environmental Assessment.

3.12.1 Fermilab

3.12.1.1 Affected Environment

As a Federal facility, Fermilab manages a Sustainability program consistent with Executive Orders 13423, Strengthening Federal Environmental, Energy, and Transportation Management, dated January 24, 2007 (EPA 2010) and 13514 Federal Leadership in Environmental, Energy and Economic Performance, dated October 8, 2009. These orders set goals in the areas of energy efficiency, acquisition, renewable energy, toxics reductions, recycling, renewable energy, sustainable buildings, electronics stewardships, vehicle fleets, and water conservation. EO 13423, Section 2(f), requires Federal agencies to ensure that new construction and major renovation of agency buildings comply with the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings (Guiding Principles) set forth in the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (EPA 2006). EO 13514 builds on previous sustainability initiatives and directs Federal agencies to reduce GHG emissions, increase energy efficiency, reduce fleet petroleum consumption, conserve water, and reduce waste. In response, DOE developed a Strategic Sustainability Performance Plan (SSPP) (DOE 2012).

Executive Order 13693, Planning For Federal Sustainability In The Next Decade, dated March 19, 2015 re-emphasized previous Sustainability goals and extends them to 2025. Federal agencies are charged with setting new goals in all areas previously contained in EOs 13423 and 13514, and those older EOs were rescinded. Until those goals are established, the Fermilab Sustainability Program will remain in place.

Fermilab also complies with DOE Order 436.1, Departmental Sustainability, which requires that DOE carry out its missions in a sustainable manner, institute cultural changes to factor sustainability and GHG emissions reductions into all management decisions, and ensure DOE achieves the goals established in its SSPP. In addition, Fermilab's environmental management system is International Organization for Standardization (ISO) 14001 certified and meets ISO standards for reducing cost of waste management, energy, and materials.

Fermilab has incorporated a number of sustainable practices and programs, including restoration of prairie, forest and wetland conservation, and water quality protection. Other sustainable programs focus on biodiversity, land management, composting, water conservation, and climate change. Since 2008, Fermilab has substantially reduced emissions of potent GHGs and has reduced waste production, including through a site-wide recycling program. The site's ICW system minimizes the use of potable water by capturing, retaining, and recycling rainwater. Further, no treated potable water is used for agriculture or landscaping.

Accelerator science inherently uses large amounts of energy. However, the lab strives to improve energy efficiency. During fiscal year 2011, the site installed a high-efficiency boiler and numerous lighting retrofits. Fermilab has focused on energy efficiency, including simplicity and economy of design for buildings and through upgrades consistent with DOE's SSPP. Fermilab also purchases Renewable Energy Certificates (RECs) to offset GHG emissions as needed to meet the goal of a 28 percent reduction by fiscal year (FY) 2020 relative to FY 2008. The purchase of RECs implies an actual reduction of GHG emissions nationwide assuming these purchases reduce the cost of producing renewable energy.

In 2010, Fermilab developed its first Site Sustainability Plan (SSP). This plan has been updated annually with new goals and progress. The 2013 SSP (Fermilab 2012f) includes goals pertinent to LBNF/DUNE that relate to reducing greenhouse gas emissions (Goal 1), energy efficient buildings (Goal 2), water conservation (Goal 4), pollution prevention (Goal 5), sustainable acquisition (Goal 6), electronic stewardship (Goal 7), and agency innovation.

3.12.1.2 Environmental Impacts

Proposed Action

The Proposed Action would comply with EO 13693, Planning for Federal Sustainability in the Next Decade, (2015). Fermilab's SSP addresses these goals for construction and operation as described in the following paragraphs.

Construction

The construction phase of the Proposed Action would be consistent with the following goals:

Goal 2: Buildings, Energy Savings Performance Contract (ESPC) Initiative Schedule, and Regional and Local Planning

The Proposed Action would be consistent with Fermilab SSP Goal 2, Buildings, ESPC Initiative Schedule, and Regional and Local Planning. Fermilab established a goal that all new construction must comply with the Guiding Principles, which include:

1. Employ Integrated Assessment, Operation, and Management Principles.
2. Optimize Energy Performance.
3. Protect and Conserve Water.
4. Enhance Indoor Environmental Quality.
5. Reduce Environmental Impact of Materials.

The Proposed Action would be consistent with this goal. Fermilab would incorporate sustainable design in the LBNF/DUNE service buildings by using technical guides and complying with Fermilab policies. These policies specify designing buildings that are more efficient and installing water conserving fixtures, energy-efficient lighting, metering, and materials with recycled and/or bio-based content.

Fermilab also established a goal of participating in regional and local planning. Current Fermilab practice includes participation in regional transportation and related sustainability planning. As part of the NEPA process, Fermilab held informational meetings, including with its Community Advisory Board to obtain public input on LBNF/DUNE and address any concerns regarding community impacts and sustainability.

Goal 5: Pollution Prevention and Waste Reduction

The Proposed Action would be consistent with Fermilab's goal of diverting at least 50 percent of non-hazardous solid waste, including construction and demolition debris. The construction contractor for LBNF/DUNE would be required to recycle non-hazardous construction and demolition waste, including paper and other packaging materials generated during construction.

Goal 6: Sustainable Acquisition

The Proposed Action would be consistent with Fermilab's sustainable acquisition goal. Fermilab requires all subcontractors to align with current sustainable acquisition.

Sustainable acquisitions for LBNF/DUNE would include reusing components from past experiments. The Proposed Action would be constructed using components from NuMI and NOνA. For powering the focusing horns for 1.2 MW operations, the Proposed Action would reuse the horn power supply from NuMI. This power supply would be used for NOνA and then for the Proposed Action. In addition, the Proposed Action would use the existing low-level electronic controls currently at NuMI. Further, Fermilab would construct the beamline using a combination of new and repurposed magnets and power supplies.

Operations

The Proposed Action's operations phase would be consistent with the following SSP goals:

Goal 1: Greenhouse Gas Reduction and Inventory

The Proposed Action would be consistent with SSP Goal 1, Greenhouse Gas Reduction and Inventory. Fermilab established a goal of having individual buildings metered for 90 percent of electricity by October 1, 2012, and for chilled water (recommended – not required) by October 1, 2015. Because of projects that were cancelled or deferred, the percentage of buildings metered for electricity dropped in 2012. However, the construction of new facilities, including the new Illinois Accelerator Research Center, Muon Campus, Cloud Computing Center, and LBNF/DUNE, would increase the percentage. As described above, most of Fermilab's GHG emissions relate to power purchases for operating High Energy Mission Specific Facilities (HEMSFs). These facilities use energy for HVAC and lighting, including during shutdowns, and additional energy when the experiment is operating. Although the Proposed Action would increase energy consumption (9 MW), its operation would minimize the net increase by complying with the energy efficiency measures outlined in the SSP (e.g., using renewable energy, installing meters, employee training). In addition, Fermilab would continue to purchase the RECs needed to offset energy consumption and meet SSP goals.

Goal 4: Water Use Efficiency and Management

The Proposed Action would be consistent with Fermilab's goal of reducing consumption of ILA water by 20 percent between FY 2010 and FY 2020. LBNF/DUNE would use the site's ICW system, which captures and recycles rainwater as well as tunnel inflow. The Proposed Action would also comply with the site-wide strategy of natural landscaping and native grassland management that requires a minimum amount of landscape watering.

Goal 7: Electronic Stewardship and Data Centers

The Proposed Action would be consistent with Fermilab's goal of metering all data centers and achieving a maximum annual weighted average PUE of 1.4 by FY 2015. Fermilab would equip LBNF/DUNE's computing centers with meters to measure the monthly PUE. The Proposed Action would also manage computers in accordance with sustainable practices. LBNF/DUNE would comply with Fermilab's Personal Computing Environmental Policy, which defines energy standards for monitors, laptop displays, processing units, and printers.

No Action

Under the No Action Alternative, there would be no construction or operational generation of additional GHGs, use of additional energy or water, or generation of additional waste. Existing operations would continue to use water and energy, and would continue to generate and dispose of wastes in a manner consistent with the SSP.

3.12.2 SURF

3.12.2.1 Affected Environment

SURF employs a sustainability plan (SURF, 2013) to efficiently use and promote clean energy, water, air, and to minimize waste. The core elements of this plan are:

1. Reduce energy usage from the preceding year by 5%.
2. Reduce surface water and groundwater contamination where practicable
3. Reduce water usage where practicable
4. Reduce air emissions where practicable
5. Use natural gas where possible to diminish carbon footprint.
6. Select and use products that minimize generation of CFCs and hazardous waste.
7. Encourage and practice waste minimization.
8. Train stakeholders on the plan elements described above.

An example of SURF's sustainability practices is its mine dewatering practices, which promote energy conservation and achieve permit compliance. The mine's dewatering pumps constitute a large portion of SURF's energy consumption. SURF monitors its dewatering pumps so as not to exceed the threshold peak electrical demand and to reduce energy demands on the local power supplier. Further, infiltration (groundwater) water is pumped wherever possible from shallow underground levels before it reaches deep areas, which minimizes energy consumption and wall rock interaction time.

SURF's sustainability policy promotes clean air. Tier 3 and 4 engines[1] are required on internal combustion engine purchases. These engines have lower emissions than older, less efficient engines. Further, GHG emissions and hazardous waste generation are limited by screening for new products that are recyclable, energy-efficient, and that limit GHG, such as paints and cleaners. The screening also applies to experiments and lab infrastructure. All site stationary emission sources are reported to the SDDENR, Air Quality Division for their review in compliance with South Dakota law. The Air Quality Division also issues construction permits.

SURF practices recycling where practicable for metals, cardboard, paper, and plastic. Unused products are returned to vendors. SURF regularly audits recycling and reuse vendors by verifying compliance history with the SDDENR.

SURF also minimizes energy usage and promotes the use of clean fuels such as natural gas. SURF conserves energy by not heating unoccupied buildings, lowering thermostats in occupied buildings, and purchasing energy efficient equipment whenever economically feasible. Natural gas is used to heat most buildings and in the shafts to avoid ice build-up. Natural gas equipment, such as back-up emergency standby generators, is also used to help reduce greenhouse emissions.

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[1] Tier 3 and 4 engines have progressively lower emissions standards than Tier 1 and 2 engines under recent EPA air quality regulations.

3.12.2.2 Environmental Impacts

Proposed Action

Construction

The Proposed Action would be constructed by contractors and each would be required to submit a sustainability plan for the management of materials, energy minimization, and the reduction of carbon emissions. The contractor's plans would address material purchases to promote green products that reduce LBNF/DUNE's carbon footprint; the use of energy efficient and recyclable materials; the quantity of expected waste materials; equipment type, and chemical usage.

Construction work would utilize local labor with a short commute to work, thereby limiting GHG emissions associated with commuting. Internal combustion equipment used in the underground excavation would employ Tier 3 or 4 engines, and in many cases scrubbers, to limit diesel particulates.

The Proposed Action would consume substantial energy and fuel in hoisting excavated rock out of the mine and moving it to the Gilt Edge Superfund site or the Open Cut. Excavated rock would be hoisted up the Ross Shaft, crushed, and then conveyed to the selected rock placement site. SURF would encourage the construction contractor to be consistent with the SURF sustainability plan.

The conveyor alternative for moving rock to the Open Cut would be an order of magnitude more energy-efficient than trucking (Brosnahan 2013). Excavating, hoisting, crushing, and transporting rock requires a substantial amount of energy. The energy usage would be minimized by using sound material movement practices consistent with reducing short-term and long-term costs. Adherence to the goals and policies set forth in SURF's sustainability plan would help prevent unnecessary or excessive energy usage and excessive materials consumption and waste generation.

The consumption of resources from construction of the Proposed Action would be similar to that of the construction of any a large, complex facility. Construction would incorporate the same general resource conservation goals outlined in the SURF sustainability policy for energy, water, air, and waste. These goals include minimizing energy usage; using natural gas where possible to heat buildings; minimizing water usage and water contamination; minimizing surface water discharge flows; and minimizing SOx, NOx, CO2, and particulate, emissions, and solid waste. GHG emissions from the Proposed Action are presented in Section 3.8, Air Quality.

Operation

Operation of the Proposed Action would meet the sustainability goals established in the SURF sustainability policy. The detector cryostat would be insulated according to design specifications that would conserve LAr and LN, reducing boil-off and truck trips for refilling the cryostats. Buildings would use energy-efficient methods, such as programmable and area temperature control. Water use would be minimal, as water would be used only intermittently for fire protection, eyewash stations, emergency showers, and sanitary systems.

Operation of the detector described in the Proposed Action would require power, access to the 4850 Level, and detector support equipment. Detector power usage is evaluated in Section 3.13, Utilities. Researchers and maintenance crews would use the Ross Hoist/Shaft to access the 4850 Level. Trips up and down the shaft would be set at regular times, typically 3-4 per day, to limit hoist energy usage.

The operation of the Proposed Action would use approximately 7 megawatts of electricity to operate the cryostat, pumps, compressors, chillers, and associated electronics. No heating of laboratory spaces would be required as the wall rock provides a heating effect.

Material that can be reused or recycled would be collected and hoisted to the surface. These materials include metals, plastic, paper, cardboard, and where possible, any chemicals.

Alternative A

Construction

For Alternative A, SURF would incorporate the same sustainability standards as the Proposed Action and would review construction materials for efficiency, recyclability, and consistency with SURF's Sustainability Plan.

Operation

The operation of the expected experiments would incorporate SURF's sustainability standards for energy efficiency. These experiments would be required to minimize use of fossil fuels and would use energy-efficient equipment per SURF requirements.

No Action

Under the No Action Alternative, there would be no construction or operational generation of additional GHGs, use of additional energy or water, or generation of additional waste. Existing operations would continue to use water and energy, and would continue to generate and dispose of wastes in a manner consistent with the SURF sustainability plan.

3.13 UTILITIES

This section describes existing site utilities at Fermilab and SURF and potential impacts of construction and operation on municipal utilities. Thus, the affected environment includes power, water, and wastewater utilities needed for LBNF/DUNE.

3.13.1 Fermilab

3.13.1.1 Affected Environment

Fermilab is supplied electrical power through the northern Illinois bulk power transmission system operated by a local investor-owned utility. The site interconnects with the bulk transmission system at two locations. Fermilab is serviced by 345 kilovolt (kV) service connections at 2 interconnections. At the interconnection sites, Fermilab takes power and delivers it along Fermilab-owned and operated transmission lines to two separate electrical substations where the power is transformed to 13.8 kV for site-wide distribution. Fermilab maintains two separate types of power systems: pulsed power and conventional power. The pulsed power loads used by accelerator facilities are large and are of the wrong type for the conventional facilities equipment; thus, the systems are separate. Fermilab's baseline power usage of approximately 20 MW is supplied by ComEd.

Fermilab's drinking water is provided through a community water system from the City of Warrenville. Wastewater effluent is discharged to the Batavia and Warrenville sewer systems and wastewater treatment plants. In 2013, these discharges included 29 million gallons to Batavia and 26 million gallons to Warrenville.

3.13.1.2 Environmental Impacts

Proposed Action

Construction

The Proposed Action would require relocation of a portion of the existing on-site electrical power duct bank system to allow construction of the embankment and beamline facilities. Existing duct banks would be removed and reinstalled in trenches excavated along the proposed access roads. This phase of construction would require open cut excavation of approximately 2,000 linear feet of trench. Electrical power requirements would also require extending and expanding the existing 13.8-kV electric distribution facilities. This includes extending the 13.8 kV distribution feeders from a nearby manhole for pulsed power and the addition of new feeders from new breakers at the Kautz Road substation for the conventional power. The physical disturbance required to upgrade utilities would occur primarily within the boundaries of the existing Kautz Road substation and within the shoulder of Kautz Road and Indian Creek Road where new duct banks would be installed. This area consists of grassy and industrial areas, is previously disturbed, and has no waterway crossings. Potential impacts of excavation would be low and are addressed in other sections of this EA, including 3.2, Biological Resources; 3.3, Cultural Resources; 3.5, Hydrology and Water Quality; and 3.10, Geology and Soils.

Construction would occur under the existing City of Batavia-owned transmission power line that runs parallel to Kirk Road but would not require power disruption. A portion of the Batavia power line would be temporarily relocated to wood poles during the excavation for beamline components, and then replaced on the existing metal tower. Utility service impacts during utility construction or relocation, although not expected, would be limited to areas on the Fermilab property, where temporary power would be supplied. Power requirements during construction would be limited and would include lighting of construction trailers, operation of small tools, powering ventilation and pumps. Therefore, construction of the Proposed Action would use very limited power and would have very low impacts on power utility capacity. Other utility requirements, including water required for construction, including for potable water and dust control would be supplied by the construction contractor and would have no impacts on water supply or wastewater treatment utility capacity.

Operations

The total power requirements for LBNF/DUNE beginning in approximately 2026 would be 9 MW, including HVAC and lighting. The increase in Fermilab power requirements from LBNF/DUNE operations likely would not affect power providers or require off-site upgrades to existing generation or distribution systems. The existing system's capacity is designed to accommodate other large power users, including industrial and commercial customers such as O'Hare International Airport. In 2026, Fermilab's projected power demand (without LBNF/DUNE) would be approximately 60 – 70 MW. This power would be split between the Kautz Road and Master substations, resulting in a power load of between 40 and 50 MW at the Kautz Road substation. According to ComEd (2014), the power load required by LBNF/DUNE for construction and then 20 years of operation would not exceed power or distribution system capacity. The closure of the Tevatron in 2011 reduced power consumption at Fermilab by approximately 18 MW. Closure of other experiments would result in an overall reduction in operational power usage over time.

The Proposed Action would also require other utilities for operation, including potable water, wastewater treatment, and natural gas. The LBNF/DUNE structures would not be regularly occupied; therefore demand for these utilities is not high. LBNF/DUNE's potable water requirements would be limited to the restrooms and would be within the capacity of the City of Warrenville community water system. Wastewater would be discharged to the Batavia and Warrenville sewer systems and would be within Batavia and Warrenville's projected capacity for treatment and discharge.

Natural gas is provided by Nicor under a supply contract with the Defense Energy Supply Center. Gas would be easily accessible to the Proposed Action from the Central Utility Building and would be used to heat the 60,000 square feet of internal space required by LBNF/DUNE’s surface and subsurface buildings. Particularly given the increased natural gas supply nationwide, the natural gas required by LBNF/DUNE would be within Nicor’s capacity.

No Action

Under the No Action Alternative, LBNF/DUNE would not be constructed or operated and Fermilab would not require power or other utility upgrades. Fermilab would continue to operate existing experiments and pursue energy efficiency and other the other sustainability goals outlined in its Site Sustainability Plan.

3.13.2 SURF

3.13.2.1 Affected Environment

SURF contains a substantial existing utility infrastructure that is a vestige of the former Homestake mine. The existing power, water, and airflow systems were designed to support safe operations of the underground mine and surface mill facilities. These facilities are now reclaimed or inactive, but utility infrastructure remains mostly intact. For example, the Oro Hondo power substation was one of the main power feeds to the mine and mill and has a capacity of 18 MW. However, only 3 MW are currently used for operating SURF. Black Hills Power (BHP) is the electricity supplier for SURF. The Ross substation, which is owned by SURF and serviced by BHP, has a capacity of 30 MW; however, only 3 MW is currently used. SURF conducts a constant process of maintaining and replacing aged underground utilities.

Water used by Homestake was approximately 1,000 to 2,000 gallons per minute (gpm). An extensive water supply system with validated water rights was in place to supply approximately 3,500 gpm to the former mine (Mitchell 2009). Currently, these water rights have been given away or sold by Homestake, but the conveyances and cisterns to deliver this water to SURF are still in place and managed by the City of Lead. Drinking water and water needed for fire safety are provided by the Lead-Deadwood Sanitary District.

The ventilation system in the underground mine was extensive in order to support miners in many different locations. The current air delivery system supplies approximately 250,000 cubic feet of fresh air per minute (cfm), with capacity to provide as much as 750,000 cfm. Many of the former mine openings have been closed off or sealed. The existing ventilation supply facilities are concentrated in areas near the Ross and Yates Shafts. An abundant air supply flows directly down these shafts, past science experiments located near shafts, and exits the underground spaces via the Oro Hondo shaft. Tens of thousands of cubic feet of air per minute are available to support underground physics experiments at a volume that greatly exceeds minimum ventilation standards.

Communication lines, including fiber and telephone lines, are currently available at many underground levels with redundant connections off site. Gas fired heat is installed at the Ross and Yates Shaft air intakes to prevent ice buildup near the shaft openings. Heat is not necessary to heat the underground laboratory, as the wall rock is sufficiently warm to perform this function at levels below the 800 Level.

SURF treats underground water at the SURF waste water treatment plant. The underground water is composed of storm water, ground water, and tailing water from Homestake’s tailing pond. SURF has the capacity to pump and treat 1,300 gpm of underground water and 1,200 gpm of tailing water. The plant currently treats an average of 600-800 gpm of underground water and 600 gpm of tailing water.

3.13.2.2 Environmental Impacts

Proposed Action

Construction

A total of 7 MW of electrical power would be needed for the construction of the Proposed Action, including the underground detector hall. This additional power would be needed for cryogen handling, rock crushing, and transporting excavated rock to the Open Cut via conveyor, if selected. Electrical power to SURF is supplied by Black Hills Power (BHP). The Ross substation, which is owned by SURF and serviced by BHP, has a capacity of 30 megawatts; however, only 3 megawatts is currently used. BHP indicates that there is sufficient power to meet demands from the public, LBNF/DUNE, and other anticipated projects (Keck 2014). Thus, the additional 4 MW needed for the construction of the Proposed Action is well within the capacity of BHP and the Ross substation. Current BHP projections include future power demands for LBNF/DUNE construction and operation, and projected available power levels would be sufficient to meet projected future demands (Keck 2014).

A system capable of supplying approximately 800 gpm of clean water would be necessary for LBNF/DUNE construction, including dust suppression and fire protection. The water would be supplied to SURF by the City of Lead through the Lead-Deadwood Sanitary District. The infrastructure and water supply for drinking and fire safety would be well within the City's capacity as the water collection system and infrastructure has remained intact from mining operations. The additional demand for city water would not impact the public as the City has an excess water supply capacity due to decreased residential business demand since the mine closed in 2002 (Toscana 2014).

The SURF underground pumping and water treatment utilities would continue to operate with low impact. An average pumping rate of 1000-1200 gpm would be required to meet an average LBNF/DUNE construction requirement of 800 gpm but average use would be 200-300 gpm.

Given the information provided by local utilities, construction of the Proposed Action would have low impacts on the ability of utilities to deliver power and water.

Operation

All utilities for operation of the Proposed Action would be supplied by infrastructure located in the Ross Shaft. Operation would require approximately 10.5 MW of additional power over the current power consumption at SURF of 3 MW and would be within the capacity of BHP (Keck 2014). Communications would be installed during construction for use during operation. Average operational water demand would be approximately 100 gpm. This supply, as well as occasional need for fire safety, would be within the utility's capacity (Toscana 2014).

Alternative A

Construction and Operation

The utility needs for construction and operation of the smaller experiments of Alternative A would be lower than the Proposed Action and would not exceed utility capacity (Keck 2014, Toscana 2014) or the existing distribution system supply provided by SURF infrastructure and would therefore have very low impacts on existing utilities.

No Action

Under the No Action Alternative, LBNF/DUNE would not be constructed and no changes to utilities would be needed.. Existing operations would continue and utility maintenance and upgrades needed to supply existing SURF physics experiments would continue. The ongoing replacement of underground utilities would continue.

3.14 WASTE MANAGEMENT

This section describes existing waste generation and management at Fermilab and SURF and the potential environmental effects of the Proposed Action and Alternatives on waste management practices and facilities. The affected environment includes the waste management compliance environment and programs at Fermilab and SURF, as well as on- and off-site waste management and disposal areas.

3.14.1 Fermilab

3.14.1.1 Affected Environment

Current operations at Fermilab generate non-hazardous and hazardous wastes, including chemical and radiological wastes. Fermilab manages waste in compliance with applicable regulations including the Resource Conservation and Recovery Act (RCRA); the Toxic Substances Control Act (TSCA); the Superfund Amendments and Reauthorization Act (SARA); the Federal Clean Air (CAA); Clean Water Act (CWA); the Safe Drinking Water (SDWA) Act; and other applicable Federal and state regulations.

Fermilab has implemented a waste management program that also complies with DOE Orders and IEPA regulations. DOE Orders include DOE Manual 435.1-1 (Radioactive Waste Management) (DOE 1999), DOE Order 460.1A (Packaging and Transportation Safety) (DOE 1996), and DOE Order 460.2A (Departmental Transportation and Packaging) (DOE 2004b). These requirements flow down to Fermilab's plans and procedures, such as the Fermilab EH&S Manual and the FRCM. Fermilab maintains a permit under RCRA to manage the proper disposal or reclamation of hazardous waste generated at the Laboratory. Radioactive waste is not governed under RCRA and is managed following DOE requirements. Fermilab does not treat, or dispose of any regulated wastes on site. All wastes are properly disposed though licensed waste handling, transport or disposal facilities. An annual Hazardous Waste Report is transmitted to IEPA and radioactive waste summaries are provided to the DOE Fermi Site Office.

Table 3.14-1 shows the volumes of various waste categories managed in 2013 by the Fermilab Hazard Control Technology Team (HCTT).

Table 3.14-1 Waste Volumes Managed by Fermilab - 2013

Waste Type	Volume (cubic yards)
Non-Routine Hazardous Waste (RCRA + TSCA)	12.7
Routine Hazardous Waste (RCRA + TSCA)	10.0
Non-Routine Non-Hazardous Special Waste	2.9
Routine Non-Hazardous Special Waste	15.7
De-Classified Special Wastes	14.4
Dumpster/Landfill Waste	8,201
Radioactive Waste (DOE regulated)	164

Fermilab has implemented approved programs and plans to ensure proper waste packaging, transportation, disposal, and reuse/recycling. These plans and programs include:

- Radioactive Waste Management Program
- Waste Management Plan
- Low-Level Waste Certification Program
- Spill Prevention Control and Counter Measures Plan
- Storm Water Pollution Prevention Plan
- Emergency Response Plan
- Integrated Environment, Safety, and Health Management Plan

Each Fermilab waste generator is responsible for waste characterization and packaging, in compliance with DOE Order 460.1C for hazardous waste packaging and transportation (DOE 2010). Fermilab reduces waste and practices pollution prevention through process change and substitution; material reuse and recycling; using control technologies; and proper disposal if other more sustainable options cannot be implemented. Fermilab has an extensive waste minimization program that includes recycling to collect a variety of waste material including white office paper, mixed office paper, cardboard, plastic, glass, metal containers, scrap metal, electronic components, laser printer cartridges, batteries, fluorescent lamps, non-polychlorinated biphenyl (PCB) ballasts, oil, and construction debris. Receptacles are placed in appropriate locations to collect these materials.

Non-hazardous waste includes municipal landfill waste and industrial waste that is specially packaged and identified for disposal. These later wastes are from laboratory and remediation operations, such as soils containing petroleum hydrocarbons, and PCBs. Waste materials leaving the site are screened for radiation prior to pick-up and again before off-site transport to a licensed disposal facility.

Fermilab regularly handles, stores, and uses hazardous materials as part of ongoing experimental programs and daily operations. These hazardous materials include solvents, corrosives, acids, adhesives, paints and epoxies, metals, and radioactive materials. Fermilab hazardous waste procedures include characterization, packaging, marking, labeling, and hazard communication. Fermilab employees handling and packaging hazardous waste are trained in accordance with approved procedures that meet DOE Orders and RCRA requirements.

The site also discharges effluent to the Batavia and Warrenville sewer systems and wastewater treatment plants. Fermilab has an NPDES pre-treatment permit for process discharges to the Batavia treatment plant. The permit requires effluent sampling and analysis for heavy metals. In 2013, approximately 60,000 gallons of process wastewater were discharged to the Batavia sewer system under the permit. Total sanitary discharge volume to the Batavia system in 2013 was approximately 29 million gallons and total discharges to Warrenville were approximately 26 million gallons. All effluent discharges complied with the pre-treatment permit as well as specified levels in the DOE Derived Concentration Guide for radionuclides (DOE 2011b).

Fermilab also generates low-level radioactive and mixed waste as part of operating its high-energy physics research program. Mixed waste is both radioactive and otherwise regulated waste. Radioactive waste includes waste materials contaminated with radionuclides or activated by exposure to prompt radiation. Fermilab currently generates low-level radioactive waste (LLRW) from routine operations, maintenance, and experiments. Radioactive waste is packaged, marked, labeled, and transported in accordance with DOE Orders and U.S. Department of Transportation (DOT) requirements. Fermilab generated 164 yd^3 of radioactive waste in 2013 (**Table 3.14-1**).

Finally, Fermilab generates radioactive experimental components after they are exposed to beam radiation. Property exposed to radioactivity is surveyed as required by 10 CFR 835 for contamination before removal from Fermilab. Materials with detectable radioactivity are retained for reuse on-site, disposed as radioactive waste, or as both a hazardous and radioactive waste.

3.14.1.2 Environmental Impacts

Proposed Action

Construction

The Proposed Action would result in the generation of solid waste and hazardous waste. Non-hazardous wastes generated by construction would consist of construction debris and sanitary waste. Construction of the Proposed Action would require the excavation of up to 460,000 yd^3 of soil and rock. Excavated material would be stored on-site or reused as fill for the embankment to shield the Primary Beamline Enclosure and Target Hall or as backfill for the Decay Pipe and Absorber Hall excavation. If needed, additional clean borrow material to complete the backfill and embankment construction would be brought from non-contaminated areas including existing soil stockpiles. To ensure that borrow material was suitable and not contaminated with radionuclides, Fermilab would conduct a radiological survey on each source. Excavated soils would not be expected to contain radionuclides. However, a portion of the borrow material for the embankment would be obtained from an area adjacent to the MI.

Construction would result in potential short-term impacts from increased waste generation during periods of active construction. Subcontractor specifications would require compliance with Federal, state, and local requirements and with Fermilab policies regarding waste management. Solid waste generation would increase relative to current conditions, but the quantity of waste would be well within the existing capacity of the Fermilab waste system and would not substantially affect waste disposal handling capacity or facilities. The Proposed Action would not require construction of new facilities on-site or off-site to accommodate the increased amount of construction waste, and the overall effect would be low because Fermilab would follow strict SOPs for managing and minimizing wastes, including reuse/recycling. Once construction is complete, waste generation of this nature would decrease substantially.

The total volume of waste generated and disposed of at Fermilab would be reduced by Fermilab's active minimization program. Construction of the experimental facilities and service buildings and site excavation would generate approximately 18,000 yd^3 of construction debris. General refuse from the Proposed Action would be discarded into dumpsters located at the construction site. Wastes placed in dumpsters would be collected by a commercial waste hauler and transported to the hauler's processing facility, where recyclable materials would be removed and the remainder disposed of in a permitted off-site landfill. The remaining organic waste would be transported for disposal in a permitted off-site sanitary landfill.

Construction of the Proposed Action would generate small quantities of petroleum waste. The quantities generated would increase relative to current conditions, but would be well within the existing capacity of the Fermilab waste system. These wastes would be generated by construction equipment maintenance such as routine changes of hydraulic hoses and fittings to minimize ruptures and fluid releases. Some inadvertent mechanical failures, vehicle mishaps, or fluid releases would require minor cleanup. Other wastes would include oily rags used during equipment maintenance and cleanup of residual hydraulic fluids and fuels, adhesives, paint, and solvents. These construction wastes would be disposed of in accordance with DOE requirements and would meet disposal facility Waste Acceptance Criteria (WAC). Wastes would be packaged, marked, and labeled for transport in accordance with DOE Orders and 49 CFR requirements. Based on Fermilab construction experience, **Table 3.14-2** presents estimated waste volumes that would be generated during construction of the Proposed Action.

Table 3.14-2 Estimated Construction Waste Volumes – Fermilab

Hazardous Waste	Volume[1]	Disposal Method
Oily Rags	1,500 gallons (5,700L)	Incineration
Spent Solvents	200 gallons (760L)	Incineration
Epoxy Paint	10 gallons (38L)	>50% Recycle or incineration
Hydraulic Fluid (spills)	200 gallons (760L)	Incineration
Fuel (spills)	50 gallons (190L)	Incineration
Used Motor Oil & Lubricants[1]	6,300 gallons (2,3940L)	100% Recycle or Incineration

Notes:
1 Volume estimate 25 equipment pieces x 14 gallons/piece oil x 3 changes/year x 6 years.

In summary, construction would increase the amount of waste generation and subsequent waste handling and disposal; however, contractor specifications require compliance with Federal, state, and local requirements and with existing Fermilab policies. The minimal quantities of regulated waste streams would not adversely affect off-site disposal facilities, nor would the Proposed Action require modification of existing on-site waste handling facilities. The generated waste streams would not add substantial volumes that would adversely affect facility disposal capacity, nor would existing disposal facilities require modification. Waste would be managed following Fermilab's existing SOPs for storage, recycling, and disposal.

Operation

Operation of the Proposed Action would result in the generation of non-hazardous waste, hazardous waste, and radioactive waste. These waste streams would be very similar to those generated by other past and present facilities at Fermilab, including Tevatron and NuMI, and would be handled in accordance with Fermilab's approved plans and procedures as previously described. However, the Proposed Action would not generate new waste streams that would require development of new procedures or new facilities.

Small quantities of hazardous materials would be used during operation of the Proposed Action, including solvents, oil, epoxies, paint, and lead shielding. The quantities of hazardous wastes generated would increase relative to current conditions, but would be within Fermilab's existing waste system capacity. Some hazardous materials may be recycled, such as the unused or useable solvents, paints, and lead shielding. Hazardous materials that cannot be recycled/reused would be disposed of in accordance with approved plans and procedures in a safe and compliant manner. Because operations would generate a minimal quantity of hazardous waste, no new on-site or off-site facilities would be needed.

Proposed Action operations would generate small quantities of radioactive waste including activated shielding components (e.g., steel, concrete) and activated experimental components (e.g., horns, magnets, etc.). These radioactive waste streams and radionuclides would be managed the same as those previously and currently generated by Fermilab through similar research, including Tevatron and NuMI.

Small amounts of soil and water at the interface between the beamline shielding and surrounding soils and groundwater may become slightly radioactive. Activated shielding and soils around the beamline would be left in place for the life of the experiment. However, any shielding or components activated as a result of a beamline mis-steering accident would be surveyed and stored underground in a shielded compartment until final disposal in compliance with DOE Orders (Section 3.15, Accident Analysis). As described in Section 3.5, Hydrology and Water Quality, groundwater immediately adjacent to the shielding would be collected, drained to a sump, pumped into the ICW system, and recycled for cooling of experimental power sources and components. Activation of groundwater is thus minimized by removing it from any possible radioactivity source. Cooling water from sumps enters surface waters, which are monitored for tritium. Surface water tritium levels are several times less than the EPA Drinking Water standard. Water released from the site would be discharged in compliance with the Fermilab NPDES permit. Similarly, air discharged to the open environment may contain activated water vapor and would be discharged in compliance with Fermilab's NESHAP operating permit.

Materials exposed to radioactivity and potentially activated would be surveyed prior to removal from Radiologically Controlled Areas. Radiological surveys would be performed by qualified radiological control technicians and documented before releasing these materials for disposal or reuse in accordance with approved DOE procedures and shipped in accordance with DOT requirements. For example, filters or filtrates containing radioactive constituents would be characterized and packaged for compliant disposal as required by the approved disposal facility's WAC.

Overall, impacts from radioactive waste would be low and minimized by design measures and engineering controls (shielding and beamline design) site security, and safety procedures in place, accident procedures to isolate hot components, surveying components to determine disposal/reuse procedures, and on-site management of collected groundwater.

No Action

The No Action Alternative would not generate additional solid, hazardous, or radioactive waste requiring management and disposal. The types and quantities of solid, hazardous, or radioactive waste generated at and disposed by Fermilab would continue as described above under the affected environment, and there would be no incremental environmental impacts from packaging, transportation, or disposal of LBNF/DUNE wastes beyond that currently generated and disposed of for existing experiments.

3.14.2 SURF

3.14.2.1 Affected Environment

Current waste management practices, which include generation, identification, storage, use, transport, and disposal of wastes at SURF, comply with applicable state and Federal regulations. SURF manages hazardous materials and wastes as part of its ongoing infrastructure work and experimental programs. Examples of hazardous materials present at SURF include paints, solvents, petroleum products, corrosives, and various cleaners. Some of these materials become waste. There are a small number of sealed radioactive sources at the site that contain very low levels of radioactive materials. Sealed sources no longer used at SURF are returned to the supplying laboratories or universities. There are no radioactive or mixed wastes generated at the SURF site. SURF has established various waste disposal programs and associated training as part of its Environmental Compliance Plan (SURF, 2011) to comply with regulatory requirements including:

- Emergency Response Plan
- Hazard Communication Plan

- Storm Water Pollution Control Plan
- Spill Prevention, Control, and Countermeasures Plan
- Chemical Inventory Spreadsheet
- Waste Management Plan

These programs and procedures ensure the safe management of wastes for the protection of SURF's employees, the public and the environment.

Hazardous materials at SURF are screened by reviewing the Safety Data Sheets (SDSs) before they are transported on-site. Materials with the potential for creating hazardous waste are either rejected in favor of a non-hazardous waste candidate, or if a substitute does not exist, the material is entered into a database for tracking and management. Hazardous materials are also screened for potential recycling or reuse to minimize waste.

Wastes at SURF are identified by characterization or generator knowledge and then managed and disposed of according to State, Federal, and site regulations. Wastes are divided into several different classifications consistent with Federal regulations. These classifications include hazardous wastes and non-hazardous wastes, including construction (inert) wastes, universal wastes, and Toxic Substances Control Act (TSCA) wastes. SURF generated and disposed of the following wastes in 2011 (SURF 2011):

- 844 pounds of hazardous waste
- 62 pounds of universal waste (batteries and lamps)
- 526 yd^3 of industrial (non-hazardous solid) waste
- 620 yd^3 of non-recyclable waste (rubble) which was placed in a sanitary landfill (Subtitle D)

Wastes transported off-site are completely destroyed to minimize liability and comply with land disposal restrictions. For example, on-spec oils and greases are burned at an off-site permitted facility for Btu value. Non-hazardous wastes include wastes that cannot be reused or recycled and are not hazardous per 40 CFR 261. SURF characterizes wastes by sampling and laboratory analysis to ensure that they meet non-hazardous criteria and to determine if they are industrial wastes that would not be accepted by a landfill. Non-hazardous wastes are segregated, labeled, temporarily stored, and shipped off-site per 40 CFR 261 through 280 to a Treatment, Storage, and Disposal (TSD) facility that specializes in managing the specific industrial waste stream. Examples of industrial waste include soils with low levels of petroleum hydrocarbons, low-level PCB waste (greater than 2 but less than 50 parts per million PCB), and metal-bearing non-hazardous sludge not accepted at municipal landfills.

Because SURF typically generates less than 220 pounds of hazardous waste per month, it is classified as a Small Quantity Conditional Exempt Generator (SQCEG) of hazardous waste under RCRA. Common hazardous waste items include corrosives, aerosol cans, paints, solvents, lead-contaminated debris, and adhesives. If greater than 220 pounds (but less than 2,200 pounds) of hazardous waste were generated in one month, SURF would be classified for that month as a Small Quantity Generator (SQG) of hazardous waste. This has occurred once and was associated with the construction of the Davis Cavern. SURF consistently complies with State and EPA SQG requirements as a matter of BMPs. SURF regularly submits waste management practices to the SDDENR for review and concurrence. The State of South Dakota has been given authority by EPA to implement the Federal RCRA hazardous waste program.

3.14.2.2 Environmental Impacts

Proposed Action

Construction

Construction of LBNF/DUNE at SURF would generate a large volume of excavated rock and other solid waste. The excavated rock would be transported to the Gilt Edge Superfund site or placed in the Open Cut. Both transport and placement methods would minimize potential impacts on water quality (see Section 3.5- Hydrology and Water Quality). Waste petroleum products would be tested to determine recyclability and reuse potential. Solvents would be managed as hazardous waste by a licensed TSD contractor. SURF would have the solvents and paint-solvent mixtures filtered and reused where practicable by a TSD contractor. Unused and unopened paints would be returned to vendors. Construction debris would be sent to the Rapid City Municipal Recycling Facility (RCMRF), where more than 95 percent would be recycled.

Mining equipment, such as rock drills, loaders, and shotcrete applicators, would be used to prepare the detector cavern. Blasting materials would be used, creating empty explosive packaging and waste explosives from an occasional unfired hole. This waste material would be destroyed in an underground area. The shotcrete equipment would be washed underground, and the resulting wash water would mix with mine water, requiring an approval under the EPA Underground Injection Control (UIC) Program. The mixed water would be treated at SURF's WWTP.

Rock crushing and the transport of the rock would generate additional petroleum waste. These would be recycled or reused whenever possible. Grease and oils would result from crushing activities and maintenance of trucks and conveyor. Haul truck maintenance would be the responsibility of the subcontractor. SURF would require the subcontractor to recycle antifreeze, oils, oil filters, and greases where possible. Petroleum contaminated rock and debris would be collected, characterized, and taken to a state-approved licensed land application facility in accordance with SURF's SPCC plan. Hazardous waste generated and managed by the subcontractors would be audited by SURF.

The crusher and trucks used to haul excavated rock would require maintenance and the use of solvents such as brake cleaner, carburetor cleaner, and fuel additives. Disposal of these items would generate hazardous waste. Approximately 500 gallons of solvent would be required for the rehabilitation and operation of the crushers. This solvent would be a listed RCRA-hazardous waste and would require disposal by an outside vendor. The timing of the hazardous waste generation may place SURF in a different hazardous waste generator status for a short period of 1 – 2 months, which would result in an increased level of regulation and oversight. The SDDENR would be made aware of this in advance of disposal, and regulatory requirements would be met. The waste solvent would be filtered and reused where practical.

The subcontractor responsible for outfitting the LBNF/DUNE cavern would execute their management plan for construction materials and their disposal in accordance with SURF's ES&H requirements. Specifically, all hazardous construction material must be approved by SURF and conform to SURF environmental policies and procedures. The construction contract would require the construction contractor to be the waste generator and be responsible for managing the waste produced on-site according to state and Federal requirements. SURF would audit the contractor to ensure compliance.

Fuel storage tanks and drums used underground and on the surface would require secondary containment. Containers of petroleum products greater than 55-gallons would be double-walled in accordance with SURF's SPCC plan. Underground fueling stations would also require containment to limit spills. Fuel stations and petroleum containers would be inspected monthly to help prevent or detect leaks and damaged containers.

Table 3.14-3 summarizes the projected waste amounts that would be generated during construction of the Proposed Action at SURF based on an extrapolation of waste generated in the creation of the Davis Cavern and outfitting.

Table 3.14-3 Projected Construction Waste for the Proposed Action – SURF

Petroleum Products (non-hazardous oil and grease recycled)	800,000 pounds (over 5 years)
Solvents (hazardous waste and disposed)	5,000 pounds (over 5 years)
Solvents (non-hazardous and recycled)	4,500 pounds (over 5 years)
Paints (disposed)	4,000 pounds (3,500 pounds hazardous waste and 500 pounds non-hazardous waste - over 5 years)
Construction debris (disposed)	1,500 tons (over 5 years)
Wash Water (disposed)	600,000 gallons (to be discharged to underground water) over 5 years
Petroleum contaminated soils (disposed)	2,500 pounds (non-hazardous - over 5 years)

In conclusion, construction of Proposed Action would increase waste generation above current levels. The potential impact of increased waste generation would be minimized with selective purchasing and product review practices, recycling, unused material returns (restock), contractor oversight, auditing of disposal facilities, state and Federal awareness of waste management practices, and good waste characterization practices.

Operation

The operation of the Proposed Action would generate very little additional waste. The expected waste streams and quantities are listed below with a short description in the following paragraphs. **Table 3.14-4** shows the projected amounts of waste associated with Proposed Action during operations.

Table 3.14-4 Projected Operational Waste for the Proposed Action – SURF

Waste Stream	Quantity
Cleaning Agents (shelf-brand cleaning agents)	30 gallons/year
Oil and Grease (non-hazardous, and recycled where possible)	500 gallons/year
Glycols (non-hazardous waste	300 gallons/year
Light Bulbs (universal waste)	40 pounds/year
Batteries (Alkaline, only)	50 pounds/year
Condensate (from compressors)	100,000 gallons/year
Aerosol Cans (hazardous waste)	20 pounds/year
Solvents (hazardous waste)	200 pounds/year

The expected non-hazardous wastes include water mixed with a commercially available biodegradable cleaning agent such Micro-90 or Simple Green, glycols, oils, greases, light bulbs, batteries, lamp ballasts, condensate water, and small volumes of compressor blow-down water. The bulbs and batteries are universal waste, which must be collected and disposed of by an audited managed vendor. The waste glycols, oils, and greases, would be collected and reused or disposed of by an audited managed vendor. Condensate water and compressor blow-down water would be discharged to the mine water pool with EPA and State approval. This discharge would not affect mine pool water quality or the waste water treatment process as both these waters do not contain toxic contaminants. Cleaning agents (not a listed or characteristic hazardous waste) mixed with water would be collected and sent to the surface for disposal to the city sewer along with sanitary waste. Notification of, and approval by the Sanitary District would be required for this discharge. No radioactive material would be used in the detector, with the possible exception of a sealed calibration source, which has very low radioactivity, and which would not be discarded. There would be no mixed waste generated in the operation of the detector.

The hazardous waste generated during operation of the detector would be aerosol cans and solvents. These cans would be managed according to existing SURF procedures. The limited amount of hazardous waste generation during operation would not likely affect SURF's conditionally exempt generator status. All hazardous wastes would be disposed of by an audited, licensed TSD contractor at an approved off-site facility.

The operation of the Proposed Action would generate additional petroleum waste from hoisting and lowering people and materials to the 4850 Level. Gear oil changes would be required and result from more frequent hoisting and lowering workers and equipment. The operation of the underground detector would approximately double the number of hoist runs/trips at the Ross Shaft. The increased hoist operation would result in an additional 250 gallons per year of additional oil being used and recycled.

Few chemicals would be used to operate and maintain the detector. Wastes resulting from operations of the Proposed Action would typically be non-hazardous and recyclable. Wastes would be managed and disposed of off-site in accordance with state and Federal requirements.

Alternative A

Construction

Solid waste (e.g., construction debris, sanitary waste) would be managed and disposed of in accordance with SURF policies and procedures. Alternative A would generate the same types of solid wastes as the Proposed Action, but in much smaller quantities. Identified waste streams (non-hazardous, hazardous, or other) would be managed according to SURF policy and reviewed and approved by the state or EPA.

Operation

Solid waste would be managed and disposed of in accordance with SURF policies and procedures. Alternative A operations would generate the same types of solid wastes as the Proposed Action, but in much smaller quantities. Identified waste streams (non-hazardous, hazardous, or other) would be managed and approved by the state or EPA. No new waste streams would be generated beyond what SURF currently manages associated with existing experiments.

No Action

The No Action Alternative would not generate additional solid, hazardous, or radioactive waste and would have no added effect on waste management practices or disposal sites. Under the No Action Alternative, SURF's existing operation would continue to generate the same types and quantities of wastes as they do now and these wastes would be handled under existing waste management programs and there would be no need for increased handling and disposal of regulated wastes on-site or off-site at regulate facilities.

3.15 ACCIDENT ANALYSIS

This section presents the DOE-required evaluation of potential environmental effects of accidents and malevolent acts at both Fermilab and SURF. In addition to addressing potential impacts on public and worker health and safety (Section 3.4), DOE recommends consideration of the potential impacts of “reasonably foreseeable accidents” (DOE 2002a). The term "reasonably foreseeable" refers to incidents with a risk in the range of one in a million to one in ten million (DOE 2002a). Accident analysis also includes the results of an intentional destructive or terrorist act (DOE 2006). The results of the accident impact analysis provides information to the decision process with regard to the possible (as opposed to the expected) impacts from choosing a given course of action.

Accident risk is based on two factors: probability of occurrence and magnitude of consequence. Accident types may include occasional accidents (risk of 1 in 100 to 1 in 10,000) such as trips and falls, remote accidents (probability of 1 in 10,000 to 1 in 1,000,000) such as a tank rupture, and improbable accidents (probability of less than 1 in 1,000,000) such as a plane crash. The NEPA accident analysis focuses on the highest consequence credible accident in terms of human or environmental impact, such as an accident involving multiple casualties or a release of a toxic chemical to a wetland or waterway requiring a rapid response. The following subsections analyze these kinds of events.

The affected environment for accidents and malevolent acts would be the area directly and indirectly affected by a reasonably foreseeable incident that would be the highest consequence credible accident. For Fermilab, the affected environment would be contained to the area within the underground enclosures that could be affected by a beam mis-steering event. For SURF, the affected environment would include outdoor areas along cryogen delivery routes potentially affected by a trucking accident and release of LAr or LN, as well as the 4850 Level cavern.

3.15.1 Fermilab

Construction of the Proposed Action could potentially result in hazards identified as low risk based on the Preliminary Hazard Analysis Report (PHAR) (Fermilab 2012d), such as non-routine accidents, fires, hazardous materials release, and natural disasters such as tornados. These types of events have a higher probability of occurring but would be routinely addressed by safety and response programs and plans. Because of design measures and existing safety programs, there is no major reasonably foreseeable accident scenario arising from construction, such as a major fire or structural failure with severe impacts. Intentional destructive actions would not result in the types of concerns that would arise for construction requiring large volumes of hazardous or radioactive materials. The Proposed Action would not use these types of materials. Rather, the potential impacts of an act of sabotage could include a fire or explosion involving fuel or explosives stored at the construction site. However, the quantity of these materials would be limited. There would be no effect from radiation because beam operation would not have started and no radioactive materials caused by beam irradiation would be present. Furthermore, any intentional destructive act would be deterred by site security and would have little effect on surrounding residential areas because construction would occur primarily away from adjacent roads and neighborhoods, or in a deep and relatively inaccessible shaft excavation. Therefore, intentional destructive acts during construction would have an uncertain but low probability and limited impacts because of the isolated nature of the construction activity.

Loss of control of the beam during operation, as a result of human error or mechanical failure could cause substantial damage to components within just a few beam pulses. Reasonably foreseeable accidental beam loss would result in component heating and damage, groundwater activation, and radiation concerns outside the beamline enclosure. Under a maximum reasonably foreseeable accident, magnet temperatures would rise rapidly and would effectively destroy or even melt the components. Although not expected, this type of event would result in several adverse impacts including additional radiation exposure of workers involved in activities within the enclosure to isolate and replace the damaged component. Many of the components weigh several tons, and handling would result in additional risk of injury. Component replacement would require many hours of exposure to activated components. Potential health effects of radiation exposure would include latent cancers and related fatalities, although radionuclides would not include transuranic isotopes and would be of relatively short half-lives. Facility operations would be affected because replacement of damaged components would require an operational shutdown. Although workers routinely manage irradiated components, under this scenario, workers involved in responding to the accident would be exposed for the additional time required to move hot or damaged components to temporary storage in a concrete-shielded cell until they could be moved to a long-term storage facility. Hazards to radiation workers would be managed by limiting the acute exposure time to individuals, based on dose measurements, to ensure that administrative radiation limits for workers were not exceeded. Public exposure would be very low because the damaged components would be contained within the underground enclosures. Therefore, the beamline would be designed, constructed, and operated to minimize the probability of damage.

As described above for construction, intentionally destructive, malevolent, or terrorist actions would not result in the types of concerns that would arise at facilities that store large volumes of hazardous or radioactive materials. Instead, the impacts of an act of sabotage or terrorism could include beam loss and activation or damage of components, resulting in the same environmental impacts described above for a beam loss accident. Specifically, replacement of damaged components would require many hours of close work to move damaged components along with potential for other injuries and accidents inherent with responding to a low incidence event.

An intentionally destructive act, such as a terrorist attack or sabotage, would have a low probability of success. Such an event would have to overcome several existing preventive measures. The probability of such an attack would be minimized by site security. The maximum reasonably foreseeable scenario would be a fire or explosion that would disperse radioactive material, potentially resulting in on-site and off-site exposure. Such an incident would have a low probability however; the emergency response to contain and reduce the severity of environmental exposure would be immediate and robust with coordination among a number of agencies, including the Fermilab Comprehensive Emergency Management Plan (CEMP). Further, the probability of releasing radioactive materials is remote, as any activated material would be underground (e.g., the Decay Pipe's concrete shielding), shielded by steel and concrete, and less vulnerable to fire or explosion than surface infrastructure.

3.15.2 SURF

SURF continually evaluates accident conditions through project design and work planning to protect workers, the pubic, and the environment. As described above, the LBNF/DUNE team completed a hazard review (Fermilab 2012d). This section addresses two potential accident scenarios consistent with DOE regulations – an underground fire and a cryogen release.

Underground Fire

The impacts from an underground fire would be wide-ranging depending on the type of fire, where the fire occurred, and the fire's intensity. An equipment fire on the 4850 level deserves consideration because such a fire recently occurred at the Waste Isolation Pilot Plant (WIPP) site in New Mexico and because such a fire would likely impact construction and operation of underground experiments including the LBNF/DUNE. Rubber tired equipment would be used in the LBNF/DUNE construction. The WIPP fire was initiated from mine equipment leaking combustible fluids that came in contact with the exhaust housing of catalytic converter. Ignition ensued and was not extinguished by discharging a hand-held extinguisher or the equipment's on-board fire suppression system. The fluid fire ignited the tires. The resultant toxic smoke endangered the health of personnel located downstream of ventilation, those near the fire, the integrity of nearby rock (salt), and equipment (soot).

The probability of an underground equipment fire is difficult to quantify due to varying degrees of engineering and administrative controls in each underground setting. However, it is not unusual for this type of fire to occur as evidenced by the WIPP fire (DOE, 2014), and the 2010 underground equipment fire at Doe Run Mining Company's Viburnum #29 Underground Mine (U.S. Department of Labor, 2010). Equipment fires are typically the result of improper pre-shift inspections that would identify buildup or leaking combustibles, improper tire inflation, and poorly maintained equipment automatic fire suppression systems.

An underground equipment fire would result in the evacuation of the underground, damage to mobile equipment, damage to science experiments (from possible heat and particulate matter), lack of access to science experiments, and loss of safety reputation. An equipment fire on the 4850 Level at SURF would result in all of the above consequences with varying levels of severity associated with fire location and intensity.

An underground equipment fire would be prevented and controlled by many of the same requirements and systems SURF currently imposes for the underground. Comprehensive pre-shift inspections would be required on all equipment with a focus on fire prevention and initial response. The build-up of combustibles and fluid leaks would be controlled by inspection and washing or wiping-down equipment. Automatic fire suppression systems would be maintained by authorized employees and vendors. Ignition sources such as a welder would be used distant from combustibles as required by burn permits.

Monitoring systems would also be in place to initially detect a fire. The most important monitoring system would be a network of carbon monoxide sensors connected to continuously monitored alarm system. Automated shaft sprinkler systems and a shaft deluge system would be employed to extinguish a fire. A dedicated redundant ventilation system would be in place, using air doors to redirect ventilation past operational areas including the LBNF/DUNE. For example, smoke from a fire occurring in the Davis Campus or Yates Shaft would be detected by carbon monoxide (CO) sensors and rapidly be extinguished by an automated sprinkler system or, in the case of the shaft, water deluge. Smoke from a fire in these areas would be directed, through the use of air doors, to the Oro Hondo exhaust shaft, by-passing the LBNF/DUNE.

Multiple shafts facilitate underground evacuation in the event of a fire. Underground users would evacuate the underground by egressing up the shaft that was not impacted by fire and smoke. Both access shafts provide fresh air to the underground and are isolated from each other, so one should always provide fresh air. In the event that power was lost to the hoists, workers would stay in an underground refuge chamber until the power was restored. The contractor would ensure that the refuge chamber would be sufficient to supply oxygen, food and water capacity to safely support all underground workers for 96 hours. There is no record of any power loss to the facility longer than 1 hour since the local provider has kept records.

Fire and Life Safety is an important consideration at SURF. Smoke and CO from a distant underground fire may affect personnel downstream in the ventilation exhaust path. SURF is acutely aware of the fire danger and has implemented controls underground to prevent such fires including limiting fuel sources, using non-sparking tools, using non-flammable low-smoke wire insulation, using flammable storage cabinets for flammables not in use, and careful control of underground ignition sources through the use of burn permits.

In addition to the detection and response items mentioned above SURF maintains a trained underground Rescue Team which would respond to all envisioned underground emergencies in some capacity which include fire rescue and response, rock fall, medical emergencies, high angle rescue, and releases of hazardous chemicals. The Underground Rescue Team meets 8-hours per month to train for emergencies. Underground Rescue Team members are trained using state-of-the-art Draeger BG-4 re-breathing apparatus which allow the team to perform rescue work in heavy smoke and CO.

Evacuation training for all underground personnel is conducted each quarter. Evacuation drills test and reinforce procedures that use primary and secondary egress routes corresponding to different accident scenarios. Other regular training for all personnel includes issuing and training requirements on the use of self-rescuers, oxygen supplied breathing devices, and use of the refuge chamber.

Cryogen Release

The LBNF/DUNE experiment would employ substantial volumes of LAr and LN as cryogens. A cryogen leak at the underground detector or the associated piping would release LAr or LN, which would rapidly change states to a gas, displace oxygen, and result in a possible Oxygen Deficiency Hazard (ODH) situation that would be dangerous to personnel. The consequences of the leak or spill depends on many factors including pressure, size of the leak, the location of the leak, and location of surrounding personnel. A leak or spill in a confined space could result in an oxygen deficient atmosphere and cause asphyxiation. In open areas a leak or spill would result in temporary zones of oxygen depletion. In the event of a cryogen release, controls are addressed in the LBNF Hazard Analysis Report (Fermilab 2012d).

The release of cryogen from a delivery truck is another accident scenario considered since it was a concern in informational meetings. An estimated 4,500 LAr tanker trucks would be needed to fill the underground detector. An additional ten tanker trucks of LN would be required initially to fill the LN chiller tanks. The large number of cryogen deliveries deserves a discussion on tanker truck tanker safety and emergency response to inform the public of the engineering controls in place to prevent such an accident and if it would occur detail the planned response.

LAr and LN are cryogens. Both liquids boil-off to a gas when exposed to ambient pressure and temperature. Argon is a non-toxic (inert) gas that comprises approximate 0.93 percent of the earth's atmosphere and does not pose any known health risks other than it may displace oxygen to create an ODH. Nitrogen gas is also a non-toxic gas and comprises more than 76 percent of the earth's atmosphere. Nitrogen gas in concentrations over 76 percent may also displace oxygen and produce an ODH.

An accident involving a tanker truck could result in a release of LAr or LN to the environment. Such a release would result in a rapid phase change from the LAr to a gas. Under such a circumstance Ar would rapidly expand to approximately 850 times its volume as a liquid. The gas is heavier than air and would locally displace oxygen which would be dependent on many factors such as size of the leak, ambient pressure and temperature, wind direction, and the location of the public.

Leak of a cryogen from a truck would be most likely to occur through puncture-type opening due to the design of the cryogen tanker trucks. The resulting spill would not be an instantaneous release but a release (leak) over time. A leak would necessitate emergency response by trained personnel, the creation a safe zone in which people would be evacuated outside a specified radius dependent on the size of the leak and weather conditions, warnings to residents ,and possible attempts to stop the leak by trained responders. Otherwise, the leak would not be considered an environmental hazard since the evolved gas is nontoxic. For reference, representative Safety Data Sheets (SDS) for LAr and LN can be obtained through http://www.us.airliquide.com/en/sds.html.

The Compressed Gas Association (CGA) and Federal Motor Carrier Safety Association (FMCSA) were asked to supply compressed gas tanker truck accident statistics. The statistics are not publically available as they reside with suppliers/transporters of bulk compressed gasses and are generally not released due to liability and competitive concerns (Pape et al. 2013). Incidental references to compressed gas transportation suggest that accident frequency is very low due to driver training and administrative controls (inspections, route selection, speed limits, etc.) and spills of cryogens are even less common due to the conservative design of transport tanker trucks (AIGA 2006).

A study undertaken by FMCSA (Craft 2004) states that, “the threat to the public of death or injury due to the normal transportation of DOT-regulated materials by large trucks is minor.” Data from the Research Special Programs Administration (RSPA) for the years 1991 through 2000 attributes fewer than 100 injuries per year due to exposure to a DOT-regulated material (of which LAr and LN are a subset) in highway crashes. During this same period the average number of miles driven per year by DOT-regulated material carriers was 9,896,000,000. The conclusion is that the probability of an exposure injury is 9.896×10^{-7} for *all* regulated materials.

The lack of published statistics for cryogen carriers led DOE to examine the accident records of cryogen tanker trucking companies. These records are considered to be Confidential Business Information and are not published. However, Fitch Trucking delivers bulk cryogens to SURF and has been transporting cryogens since 1983. The Fitch Trucking cryogen tanker truck fleet averages approximately 4.5 million road miles per year. In the past 21 years, Fitch Trucking has incurred only one cryogen tanker truck vehicle accident, a rollover that did not result in a release of cryogen. The cryogen tanker truck accident probability for Fitch Trucking is therefore calculated to be 1.06×10^{-8}. The probability of a cryogen release from a Fitch Trucking tanker truck would be less than its accident rate because its single accident did not result in a release of a cryogen.

Many safeguards are present to prevent a tanker truck leak. Bulk cryogenic trailers consist of two nested tanks that form a thermos bottle-like insulating vessel. The inner tank is stainless steel or aluminum. The outer tank is stainless steel or carbon steel. The space between the two tanks is evacuated and filled with an insulating material. The double-layered metal tanks and structural supports make the overall tank system highly resistant to physical damage. Tank systems are designed to hold pressures up to 280 psig. Typical operating pressure is 70 and 100 psig and redundant relief systems ensure pressures do not exceed design capacity. Cryogenic gas transport safety and tanker truck design is overseen by the FMCSA according to U.S. Department of Transportation (DOT) requirements.

LAr and LN are supplied by a number of manufacturers including Praxair, Air Gas, and Linweld, and are typically delivered to end-users by these companies and their subcontractors. Drivers are selected carefully and undergo extensive training regarding material hazards, emergency response, safe driving, and tanker truck safety (FMCSA, 2012).

In the unlikely event of a cryogen release in the Lead-Deadwood area, emergency response would be carried out by the Local Emergency Manager, the Lead-Deadwood fire departments, the SURF Underground Rescue Team and the Spill Prevention Control and Countermeasures (SPCC) team. These responders would be trained in advance to safely and appropriately manage a cryogen release. Further, bi-annual table-top or field exercises would be conducted in conjunction with the Local Emergency Planning Committee (LEPC) to simulate a cryogen release. This would familiarize responders with cryogen safety and would better enable a timely and appropriate response.

3.16 CUMULATIVE IMPACTS

The cumulative impact analysis is based on consideration of past, present, and reasonably foreseeable future projects that could, based on their location or types of impacts, result in cumulative impacts when considered together with the Proposed Action, Alternative A, or No Action Alternative. Cumulative impacts result from the incremental impacts of the action when added to other projects regardless of what agency or person undertakes the action. Cumulative impacts can result from individually minor, but collectively significant actions taking place over a period of time (40 CFR 1508.7). The projects included in the analysis were identified based on review of recent environmental documents, contact with local municipal officials and planning departments, and internet research.

Sections 3.16.1 and 3.16.2 address potential cumulative impacts for Fermilab and SURF, respectively. CEQ regulations also require an assessment of cumulative impact of the No Action Alternative as a baseline.

3.16.1 Fermilab

Projects for the cumulative impact analysis were identified through review of recent planning documents, internet searches, and contacts with local and state officials. This effort did not identify commercial or industrial developments, electricity generation or transmission projects, or major highway improvements with the potential to contribute to cumulative impacts. Fermilab contacted Kane County (Boesch 2013) and DuPage County (Krueger 2013) transportation departments, the Illinois DOT (Carlson 2013), the City of Batavia (Strassman 2013), and the City of Aurora (Sieben 2013). However, any projects identified were small and would not contribute meaningfully to cumulative impacts. Therefore, with the exception of the cumulative impact assessment for air quality, the geographic boundary for the cumulative impacts analysis focused on projects associated with Fermilab and adjacent public roadways.

Table 3.16-1 lists past (constructed and now operating) projects, projects currently under construction, and future projects that would overlap with the construction and/or operation of the Proposed Action. The list focuses on the last 5 to 10 years; however, it includes the Tevatron facility, which was shut down in 2011 and in some instances has contravening or offsetting effects with current projects. The table provides a brief description, the project location, and approximate schedule.

Table 3.16-1 Projects with Potential for Cumulative Impacts with LBNF/DUNE – Fermilab

Project	Project Description	Location	Construction Schedule
Neutrinos at the Main Injector (NuMI)	Fermilab neutrino beamline	Fermilab	Complete
NuMI Off-axis ν_e Appearance (NOvA)	Fermilab experiment to study neutrino transformations	Fermilab	2012–2014 (Complete)
Main Injector	Fermilab accelerator ring adjacent to Proposed Action.	Fermilab	1993 – 1999
Tevatron	Fermilab particle accelerator (Shut down in 2011)	Fermilab	1983
Mini Booster Neutrino	Fermilab neutrino experiment with	Fermilab	1997–2002

Table 3.16-1 Projects with Potential for Cumulative Impacts with LBNF/DUNE – Fermilab

Project	Project Description	Location	Construction Schedule
Experiment (MiniBooNE)	mineral oil detector. (Shut down in 2011)		
Micro Booster Neutrino Experiment (MicroBooNE)	Fermilab experiment to test detector technologies. Includes the Liquid Argon Test Facility	Fermilab	2013–2015
Main Injector Neutrino Oscillation Search (MINOS)	Fermilab experiment to examine neutrino oscillation	Fermilab	Complete
Muon g-2 and Mu2e	Fermilab muon experiments using part of the Tevatron accelerator complex	Fermilab	2013–2017
Main Injector Experiment with νs on As (MINERνA)	Fermilab experiment to study the reaction of neutrinos with carbon, iron, and lead	Fermilab	2006–2010
Illinois Accelerator Research Center (IARC)	Office complex (83,000 square feet) to promote collaboration between Fermilab, Argonne, DOE, universities, and industry	Fermilab	2012–2013 (Complete)
Short Baseline Neutrino Program	Fermilab experiment to study neutrino oscillation over short distances entirely on Fermilab site	Fermilab	2015 - 2017
Proton Improvement Project (Phase II)	Upgrade of Fermilab proton accelerator complex to deliver additional beam power for Fermilab neutrino experiments	Fermilab	2019 - 2023
Butterfield Road (Kane County)	Butterfield Road widening project	South boundary of Fermilab	2012-2013 (Complete)
Kirk Road (Kane County)	Kirk Road intersection improvements	Western boundary of Fermilab	2012-2013

Proposed Action

Land Use and Recreation

Neither the Proposed Action nor any of the projects listed in **Table 3.16-1** would adversely affect land use or recreational activities at Fermilab. The Proposed Action would occur on Fermilab property and would have no direct impacts on land use (Section 3.1). Similarly, all past, present, and future Fermilab projects would occur on Fermilab property and would be focused on physics research. Transportation projects on the roads adjacent to Fermilab have been consistent with adjacent commercial and residential land uses. LBNF/DUNE, other Fermilab projects, and off-site projects would implement measures to reduce indirect impacts, including noise and visual effects. Therefore, any cumulative impacts on land use or recreation would be low.

Biological Resources

The Proposed Action would have direct impacts on 5.0 acres of vegetated wetlands as well as Indian Creek. However, as described in Section 3.2, these impacts would be offset through purchase of wetland credits or other wetland and stream habitat replication. Early Fermilab projects likely affected wetlands but these effects have been addressed over decades through on-site environmental programs to preserve and protect resources, including wetlands, prairie, wildlife, and agricultural lands. Past and present Fermilab projects, such as the Main Injector, NuMI, and NO*ν*A have resulted in filling on-site wetlands; however, these projects offset these impacts through wetland construction on site or purchase of wetland credits at off-site wetland banks. In this way, cumulative impacts on wetlands and stream habitat (and thus wildlife, wetland vegetation, and fish) would be low.

Cultural Resources

The Proposed Action would not affect known eligible cultural resources during construction. As described in Section 3.3, surveys of identified sites in the proposed construction area determined that the sites were ineligible. Therefore, the Proposed Action would not contribute to cumulative impacts on cultural resources. Other projects at Fermilab have not resulted in substantial effects on cultural resources. Similarly, past Fermilab projects have not affected paleontological resources; however, important fossils have been found in the region. Any archaeological or fossil discoveries associated with the Proposed Action or future Fermilab projects such as PIP-II would be addressed by engaging a qualified archaeologist or paleontologist and, with minimization measures in place, the resulting cumulative impacts would be low.

Health and Safety

The Proposed Action would have potential impacts on worker health and safety during construction and operations from industrial accidents and potential exposure to radiation from irradiated beamline components. However, these risks would be identical to the potential impacts of all the high-energy physics experiments constructed and operated at Fermilab over the last four decades from projects such as Tevatron, which was shut down in 2011, and from recently constructed projects, such as NuMI and NOvA. As described in Section 3.4, potential risks of injury and exposure would be managed and minimized through existing Fermilab programs, which include extensive training. Per Fermilab policy and DOE Orders, radiation exposures would be reduced to ALARA. When considered together with other Fermilab activities, including the shutdown of Tevatron, there would be no increase in the number of workers relative to historical workforce trends and no cumulative increase in health and safety impacts. With implementation of shielding and other established Fermilab health and safety and radiological control procedures, cumulative health and safety impacts would be low.

Hydrology and Water Quality

The Proposed Action, previous Fermilab experiments, and adjacent projects to improve Butterfield Road and Kirk Road have created impervious surfaces, potentially resulting in increased stormwater runoff. These projects have the potential to affect water quality and add to flooding impacts such as those that occur on Indian Creek. To minimize stormwater impacts, local municipalities developed stormwater control programs requiring stormwater detention. Current and future development projects, including Fermilab projects, would be required to control stormwater runoff. New impervious surfaces would comply with stormwater detention requirements, and increased runoff volume would be addressed through existing stormwater programs and would not increase the peak runoff rate.

The Proposed Action would generate pumped groundwater from dewatering excavations; however, as with other Fermilab projects, this water would be conveyed to surface water including the ICW ponds. As described in Section 3.5, the ponds minimize cumulative impacts on groundwater by isolating surface water. LBNF/DUNE groundwater discharges would be managed in the same way, including following existing Groundwater Monitoring Plan procedures to track tritium concentrations and groundwater flow directions.

Experiments at Fermilab have the potential to produce tritium in cooling water and shallow groundwater, and LBNF/DUNE would potentially represent a cumulative impact. However, the Fermilab storm water management policies and practices minimize the total amounts of tritium in water. Levels of tritium in shallow (i.e., Class 2) groundwater are low (<80 pCi/ml), very localized, and the water migrates at a very low rate to Class 1 waters. Levels of tritium in surface water are regularly monitored, and are several times less than the drinking water standard. The contribution by LBNF/DUNE would be very low, given the design of beamline components and the decay pipe, which would be built specifically to keep water segregated from radioactivation sources.

Stormwater would have the potential to impair water quality if discharged directly to Indian Creek; however, Fermilab stormwater is addressed through stormwater programs and the site's NPDES permit. Past Fermilab projects as well as projects currently under construction generate stormwater runoff addressed by BMPs and operational water that is stored and reused in the ICW system. Therefore, given compliance with the site-wide and LBNF/DUNE-specific stormwater controls, cumulative water quality impacts would be low.

The Proposed Action would have only minor, localized groundwater drawdown effects from pumping. Because existing and current Fermilab projects would have similar localized impacts on groundwater hydrology that would not overlap, there would be low cumulative impacts on groundwater hydrology. The Proposed Action would have only minor risks of contamination that would be minimized through SEPMs, BMPs to prevent leaks and spills, and according to procedures presented in site-specific SWPPP and SPCC plans. Past and current experiments, such as NuMI and NOvA, use similar measures to minimize impacts on groundwater through spills and there would be low cumulative impacts on groundwater quality on or off the LBNF/DUNE site.

Noise and Vibration

During construction, the Proposed Action would generate noise and vibration from excavators as well as blasting to remove rock for both the Absorber Hall and NND. To minimize noise, Fermilab would evaluate equipment with lower noise profiles and would conduct blasting only during the day and after public notification (see Section 3.6). Other Fermilab activities could generate short-term, localized noise and impacts. However, because of the distance between LBNF/DUNE and past projects, the distance between the Fermilab central campus and any off-site receptors, intervening features (e.g., trees, buildings, and berms), the substantial ambient noise generated by Kirk Road and other adjacent land uses, there would be low cumulative off-site noise or vibration effects.

Transportation

The Proposed Action would result in a minimal increase in the volume of traffic on the state and county road systems (see Section 3.7). Increases in traffic associated with the Proposed Action or other Fermilab projects would be offset by the shutdown of Tevatron and other facilities; thus, the number of Fermilab staff would be consistent with historical workforce trends. Impacts of accidents and injuries on public roadways would be commensurate with the minor increases in traffic volume. Traffic impacts from the Proposed Action and other Fermilab construction projects would be minimized by routing construction traffic to the site's construction entrance at Kautz Road and avoiding large deliveries during peak traffic hours. Further, improvements in local transportation, including widening of Butterfield Road and intersection improvements along Kirk Road, would have contravening effects with traffic increases or effects from materials deliveries. With these improvements, trucks and workers would be more likely to approach the site using N. Eola and Butterfield Road and make a right turn onto Kautz Road, thereby minimizing the number of left hand turns into the construction entrance against oncoming traffic. Therefore, the Proposed Action would not contribute substantially to traffic or transportation impacts, and recent roadway projects may have offsetting effects.

Air Quality

Each state must meet Federal air quality standards by specific deadlines, and the plan for meeting these standards is outlined in the State's State Implementation Plan (SIP). To determine whether the Proposed

Action would be aligned with the State SIP, the EA contains a conformity analysis (Section 3.8.1) as well as an analysis of potential cumulative impacts in conjunction with existing conditions in the air basin and future projects.

Criteria pollutant emissions estimated for the Proposed Action would be slightly above Conformity Analysis *de minimis* levels for NO_x during the fifth and sixth years of construction but would be offset through purchase of emissions credits and would be low during operations (Section 3.8). Similarly, if constructed as currently envisioned, PIP-II would overlap with LBNF/DUNE in the later years of construction and would result in additional NO_x emissions that would require purchase of offset credits. While the area is in nonattainment for ozone and $PM_{2.5}$, the Proposed Action, when considered together with other Fermilab projects, including PIP-II and others that would generally be much smaller or are in the operations stage, would not delay attainment for these criteria pollutants and cumulative air quality impacts would be minor.

The potential cumulative impacts of GHG emissions would result from the aggregated emissions at Fermilab and SURF as well as regional, national, and global GHG emissions. Section 3.8 addresses the measures the Federal government implements to reduce these emissions.

Visual

The Proposed Action would be visible from Kirk Road, including the embankment and the NND (Section 3.9). However, all the other Fermilab features in the same viewshed have been present for many years. All other past and present Fermilab projects, including surface facilities constructed as part of NuMI, MINOS, NOvA, and Muon Campus projects (currently under construction), are located in the central campus area or to the north or east of Wilson Hall and not visible from Kirk Road. Similarly, PIP-II, a potential future Fermilab project, would be located east of Wilson Hall within the Tevatron ring and would not be visible from off-site. Therefore, there would be very low cumulative visual impacts.

Geology and Soils

The Proposed Action would have short-term impacts on soils, including increased risk of erosion from grading and vegetation removal during construction. These potential effects were evaluated in Section 3.10 and would be reduced through erosion control BMPs. Other past and present Fermilab projects have resulted in similar short-term impacts on geology and soils from grading and tunneling that have been addressed through BMPs, such as preservation of topsoil, and site restoration. All projects at Fermilab and off-site, including transportation improvements (e.g., Butterfield Road) would be subject to engineering design and geotechnical measures as required by local and state building codes, as well as erosion control BMPs. Considered together with other Fermilab and adjacent transportation projects, cumulative impact on soils and geology would be low.

Socioeconomics and Environmental Justice

Construction would have beneficial economic benefits on the local and regional economy due to construction-related spending, worker salaries, and the purchase of goods and services from area merchants and specialty vendors (see Section 3.11). Past activities at Fermilab have not adversely affected, disproportionately or otherwise, low-income or minority groups. Future operations, considered together with other on-going Fermilab projects and local development, would likely result in cumulative, local economic benefits from continued experimental activity and spending of visiting scientists.

Sustainability

The Proposed Action and all other Fermilab projects would comply with the goals set forth in Fermilab's SSP, including GHG emissions reduction, energy conservation, water conservation, pollution prevention, sustainable acquisition, and innovation (see Section 3.12). Overall, Fermilab and individual projects would consider site-wide goals including environmental restoration (e.g., wetlands, prairie) and recycling.

Taken together, past projects and current activities, in addition to the Proposed Action and reasonably foreseeable future projects, all would consider the SSP sustainability goals. The incorporation of operational efficiency measures in energy use and conservation along with waste minimization and pollution prevention as part of Fermilab's normal daily operations and corporate culture. Experiments at Fermilab, by their very nature, require large amounts of electrical energy, which results in indirect generation of GHG. An essential feature of the Fermilab SSP is the purchase of renewable energy certificates to offset the increased electrical energy use, which serves to minimize environmental impacts. Therefore, the Proposed Action would not detract from achieving the goals of the SSP.

Utilities

The Proposed Action would have very low impacts on utility suppliers. As described in Section 3.13, the utility construction or interruptions would be limited to Fermilab and would occur primarily within the substation and roadway areas. The increased power, water, and other utility requirements of the Proposed Action and potential future projects, such as PIP-II, would be within the capacity of electricity suppliers. Moreover, long-term trends including shutdown of Tevatron and other facilities have reduced Fermilab's utility requirements. Therefore, the Proposed Action, considered together with other cumulative activities, would have low cumulative impacts on utilities and only a minor contribution to impacts on power usage over existing (but not long-term) conditions.

Waste Management

The Proposed Action would generate only nominal amounts of solid and hazardous waste in the form of construction wastes (e.g., wood, packaging) and oily waste. However, as described in Section 3.14, these impacts would be minimized through Fermilab's existing waste management programs. Similarly, other Fermilab projects, together with the Proposed Action, including those currently operating and under construction, would produce similar wastes throughout their lifecycle. However, in compliance with Fermilab policies, state and local regulations, DOE Orders, and Federal EOs, much of this material would be reused or recycled, reducing their effect on waste management. Considered together, there would be low cumulative impact on waste management.

No Action

Under the No Action Alternative, Fermilab would not construct the LBNF/DUNE facilities, resulting in no contribution to cumulative impacts. Impacts from ongoing Fermilab projects and activities, as well as off-site projects, would continue into the future. Cumulative impacts from other future projects at Fermilab and offsite would be lower than if the Proposed Action were constructed. Potential impacts on biological, cultural, geological, and water resources as well as the noise environment would be avoided or minimized by complying with local, state, and Federal laws as well as by employing Fermilab's own environmental management and sustainability guidelines. Other future projects, including those at Fermilab, could have cumulative impacts that would be minimized by existing plans, regulatory programs, and BMPs.

3.16.2 SURF

Table 3.16-2 summarizes projects planned to occur in the next 10 years at SURF and in the City of Lead. The first three rows (1-3) in **Table 3.16-2** identify current and anticipated construction projects at the SURF site. Rows 4-6 identify expected projects not associated with SURF and which do not occur on SURF land. The projects were identified based on information from science collaborations, Lead City officials, Lawrence County Planning and Zoning Department, County and State Highway offices, SURF engineering department, Homestake, Lead Chamber of Commerce, Black Hills Power, and the Lead School District.

Table 3.16-2 Project with Potential for Cumulative Impacts with LBNF/DUNE – SURF

Project	Project Description	Location	Construction Schedule
Ross Shaft Rehabilitation	Replace steel in Ross Shaft	Ross Shaft SURF site	2012-2017
Yates Shaft Rehabilitation	Replace wood in the Yates shaft with steel	Yates Shaft at the SURF site	Post-LBNF/DUNE construction
Education and Outreach Building (E&O) Rehabilitation	Rehabilitation of the basement and sub-basement of the Education and Outreach Building	Education and Outreach Building at the SURF site	2015
Highway 85 Construction	Rebuild and widen Lead Main Street (Hwy 85)	Lead, SD	2014-2015
Existing underground physics experiments (LUX, Majorana)	Physics Experiments	Davis Campus at 4850 L	2009-2012
Compact Accelerator System Performing Astrophysical Research (CASPAR) Experiment	Physics experiment	Davis Campus at 4850 L	2015
Homestake	Grizzly Gulch Tailing dam reclamation	Grizzly Gulch Tailing dam	2014-2017
Homestake Visitors Center	Construction of a new Homestake/SURF Visitors Center	South end of Open Cut	2014
Low Background Counting	Counting background concentrations of Uranium, Thorium and Potassium and their respective daughter elements for future experiments	Underground	2014
Gilt Edge Superfund site	Remediation of former Gilt Edge Mine	Deadwood	TBD

The past actions at the SURF site were primarily related to mining. These actions were extensive and created disturbances readily observed and taken into account in many of the EA sections. Past actions are not discussed in the following subsections unless their impact merits new or additional discussion.

Proposed Action

Land Use and Recreation

Construction of the Proposed Action would result in the use of approximately 21 acres of private land that has a history of re-occurring disturbance. Land use by the Proposed Action would not result in a loss or change in land use as it returns the land to its preconstruction use. Rock placement at the Gilt Edge Superfund site would occur within an existing remediation site with land use restrictions and thus would have low contribution to cumulative impacts. Placement of the rock in the Open Cut, likewise would have a low level of impact due to the large size of the existing Open Cut and the similarity of the rock to that existing in it.

Recreation would not be incrementally impacted by the Proposed Action or other area projects. These projects are specific to improving access for the community, improving recreation and tourism, improving access to the underground laboratory, and performing science.

Biological Resources

The Proposed Action would have low impacts on Biological Resources. Combined with the projects in **Table 3.16-2** the cumulative impact to biological resources in the area would likewise be low. Two projects that would potentially add to the Proposed Action's 21 acres of disturbance include the US 85 widening project and the Open Cut Visitor's Center construction. Both projects are in progress and the impact to vegetation will be less than 0.5 acre. The amount of lost vegetation would likely be limited as both projects would primarily disturb buildings and concrete adjacent to their planned construction footprint. The Visitor Center and US 85 construction would occur before the construction of the Proposed Action. Placement of rock at either the Gilt Edge Superfund site or Open Cut would not contribute to cumulative impacts on vegetation.

Impacts to wildlife and fisheries resulting from the proposed action in combination with other actions would be low. Potential cumulative impacts would result from increased runoff during construction, increased traffic, and increased opportunity for development. These impacts would be avoided or minimized by the use of erosion control BMPs, and the small construction footprints.

Cultural Resources

The Proposed Action would be both inside and outside the Lead Historic District and would involve activities on the property of the former Homestake Mine site, which is considered culturally significant by the South Dakota SHPO. A Programmatic Agreement (PA) is being developed for the Proposed Action and future projects to address potential issues concerning historic properties, buildings, and artifacts, which would be evaluated under Section 106 of the NHPA. The proposed transport and placement of rock at the Gilt Edge Superfund site or the Open Cut would have no impacts on cultural resources and therefore this rock handling alternative, if selected, would not contribute to cumulative impacts. In addition, due to past miming activities and current existing disturbance, cumulative impacts from future projects on traditional cultural resources would be low.

The US 85 widening project would require a cultural resource evaluation. The Visitor Center would be constructed with private funds; however, the design and construction would be reviewed by the Lead Historical Preservation Commission. According to the PA, the Ross and Yates Shaft rehabilitation would be exempt from Section 106 review, as this work would be performed underground. The E&O Building rehabilitation would be performed with private funds with modifications documented and communicated to the city of Lead and the South Dakota SHPO.

Taken together, the cumulative impacts on cultural resources from LBNF/DUNE and other reasonably foreseeable projects are expected to be low, with unforeseen adverse effects to the Lead Historic District addressed in the PA for LBNF/DUNE.

Health and Safety

The Proposed Action in combination with other projects would have not have a substantial impact on worker health and safety. This impact would be primarily restricted to SURF and subcontractor employees. Anticipated health and safety impacts associated with the Proposed Action are discussed in Section 3.4. Other projects conducted at SURF (Table 3.16-2) would be expected to add 7.5 incidents to SURF employees and contractors over a 10-year period assuming the current SURF incident rate and 500,000 total work hours. Health and safety impacts due to projects not associated with SURF are unavailable, but would be based on total hours worked and the construction incident rate and would be primarily associated with project subcontractor employees.

Hydrology and Water Quality

Impacts on surface water and groundwater resulting from the Proposed Action in combination with other actions would be low. The Proposed Action and other projects would be within the Whitewood Creek drainage basin, which would increase the potential for additional sediment load to be transported to Whitewood Creek. Stormwater runoff volumes from construction of either the Proposed Action or other reasonably foreseeable projects would be low because the amount of impervious surface would not appreciably change due to construction. Stormwater controls implemented by all projects would minimize the potential for sedimentation.

The Proposed Action in combination with other projects would not increase temperature in Whitewood Creek. Most of the projects described in Table 3.16-2 are improvements to existing features; therefore they would have disturbance footprints similar to existing conditions, during and after construction. The volume and temperature of storm water runoff discharged to Whitewood Creek would remain unchanged. A small additional volume of water, such as rock dust wash down water, compressor blow-down water, and condensate water would be added to the SURF underground pool where water would be warmed by the wall rock. However, this additional volume of water would be small and add minimal thermal or other contaminants. SURF would manage its discharge and facilitate stream temperature for compliance by modifying the blending ratio of warmer underground water with cooler water from Homestake's tailing impoundment.

Placement of rock at the Gilt Edge Superfund site would have low incremental effects on runoff volume or water quality as the rock would be stockpiled on the already disturbed surface of the mine and any runoff or infiltration water would be collected and treated as part of the ongoing Superfund remedy. Placement of rock in the Open Cut, likewise would have a low level of impact due to the large size of the existing Open Cut and the similarity of the rock to that existing in it.

Noise and Vibration

The Proposed Action would generate noise and vibration associated with surface activities including rock crushing and rock transport to the Gilt Edge Superfund site or the Open Cut. Construction would generate noticeable increases in noise levels when compared to background noise, so there are cumulative impacts by definition. Underground noise and vibration, however, would be very low. Transport and placement of rock at the Gilt Edge Superfund site would have low incremental effects at that site beyond the planned remedy, which requires import of rock at other fill for remediation of the former mining pits. Cumulative impacts from other projects at SURF would occur principally underground, such as the Yates Shaft rehabilitation and other expected experiments. The noise and vibration from these experiments would also be very low. Non-SURF projects would be required to meet Lead city ordinance noise and vibration guidelines. Known projects do not occur in the same time frame as the Proposed Action and are thus not additive.

Transportation

The Proposed Action and other projects in the area would result in minimal increases in traffic volume over most of the state and county road systems. Vehicle miles traveled in Lawrence County in 2012 were over 255 million miles (South Dakota Department of Transportation, 2013) and continue to increase due to county development and increased tourism. The construction and operation of the Proposed Action and other area projects would be expected to increase the traffic on roads used by LBNF/DUNE by approximately 1 – 3 percent except for Kirk Road in Lead and Gilt Edge Road in Deadwood during construction. Based on an average of 75 round trips per day, with a peak of 150 round trips, traffic would increase by approximately 96 percent on Kirk Road and 146 percent on Gilt Edge Road. However, based on the history of the Lead area being a mining area, these increases would have low impact to transportation in the community in this context.

Air Quality

The annual and aggregate emissions associated with cumulative projects identified in Table 3.16-2 would not result in deterioration of air quality when added to the Proposed Action emissions. The cumulative projects are short-lived, do not result in large quantities of emissions due to the nature of work, are staggered of 10 years and do not occur at the same time as the Proposed Action. For example, the Homestake Visitor Center and Education and Outreach Building construction would be short-lived (8 months), would primarily consist of steel and concrete construction, and not occur during the Proposed Action. The Ross and Yates Shaft refurbishment would occur before and after the Proposed Action and would not be emission intensive as much of the work is manual labor removing and setting steel with compressed air jackhammers. Any criteria pollutant emissions would be temporary and the majority would occur during construction rather than long-term operations. No other projects (present or reasonably foreseeable future) of comparable magnitude to the Proposed Action nor have any other projects been identified in the area that would overlap with the Proposed Action.

Visual

The Gilt Edge Superfund site is a highly disturbed former gold mine located in a small depression on top of Strawberry Hill. The site includes large rock piles and open pits partially filled with acid mine drainage water. A portion of the site, the rock pile, can be seen from several miles away if viewed from the east.

Visual resources of the Gilt Edge Road area are similar to Lead's Kirk Road and include views of wooded areas and several rural residences. Highway 385 is a north-south paved road carved into Strawberry Hill. Many rock cut walls were exposed on the east side of this highway to accommodate three lanes. A series of residences occupy the northern edge of Highway 385 in the small community of Pluma. These residences are concentrated in a one-quarter mile section of the road.

The Proposed Action and projects beyond SURF's property boundary (4-6 in **Table 3.16-1**) would be visible from portions of the City of Lead and as a result would have a cumulative impact. This impact would be minimized as the timing of the projects would not overlap and the projects would be designed to improve the city's infrastructure and tourist base. Transport of rock to the Gilt Edge Superfund site would have very low visual impacts., as the rock would be stored in the interior of the existing mine site and would be deposited within the existing pits that would be addressed by the remedial action.

Geology and Soils

Short-term cumulative impacts on soils and geology would result from the Proposed Action and other projects. Future projects beyond SURF boundaries may disturb soils within small areas. Soils would be preserved and managed through erosion control BMPs. Other projects conducted at SURF (Ross and Yates shaft rehabilitation) would be performed underground and would not impact soils or geology.

Socioeconomics and Environmental Justice

Construction of the Proposed Action would have a beneficial economic effect and no disproportionately high and adverse human health or environmental impacts on environmental justice and thus very low cumulative adverse effects. Operations, considered together with other SURF projects and local development would result in cumulative, local economic benefits from continued experimental activity and spending by additional maintenance staff and visiting scientists. Overall, the projects planned by the city, SURF, and DOT would help establish new infrastructure to support the Proposed Action.

Sustainability

The Proposed Action and other projects would consume resources and thus create a cumulative impact. SURF would minimize the impact by adhering to the goals set forth in SURF's Site Sustainability Plan (SSP), including reducing GHG emissions, energy conservation, water conservation, pollution prevention, sustainable acquisition, and materials reuse. Transport of rock to the Gilt Edge Superfund site would contribute to the Superfund remedy at that site. Other non-SURF projects would consume resources according to their own sustainability plans. Sustainability, in general, would be addressed and practiced in all SURF projects through contractual commitments by subcontractors and experimental groups. Transport of rock to the Open Cut would have low impacts on the environment and be consistent with the past use of the site.

Utilities

The Proposed Action would have low impacts on additional utility construction. Utility infrastructure construction, where needed, would be on the SURF site and costs would be borne by LBNF/DUNE. There would be no utility interruptions to the public. The Homestake mine power usage during mining operations was very large. Hence, the power requirements for the Proposed Action and the city of Lead's requirements would easily be met by nearby substations and redundant distribution systems. Homestake also constructed a very complex and wide-ranging water collection and distribution system. This system was donated to the city of Lead in 2002 and it continues to supply water to the city of Lead and SURF. Water is readily available as it was used extensively and in large volumes by the mine to process ore during mine operation. The future water demands of the Proposed Action and the city would be very modest compared to the demands of Homestake's past mine operation. Therefore, the Proposed Action, considered together with other projects would have low cumulative impacts on utilities and only a minor contribution to impacts on power usage over existing (but not historical) conditions.

The power requirements for the Proposed Action and other projects would not affect the public in a measurable way. The SURF infrastructure projects would be completed with the exception of the Yates Shaft rehabilitation, which is not power intensive. Projects beyond the SURF property would be complete. In addition, the Alternative A projects, by their nature would be small in scope, would consume very little power (less than 100 KW).

Waste Management

The Proposed Action would generate only a small amount of hazardous waste in the form of construction materials such as paints, paint solvents, flammables, and aerosol cans. The quantity of generated waste from the Proposed Action is not expected to change SURFs CESQG generator status with possible exception of an episodic, or one time, event. Other projects at the SURF, such as shaft rehabilitation, expected experiments (existing or planned) and Education and Outreach Building rehabilitation would not generate substantial volumes of hazardous waste, as very few hazardous materials would be used by these projects. Other projects not associated with SURF, such as the Homestake Visitor's Center and US 85 widening, would be required to meet state and Federal requirements for hazardous waste management and waste minimization. Overall, other projects would have a minor effect on hazardous waste generation.

Solid waste would be generated by the Proposed Action and other area projects. Efforts would be made to limit solid waste impacts from all projects by recycling and reuse of equipment. Other projects on SURF property would adhere to SURF's Sustainability Plan. Other projects conducted at SURF that would generate solid and hazardous waste would be managed by the same policies and procedures currently employed at SURF. Overall, hazardous waste from the other projects would have a low impact on waste management as they employ very small volumes of hazardous materials.

Alternative A

Alternative A involves multiple small projects occurring over different timeframes, with disturbance within the confines of SURF. Consequently, in consideration of implementing the Proposed Action as well as non-SURF actions, any cumulative impacts would be low.

No Action

Under the No Action Alternative, the detector and its support facilities would not be constructed, and therefore, there would be no increase in construction or operational impacts. The current SURF operations would continue.

4. AGENCIES AND INDIVIDUALS CONTACTED

This section summarizes Federal, state, and local agency consultation and coordination regarding LBNF/DUNE. Appendix B and C presents related correspondence.

4.1 FERMILAB

Federal Agencies
U.S. Army Corps of Engineers, Chicago District
U.S. Fish and Wildlife Service

State Agencies
Illinois Environmental Protection Agency
Illinois Department of Natural Resources
Illinois State Historic Preservation Officer
Illinois Department of Transportation

Local Government Organizations
DuPage County
Kane County
City of Batavia
City of Aurora

4.2 SURF

Federal Agencies
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
Bureau of Indian Affairs

State Agencies
South Dakota Department of Game, Fish and Parks
South Dakota State Historic Preservation Officer

Native American Tribes
Cheyenne River Sioux Tribe
Crow Creek Sioux Tribe
Flandreau Santee Sioux Tribe
Lower Brule Sioux
Sisseton-Wahpeton Oyate
Standing Rock Sioux Tribe
Yankton Sioux Tribe
Spirit Lake Tribe
Three Affiliated Tribes
Turtle Mountain Band of Chippewa Indians
Winnebago Tribe of Nebraska
Santee Sioux Nation
Northern Arapahoe Tribe
Eastern Shoshone Tribe
Northern Cheyenne Tribe
Fort Peck Assiniboine and Sioux
Rosebud Sioux Tribe
Oglala Sioux Tribe
Crow Tribe

Local Government Organizations
City of Lead
City of Deadwood
Lawrence County Highway Department
Black Hills Power

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APPENDIX A

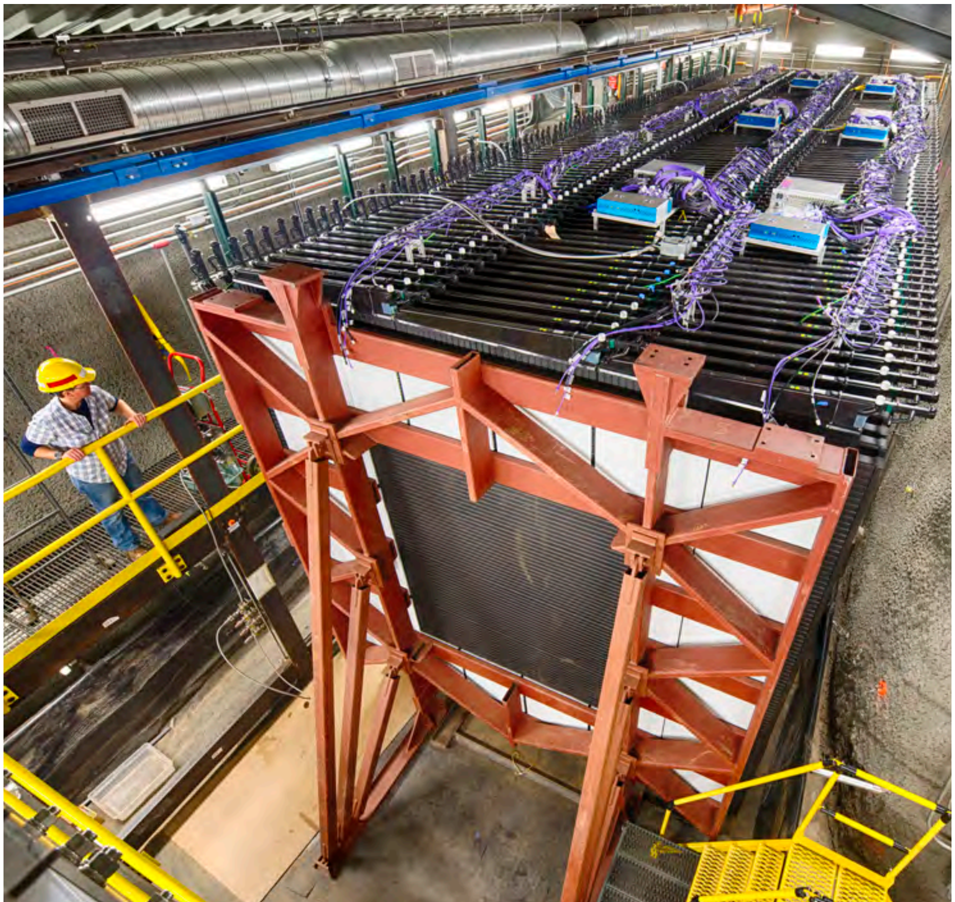
Neutrino Science

APPENDIX A-1

Fermilab Neutrino Fact Sheet

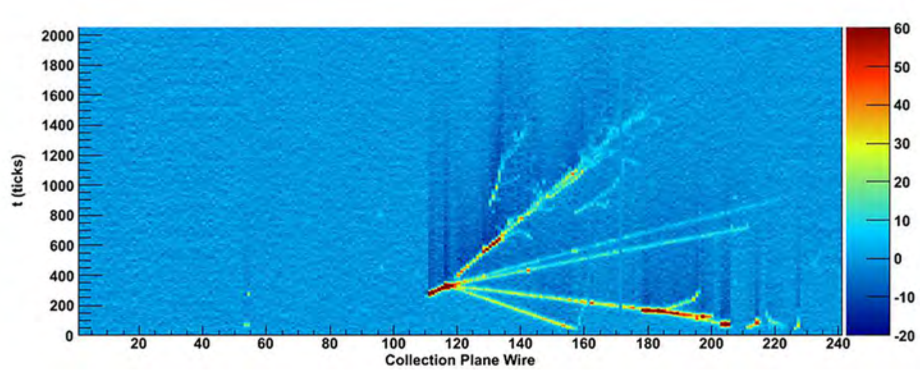
Neutrino experiments at Fermilab

Scientists from around the world use Fermilab's particle accelerator complex to research some of the least understood particles in the universe: neutrinos. A suite of experiments aims to discover the role that these mysterious particles have played in the evolution of the universe.



Neutrinos have mass, contrary to what was previously thought. However, the three known types of neutrinos all are very light: each one weighs less than a millionth of the mass of an electron. With the NOvA experiment, scientists aim to discover the neutrino mass hierarchy.

Particle tracks created by a neutrino interaction in liquid argon.



Mysterious neutrinos

Neutrinos are among the most abundant particles in the universe. Each second, a trillion neutrinos from the sun and other celestial objects pass through your body. Although neutrinos are all around us, they are very difficult to study. Neutrinos go through all matter and rarely leave a trace.

Why are neutrinos important?

Neutrinos may provide the key to answering some of the most fundamental questions about the nature of our universe. The discovery that the three known types of neutrinos oscillate and transform into each other has revolutionized scientists' understanding and raised new questions about matter, energy, space and time. Neutrinos might be the reason we exist, why the universe is filled with matter rather than light and radiation.

Intense beams for groundbreaking experiments

Fermilab strives to be the best laboratory for neutrino research in the world. Its particle accelerator complex produces the most intense beams of high-energy neutrinos. The laboratory operates seven neutrino detectors that weigh from a few hundred pounds to more than 14,000 tons, employ different detection technologies and probe neutrino beams at short and long distances, from a few hundred meters to 800 kilometers. These detectors enable scientists to study neutrino oscillations, search for new neutrino interactions and look for new types of neutrinos.

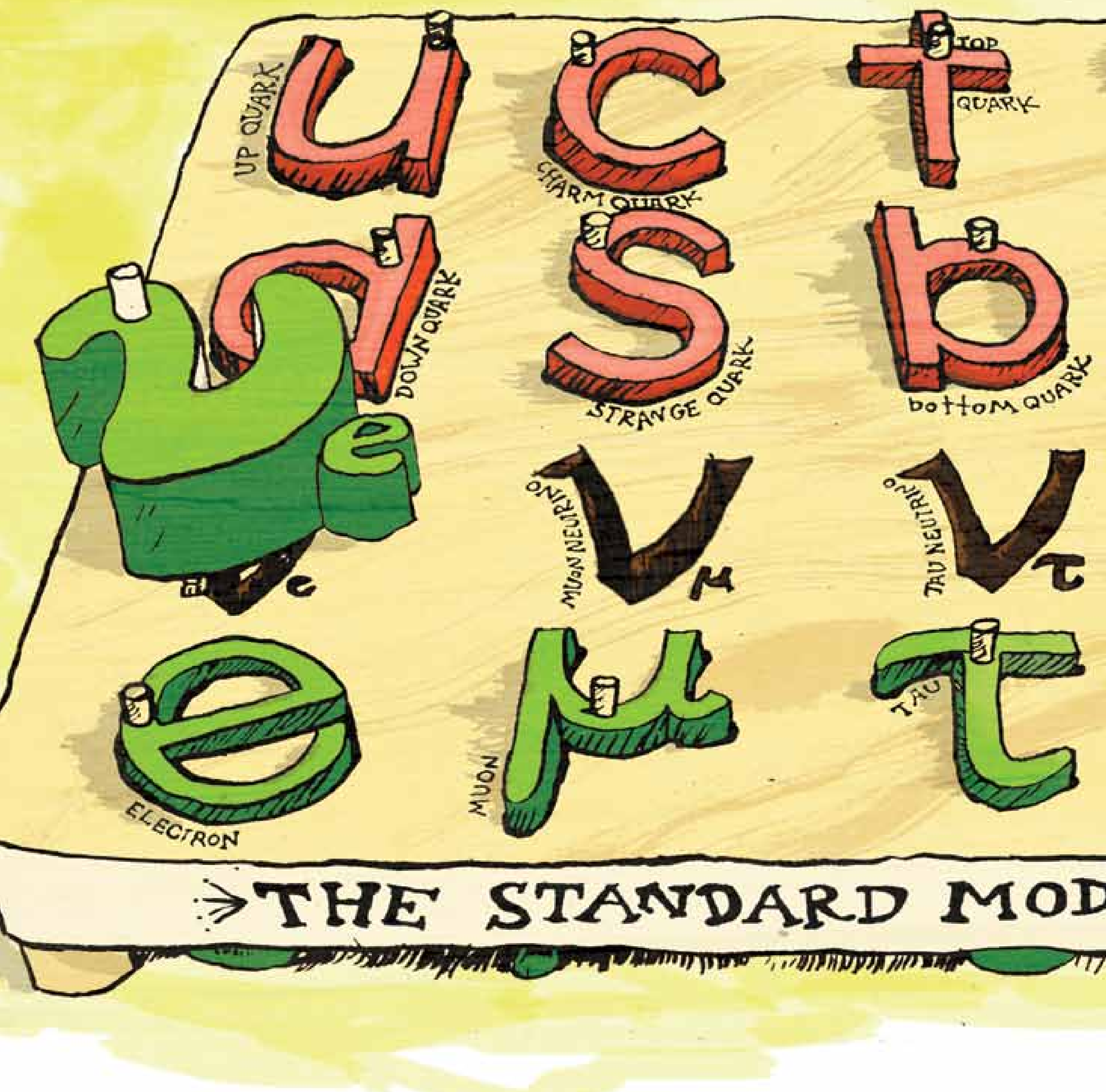
Plans for the future

An international collaboration of scientists plans to use the Fermilab accelerator complex for a new experiment that would send neutrinos 1,300 kilometers through the Earth from Fermilab in Batavia, Illinois, to the Sanford Underground Research Facility in Lead, South Dakota. That distance is ideal for discovering subtle differences in neutrino and antineutrino oscillations, perhaps the key to the dominance of matter in our universe. For more information visit neutrino.fnal.gov.

APPENDIX A-2

DOE Symmetry Magazine Article on Neutrino Science

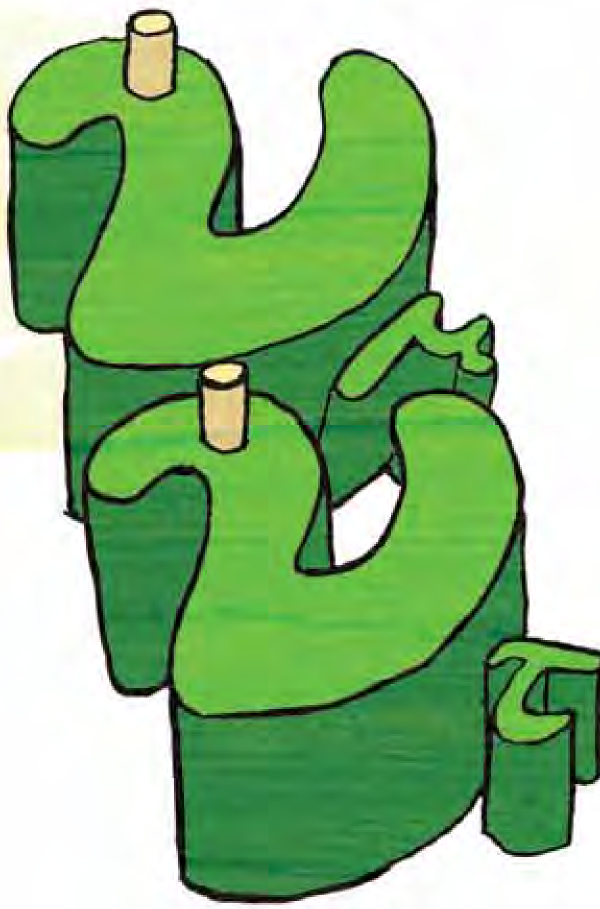
Illustrations: Sandbox Studio, Chicago



NEUTRINOS, THE STANDARD MODEL

For years, scientists thought that neutrinos fit perfectly into the Standard Model. But they don't. By better understanding these strange, elusive particles, scientists seek to better understand the workings of all the universe, one discovery at a time.

By Joseph Piergrossi



MISFITS

Neutrinos are as mysterious as they are ubiquitous. One of the most abundant particles in the universe, they pass through most matter unnoticed; billions of them are passing harmlessly through your body right now. Their masses are so tiny that so far no experiment has succeeded in measuring them. They travel at nearly the speed of light—so close, in fact, that a faulty cable connection at a neutrino experiment at Italy's Gran Sasso National Laboratory in 2011 briefly led to speculation they might be the only known particle in the universe that travels faster than light.

Physicists have spent a lot of time exploring the properties of these invisible particles. In 1962, they discovered that neutrinos come in more than one type, or flavor. By the end of the century, scientists had identified three flavors—the electron neutrino, muon neutrino and tau neutrino—and made the weird discovery that neutrinos could switch flavor through a process called oscillation. This surprising fact represents a revolution in physics—the first known particle interactions that indicate physics beyond the extremely successful Standard Model, the theoretical framework that physicists have constructed over decades to explain particles and their interactions.

Now scientists are gearing up for new neutrino studies that could lead to answers to some big questions:

If you could put neutrinos on a scale, how much would they weigh?

Are neutrinos their own antiparticles?

Are there more than three kinds of neutrinos?

Do neutrinos get their mass the same way other elementary particles do?

Why is there more matter than antimatter in the universe?

The answers to these questions not only offer a window on physics beyond the Standard Model, but may also open the door to answering questions about the universe all the way back to its origins.

Nature vs. Machine

When it comes to finding neutrinos to study, scientists have three choices.

They can catch naturally occurring neutrinos, such as the ones produced by nuclear reactions in stars like our sun, in collisions of cosmic particles with Earth's atmosphere or in stellar explosions known as supernovae. Stars like our sun produce electron-flavor neutrinos, while cosmic particles and supernovae produce a mixed bag of all three neutrino flavors and their antineutrino counterparts.

Alternatively, scientists can investigate neutrinos made in the nuclear reactors that generate power for homes and businesses. Reactors produce electron-flavor antineutrinos. Experiments to study neutrinos from this type of source require the construction of a particle detector near a nuclear power plant and yield valuable information about neutrinos and their interactions with matter.

Finally, scientists can deliberately produce neutrinos for experiments by firing protons from an accelerator at pieces of graphite or similar targets, which then emit specific types of neutrinos. Accelerator experiments have the advantage of being able to examine either neutrinos or antineutrinos. The intense beams of these accelerator-made particles increase the chance for a neutrino interaction to occur in detectors. In addition, accelerators can produce neutrinos that have higher energy than those emerging from reactors and the sun. That makes accelerator experiments extremely valuable in determining the exact nature of neutrinos.

The two types of manmade neutrino sources have another advantage: Detectors can be placed at specific distances from the source, depending on the science to be done. The optimal distances can range from tens of meters to a few hundred kilometers for reactor experiments and hundreds to thousands of kilometers for long-baseline oscillation experiments that use neutrinos from accelerators.

For example, the planned Long-Baseline Neutrino Experiment, which will use an existing accelerator at Fermi National Accelerator Laboratory, will have a detector situated at what former LBNE Spokesperson Bob Svoboda calls "the sweet spot"—a place just far enough away that neutrinos should have close to maximum mixing of their flavors by the time they hit the detector. "From this, we can learn a great deal about how neutrinos change," says Svoboda, who is a professor at the University of California, Davis. And since LBNE will produce both neutrinos and antineutrinos, physicists can explore the differences between matter and antimatter interactions and what this might mean for the imbalance between matter and antimatter in our universe.

Catch them if you can

Neutrino detectors also come in a variety of flavors. Since neutrinos themselves are invisible to detectors, scientists must take an indirect approach: They record the charged particles and flashes of light created when a neutrino hits an atom, and thus infer the neutrino's presence.

Because the tiny neutrino interacts with matter so rarely, the only way to detect it is to put lots of matter in its way. Super-Kamiokande, a now-classic neutrino detector in Japan, is filled with 50,000 tons of water. Neutrinos—produced in Earth's atmosphere, coming from the sun and generated by an accelerator 295 kilometers away—interact with water molecules and produce charged particles. In turn, these particles produce blue flashes called Cherenkov radiation. Light sensors within the water tank capture and record the glow.

The new NOνA detector, under construction in Ash River, Minnesota, advances SuperK's technology. Instead of water, NOνA will use liquid scintillator—a chemical that flashes as particles pass through—to observe neutrinos fired at the detector from Fermilab, about 800 kilometers away. At more than 60 meters long and 15 meters tall, NOνA will be one of the largest plastic structures in the world.

Instead of using one large tank filled with liquid, the NOνA detector is highly segmented to glean more information about each incoming neutrino's identity and energy. The 14,000 tons of liquid scintillator will be divided among hundreds of thousands of tubes made of PVC plastic, says Fermilab's Pat Lukens, a project manager for the experiment. When a neutrino hits a nucleus in the detector, producing charged particles and flashes of light, researchers will be able to tell precisely where the interaction occurred and which way the particles went.

Another technology for getting more information about neutrino interactions is a grid of wires submerged in a detector liquid. Placed under high voltage, the wires attract charged particles that appear when neutrinos interact with the liquid. This technique, employed in the ICARUS neutrino

detector in Italy, reveals the precise tracks of the charged particles produced when neutrinos interact in liquid argon. For the much larger LBNE detector, to be located at the Sanford Lab in South Dakota, scientists are designing the next generation of this type of detector.

THE NEXT STEPS

The results of recent neutrino experiments have opened the door to learning much more about neutrinos and their habits. In 2011, researchers turned on the first set of detectors at the Daya Bay Reactor Neutrino Experiment in southern China, hoping to make a key measurement that would help them understand how one type of neutrino turns into another.

In March 2012, after only seven months of taking data, the Daya Bay scientists announced success: They nailed the measurement of θ_{13} (pronounced theta-one-three), one of three so-called "mixing angles" that describe the oscillation of neutrinos between one flavor and another. Previous experiments had shown that θ_{13} had to be small, and scientists had begun to wonder whether this mixing angle might be zero. The Daya Bay result, in combination with other neutrino measurements in Japan, South Korea, France and the United States, showed that the angle is small, but definitely not zero.

When the size of that angle was announced, neutrino physicists from around the world cheered. The result opened up the possibility that neutrinos behave differently than antineutrinos, which in turn might help explain the preponderance of matter over antimatter in the universe.

This leaves scientists in a good position to learn more about one of the most abundant and ubiquitous particles in the cosmos. New neutrino oscillation experiments "have a good shot of reaching their goals," says Boris Kayser, a theorist at Fermilab. Using the θ_{13} result, they could determine the neutrino mass hierarchy and find out whether neutrino interactions violate the matter-antimatter symmetry. These are crucial steps toward understanding whether neutrinos are the reason for the dominance of matter over antimatter in our universe.

The most difficult question to answer, Kayser says, is "What are the unknown unknowns?" While physicists have some expectations about what they will see, neutrinos again and again have proven themselves difficult to predict. Given their bizarre nature, it's entirely possible that neutrinos may hold many more surprises for scientists down the line.

BIG QUESTIONS

Through experiments that use a range of approaches and technologies, physicists are beginning to get a fuller picture of neutrino behavior. The results could be key to answering questions that have stymied scientists for years.

WHAT ARE THE MASSES OF THE THREE KNOWN NEUTRINO TYPES?

Experiments have shown that neutrinos have a tiny, non-vanishing mass. Although each neutrino must be a million times lighter than an electron, their exact masses are not known. Due to their abundance, neutrinos could account for several percent of the mass of the universe and play a significant role in the evolution of the universe.

The frequency of neutrino oscillations depends on the mass difference among the three different neutrino types. The NOvA experiment will soon begin to send neutrinos from Fermilab to Ash River, Minnesota, a distance of 810 kilometers. Scientists hope that the observation of the resulting oscillations will determine which type of neutrino is the heaviest and which is the lightest.

Discovering this mass hierarchy is the first step. To complete their understanding of neutrino masses, scientists also need to determine the absolute neutrino mass scale by measuring the mass of one of the neutrino types. The KATRIN experiment in Germany will attempt to do just that. The experiment will study the nuclear decay of tritium, an unstable form of hydrogen. It will compare the mass and kinetic energy of particles before and after the decay, which produces an electron antineutrino. Because the total energy of all particles involved in the decay must be preserved, scientists can determine the mass of the antineutrino if they can measure the kinetic energy of particles with sufficient precision.

ARE NEUTRINOS THEIR OWN ANTIPARTICLES?

Scientists have observed the interactions of both neutrinos and antineutrinos with matter. But it is not clear whether a neutrino and its antiparticle are two separate particles. In the case of charged particles, scientists easily can distinguish particles and their antiparticles by their electric charge. An electron has negative charge, and a positron has positive charge. Neutrinos, however, have no electric charge. So it's possible that a neutrino could be its own antiparticle. Theorists refer to this case as the Majorana neutrino, in honor of Italian physicist Ettore Majorana, who recognized this possibility. Alternatively, neutrinos and antineutrinos could be separate particles and behave according to the equations developed by theorist Paul Dirac.

Several nuclear experiments, including the Enriched Xenon Observatory in New Mexico and the Majorana experiment in South Dakota, aim to settle the Majorana-vs.-Dirac neutrino question. They are examining radioactive nuclei that exhibit the simultaneous decay of two neutrons—a process known as double beta decay and first observed in 1986. This nuclear reaction normally ejects two antineutrinos, which carry away energy from this decay process. If the Majorana theory is correct, the two antineutrinos would also be neutrinos, and they could "cancel each other out." The result would be the occasional neutrinoless double beta decay, in which neither neutrinos nor antineutrinos are emitted. If experiments observed this rare process, it would confirm the Majorana theory and pave the way for many elegant theories that explain how neutrinos acquire mass and why their mass is so much smaller than that of any other particle of matter we know.

ARE THERE MORE THAN THREE NEUTRINO FLAVORS?

The Standard Model describes only three neutrino flavors, each linked to the electron or one of its heavier cousins via the weak nuclear force—the fundamental force responsible for radioactive decay and the production of neutrinos. But a variety of evidence suggests that additional neutrino flavors may exist, with properties quite different from the three known types of neutrinos. Experiments will continue to look for these "sterile" neutrinos, which get their name from the fact that they do not interact with other matter through the weak force, as other neutrinos do.

DOES THE HIGGS GIVE MASS TO NEUTRINOS?

According to the Standard Model, the field associated with the Higgs boson provides quarks and charged leptons—a group of elementary particles that includes the electron—with mass. However, many scientists think the masses of the ultra-light neutrinos arise, at least in part, in some other, yet-unknown way. Experiments at the Large Hadron Collider, which discovered a Higgs-like particle, won't be able to measure neutrino properties. Instead, future nuclear experiments and neutrino oscillation experiments such as NOvA and the Long-Baseline Neutrino Experiment could weigh in on the origin of the neutrino masses. "LBNE and NOvA could help us to interpret the results of those nuclear experiments," says Boris Kayser, a theorist at Fermilab.

WHY DID MATTER WIN OVER ANTIMATTER?

According to physicists' current understanding of the big bang, matter and antimatter formed in equal amounts when the universe began. But if that were the case, every last smidgen of matter should have collided with every last smidgen of antimatter by now. This would have released lots of energy and filled the universe with light and radiation, but left it without any matter at all. "Why isn't the universe entirely energy?" asks Kayser. "Why didn't the matter and the antimatter annihilate each other as soon as they were made?"

The answer to that question lies in something called charge-parity symmetry violation. Finding the right kind of CP violation to explain the preponderance of matter is a top priority, and neutrinos are prime candidates. "It's often called the Holy Grail of neutrino physics," says Mark Messier, co-spokesperson of the NOvA experiment and a professor at Indiana University.

Previous studies found CP violation—a difference in the behavior of particles and their antiparticles—among elementary particles known as quarks. But this CP violation does not explain the overall matter-antimatter imbalance.

Neutrinos come into play because their incredible lightness suggests, through a theory called the "see-saw picture," that they are the ultra-light relatives of very heavy particles that lived briefly in the early universe. The disintegration of these heavy particles may have violated CP symmetry in a way that led to the present-day imbalance between matter and antimatter. If that is indeed how the imbalance arose, then scientists should also find CP violation in the oscillation of today's neutrinos.

APPENDIX B

ESA Correspondence

APPENDIX B-1

Fermilab ESA Correspondence

U.S. Fish and Wildlife Service
Chicago Illinois Field Office
1250 South Grove, Suite 103
Barrington, IL 60010
Attn: Mr. Shawn Cirton

SUBJECT: Informal Consultation for Threatened/Endangered Species under Section 7 of the Endangered Species Act for the Long Baseline Neutrino Facility (LBNF) Project at Fermi National Accelerator Laboratory (Fermilab)

Dear Mr. Cirton:

We are requesting concurrence from the U.S. Fish and Wildlife Service that the proposed Long Baseline Neutrino Facility (LBNF) Project at Fermi National Accelerator Laboratory (Fermilab) is not likely to adversely affect the Eastern Prairie Fringed Orchid, the Sheepnose Mussel or the Northern Long-eared Bat. The project was previously known as the Long Baseline Neutrino Experiment (LBNE) Project. The proposed project is located in Kane County, Illinois. Fermilab is owned and managed by the U.S. Department of Energy (DOE). DOE is currently preparing an Environmental Assessment under the National Environmental Policy Act, and Fermilab has submitted a permit application under Section 404 of the Clean Water Act to the U.S. Army Corps of Engineers.

Fermilab plans to construct an underground facility in the southern portion of the Fermilab site as well as associated aboveground service roads and buildings. Construction is expected to last approximately 7 years. The first phase would construct a large embankment on the project site with material excavated from the surrounding area on the Fermilab site. Subsequently, underground and aboveground experimental and support structures would be built and outfitted. Pursuant to their responsibilities under the National Environmental Policy Act (NEPA), DOE is preparing an Environmental Assessment (EA) for the LBNF project. Part of the planning process involves measures described in the EA that will be implemented to avoid or minimize impacts to Biological resources, including listed species and habitats.

Planning Resources Inc. (PRI) was contracted by Fermilab in 2010 to perform a wetland delineation at the site of the LBNF project. The project area is located entirely on the property of Fermilab at the southeast corner of Giese Road and Kautz Road. The parcel is situated in the Indian Creek watershed, part of the larger Fox River watershed. The study area is approximately 105 acres. The legal location is in the northwest quarter of Section 25, Township 39 North, Range 8 East of the Third Principal Meridian. The site contains areas of prairie, marsh, and mesic woodland. Nine low quality wetlands and three high-quality wetlands were identified on the site. In addition, there are two high quality waters of the U.S.

In 2014, AECOM was contracted by Fermilab to update and verify the 2010 wetland delineation. During that time, an additional 41 acres were added south of the initial project area. Three additional wetlands were identified, comprising less than 0.5 acres. Floristic Quality Assessments for all wetland areas are included in the attached reports from PRI and AECOM.

We have carefully reviewed the USFWS Section 7 Consultation website for a list of species and critical habitat that "may be present" within the project area. There are three species listed: the Eastern Prairie Fringed Orchid (*Platanthera leucophaea*), the Sheepnose Mussel (*Plethobasus cyphyus*) and the Northern Long-eared bat (*Myotis septentrionalis*).

Eastern Prairie Fringed Orchid – Marshes and sedge meadows occur within the project area. The area contains potential habitat for the orchid in areas with wet meadow vegetation, namely in the large wetland B complex identified in the attached reports. Some wetlands in the area would be unavoidably impacted, and therefore if the species is present, negative effects could occur. There were no observations of the orchid during the three investigations of the project area in 2010 and 2014. Furthermore, Fermilab has conducted extensive restoration and conservation activities on the site since 1975, including vegetative surveys. The orchid has never been observed on the entire Fermilab site (6800 acres) including the project site. Any effect on the Eastern Prairie Fringed Orchid would therefore be discountable.

Sheepnose Mussel – No large streams occur within the project area. Currents within Indian Creek are slow, not moderate to swift as required by the mussel. The Sheepnose mussel likely does not occur in the project area and therefore any effect on the mussel would be discountable.

Northern Long-eared Bat - Since the original review in 2010, the Northern Long-eared bat (*Myotis septentrionalis*) has been proposed as Endangered in the area. There are no hibernacula (mines, caves) in the area, but the species roosts in upland forests during the summer. Therefore, roosting could occur in the project area, although no Long-eared bats have ever been observed at Fermilab. Some mature trees will be removed during the project, which could potentially result in negative impacts. In order to minimize this risk, tree removal would be scheduled for winter months if feasible. Any effect on the Northern Long-eared bat would therefore be insignificant.

For these reasons, we conclude that the LBNF project is not likely to adversely affect the Eastern Prairie Fringed Orchid (*Platanthera leucophaea*), the Sheepnose Mussel (*Plethobasus cyphyus*) or the Northern Long-eared bat (*Myotis septentrionalis*). We request your concurrence with our determination.

Attachments (2)

Womack, Carrie

From: Rodney Walton <rwalton@fnal.gov>
Sent: Wednesday, February 04, 2015 2:14 PM
Subject: Re: Section 7 Informal Consultation

Shawn,

Thanks for your help! I didn¹t go far enough into the web site to get to the real heart of the matter. From the 2 wetland reports dated 2010 and 2014, I determined that the large wetland complex identified as wetland B (approx. 12 acres, including wetland 2 from the 2014 report) and a very small wetland identified as wetland J (0.04 acres) fit the criteria for high quality. Comparing the species lists for the 2 wetlands with the associate list from the FWS web site, I find that both areas contain at least 4 species associated with EPFO. Therefore, we will retain a sub-contractor to conduct 3 searches for EPFO in these areas on non-consecutive days during the period from June 28 to July 11.

I understand from your email that we don¹t need any additional information on the long-eared bat, and the sheep nose mussel is not present in Kane County.

Thanks again,
Rod Walton
Fermilab Facilities Engineering Services Section
630-840-2565

From: <Cirton>, Shawn <shawn_cirton@fws.gov>
Date: Tuesday, February 3, 2015 at 1:49 PM
To: Rod Walton <rwalton@fnal.gov>
Cc: Rick Hersemann <rick.hersemann@science.doe.gov>, Kate Sienkiewicz <kateps@fnal.gov>, Kimberly Kubiak <kimberly.j.kubiak@usace.army.mil>, "Wozniak, Keith L LRC" <Keith.L.Wozniak@usace.army.mil>
Subject: Re: Section 7 Informal Consultation

Rod,

The typical process is that I review the wetland information once we receive the notice from the COE. At that point I would provide comments to the COE, if we have any concerns.

Regarding section 7 of the Endangered Species Act, we only provide a concurrence letter if there is a May Affect, Not Likely to Adversely Affect (NLAA) or Likely to Adversely Affect (LAA) determination. Keep in mind that we would only provide a concurrence letter to the COE because they are the Federal action agency making the determination and section 7 consultation is between the USFWS and the COE, in this case. The other determination, which we do not provide a concurrence letter for, is a No Effect determination. Based on the info in the letter provided, I'm not sure which determination is being made for the 3 species. We usually discuss section 7 when the notice is issued but I do provide technical assistance to the COE and applicants during the process.

Therefore, I will provide technical assistance now. Based on our website, there should only be 2 species listed in Kane County, the orchid (EPFO) and the northern long-eared bat (NLEB). The sheepnose is not listed as potentially occurring in Kane County. Although, EPFOs have not been observed in the past and recently, you need to follow the guidance provided on our website to determine if surveys are needed. That would require you to look at the FQA sheets for the wetlands proposed to be impacted and determine whether the FQI is 20 or above and if the Native Mean C is is 3.5 or above. If either scenario is the case, then you should follow the rest of the guidance on the link for the EPFO on the FWS web page. This is something that I will be looking at when we receive the notice from the COE.

Regarding the NLEB, the letter states that tree removal will occur during winter months, if feasible. Since the species is proposed to be listed, there is no effect determination for the bat, unless the project jeopardized the continued existence of the species, which this project will not do. If trees need to be removed after April 1st, then we are not sure what the determination will be because the bat is proposed to be listed by April 2 and if listed, all details will be provided then. If trees have to be removed after April 1 and the bat is listed, I will work with the COE to address that scenario.

Please contact me if you have any further questions.

Shawn Cirton
Fish and Wildlife Biologist
USFWS - Chicago Illinois Field Office
1250 South Grove Avenue, Suite 103
Barrington, IL 60010
(847)381-2253 xt.19
(847)366-2345 (work cell)
Tuesdays and Thursdays - USACOE - (312)846-5545
http://midwest.fws.gov/chicago

On Tue, Feb 3, 2015 at 12:40 PM, Rodney Walton <rwalton@fnal.gov> wrote:
Shawn,

Thanks! That does simplify things enormously. I¹ve included the formal letter that I drafted and the 2 reports. Please let me know if there is anything else you need from us.

Rod Walton
Fermilab Facilities Engineering Services Section
630-840-2565

From: <Cirton>, Shawn <shawn_cirton@fws.gov>
Date: Tuesday, February 3, 2015 at 10:23 AM
To: Rod Walton <rwalton@fnal.gov>
Subject: Re: Section 7 Informal Consultation

Rod,

To simplify things, you can send me all the info above via email. Regarding section 7 for the project, I will be the one reviewing the info that you submit to the COE so you can just send me that as well. No need to change anything even if the letter is addressed to Cathy.

So, no need to send anything to Cathy since this is a COE project that I am reviewing. This could save you postage... Let me know if you have any other questions.

Shawn Cirton
Fish and Wildlife Biologist
USFWS - Chicago Illinois Field Office
1250 South Grove Avenue, Suite 103
Barrington, IL 60010
(847)381-2253 xt.19
(847)366-2345 (work cell)
Tuesdays and Thursdays - USACOE - (312)846-5545
http://midwest.fws.gov/chicago

On Mon, Feb 2, 2015 at 12:58 PM, Rodney Walton <rwalton@fnal.gov> wrote:
Shawn,

Good afternoon! You may remember the LBNE project we discussed in a pre-app meeting here last summer. I have gone through the process as described in your web site as you suggested. I just have a couple of procedural questions for you. First, I have assumed you would want the wetland reports enclosed with the letter. There are 3 reports; one from 2010 and two from 2014. Secondly, the web site implies the letter should go to Cathy Pollack, to whom the letter is currently addressed. Is that correct, with CC to you? Finally, does the letter be mailed by USPS or can it be emailed as attachments to Ms. Pollack?

Thanks,

Rod Walton
Fermilab Facilities Engineering Services Section
630-840-2565

APPENDIX B-2

SURF ESA Correspondence

HDR ONE COMPANY | *Many Solutions*

RECEIVED
OCT 17 2013
U.S. FISH & WILDLIFE SERVICE

October 2, 2013

U.S. Fish & Wildlife Service
SD ES Field Office
Project as described will have no significant impact on fish and wildlife resources. It does not involve any federally listed threatened or endangered species or their habitats. If project design changes, please submit plans for review.
10/22/13 Scott Larson
Date Field Supervisor

Mr. Scott Larson
U.S. Fish and Wildlife Service
421 South Garfield Avenue
Suite 401
Pierre, SD 57502

RE: Threatened and Endangered Species

Dear Mr. Larson:

The South Dakota Science and Technology Administration (SDSTA) Sanford Underground Research Facility (SURF) is collaborating with Fermilab, located in Chicago, IL to evaluate constructing facilities in Chicago and Lead, SD for the Long Baseline Neutrino Experiment or LBNE (see http://lbne.fnal.gov/project/general_info.shtml). SURF would be the location for the 'Far Site' surface or underground facility, while Fermilab facilities in Chicago would be the location of the 'Near Site' or neutrino beam generation site (the Project). SURF and Fermilab are undertaking an Environmental Assessment (EA) for the LBNE project lead by the Department of Energy (DOE). The six-acre surface detector site would be situated on land owned by the SURF and Homestake Mining Company/Barrick Gold Company and would be located 0.4 miles south of the City of Lead, Lawrence County, South Dakota. The underground detector, located on the 4850' level of the underground laboratory would result in a surface disturbance of 10 acres for a surface support building and the route needed to transport rock (Figure 1). All areas that are being chosen for the surface or underground detector have been previously disturbed from past mining activities.

One endangered species and one candidate species are listed for Lawrence County. This coordination letter contains an overview of the listed threatened and endangered species for Lawrence County, proposed effect determinations, and measures to minimize any potential impacts.

Early agency coordination is being completed as part of the proposed Project to solicit information to be used for the environmental documentation.

The following sections summarize species and habitat descriptions, and propose an effect determination on threatened and endangered species.

Whooping Crane—The whooping crane is an endangered species and only one population occurs in North America. They nest in Wood Buffalo National Park and adjacent areas in Canada and winter in coastal marshes in Texas and Kansas. They utilize wetlands as stop-over habitat to feed and rest during their migrations. Lawrence County is within the migration corridor; however the Project is located outside of potential Whooping Crane habitat. Additionally, human disturbance is prevalent within and adjacent to the Project Area from existing roadways, homes, and mining facilities. Due to the lack of suitable stopover habitat within or adjacent to the Project Area, a determination of no effect on whooping crane is proposed for the Project.

Sprague's Pipit— The Sprague's pipit is a ground-nesting species that breeds and winters in open grasslands. It is a candidate species found in native prairie habitat. Since the Project Area does not contain suitable native habitat, and due to its highly disturbed nature, the Project is anticipated to have an insignificant effect on the species.

Bald and Golden Eagle— The Bald and Golden Eagle Protection Act prohibits anyone, without a permit issued by the Secretary of the Interior from "taking" bald eagles or their associated nests or eggs. Bald and Golden Eagles are known to use ponderosa pine forests for nesting and roosting. Tall ridges are also used by Bald and Golden Eagles. This habitat is typical within the Project Area where the surface or underground detector will be built. There are approximately 35 acres of forested area that exists within the proposed Project Area.

Migratory Birds – Birds protected under the Migratory Bird Treaty Act (MBTA) include all common songbirds, waterfowl, shorebirds, hawks, owls, eagles, ravens, crows, native doves and pigeons, swifts, martins, swallows and others, including their body parts (feathers, plumes etc.), nests, and eggs. A complete list of protected species is found at 50 CFR 10.13. Take is defined as "to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or any attempt to carry out these activities." A take does not include habitat destruction or alteration, as long as there is not a direct taking of birds, nests, eggs, or parts thereof.

Surveys for migratory birds would occur in suitable areas that have not been mowed or cleared prior to April 1 to determine if there are current nests and to determine offsetting measures to compensate for impacts to migratory birds. Removal of inactive nests of migratory birds would not be accomplished prior to consultation with the USFWS. SDSTA will coordinate with the USFWS to determine appropriate offsetting measures for impacts to migratory birds after potential impacts have been identified. Surveys would be conducted within the same year, but prior to construction start in order to capture the current conditions and address possible effects more concisely.

The SDSTA believes that, with the implementation of the recommendations and project conditions noted above, the potential for direct and indirect impacts is negligible, and anticipates that the proposed actions will not significantly impact candidate species, migratory birds or Bald and Golden Eagles.

We respectfully request your concurrence with our determination and request any further comments you may have on the Project.

If you have any comments or questions or need additional information, please don't hesitate to contact me at 605-977-7756. Thank you for your consideration of this Project.

Sincerely,

Rebecca Baker

Rebecca Baker
Environmental Scientist
HDR Engineering, Inc.

Attachments:
Figure 1: Project Location

APPENDIX C

Cultural Resources Correspondence

APPENDIX C-1

Fermilab Cultural Resources Correspondence

FEB 8 2013

Mr. Joseph Phillippe
Illinois Historic Preservation Agency
Preservation Services
#1 Old State Capitol Plaza
Springfield, IL 62701-1507

Dear Mr. Phillippe:

SUBJECT: PHASE II ARCHAEOLOGICAL TESTING OF THE TADPOLE AND FROG SITES (11K18 AND 11K19) WITHIN THE FERMI NATIONAL ACCELERATOR LABORATORY (FERMILAB), BATAVIA, ILLINOIS

Reference: *Phase II Archaeological Testing of the Tadpole and Frog Sites (11K18 and 11K19) within the Fermi National Accelerator Laboratory, Batavia Township, Kane County, Illinois,* January 23, 2013, copy enclosed.

In compliance with Section 106 and 110 of the National Historic Preservation Act and the Department of Energy Order 141.1, Phase II testing was conducted and the above report developed by Midwest Archaeological Research Services, Inc. in order to determine National Register of Historic Places (NRHP) eligibility of the Tadpole and Frog sites. This was done in anticipation of construction plans, for the Long Baseline Neutrino Experiment Project, that have the potential to impact these previously identified cultural resource sites. The report concludes that no *in situ* archaeological material was encountered on either site and neither site is eligible for the NRHP. In addition, Illinois State site update forms for both sites and a correction form for the Frog site are included in an appendix to the report.

Enclosed for your review are two paper copies and a digital copy (CD) of the report. If you have any questions, please contact Rick Hersemann, of my staff, at (630) 840-4122.

Sincerely,

Michael J. Weis
Site Manager

Enclosures:
As Stated

cc: P. Oddone, Fermilab, w/o encls.
Y. - K. Kim, Fermilab, w/o encls.
N. Grossman, Fermilab, w/o encls.
R. Ortgiesen, Fermilab, w/o encls.

bc: R. Hersemann, w/o encls.
J. Scott, w/o encls.
A. Kenney, w/o encls.
T. Dykhuis, w/o encls.
G. Eargle, w/o encls.
R. Walton, w/o encls.
E. McCluskey, w/o encls.

Illinois Historic Preservation Agency

1 Old State Capitol Plaza • Springfield, Illinois 62701-1512 • www.illinois-history.gov

Kane County PLEASE REFER TO: IHPA LOG #010021313
Batavia
SE of Giese Road and Kirk Road
Section:25-Township:39N-Range:8E
11K18, 11K19
DOE, MARS-1687
Phase II Archaeological testing - Tadpole & Frog sites, Fermi Laboratory

March 6, 2013

Michael J. Weis
Department of Energy
Fermi Site Office, P.O. Box 2000
Batavia, IL 60510

Dear Mr. Weis:

We have reviewed the documentation submitted for the referenced project(s) in accordance with 36 CFR Part 800.4. Based upon the information provided, no historic properties are affected. We, therefore, have no objection to the undertaking proceeding as planned.

Please retain this letter in your files as evidence of compliance with section 106 of the National Historic Preservation Act of 1966, as amended. This clearance remains in effect for two (2) years from date of issuance. It does not pertain to any discovery during construction, nor is it a clearance for purposes of the Illinois Human Skeletal Remains Protection Act (20 ILCS 3440).

If you are an applicant, please submit a copy of this letter to the state or federal agency from which you obtain any permit, license, grant, or other assistance.

Sincerely,

Anne E. Haaker

Anne E. Haaker
Deputy State Historic
Preservation Officer

SEP 06 2013

Mr. Joseph Phillippe
Illinois Historic Preservation Agency
Preservation Services
#1 Old State Capitol Plaza
Springfield, IL 62701-1507

Dear Mr. Phillippe:

SUBJECT: CULTURAL RESOURCE REPORT FOR FERMI NATIONAL ACCELERATOR LABORATORY (FERMILAB), BATAVIA, ILLINOIS

Reference: Letter, from *Midwest Archaeological Research Services, Inc.* to R. Walton, dated August 19, 2013, Subject: Potential Effect of the Long-Baseline Neutrino Experiment (LBNE) on the Cultural Resources at Fermi National Accelerator Laboratory (Fermilab) in Batavia Township, Kane County and Winfield Township, DuPage County, copy enclosed.

In compliance with the National Historic Preservation Act, and the Department of Energy Order 141.1, Midwest Archaeological Research Services (MARS), Inc. conducted Phase II testing in order to determine National Register of Historic Places (NRHP) eligibility of three farmstead sites: John and Margaret Theis Farmstead (11-Du-551), Herman and Wilhelmina Schwahn Farmstead (11-K-1226), and the William and Mary Williams Farmstead (PS 71). This was done in anticipation of construction plans for the proposed LBNE Project that have the potential to impact these previously identified cultural resource sites.

MARS, Inc. concluded that none of the three sites are eligible for the NRHP. MARS, Inc. also concluded that the LBNE construction project as currently planned will not adversely impact any significant historic properties and recommended project clearance.

Enclosed are two paper copies and a digital copy of the report for your review and approval. If you have any questions, please contact Rick Hersemann, of my staff, at (630) 840-4122.

Sincerely,

Michael J. Weis
Site Manager

Enclosure:
As Stated

cc: N. Lockyer, Fermilab, w/o encls.
J. Anderson, Fermilab, w/o encls.
M. Michels, Fermilab, w/o encls.
R. Ortgiesen, Fermilab, w/o encls.

bc: R. Hersemann, w/o encls.
J. Scott, w/o encls.
A. Kenney, w/o encls.
T. Dykhuis, w/o encls.
R. Walton, w/o encls.

Illinois Historic Preservation Agency

FAX 217/782-8161

1 Old State Capitol Plaza • Springfield, Illinois 62701-1512 • www.illinois-history.gov

Kane County PLEASE REFER TO: IHPA LOG #004091213
Batavia
SE of Giese Road and Kirk Road
DOE
New construction, Long-Baseline Neutrino Experiment-Fermi Lab

October 18, 2013

Michael J. Weis
Department of Energy
Fermi Site Office, P.O. Box 2000
Batavia, IL 60510

Dear Mr. Weis:

We have reviewed the documentation submitted for the referenced project(s) in accordance with 36 CFR Part 800.4. Based upon the information provided, no historic properties are affected. We, therefore, have no objection to the undertaking proceeding as planned.

Please retain this letter in your files as evidence of compliance with section 106 of the National Historic Preservation Act of 1966, as amended. This clearance remains in effect for two (2) years from date of issuance. It does not pertain to any discovery during construction, nor is it a clearance for purposes of the Illinois Human Skeletal Remains Protection Act (20 ILCS 3440).

If you are an applicant, please submit a copy of this letter to the state or federal agency from which you obtain any permit, license, grant, or other assistance.

Sincerely,

Anne E. Haaker

Anne E. Haaker
Deputy State Historic
Preservation Officer

A teletypewriter for the speech/hearing impaired is available at 217-524-7128. It is not a voice or fax line.

APPENDIX C-2

SURF Programmatic Agreement for Cultural Resources

DRAFT PROGRAMMATIC AGREEMENT

AMONG THE

UNITED STATES DEPARTMENT OF ENERGY,

SOUTH DAKOTA SCIENCE AND TECHNOLOGY AUTHORITY,

AND THE

SOUTH DAKOTA STATE HISTORIC PRESERVATION OFFICER,

ADVISORY COUNCIL ON HISTORIC PRESERVATION,

OTHERS (TBD)

REGARDING CONSTRUCTION AND OPERATION OF THE

LONG-BASELINE NEUTRINO FACILITY AND

DEEP UNDERGROUND NEUTRINO EXPERIMENT

WHEREAS, the United States Department of Energy (DOE) proposes to fund the construction, operation, and decommissioning of the Long-Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (LBNF/DUNE),[1] being located at the Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois and the Sanford Underground Research Facility (SURF) in Lead, Lawrence County, South Dakota; and

WHEREAS, consultation with the Illinois State Historic Preservation Officer pursuant to Section 106 of the National Historic Preservation Act (NHPA – 16 United States Code (U.S.C.) 470(f)) for those components of LBNF/DUNE located at Fermilab has concluded; and

WHEREAS the Undertaking consists of those remaining components of LBNF/DUNE located at SURF, consistent with the description provided in Appendix A-1; [2] and

[1] Other names for LBNF/DUNE have been used, including “Long Baseline Neutrino Experiment” and “Long Baseline Neutrino Facility and Experiment.”

[2] The Undertaking is also described in the Proposed Action and Alternatives Section of the LBNF/DUNE

WHEREAS the Area of Potential Effect is illustrated in Appendix A-2; and

WHEREAS, DOE funding qualifies this as an Undertaking, requiring DOE's compliance with Section 106 of NHPA and the implementing regulations of the Advisory Council on Historic Preservation (ACHP) set forth at 36 U.S. Code of Federal Regulations (CFR) Part 800 (36 CFR Part 800); and

WHEREAS, DOE has consulted with its partner, the South Dakota Science and Technology Authority (SDSTA), a state-chartered entity created to foster scientific and technological investigations, experimentation, and development in South Dakota that operates the SURF and has been involved in planning and coordinating the Undertaking including the Section 106 review, and SDSTA is a Consulting Party to the NHPA Section 106 process and Signatory to this Programmatic Agreement (PA); and

WHEREAS, the Lead Historic District is listed in the National Register of Historic Places (NRHP) for its historical significance related to architecture, community development, and mining for the period of 1880 to 1948, and encompasses most of the City of Lead including the Open Cut, contributing primary buildings and additional secondary buildings, and certain structures and objects of the former Homestake Mine some of which are now encompassed in the SURF property; and

WHEREAS, some elements of the Undertaking would be within or adjacent to the Lead Historic District, near properties that are assumed to be eligible for the NRHP but have not been

WHEREAS, DOE and SDSTA, in consultation with the South Dakota State Historic Preservation Officer (SHPO), determined that the Undertaking may have an adverse effect on the Lead Historic District (and potentially other historic properties such as the Mickelson Trail) and that a PA developed in accordance with 36 CFR 800.14(b) will address these potential adverse effects and provide a framework for additional future undertakings at SURF; and

WHEREAS, by letter dated February 25, 2015, DOE, in consultation with SDSTA, notified the ACHP of its intention to develop a PA and the ACHP has determined that it will be a signatory to this agreement; and

WHEREAS, the Cheyenne River Sioux Tribe, Crow Creek Sioux Tribe, Flandreau Santee Sioux Tribe, Lower Brule Sioux, Sisseton-Wahpeton Oyate, Standing Rock Sioux Tribe, Yankton Sioux Tribe, Spirit Lake Sioux Tribe, Three Affiliated Tribes, Turtle Mountain Band of

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Environmental Assessment (DOE/EA-1943), prepared pursuant to the National Environmental Policy Act.

Chippewa Indians, Winnebago Tribe of Nebraska, Santee Sioux Nation, Northern Arapahoe Tribe, Eastern Shoshone Tribe, Northern Cheyenne Tribe, Fort Peck Assiniboine and Sioux, Rosebud Sioux Tribe, Oglala Sioux Tribe, and the Crow Tribe (American Indian Tribes, hereinafter), having connections to the area of the Undertaking, are Consulting Parties to the NHPA Section 106 Process; and

WHEREAS, the City of Lead, representing the residents of Lead, has interests in promoting and ensuring the preservation of the Lead Historic District, and is a Consulting Party to the NHPA Section 106 Process; and

WHEREAS, the City of Deadwood and the South Dakota Game, Fish, and Parks (SDGFP), having management responsibilities over the Mickelson Trail, a portion of which may be affected by the Undertaking, are Consulting Parties to the NHPA Section 106 Process; and

WHEREAS, through numerous public and private meetings, school programs, oral conversations, written correspondence, and through coordination of the NHPA and National Environmental Policy Act (NEPA) compliance process, DOE and SDSTA have provided regular means of involvement to the Consulting Parties and the public regarding the Undertaking; and

WHEREAS, execution of the PA and completion of its terms evidence that DOE has considered the effects of the Undertaking on historic properties and afforded the ACHP, SDSTA, SHPO, American Indian Tribes, Cities of Lead and Deadwood, SDGFP, and the public an opportunity to comment, satisfying DOE's responsibilities under Section 106 of the NHPA.

NOW, THEREFORE, DOE, SHPO, ACHP, SDSTA, and [Others TBD] agree that the Undertaking shall be implemented in accordance with the following stipulations to take into account the potential adverse effects of the Undertaking on historic properties.

STIPULATIONS

The Signatories shall ensure that the following measures are carried out:

1. DOE Authorization to SDSTA

   DOE authorizes SDSTA to carry out the terms of this PA except where DOE's responsibilities are specified in the PA. SDSTA will maintain records of its actions to implement the PA, and will keep DOE informed of its actions.

2. Standards, Definitions, and Qualifications

   A. Standards and Definitions

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Terms used in this PA are defined in 36 CFR Part 800. In addition, the standards and guidance in Appendix B are applicable to this PA.

B. Qualifications

All cultural resources documentation and related work carried out under this PA will be performed by qualified professionals (e.g., architect, historian, architectural historian, archaeologist, who at a minimum meet the Secretary of the Interior's *Professional Qualification Standards* (48 Federal Register (*FR*) 44716, September 26, 1983) and has experience relevant to the type of historic resources being investigated and type of cultural resources investigation.

3. American Indian Tribes

The American Indian Tribes are Consulting Parties to the NHPA Section 106 process, and have a continuing role in it during the implementation of the PA. SDSTA seeks additional opportunities to outreach to American Indian Tribes, and hence, in 2009, SDSTA created a Cultural Advisory Committee. The role of the Committee is to ensure SURF operates in a way that is sensitive to the diverse cultures represented in the City of Lead, the surrounding region and across the State of South Dakota. The Committee will:

- Advise key stakeholders, including the SDSTA Board of Directors, Sanford Lab staff, Sanford Lab's Berkeley Operations Office and members of scientific collaborations;
- Meet quarterly to recommend policies and initiatives that support the facility's commitment to integrate South Dakota's diverse cultures into its operation;
- Encourage SDSTA and Sanford Lab management to actively integrate regional cultures into their designs, procedures and operations.

DOE recognizes the government-to-government relationship between the U.S. Government and each American Indian Tribe. The Tribes and/or DOE will request government-to-government when deemed necessary.

4. Survey-Level Documentation

A. Baseline Documentation of the SURF Property

1.) Documentation will be prepared by SDSTA, in consultation with DOE, consisting of the following:

i. a brief discussion of the historic context for the SURF property, and

ii. an overall site plan(s) of the SURF property.

B. Baseline Documentation of Modified or Disturbed Properties and Associated Complexes

The former Homestake Mine's buildings, structures, and other components were organized into complexes, including but not limited to the Yates Complex, Ross Complex, Ellison Complex, B&M Complex, Kirk Fan Complex, Tramway Complex, and the Oro Hondo Complex. In lieu of surveying and evaluating potentially affected buildings, structures, or components prior to approval of the Undertaking per 36 CFR 800.3, except as outlined in Appendix C, if a building, structure, component, or ground area will be disturbed or modified, the Complex of which it is a part will be documented as detailed in 36 CFR 800.4(b)(2) and outlined below.

1.) Documentation will be prepared by SDSTA, in consultation with DOE, consisting of the following:

i. historic and current photographs of the Complex and each building and structure or component within it (consistent with Stipulation 6.B.1);
ii. a site plan(s) of the Complex;
iii. a SHPO *Intensive Historic Site Survey Form* for each building or structure or component that makes up the Complex;
iv. an evaluation whether the building, structure, or component contributes to the Lead Historic District or is otherwise eligible for listing on the NRHP; and
v. a description of the proposed activity, including disturbance and modifications.

2.) Documentation of a Complex will be submitted by SDSTA for review by the Signatories and Consulting Parties at least 90-days prior to the proposed modification or disturbance. The Signatories and Consulting Parties will be afforded 30 days for their reviews of the documentation once complete information has been provided. If SDSTA does not receive comments on the documentation from a reviewing party within 30 days, it may assume that the party has no comments to offer. At its option, SDSTA may grant any reviewing party additional time for review, or continue consultations with a reviewing party. The SHPO will be provided an opportunity to review and comment on the revised documentation to ensure it addresses submitted comments. The Signatories and Consulting Parties will be provided the final documentation, which will also be made available to other interested parties.

C. Report of Archaeological Survey

Within 60 days of the execution of this PA, DOE, and SDSTA will provide the Signatories and Consulting Parties a plan and schedule for conducting a Level III Intensive Survey of the particular complex(es) per Stipulation 4.B. above. Within 60 days of completing field activities, DOE, and SDSTA will provide the Consulting Parties and Signatories a report that is consistent with guidance found in the document "South Dakota Guidelines for Compliance with the National Historic Preservation Act and South Dakota Codified Law 1-19A-11.1," meeting SHPO Level III standards of the archaeological survey for review per Stipulation 4B.

5. Undertaking Related Project Consultation

A. Exempt List

Projects and activities meeting the Exempt List in Appendix C do not require any review or consultation under 36 CFR Part 800 or this PA. Other projects and activities not meeting the Exempt List would be reviewed per Stipulation 5.B. or C. below.

B. Consultation at Annual Meeting

SDSTA, in consultation with DOE, and the SHPO will plan an annual meeting to discuss projects and needs for the coming year, historic preservation issues, and other matters of interest. At least 30 business days prior to the meeting, SDSTA will provide the SHPO and other Consulting Parties and Signatories with a list of projects planned for the coming year that do not meet the Exempt List (Appendix C). As available, brief descriptions of the projects pursuant to 36 CFR 800.11 will be provided. Concerning the latter, the parties at the Annual Meeting, working collaboratively, will determine whether treatment of historic properties is warranted and the appropriate treatment measure. SDSTA will implement the project with the agreed upon treatment measures. If measures cannot be agreed upon, SDSTA will inform DOE per Stipulation 10. SDSTA will maintain copies of the project documentation and minutes of the meetings.

C. Project Consultation Not at Annual Meeting Same comment as for B, above.

For projects for which there was no consultation at an Annual Meeting, or for which desired documentation was unavailable, SDSTA, in consultation with DOE, will provide the SHPO and Consulting Parties with documentation pursuant to 36 CFR 800.11 and proposed treatment measures if necessary. The parties will be afforded 30 business days from the date of receipt of adequate information to provide written comments and to consult on the treatment measures, if necessary. If SDSTA does not receive comments from a reviewing party within the 30 days, it may assume that the party has no comments to offer. At its option, SDSTA may grant any reviewing party additional time for review, or continue consultations with a reviewing party. SDSTA will implement the project with the agreed upon mitigation measures. If mitigation measures cannot be agreed upon, SDSTA will inform DOE per Stipulation 10.

6. Mitigation of Historic Properties

A. Standard treatment measures for historic properties are outlined in this PA. No separate Section 106 agreement documents (Memorandum of Agreement) are necessary or required under this PA to mitigate Adverse Effects. Consultation and review provisions are set forth in Stipulation 5, above. How would DOE document resolution of adverse effects?

B. Intensive-Level Documentation of Demolished Buildings and Structures

1.) Prior to demolition of a property located within the Lead Historic District or any property individually listed or determined eligible for listing on the NRHP, SDSTA, in consultation with DOE, will document the property as follows:

i. sketch plan
ii. Photographs
   a. exterior and interior
   b. digital
      - 300 dpi; 2000-3000 pixel
      - TIFF (either original or converted)
      - converted to black and white images
      - label that includes name, location, and direction and date of photograph (Example: Ross Boiler,_Lead SD_NW)
      - photographs on CD-R Archival Gold Disk; both disk and case labeled with project name, number and date.

2.) History Report

I. architectural description (can embed images or other pertinent information)
II. building/structure history
   a. information can be obtained from secondary sources
   b. bibliography
III. PDF of report on CD-R Archival Gold Disk (can be on same disk as photographs).

This documentation will be subject to a review per Stipulation 4.B2., and be accepted by the SHPO prior to demolition of the property.

C. New Undertaking-related Above Ground Construction

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When occurring within or near the boundaries of the Lead Historic District, new construction will follow the *Secretary of the Interior's Standards for the Treatment of Historic Properties*, revised 1995, National Park Service, U.S. Department of the Interior, specifically the new construction provisions of the *Standards for the Rehabilitation of Historic Properties* (*Rehabilitation Standards),* which is in the cited *Treatment Standards.*

D. Excavated Rock Transport and Disposal System

1.) The Undertaking will involve the expansion of underground laboratory spaces and removal and transport of excavated rock to either the Gilt Edge Superfund site or Homestake's Open Cut. Removal of underground excavated rock and disposal does not require review by the Signatories and Consulting Parties. The transport of excavated rock to the Open Cut will require design and operation as outlined below.

2.) DOE and SDSTA will design, construct, and operate the excavated rock transport (e.g., truck, rail, pipe conveyor) and disposal system in a manner that minimizes visual, auditory, and vibrations effects to historic properties to the extent feasible. Beginning at the conceptual design stage, DOE and SDSTA will work cooperatively with the Signatories and Consulting Parties to incorporate measures into the design of the transport infrastructure to minimize effects to historic properties. For the rail and/or pipe conveyor transport systems, DOE and SDSTA will use historic photographs and other information about Lead's historic tram mining and recent conveyance infrastructure (such as the pipe conveyor system) as a reference for the design of the new infrastructure. The infrastructure design will follow the new construction recommendations of the Secretary of the Interior's Standards for Rehabilitation and be reviewed per Stipulation 5B/C.

E. Mickelson Trail

Within one year of the execution of this PA, SDSTA, in consultation with DOE, the Cities of Lead and Deadwood, SDGFP, and the SHPO, will install one or more interpretive signs on the Mickelson Trail near the Oro Hondo Complex and at other locations on the trail where Undertaking elements are nearby. The sign(s) will describe the history of the former Homestake Mine and the scientific activities at SURF.

F. Other Mitigation Measures

In addition to the standard mitigation measures described above, SDSTA, in consultation with the other Signatories and Consulting Parties, may adopt other alternative measures to avoid, minimize, or mitigate effects to historic properties including but not limited to developing educational materials, historic property management plans, tribal education and outreach programs etc.. Mitigation may be directly or indirectly related to the Undertaking.

These measures will be subject to SHPO review and acceptance.

7. Historic Preservation Training

The SHPO will be available to provide historic preservation training to SDSTA. DOE, American Indian Tribes, and the other Consulting Parties will be invited to participate in the training. SDSTA and/or SHPO will initiate discussions regarding dates, times, and locations when needs are identified. Topics may include application of the *Rehabilitation Standards*, appropriate methods of maintenance and preservation of historic buildings at the SURF, guidance literature with technical information (*Preservation Bulletins* and *Preservation Briefs*, etc.), and other topics.

8. Discovery During Undertaking Implementation

A. Inadvertent Discovery of Human Remains

1.) In the event of an inadvertent discovery of human remains or funerary objects on state or private lands, the following steps shall be taken pursuant to South Dakota Codified Law Chapter 34-27-25, 34-27-28, 34-27-31 per Appendix D.
2.) For inadvertent discovery of human remains or funerary objects on federal land, SDSTA and DOE will follow the Native American Graves Protection and Repatriation Act (NAGPRA).

B. Inadvertent Discovery of Other Cultural Resources

If a previously undiscovered cultural resource is discovered during construction activities, construction activities will be ceased in the area of the discovery and a buffer zone established (if human remains are discovered, per Appendix D the buffer zone would be a minimum of 150 feet). The property will be secured by SDSTA and protected. SDSTA shall notify DOE immediately of the discovery and contact a qualified professional to evaluate the property for NRHP eligibility. Once the property is assessed, DOE and SDSTA shall notify the SHPO, Cities of Lead and Deadwood, and American Indian Tribes who might attach religious and cultural significance to the affected

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property. The notification shall describe DOE and SDSTA's assessment of the property's NRHP eligibility and actions it proposes to take to resolve the adverse effects based on the qualified professional's assessment. The SHPO and American Indian Tribes shall be afforded three working days from the notification to respond. DOE and SDSTA shall take into account recommendations provided by the SHPO and American Indian Tribes regarding NRHP and any proposed actions, and then carry out appropriate actions. DOE and SDSTA shall provide a report of their actions to the SHPO and American Indian Tribes when they are completed.

9. Dispute Resolution

Should any Signatory object at any time to any actions proposed or the manner in which the terms of this PA are implemented, it should inform SDSTA and DOE. DOE, in consultation with SDSTA, will consult with the party to resolve the objection. If DOE determines that such objection cannot be resolved, DOE will:

A. Forward all documentation reasonably relevant to the dispute, including DOE's proposed resolution, to the ACHP. The ACHP, at its discretion, will provide DOE with its advice on the resolution of the objection within thirty (30) days of receiving reasonably adequate documentation. Before reaching a final decision on the dispute, DOE will prepare a written response that takes into account any timely advice or comments regarding the dispute from the ACHP and other Signatories. Consulting Parties will receive a copy of this written response. DOE will then proceed according to its final decision.

B. If the ACHP does not provide its input regarding the dispute within the thirty (30) day time period, DOE may make a final decision on the dispute and proceed accordingly. Before reaching such a final decision, DOE will prepare a written response that takes into account any timely comments regarding the dispute from the Signatories and Consulting Parties to the PA, and provide them and the ACHP with a copy of such written response.

C. DOE's responsibilities to carry out all other actions subject to the terms of this PA that are not the subject of the dispute remain unchanged.

10. Effective Date and Duration

The terms of this PA will become effective upon the date of the last signature by the Signatories. It will remain effective for the life of the Undertaking, which is 20 years, unless amended or terminated.

11. PA Review

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Suggest breaking amendment into its own stipulation. Typically, Amendments are always possible and not generally prohibited for periods of time.

The Signatories will independently review this PA every year prior to the annual meeting, where continued adequacy will be discussed.

12. Amendment

The PA will be amended when such an amendment is agreed to in writing by the Signatories. The amendment will be effective on the date a copy signed by all the the Signatories is filed with the ACHP or signed by the ACHP if it is participating.

13. Termination

A. If any Signatory to this PA determines that its terms will not or cannot be carried out, that party will immediately consult with the other parties in attempt to develop an amendment. If within thirty (30) days (or another time period agreed to by the other Signatories) an amendment cannot be reached, the objecting Signatory may terminate the PA upon written notification to the other Signatories.

B. Once the PA is terminated, and prior to work continuing on the Undertaking, DOE will either (a) execute another PA pursuant to 36 CFR § 800.6 or 800.14(b), or (b) request, take into account, and respond to the comments of the ACHP under 36 CFR § 800.7. DOE will notify the Signatories as to the course of action it will pursue.

14. Anti-Deficiency Act

Nothing herein will be interpreted to require obligation or payment of funds in violation of the Anti-Deficiency Act, 31 U.S.C. Sec. 1341. This PA is neither a fiscal nor a funds obligation document. Nothing in this PA authorizes or obligates DOE to expend, exchange, or reimburse funds, services or supplies, or to transfer or receive anything of value. Always a good idea to incorporate anti deficiency act stipulations in PA's.

15. Availability of Funds

DOE obligations are subject to funds appropriated by the Congress of the United States for this purpose.

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SIGNATORIES

U.S. DEPARTMENT OF ENERGY

____ Date: __________
Michael J. Weis, Site Manager, Fermi Site Office

SOUTH DAKOTA STATE HISTORIC PRESERVATION OFFICE

____ Date: __________
Jay D. Vogt, State Historic Preservation Officer

ADVISORY COUNCIL ON HISTORIC PRESERVATION

____ Date: __________
John M. Fowler, Executive Director

SOUTH DAKOTA SCIENCE AND TECHNOLOGY AUTHORITY

____ **Date: __________**
Mike Headley, Executive Director

PA SIGNATORY STATUS TO BE DETERMINED

CHEYENNE RIVER SIOUX TRIBE

____ Date: __________
Chairman

CROW CREEK SIOUX TRIBE

____ Date: __________
Chairwoman

FLANDREAU SANTEE SIOUX TRIBE

____ Date: __________
President

LOWER BRULE SIOUX

____ Date: __________
Chairman

DRAFT

SISSETON-WAHPETON OYATE

____ Date: __________
Chairman

STANDING ROCK SIOUX TRIBE

____ Date: __________
Chairman

YANKTON SIOUX TRIBE

____ Date: __________
Chairman

SPIRIT LAKE SIOUX TRIBE

____ Date: __________
Chairwoman

THREE AFFILIATED TRIBES

____ Date: __________
Chairman

TURTLE MOUNTAIN BAND OF CHIPPEWA INDIANS

____ Date: __________
Chairman

WINNEBAGO TRIBE OF NEBRASKA

____ Date: __________
Chairman

SANTEE SIOUX NATION

____ Date: __________
Chairman

DRAFT

NORTHERN ARAPAHOE TRIBE

____ Date: __________
Chairman

EASTERN SHOSHONE TRIBE

____ Date: __________
Chairman

NORTHERN CHEYENNE TRIBE

____ Date: __________
President

FORT PECK ASSINIBOINE AND SIOUX

____ Date: __________
Chairman

ROSEBUD SIOUX TRIBE

____ Date: __________
President

OGLALA SIOUX TRIBE

____ Date: __________
President

CROW TRIBE

____ Date: __________
Chairman

CITY OF LEAD, SOUTH DAKOTA

____ Date: __________
Mayor

DRAFT

SOUTH DAKOTA GAME, FISH, AND PARKS

____ Date: __________
Manager of Parks

U.S. DEPARTMENT OF ENERGY, OAK RIDGE NATIONAL LABORATORY SITE OFFICE

____ Date: __________
Site Manager

U.S. DEPARTMENT OF ENERGY, BERKELEY SITE OFFICE

____ Date: __________
Acting Site Manager

FERMI RESEARCH ALLIANCE, LLC

____ Date: __________
President

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Appendix A-1

Undertaking Background and Description

Background:

The SURF site is contained within a footprint of the former Homestake Mine which was the largest gold mine in the western Hemisphere producing over 40 million ounces of gold during its operational years of 1875 (discovery) through 2001 (closure). The Cities of Lead and Deadwood, SD developed coincident with mining. Lead in particular was intertwined with the mine development as it was home to miners and was regularly impacted by Mine development. Much of the City's infrastructure was operated or supported by Homestake.

Most of the City of Lead has been included in a National Register of Historic Places (NRHP) District ('District') because of its historical significance as a mining community. Section 106 of National Historic Preservation Act (NHPA) requires federal agencies to take into account the effects of its undertakings on any district, site, building, structure or object that is included in or eligible for inclusion in the NRHP. A goal of Section 106 is to identify and to consider historic properties that might be affected by a new project and attempt to resolve any adverse effects through consultation.

The South Dakota SHPO was contacted concerning Section 106 compliance because of the large size of the District, the geographical extent of the Proposed Action in and near the District, and number of structures that would likely be contributing resources to the District that may have an adverse effect on the district. In 2013 the SHPO met with SURF on-site and toured potentially affected areas inside and outside the District. The SHPO recommended development of a Programmatic Agreement (PA) per 36 CFR 800.14(b). The PA outlines actions necessary to ensure necessary Section 106 consultation for the LBNF/DUNE undertaking *and* for future federally funded undertakings that will result in surface construction/disturbance or building(s) alteration.

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Description of Undertaking:

The U.S. Department of Energy (DOE) is proposing to construct and operate the Long-Baseline Neutrino Facility and Deep Underground Neutrino Experiment (LBNF/DUNE) with facilities at the Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois, and the Sanford Underground Research Facility (SURF) in Lead, South Dakota. An Environmental Assessment (EA) is currently being prepared pursuant to the National Environmental Policy Act (NEPA). Under the Proposed Action and Alternative A, Fermilab would construct new facilities that would extract a proton beam from their existing particle accelerator, generate from that a high-intensity neutrino beam, and then direct the beam at a detector(s) constructed 1,300 kilometers away at SURF in Lead, South Dakota. The beam would be generated underground and would travel through the Earth at depths of up to 20 miles. The EA would determine potential impacts to the human health and the environment from LBNF/DUNE, one of which is related to cultural resources at the SURF site. Particularly important is the identification of existing and eligible historic properties in and near the SURF site that may be impacted due to construction and operation of the LBNF/DUNE, as well as plans for addressing those impacts. The Undertaking pursuant to the National Historic Preservation Act is limited to those activities described in the EA which would occur at or around the SURF site.

- One underground liquid argon detector with four detector modules (Far Detector);
- A new surface building to support the underground detector. This building would replace the existing Ross boiler building and its associated stack. The new structure would consist of mechanical and electrical components to facilitate delivery of liquid argon and liquid nitrogen to the 4850 Level;
- A conveyance system that would move approximately 460,000 yds^3 of rock required to create an underground cavern large enough to house the neutrino detector and supporting infrastructure. The rock would be hoisted to the surface and conveyed to the Gilt Edge Superfund Site or Homestake's Open Cut. Conveyance methods could include:
  i. Conveyor/Trucking - a newly constructed conveyor would transport rock southwest to Kirk Road. The conveyor would dump into a truck load-out bin. Trucks would haul the rock to the Gilt Edge Superfund Site, using Kirk Road, Highway 385, and the Gilt Edge Road, *or* to the Open Cut, using Kirk Road, U.S. Highway 85, U.S. Highway 14A, and Homestake's private access road.
  ii. Combination rail-pipe conveyor - rock would be moved to the Open Cut using Homestake's former tramway and pipe conveyor corridors. The underground tramway's rail line would be rehabilitated and used to move rock 1-mile to a transfer station near the tramway's portal. A *new* pipe conveyor would be loaded and transport the rock to the Open Cut utilizing the former Open Cut pipe conveyor corridor.
  iii. Rail line - rock would be conveyed to the Open Cut via the existing tramway and the pipe conveyor corridors using a narrow gage rail line and rail cars. No transfer station or pipe conveyor would be utilized.
- Reasonably foreseeable future physics experiments also investigating fundamental particles. These experiments would be smaller, both individually and in aggregate. Features include:
  i. Excavation of a total of approximately 153,000 yd^3 (250,000 tons) of rock to create underground caverns for equipment and working space.
  ii. The excavation and construction would occur after that for the liquid argon detector and support building described above. Excavated rock could be disposed of in existing underground spaces or be dispositioned similarly to the three methods described above.

iii. Construction of potential surface support structures.

Approximate Schedule:

Site preparation and excavation, including transportation of excavated rock	2017 – 2021
Buildings and infrastructure	2017 – 2021
Underground installation	2020 – 2023
Cryogenics construction and filling	2023 – 2024
Operations	2024 – 2044
Decommissioning	2044 – 2054

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Appendix A-2

Area of Potential Effect

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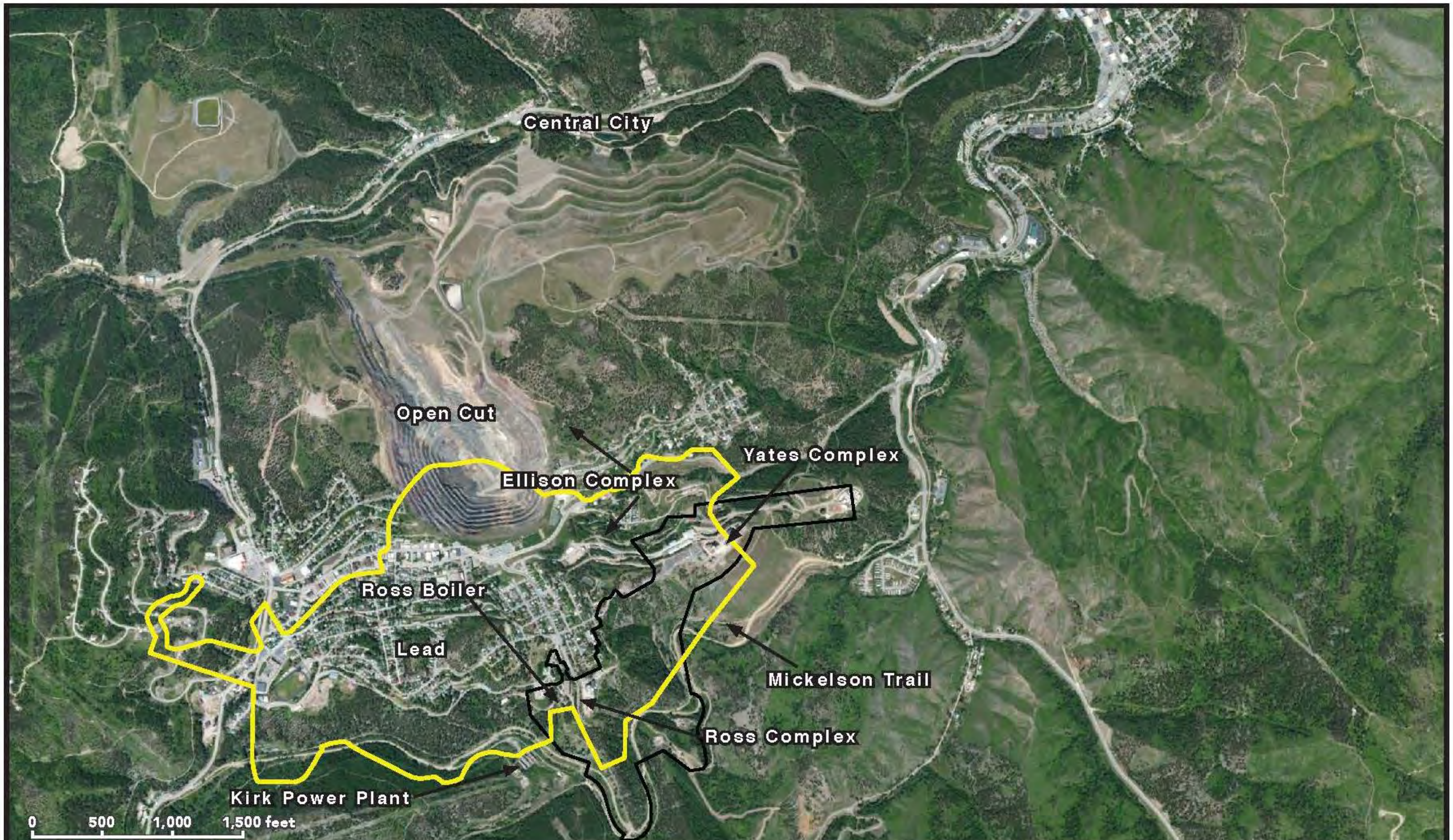
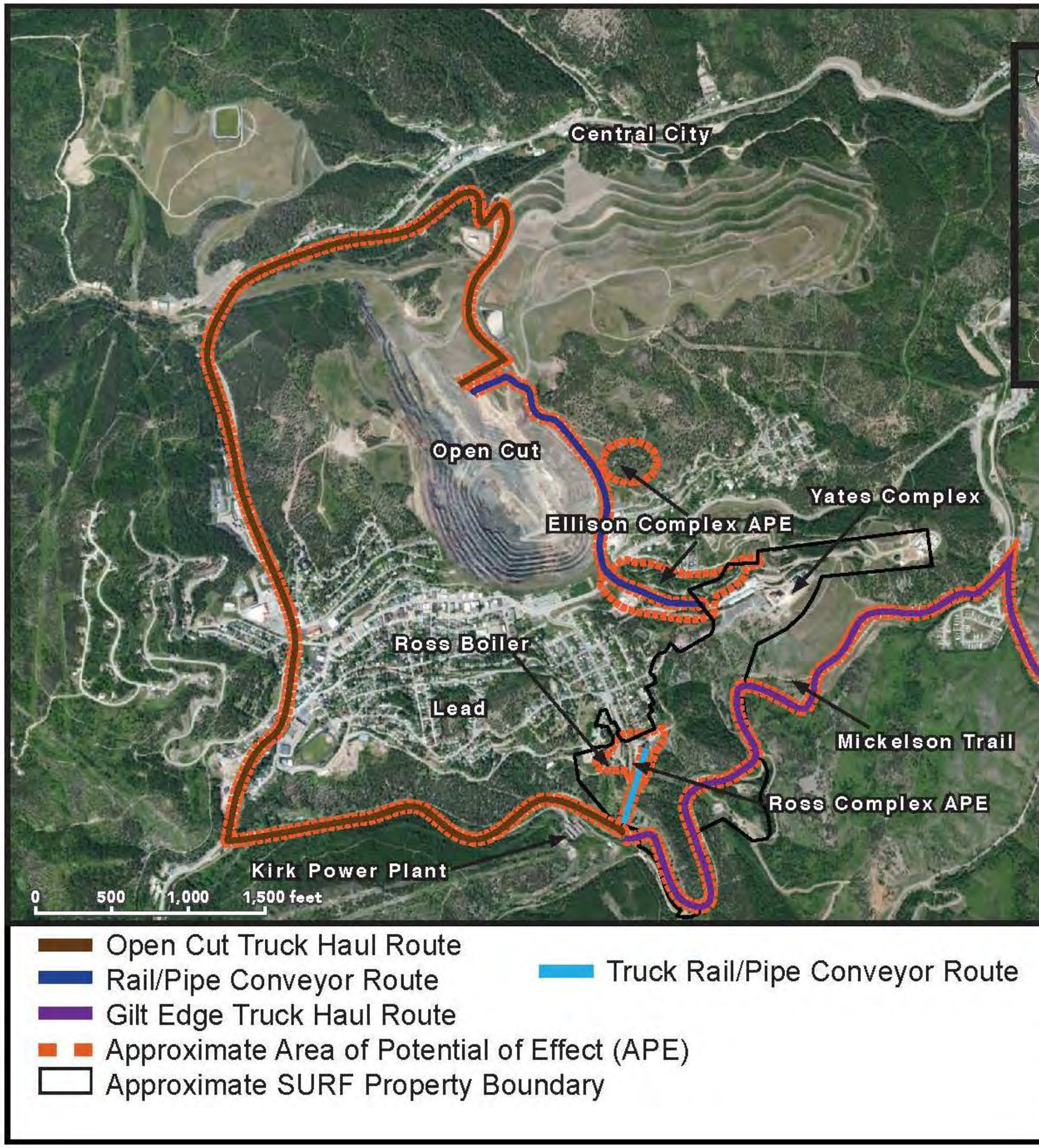


Approximate SURF Property Boundary
Approximate Lead Historic District Boundary

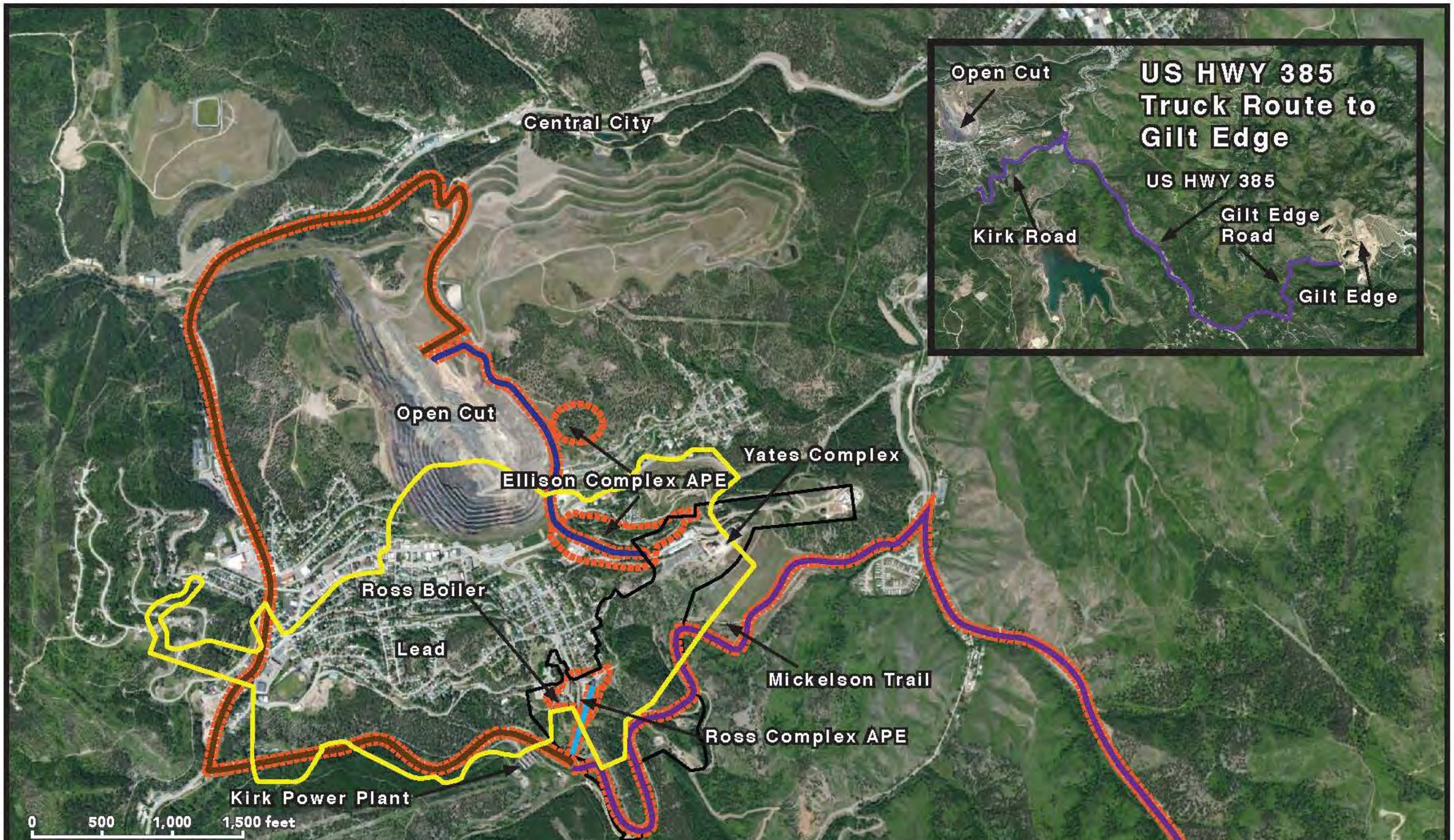
LBNF/DUNE PA	Figure 1
Lead Historic District and Sanford Underground Research Facility Boundry	



LBNF/DUNE PA

Figure 2

Area of Potential Effect for LBNF/DUNE



Open Cut Truck Haul Route
Rail/Pipe Conveyor Route
Gilt Edge Truck Haul Route
Approximate Area of Potential of Effect (APE)
Approximate SURF Property Boundary
Approximate Lead Historic District Boundary
Truck Rail/Pipe Conveyor Route

LBNF/DUNE PA

Figure 3

Combined Area of Potential Effect for LBNF/DUNE and Lead Historic District

Appendix B
Applicable Terms, Standards, and Guidance

Terms used in this PA are defined in 36 CFR Part 800. In addition, the following standards and guidance are applicable to this PA.

A. The Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation* (48 Federal Register (FR) 44716-42, September 26, 1983) (including the *Standards for the Rehabilitation of Historic Properties* (Rehabilitation Standards), *Standards for the Identification and Evaluation of Historic Properties* (Identification and Evaluation Standards), and *Standards for the Documentation of Historic Properties* (Documentation Standards), and *Professional Qualification Standards*)

B. *South Dakota Historic Resource Survey Manual* (Architectural) (2006), South Dakota State Historic Preservation Office

C. *South Dakota Guidelines for Compliance with the National Historic Preservation Act and South Dakota Codified Law 1-19a-11.1* (2012), South Dakota State Historic Preservation Office

D. ACHP, *Guidance on Conducting Archeology Under Section 106* (2007)

E. ACHP, *Policy Statement Regarding the Treatment of Burial Sites, Human Remains, and Funerary Objects* (2007)

F. ACHP, *Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities* (1991)

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Appendix C

Activities that Do Not Have the Potential to Adversely Affect Historic Properties and that are Exempt from SHPO Review

The following activities are considered not likely to cause adverse effects to historic properties to warrant documentation and consultation under this PA. These activities may be performed by SDSTA without further review under the PA or providing information to the Signatories or Consulting Parties.

1. All activities occurring underground inside the former Homestake Mine.
2. Work, except building additions, on buildings less than 45 years of age.
3. Repointing with mortar that matches the original in color and composition. Joint profile and tooling must be the same.
4. Painting or paint removal so long as removal does not use high powered water or sand blasting.
5. In-kind replacement of roofing, siding, foundation, windows, and doors.
6. Minor alterations of roofline that do not change the overall appearance of the roof.
7. HVAC/mechanical work on buildings unless it requires significant physical alteration of the architecture.
8. Maintenance of landscaping, parking lots, and supply areas.
9. Construction of new parking areas in previously disturbed areas.
10. Routine repair of landscape and facilities due to storm damage to return operations.
11. Transport and placement of excavated rock in the Open Cut or transport to the Gilt Edge Site.
12. Transportation of construction materials or excavated rock on existing roads that are not adjacent to or pass through historic properties or districts.
13. Installation of subsurface utilities in areas of previous disturbance.
14. Maintenance of existing roads on or off SDSTA property.
15. Use materials from a commercial source such as gravel, sand, borrow, etc.

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Appendix D

Procedures for Discovery of Human Remains on State or Private Lands

(State Burial Procedure)

In the event of an inadvertent discovery of human remains or funerary objects the following steps shall be taken pursuant to South Dakota Codified Law Chapter 34-27-25, 34-27-28, 34-27-31.

1. SDSTA and its contractors shall immediately halt construction activities within a 150 foot radius from the point of discovery and implement measures to protect the discovery from looting and vandalism. No digging, collecting, or moving human remains or other items shall occur after the initial discovery. Protection measures may include the following:

   a. Flag the buffer zone around the find spot;
   b. Keep workers, press, and curiosity seekers, away from the find spot;
   c. Tarp the find spot;
   d. Prohibit photography of the find unless requested by an agency official; and
   e. Have an individual stay at the location to prevent further disturbance until a law enforcement officer arrives.

2. SDSTA shall notify local law enforcement and DOE, and the South Dakota State Archaeologist (State Archaeologist) within forty-eight (48) hours of the discovery.

3. SDSTA, in consultation with DOE, shall notify the South Dakota State Historic Preservation Office (SHPO), American Indian Tribes, and other Consulting Parties within forty-eight (48) hours of the discovery.

4. If local law enforcement determines that the remains are not associated with a crime, SDSTA, in consultation with DOE, shall determine if it is prudent and feasible to avoid disturbing the remains. If SDSTA in consultation with DOE, determines that disturbance cannot be avoided, DOE, in consultation with SDSTA, shall consult with the State Archaeologist, SHPO, American Indian Tribes, and other Consulting Parties to determine acceptable procedures for the removal, treatment, and disposition of the burial or remains. DOE shall ensure that SDSTA implements the plan for removal, treatment, and disposition of the burial or remains as authorized by the South Dakota State Archaeologist.

5. DOE shall notify the SDSTA that they may resume construction activities in the area of the discovery upon completion of the plan authorized by the State Archaeologist.

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APPENDIX D

SURF Geochemical Characterization Report

Geochemical Characterization of Development Rock LBNE South Dakota

Report Prepared for

SURF

Sanford Underground Research Facility

Report Prepared by

GEOCHIMICA

srk consulting

Geochimica and SRK Consulting (U.S.), Inc.
SRK Project Number 184001.120
January 15, 2015

Geochemical Characterization of Development Rock LBNE South Dakota

SURF

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SRK Project Number 184001.120

January 15, 2015

Authors:
Mark Logsdon, Principal Geochemist, Geochimica, Inc.
David Bird, Principal Consultant, SRK Consulting

Reviewed by:
Larry Cope, Principal Consultant, SRK Consulting

Executive Summary

The Sanford Underground Research Facility requested that Geochimica, Inc. and SRK Consulting (U.S.), Inc. (SRK) conduct a geochemical characterization program to test the development rock that will be excavated for construction of the Long Baseline Neutrino Experiment (LBNE) Far Site Detector at the former Homestake Mine in Lead, South Dakota. The geochemical characterization is to be technically sufficient to support evaluation of potential water-quality impacts at the level of an Environmental Assessment in accordance with the National Environmental Policy Act. As the project developed, it became important to consider the impacts to water resources with respect to two specific locations for potential disposal, the Gilt Edge Superfund Site (Gilt Edge), and the Homestake Open Cut.

The principal geochemical risks to water quality associated with the development rock would be metal-leaching and acid-rock drainage (ML/ARD). Samples for testing were developed using stratified random sampling; the random samples were supplemented by additional samples selected by the Project Geochemist to represent features (such as accumulations of sulfide minerals or carbonates, and zones of high concentrations of graphite) that might have special geochemical characteristics that would not necessarily be captured by random sampling. Thirty-six (36) samples were collected to represent the spatial distribution, lithologic variability, and mineralogical variability of rocks from the LBNE 4850 Level cavern complex. The geochemical characterization and risks were addressed using:

- Static geochemical tests (acid-base accounting, net acid generation (NAG) testing, whole-rock chemical analyses, and petrography/mineralogy); and
- Short-term leaching tests, including solution chemistry for effluents from the NAG tests on individual sample intervals, and Meteoric Water Mobility Procedure (MWMP) tests were run on four composited samples.

Based on geologic core logging and cavern design, 90% of the development rock will be Precambrian schist, of which about 27% is notably graphite rich. The remaining 10% of the rock is Tertiary felsic intrusives present as dikes and stringers in the schist. Major mineralogical features of significance include:

- Pyrite and pyrrhotite in both the schist and the rhyolite. These sulfide minerals, if allowed to oxidize could generate acidity and dissolved sulfate and other TDS (Total Dissolved Solids) components;
- High neutralization potential in the schist, developed from widespread carbonate layers and veins. Detailed analysis shows the carbonates to be predominantly calcite and dolomite that are readily available to provide alkalinity. There is available neutralization potential from silicate minerals in the rhyolite stringers; and
- The neutralization potential of the LBNE development rocks is sufficiently great that it would provide excess neutralization potential against acidification by effluents from other rocks, such as some that may be managed at the Gilt Edge site.
- Leach testing by two procedures (Net Acid Generation and Meteoric Water Mobility Procedure) show that weathering effluents would have neutral to slightly alkaline pH, and that trace metals would be controlled at those pH ranges to part per billion to tens of parts

per billion levels. For example, median values for dissolved As and Se in the leach tests were <1 ug/L to 8 ug/L, respectively.

Kinetic limitations, both chemical and transport, on metals leachability are expected to control water-quality impacts from the LBNE development rock to levels near detection limits, provided reasonable engineering and hydraulic controls are available at either the Gilt Edge or Homestake Open Cut sites. Such engineering designs and calculations are outside the scope of this geochemical study.

On an integrated basis across the entire mass of rock tested, Geochimica/SRK consider that the geochemical characteristics indicate no risk of net acidification and very low risk of metals impacts to water resources were the development rock to be disposed at the Gilt Edge site. The potential benefits to the closure derived from the excess available neutralization potential more than offsets the risks of ML/ARD from these materials.

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Appendices

1 Introduction

The Long Baseline Neutrino Experiment (LBNE) Far Site Detector is operated by the Sanford Underground Research Facility (SURF) of Fermi National Accelerator Laboratory (Fermilab) at the former Homestake Mine in Lead, South Dakota. Construction of the LBNE Far Site Detector will require excavation of an estimated 460,000 cubic yards of development rock to create an underground cavern that will accommodate the detector. The location and two layout alternatives of the caverns are shown on Figures 1 through 3.

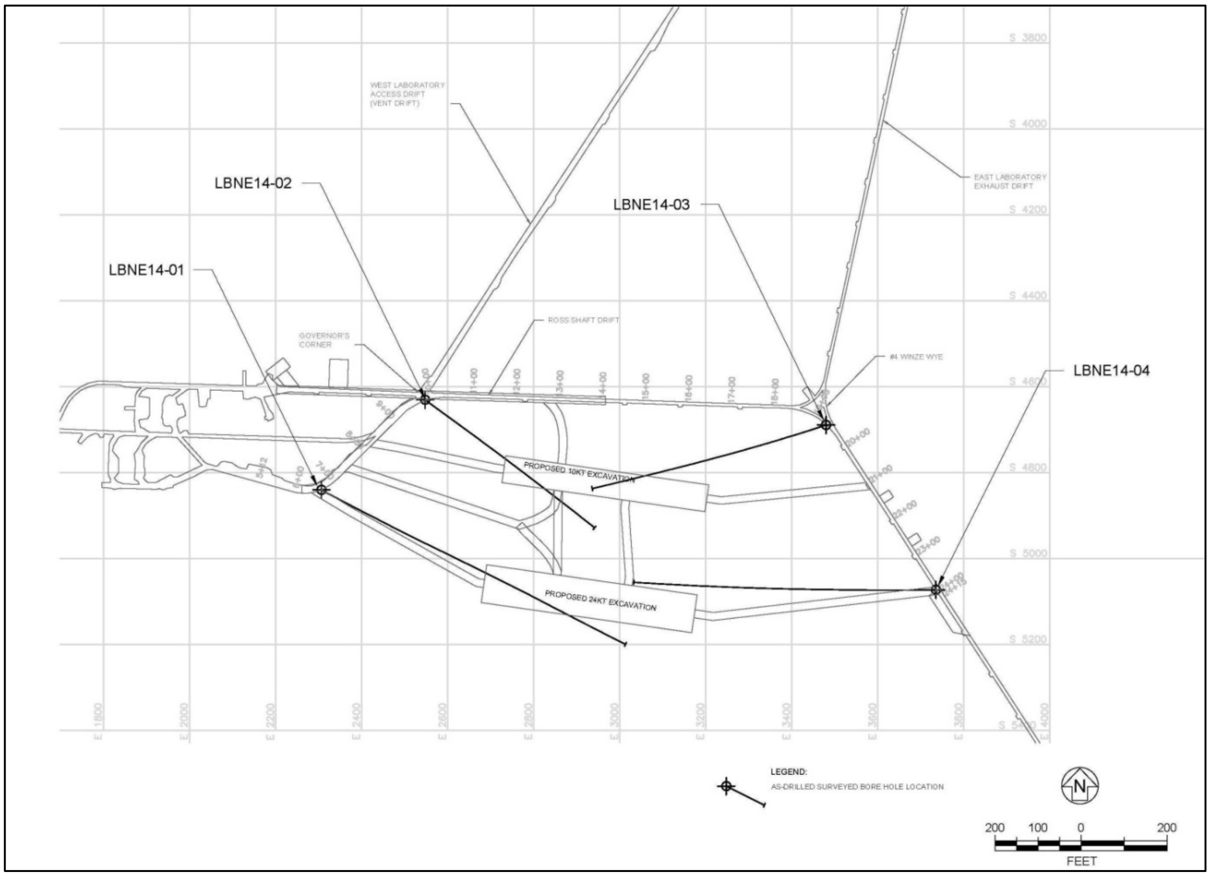

Figure 1: Location Map of 4850 Level and LBNE Cavern Complex Showing Boreholes LBNE 14-01 through LBNE 14-04

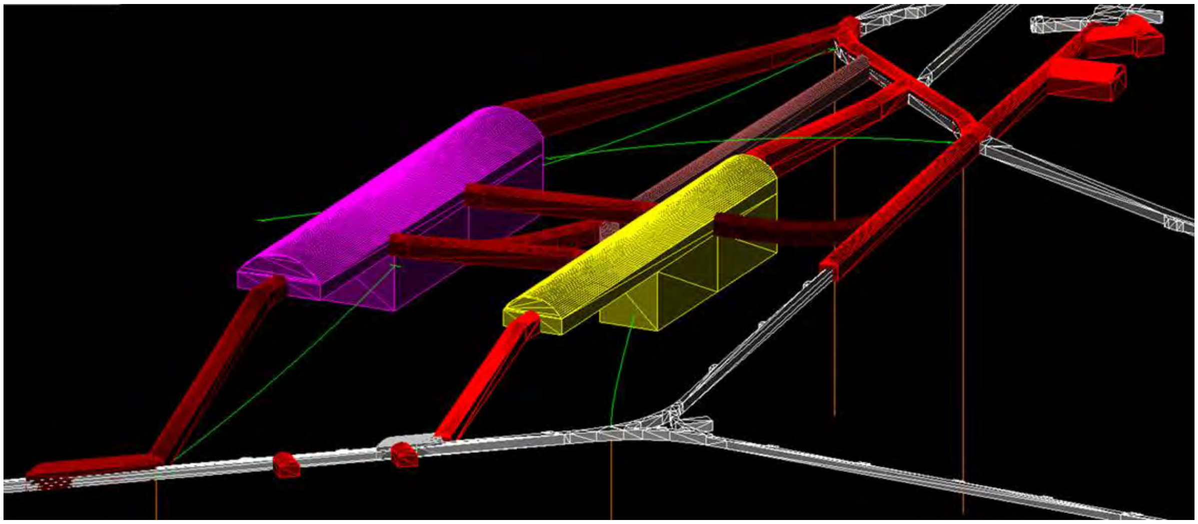

Figure 2: Isometric Drawing of LBNE Cavern Complex, View From Above Looking Southwest (drawing provided by ARUP)

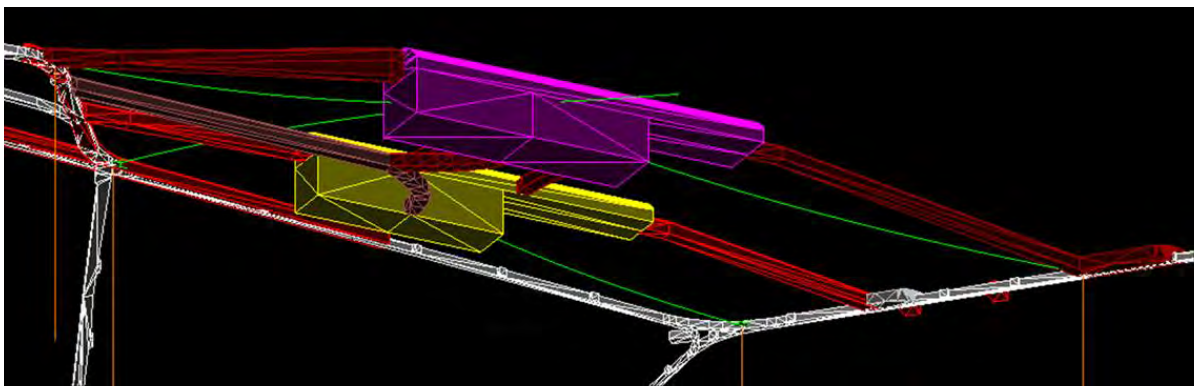

Figure 3: Isometric Drawing of LBNE Cavern Complex, View From Below Looking Northeast (drawing provided by ARUP)

In accordance with National Environmental Policy Act (NEPA) regulations, Fermilab is required to submit an Environmental Assessment (EA) for the project. One component of the EA is an assessment of the potential water quality impacts that could result from the development rock after its disposal above ground.

In support of the project EA, Geochimica, Inc. (Geochimica) and SRK Consulting (US), Inc. (SRK) jointly conducted a geochemical characterization program to test the development rock that will be excavated and to evaluate the potential for the rock to produce ML/ARD impacts after disposal. The initial terms of reference for the geochemical investigations were to prepare a technical evaluation of the risk of ML/ARD at a level of detail sufficient to support an EA; the work was intended to be comparable in scope and detail to prior EA-level investigations. Specifically, the work was intended and was technically scoped to be consistent with that documented for the DUSEL LC-1 excavations in 2010 (Geochimica, 2010). The program evolved during its development to focus particularly on interactions between the LBNE development rock and the environmental conditions relevant to two specific, potential disposal sites to assess the potential for water-quality impacts from the waste rock generated by the LBNE excavation.

Two alternatives for development rock disposal are under consideration. The favored alternative (Proposed Action) is to place the rock at the Gilt Edge site located about 7 miles southeast of the SURF property. The Gilt Edge site is owned by the State of South Dakota and would otherwise use the LBNE cavern developmental rock to facilitate site closure. This use becomes especially important if the LBNE development rock neutralizes acid mine drainage and provides no or very little added liability to Gilt Edge in terms of leachable metals. As the geochemical characterization developed, increasing importance was attached to establishing potential water-quality impacts if the rocks were to be disposed at that site. However, it should be noted that the Geochimica/SRK project team are not contractors for the Gilt Edge Superfund evaluation, and the project team did not have any engineering plans for the Gilt Edge site while planning and executing this geochemical work. As such, the level of detail for the geochemical impacts remains those of an EA. It is assumed that this technical work would be made available to the agencies working on the Gilt Edge closure for their consideration and use by their engineering contractors.

The second alternative is to place the rock in the existing Open Cut of the Homestake Mine. Advantages of this alternative include proximity to the source and hydrologic control. Incident rain water and snow melt that infiltrate into the development rock would drain downward and eventually report to the underground workings where it would be collected and treated through SURF’s Waste Water Treatment plant. This is the same conceptual end-use considered in the 2010 DUSEL studies (Geochimica, 2010).

1.1 Purpose and Objectives

The geochemical characterization described in this report is a due-diligence level review of the potential geochemical issues associated with disposal of LBNE cavern rock in a surface environment, with emphasis on potential disposal at the Gilt Edge site. The information and conclusions of this report are based on existing information and scoping-level geochemical tests. The purpose of this report is to describe the nature and extent of risks of ML/ARD from the rocks to be excavated for the LBNE cavern complex at a level of detail necessary and sufficient to determine excavation and management options for development rock from the LBNE cavern complex. Specific objectives of the study and its report include:

- Describe the technical approach of the investigation;
- Review and evaluate the basic geologic and mineralogical controls relevant to geochemical reactivity in the rocks that will be excavated;
- Collect and document samples from relevant drill core and in-place rock that can be used to reliably assess the geochemical reactivity of the LBNE cavern complex rocks;
- Determine, compile, and evaluate data for the static acid-base accounting of representative samples. The acid-base account is evaluated through multiple, independent tests to provide confirmation of the inferences drawn from the static tests;

- Determine, compile, and evaluate whole-rock chemistry including trace-metals concentrations of the LBNE cavern complex rocks[1];
- Determine, compile, and evaluate data on the leachability of metals from the LBNE cavern complex rocks using both a static leach method (NAG, Stewart et al., 2006) tied specifically to evaluation of the acid-generating potential of the rocks and also a dynamic leaching procedure (MWMP; ASTM, 2002) that is widely used in the western United States for assessing leachability of mined rock;
- Evaluate the mineralogy of samples (by major rock type) from the LBNE cavern complex to help interpret both the geochemical test data and the likely behaviors of the rocks when disposed;
- Consider other data available from Homestake-Barrick studies that are relevant to leaching of LBNE cavern complex development rock under ambient environmental conditions above ground;
- Evaluate the uncertainties in interpretation that may arise from test methods, sampling, and limitations of basic geochemical knowledge;
- Reach geochemical conclusions and recommendations to consider in plans for management of the development rock from the LBNE cavern complex. The conclusions will include consideration of advantages and disadvantages to major disposal options in light of risks that may exist from geochemical reactivity; and
- Provide, in attachments and archival data, the full documentation of the investigation for SURF's long-term records as well as to support the analysis presented in the main report.

1.2 The Investigation Team

The geochemical studies were planned by Geochimica, Inc. (Aptos, CA). Mark J. Logsdon was Project Principal and responsible geochemist. He has worked at the Homestake Mine in Lead in a variety of geochemical projects for approximately 19 years. Dave Bird, P.G. and Principal Geochemist with SRK Consulting in Denver, Colorado, conducted the field sample collection of core and underground rock chips from the 4850 level. Detailed petrographic analyses (microscopic and X-ray diffraction) were performed by Dr. Paula L. Hansley of Petrographic Consultants International (Louisville, CO). The petrographic report is provided in Attachment 1 to this report.

Laboratory analyses of geochemical properties, including acid-base accounting, total metals in rocks, and aqueous chemistry of effluents from leach testing, were performed by ACZ laboratories in Steamboat Springs, Colorado. Their formal analytical reports and QC/QA are provided in full in Attachment 2 to this report.

Project management, safety training, and logistical support (including underground geological expertise and sample handling and preparation assistance to Dave Bird) was provided by Mr. John Scheetz and his staff and colleagues at SURF. Mr. Dakotah Simpson of SURF did the majority of the work in sample collection, helping move core boxes and operating the diamond saw to split the core for sampling.

[1] Note that this is the total-metals concentration in the solid rocks that were sampled, not total metals concentrations in surface waters that would form at any disposal site. Total-metals concentrations in solids is a basic set of geochemical data, related to the formation of the lithologic units and their subsequent geochemical history. These data are standard part of all baseline geochemical characterization programs.

2 Methods

The technical approach for the present investigation was based closely on the structure of the geochemical characterization program conducted at the site by Geochimica in 2010 (Geochimica, 2010). The 2010 investigation resulted in a successful characterization of the development rock proposed for excavation of the DUSEL LC-1 complex, also located at the 4850 Level of the Homestake Mine. Given the proximity and similarity of this program to the last, it was logical to structure this investigation to parallel that program. Steps of the current investigation can be summarized as follows:

1. Geochimica reviewed the extensive body of work from the 2010 program as well as the open literature to build a basis of understanding that would guide the sampling requirements and formulation of a sampling strategy. The review included findings by Dr. David Jacobs, Ph.D., P.G., of Geochimica from a site visit he conducted in conjunction with the 2010 program. Based on the 2010 program findings and the understanding of geology of the LBNE cavern complex, it was determined that the existing geologic model was valid and could be extrapolated to the strata intersected in the LBNE cavern complex.
2. Prior to the geochemical investigations, the LBNE project team had developed four geotechnical characterization holes (LBNE14-01 through LBNE 14-04, shown on Figure 1), drilled from the 4850 level toward the cavern complex to assess the geology and engineering characteristics of the LBNE cavern zone. Geologic logs from these four boreholes were examined to understand the types and distributions of primary lithologies, secondary minerals, structural features, and anomalous occurrences of environmentally important minerals such as sulfides and carbonates.
3. Geochimica determined that a sample size of 36 would be sufficient to provide statistically valid representation (Garrett, 1979; Stanley, 2010) of the geochemical characteristics of rocks around the LBNE cavern complex sampled in the Project geotechnical drilling program.
4. A list of 20 representative drill core sample intervals (5 from each borehole) was generated using a random stratified selection method that assured uniform but unbiased representation throughout the length of each of the four boreholes while at the same time avoiding sample clustering. An additional three samples per borehole (12 total) were reserved and selected on site as representative “discretionary” samples based on features that were identified in hand specimen and considered to be important from the standpoint of environmental impacts. Examples include strongly sulfidic or graphitic zones. Finally, an additional four rock chip samples would be selected and recovered from in situ wallrock on the 4850 level. The random stratified sampling method allows us to use statistics with confidence, and the additional samples ensure that major features, such as zones of concentrated sulfides or carbonates, are tested geochemically.
5. SRK geochemist Dave Bird visited the site, examined each pre-selected drill core interval to ensure sample integrity and representation, and recovered the samples for preparation. A SURF technician was responsible for splitting the core sample intervals using a diamond saw. After sawing, the samples were packaged in cloth sample bags which were subsequently repackaged in 5-gallon buckets for shipment to ACZ Laboratories.

6. Dr. Paula L. Hansley of Petrographic Consultants International (PCI) in Louisville, CO evaluated the mineralogy of a subset of 13 samples by optical petrography. Four of the samples were also examined by X-ray diffraction analysis to confirm identification of contained minerals. Two samples were analyzed by scanning electron microscopy (SEM).
7. Geochimica/SRK compiled and analyzed the geochemical data reports from ACZ and PCI using methods that are international best-practices for evaluating the potential for impacts from geochemical reactivity from sulfide mine rocks, as documented in handbooks and publications from the United States (e.g., Sobek et al. (U.S. EPA), 1978; McLemore, 2008)); Canada (MEND, 2009; ACMER, 2000), Australia (AMIRA, 2002), and Europe (ERMITE, 2009); and peer-reviewed, open-literature sources that include studies from South America, Africa, and the European Union [e.g., the nine published symposia of the International Conference on Acid Rock Drainage (ICARD) and the publications and reports of the International Network for Acid Prevention (INAP)].
8. Based on its synthesis of the geochemical analyses, Geochimica/SRK formulated conclusions and recommendations with respect to management options for disposal of the development rocks from the LBNE cavern complex.

3 Geologic Background

The Homestake Mine, now the proposed site of the LBNE Far Site Detector, is an early Proterozoic (Precambrian) iron-formation hosted gold deposit in the Northern Black Hills, South Dakota. Mined since 1876, it is the largest known iron-formation hosted gold deposit in the world. The complete geologic history of the Black Hills is long and complex, with rock units formed from the Archean (2.5 Ga) to Holocene (Recent) time. There have been multiple periods of metamorphism (pro- and retrograde), complex structural deformations, and intrusions of existing rocks by younger igneous intrusions. Most of the metamorphic and intrusive events included movement of fluids through portions of the system, including the hydrothermal systems that led to precipitation of pyrite (FeS2), pyrrhotite (Fe1-xS), other minor sulfides, carbonates, and various silicate minerals.

For a comprehensive discussion of the geology of the Black Hills and the Homestake deposit, readers should consult Caddey et al. (1991). Briefer introductions (not entirely consistent in detailed interpretations) are available in Guilbert and Park (1986), Redden and Lisenbee (1990), Rogers (1990), and Unzular et al. (1990). The Rogers article is specific to the Precambrian rocks of the Poorman Anticlinorium in the immediate vicinity of the Homestake Mine. Recent advances in the geologic understanding of the underground zone near the proposed LBNE cavern complex are described in Terry and Redden (2008) and Terry (2010). Much of the discussion below is taken from Caddey et al. (1991), and supplemented by information developed in 2010 by Dr. Jacobs at the mine and in discussions with the Homestake-Barrick geologists and the petrographic descriptions of the samples of this project (Hansley, 2014, Attachment 1).

The LBNE cavern complex rocks comprise two basic lithologic units:

1. Dark, Precambrian phyllite/schist (approximately 90% of the rock, based on core from the four boreholes drilled toward and into the cavern complex from the 4850L drifts). Descriptions of the schist in geologic logs include sericite-carbonate-quartz schist (~61%), graphitic sericite-carbonate-quartz schist (~14%), graphitic schist (~13%), and unaltered schist (~2%). This unit is referred to as phyllite in some reports (ARUP, 2013; Hansley, 2014, Attachment 1), and schist in the geologic logs. The minor difference in lithologic terminology between phyllite and schist is not relevant to the geochemical behavior of the development rock.
2. Tertiary felsic intrusives of dacite to rhyolite composition (approximately 10% of the rock), distributed as veins and veinlets surrounded by the metasedimentary phyllite/schist.

The schist is part of the Poorman Formation, the oldest of the Precambrian rock units exposed at the mine and stratigraphically below the gold-bearing Homestake Formation. The schist overlies the lowest unit of the Poorman Formation, which is an amphibolite referred to at the site as the Yates Member, the term adopted by Caddey et al. (1991) and which is used in this report also. The Yates Member is different from the graphitic schist of the upper portion of the Poorman Formation, which is relatively higher in trace elements that Rogers (1990) discusses. The Yates Member rocks of the Poorman are not exposed near the 4850 Level cavern area and will not be excavated as part of LBNE cavern complex.

The phyllite member of the Poorman Formation is generally characterized as metasediments that consist of a variety of protoliths. These include thinly bedded, carbonate-rich siltstones and claystones, marl, iron formations, and lesser amounts of dolomite. Tuffaceous beds and carbonate-rich volcaniclastics also present in the Poorman suggest relatively near-source volcanic activity. The presence of graphite in much of this formation indicates that these rocks were rich in organic material. The lack of clastic rocks and fine laminated bedding are consistent with a low energy depositional environment such as an abyssal plain or more likely a restricted shallow to intermediate basin (Caddey et al., 1991, as described in ARUP, 2013). Thin (mm- to cm-thick) carbonate bands and veins are common and form two distinct distributions. Locally, veins and veinlets cross-cut compositional layering and/or foliation in some samples. In other places in the sampled rocks, assemblages of veinlets form “bands” that may be parallel to compositional layering. There is nothing in the optical, X-ray or SEM evaluations of this study to indicate that there are systematic differences in composition between the concordant and discordant presentations of the carbonates.

The various protoliths have undergone substantial metamorphism that produced the Poorman Formation as observed today. This formation is typically described as a dark-grey banded to laminated, micaceous phyllite to schist. Mineralogically, this formation is carbonate-rich with muscovite (sericite), biotite, pyrrhotite, graphite and garnet. Veins and veinlets of quartz and pyrrhotite are common. Most of the phyllite member of the Poorman Formation is characterized by a very well developed foliation and thin banding, which is interpreted as original bedding. Areas where the foliation fabric is less well developed may represent more massive protoliths such as volcaniclastic deposits (ARUP, 2013).

Several variations of the Poorman Member are observed within the project area. The western portion of the 4850 level displays dark gray biotite, sericite (muscovite) schist/phyllite with some graphite and a very well developed foliation. Toward the east the rock becomes more variable with local zones of greater biotite and quartz, and less developed foliation (ARUP, 2013).

The detailed petrography of the rocks from the 4850 Level is very complex, involving multi-generation metamorphic and hydrothermal changes to essentially all minerals originally present. Clearly, these events were associated with fluid fluxes across a range of temperatures and solution-rock ratios. The sulfide and carbonate mineralogy is of critical importance in determining the potential for acid-rock drainage and metals mobility. The petrographic report of Hansley (Attachment 1) provides detailed information and excellent photomicrographs that illuminate many mineralogical features.

Sulfide minerals, including both pyrrhotite and pyrite (usually trace to near 1% but locally up to 30% combined) also appear locally in the schist. Trace levels of arsenopyrite (FeAsS), bornite (Cu_5FeS_4), chalcopyrite ($CuFeS_2$), marcasite (FeS_2), sphalerite (ZnS), tennantite ($Cu_{12}As_4S_{13}$), and tetrahedrite ($Cu_{12}Sb_4S_{13}$) can be identified in some samples (Hansley, 2014, Attachment 1).

Carbonate minerals are significant for the acid-base balance of sulfide-bearing silicate rocks. Almost all of the exposed carbonate, at hand sample or larger sizes in core samples and drift exposures, has sufficient calcite that it “fizzes” mildly to vigorously across carbonate exposures when exposed to dilute hydrochloric acid. However, detailed petrographic analysis (Hansley, 2014, Attachment 1) shows that, in addition to the calcite in the bands and veins, the phyllite includes lesser amounts of iron- and manganese-bearing ankeritic carbonate minerals [$Ca(Mg,Fe,Mn)(CO_3)_2$].

Where the cation is dominantly Fe, the carbonate rock is called ankerite in this report; where Ca is absent in the ankerite the mineral is essentially $FeCO_3$, and is called siderite. Both are common in the Yates Member (Geochimica, 2010), but neither manganiferous carbonates nor siderite were positively identified in the petrographic work of the upper Poorman Formation for the LBNE development rock. The distinction is important for these rocks, because it means that full credit for the neutralization potential of carbonates can be assumed from the rocks to be excavated. Dolomite is common (up to 45% in one sample analyzed by X-ray diffraction) and ankerite was noted in several samples evaluated by PCI (Hansley, 2014, Attachment 1). PCI noted that two or even three carbonate minerals may be present in the same carbonate band in a single, small sample. Given the multiple metamorphic, deformational, and hydrothermal events to which the rocks have been exposed, it seems likely that the currently identified carbonates represent a complex history, much affected by mobilization and remobilization of Fe and Mg.

The felsic rocks, essentially rhyolitic in composition, intruded the metamorphics (Unzular et al, 1990; Caddey et al. 1991). In this report the terms, “rhyolite” “felsites”, and “felsic intrusive” are used interchangeably to describe quartz-rich intrusives. In the cores obtained to characterize the LBNE development rock, the felsic rocks exist entirely as veins and veinlets within the schist; there are no massive exposures in these cores. The felsic rocks clearly cross-cut the metamorphics, and are not deformed or metamorphosed. The felsites generally have sharp contacts with the metamorphics. Petrographic evidence suggests that there are at least three stages of Tertiary mineralization at the mine, each of which had some measure of hydrothermal solution associated with it (Caddey et al., 1991). Pyrrhotite appears to have been the initial iron-sulfide, and on the basis of stable-isotope interpretations probably was a primary mineral associated with the initial deposition of the basaltic (iron and magnesium rich) materials (Rye and Rye, 1974). Petrographic relationships suggest that the early pyrrhotite was affected by the older Proterozoic metamorphism, and was partially converted to pyrite, probably in part in later Proterozoic metamorphism and in part in response to the hydrothermal impacts of the Tertiary intrusives.

Carbonates, locally in excess of 20% of the rock mass, are common. Based on stable-isotope analyses, carbonates in the Yates Member amphibolites are primary (though probably redistributed by metamorphic events (Rye and Rye, 1974)); carbonates in the Tertiary rhyolites may include remobilized carbon but also have a signature that is representative of hydrothermal, not primary spring-deposit, origin (Rye and Rye, 1974). It seems reasonable thermodynamically to assume that the final form of the carbonate minerals represents reactions and progress toward re-equilibration of the specific mineral assemblage under Tertiary T/P conditions and the solution chemistry of the latest mobile phases.

4 Results

Data developed for this study are provided in their entirety as the following Attachments:

- Attachment 1: Petrographic Report, X-ray diffraction report, raw SEM data; and
- Attachment 2: Laboratory Reports for Static Geochemical Testing, including:
  - Static acid-base accounting,
  - Whole-rock chemical analyses of solids,
  - Net Acid Generation (NAG) Tests,
  - Aqueous chemistry for NAG test effluents, and
  - Aqueous chemistry for MWMP test effluents.

The analytical reports from ACZ Laboratory include detailed QA/QC notes. No major qualifiers were required, all tested were performed in a timely manner, and no results were rejected.

The results of these geochemical evaluations are described in the sections that follow. Where numerical tables are used, values that were analyzed at less than the analytical detection limit are treated at 0.5 times the detection limit. This is the expected valued for a uniform distribution between zero (below which no concentration is possible) and the analytical detection limit. Where statistics have been compiled (e.g., Tables 2 and 3), the calculated statistics are derived only for samples that has reported concentrations greater than the detection limit. This ensures that the statistics are conservative estimators for the distributions being evaluated, because if non-detects were used the apparent value would be lower.

4.1 Sampling Activities

During the week of July 7, 2014, SRK, under the direction of Mark Logsdon of Geochimica, Inc., collected 36 rock samples for geochemical testing from representative drill core and rock chips from the LBNE 4850 level. Of the 36 samples, 32 were from split drill core from boreholes LBNE-1 through LBNE-4 that were drilled earlier in 2014. An additional four rock chip samples were collected from the 4850 level during an underground visit on July 9, 2014.

The 36 rock samples were submitted to ACZ Laboratories in Steamboat Springs, Colorado, where they were tested for a standard suite of analyses to determine their ML/ARD potential. A subset of 4 samples were subjected to a standardized short-term leaching test (MWMP), and splits from 13 rock samples were sent to PCI in Boulder, Colorado for petrographic analyses.

4.2 Petrography

Petrographic interpretation was conducted by Dr. Paula Hansley of PCI on 13 core and underground wallrock samples from the overall set of 36. The report on those analyses is included as Attachment 1. The optical petrography was supported by X-ray diffraction analyses of four of those samples, specifically to document the carbonate, sulfide, and graphitic mineral identifications. In addition, Scanning Electron Microscopy (SEM) was performed on two samples. The SEM data are included in Attachment 1.

4.3 Static Acid Base Accounting

Acid-Base Accounting (ABA) is the process of determining and then comparing the ability of a sample to generate and to neutralize acidity; bases neutralize acids, hence the term “acid-base”. Table 1 summarizes the results of the acid-base accounting using the commonly used Modified Sobek Method, supplemented by evaluation of carbonate neutralization. The carbonate neutralization potential is determined by pyrolysis and infra-red spectrographic analysis for CO_2, with inorganic carbon converted stoichiometrically to equivalent $CaCO_3$ (ASA No. 9 29-2.2.4). The method is parallel to the use of a Leco furnace for analysis of sulfur, which is then converted to acid potential as conventional FeS_2. All 36 samples were analyzed for ABA. Acid-rock drainage potential as determined by the NAG procedures (EGI, 2004; Stewart et al., 2006) is addressed in the Discussion Section. Laboratory analytical data are presented in Attachment 2.

Table 1: Summary of ABA Testing

Lab ID	Sample Name	Sulfide (%)	MPA (kg/t)	NP_{Sob} (kg/t)	NP_{Carb} (kg/t)	NPR_{Sob}	NPR_{Carb}	NNP_{Sob} (kg CaCO3/t)	NNP_{Carb} (kg CaCO3/t)
L19455-01	STATION 1310	1.535	48.0	520	375	10.8	7.82	472	327
L19455-02	STATION 1312	1.88	58.8	390	300	6.64	5.11	331	241
L19455-03	STATION 1317	0.53	16.6	595	75	35.9	4.53	578	58
L19455-04	SIX WINZE DOGHOUSE	0.25	7.81	445	367	57.0	46.9	437	359
L19456-01	14-1: 34.40-38.57	0.54	16.9	345	342	20.4	20.2	328	325
L19456-02	14-1: 137.75-141.52	1.22	38.1	575	525	15.1	13.8	537	487
L19456-03	14-1: 258.85-263.15	0.22	6.88	815	500	119	72.7	808	493
L19456-04	14-1: 355.67-359.60	0.12	3.75	675	600	180	160	671	596
L19456-05	14-1: 446.0-450.0	0.14	4.38	610	600	139	137	606	596
L19456-06	14-1: 580.70-585.10	0.12	3.75	645	575	172	153	641	571
L19456-07	14-1: 600.33-605.13	2.05	64.1	380	333	5.9	5.20	316	269
L19456-08	14-1: 791.0-795.0	0.16	5.00	470	392	94.0	78.3	465	387
L19457-01	14-2: 32.0-37.0	1.72	53.8	915	500	17.0	9.30	861	446
L19457-02	14-2: 142.0-148.3	0.12	3.75	780	667	208	178	776	663
L19457-03	14-2: 234.6-240.3	1.02	31.9	470	375	14.7	11.8	438	343
L19457-04	14-2: 261.66-267.0	0.29	9.06	610	500	67.3	55.2	601	491
L19457-05	14-2: 298.10-304.20	0.51	15.9	690	400	43.3	25.1	674	384
L19457-06	14-2: 358.0-365.0	0.41	12.8	550	375	42.9	29.3	537	362
L19457-07	14-2: 388.0-393.50	0.005	0.16	515	475	3296	3040	515	475
L19457-08	14-2: 401.0-407.0	0.55	17.2	485	283	28.2	16.5	468	266
L19458-01	14-3: 35.0-41.2	1.18	36.9	665	250	18.0	6.78	628	213
L19458-02	14-3: 174.50-181.0	1.31	40.9	605	158	14.8	3.87	564	117
L19458-03	14-3: 275.0-281.2	0.65	20.3	620	392	30.5	19.28	600	371
L19458-04	14-3: 379.10-384.2	1.09	34.1	620	408	18.2	11.99	586	374
L19458-05	14-3: 492.8-498.9	0.4	12.5	665	533	53.2	42.66	653	521
L19458-06	14-3: 500.0-505.16	1.25	39.1	600	383	15.4	9.81	561	344
L19458-07	14-3: 510.83-516.23	0.2	6.25	455	367	72.8	58.66	449	360
L19458-08	14-3: 545.0-550.0	0.21	6.56	640	450	97.5	68.57	633	443
L19459-01	14-4: 4.4-9.4	0.6	18.8	485	275	25.9	14.67	466	256
L19459-02	14-4: 83.7-89.4	0.66	20.6	295	66.7	14.3	3.23	274	46
L19459-03	14-4: 202.1-209.45	0.82	25.6	600	442	23.4	17.2	574	416
L19459-04	14-4: 320.0-324.52	2.82	88.1	770	292	8.74	3.31	682	204
L19459-05	14-4: 413.0-417.9	4.54	142	375	383	**2.64**	**2.70**	233	241
L19459-06	14-4: 480.5-485.33	2.27	70.9	535	392	7.54	5.52	464	321
L19459-07	14-4: 545.4-549.7	1.1	34.4	645	408	18.8	11.9	611	374
L19459-08	14-4: 573.0-578.0	0.89	27.8	595	342	21.4	12.3	567	314
	Count	36	36	36	36	36	36	36	36
	Maximum	4.54	141.9	915	667	3296	3040	861	663
	Minimum	0.01	0.16	295	66.7	2.64	2.70	233	46.0
	Mean	0.93	28.98	574	392	139.3	121.2	545	363
	Median	0.63	19.53	598	387	24.6	15.6	566	361
	Std Dev	0.91	28.49	133	131	536	496	140	141
	Percentile (5%)	0.12	3.75	368	137	6.5	3.29	306	103
	Percentile (10%)	0.13	4.1	385	262	8.1	4.20	330	208
	Percentile (25%)	0.24	7.58	481	340	15.0	7.56	465	268
	Percentile (75%)	1.23	38.36	645	481	68.7	56.04	629	453
	Percentile (90%)	1.97	61.41	730	554	156	145.23	678	546
	Percentile (95%)	2.41	75.23	789	600	187	164.44	784	596

The Maximum Potential Acidity (MPA, also called Acid Generation Potential in some studies) is determined by standard stoichiometric calculation for the sulfide-sulfur concentration in this study. Sulfide sulfur is the difference between total and sulfate sulfur. Sulfate minerals cannot oxidize, therefore their sulfur does not contribute to the equivalents of acid produced. In quantitative hydrometallurgy, it is known that pyrrhotite can be leached under reduced conditions by strong hydrochloric acid, the digesting acid used in the Sobek methodology to remove sulfate minerals. The hydrometallurgical process requires redox control and is a strongly kinetic-dependent process (Nicoll and Scott, 1979). Typical hydrometallurgical leaching periods are 60 hours or longer and use high-normality HCl. Under conditions typical of the sulfur-speciation analyses used for ARD evaluations, the slow kinetics of the pyrrhotite reaction are considered by this team to minimize the potential that some pyrrhotite may have been leached, this underestimating the sulfide-sulfur concentration. Neutralization Potential (NP) by the Modified Sobek procedure calculates the total neutralization by the sample and refers to the acid consumed to a stoichiometrically equivalent mass of $CaCO_3$ needed to achieve the same effect. The Carbonate NP is the amount of $CaCO_3$ that would exist in the sample if all the Total Inorganic Carbon (TIC) were present as $CaCO_3$. Net NP (or NNP) is the difference between NP and MPA. In addition to a subtractive approach, the relative magnitudes of NP and MPA can be compared through ratios, effectively factor-of-safety calculations, or the ratio of NP to MPA, commonly referred to as the Neutralization Potential Ratio (NPR).

Conventionally, neutralization potential ratios (NP÷MPA) > 3 are considered to be Non Acid Forming (NAF), those with ratios < 1 are considered to be Potentially Acid Forming (PAF), and those with ratios between 1 and 3 are considered ‘uncertain’. In this study only one sample has an NPR_{Sobek} and an NPR_{Carbon} less than 3. It is a sample of schist from a depth interval of 413 - 417.9 ft in borehole LBNE 14-4, which was a discretionary sample collected to intentionally target a strongly sulfidic-graphitic zone. However, as Table 1 shows, this sample has both NNP_{Sobek} and NNP_{Carbon} values over 200 kg $CaCO_3$/t, which indicates an excess of acid neutralizing capacity. Figure 4 graphically depicts the NPR_{Sobek} values of all rock samples.

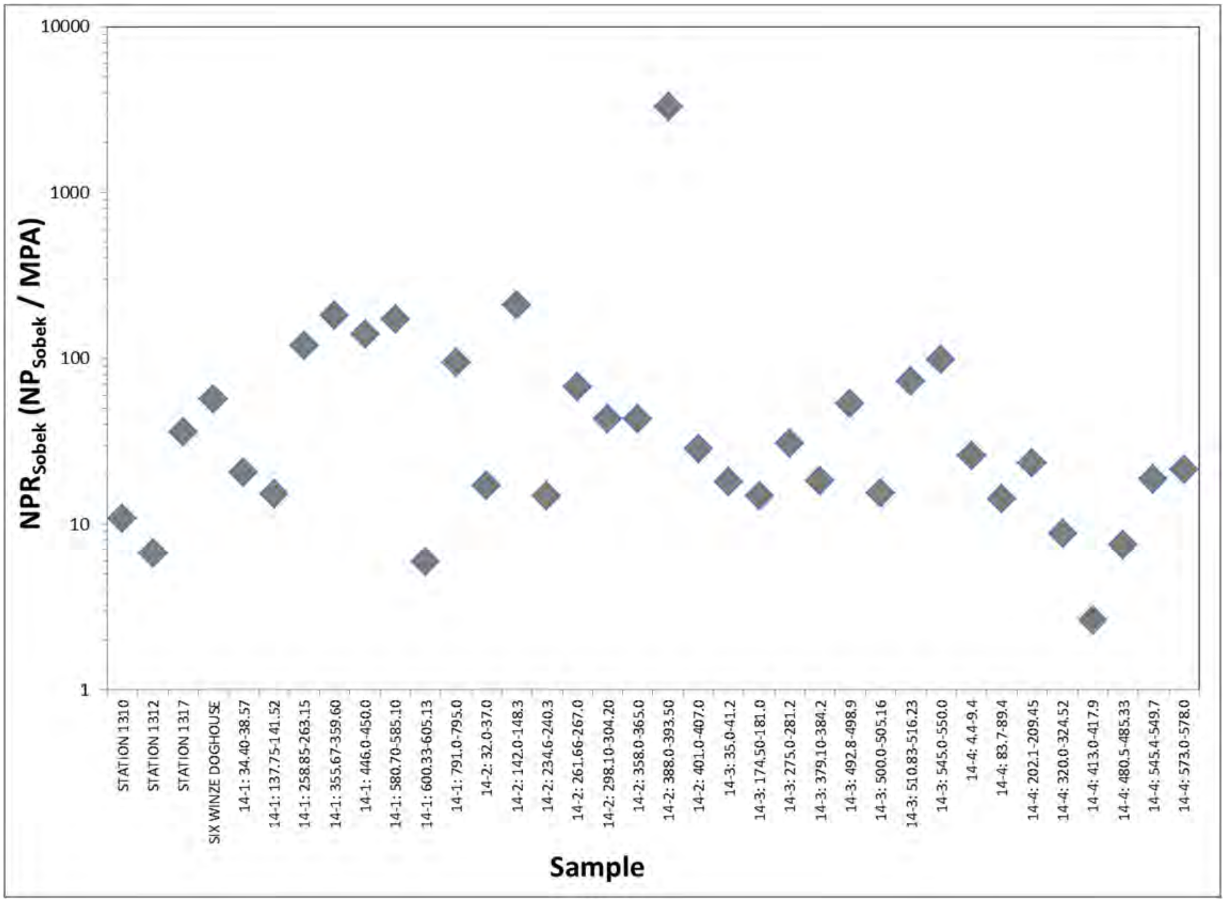

Figure 4: Neutralization Potential Ratio (Modified Sobek Method) of Rock Samples

It is essential to understand that the evaluations are based on bounding tests of separate aliquots of rock in reviewing and assessing static ABA data determined by the Modified Sobek methodology. One aliquot is used to determine the maximum acidity that could be generated if 100% of the sulfide were (a) pyrite and (b) reacted with an unlimited supply of O_2 to produce as much H_2SO_4 as is possible. The second, completely independent test (Stewart, 2006) determines the maximum capacity of the rock to neutralize a strong acid, and converts those results to a chemically equivalent amount of $CaCO_3$, whether there is or is not any physical $CaCO_3$ in the materials. The two separate bounding measures (MPA and NP) are then compared arithmetically in a factor-of safety approach, either as a ratio (NP ÷ MPA) or as a difference (NP-MPA, called net neutralization potential, NNP). The test does not address rates of acid generation or acid neutralization, and it specifically is not a bulk test of the oxidation and neutralization available for the rock. A single test that allows rock samples to oxidize and then the rest of the rock to neutralize whatever acid is available (the NAG Test) and is applied in this study to illuminate the standard ABA results by an independent analysis. This will be further described in the Discussion Section.

4.4 Total Metals

Table 2 provides a statistical summary of the whole-rock chemistry of solids from the LBNE cavern complex rocks. Laboratory reports are provided in Attachment 2. In the whole-rock analysis, rock samples are ground and dissolved in multiple acids. Solutions then are analyzed using inductively-coupled plasma sources and various spectroscopic finishes depending on the metals of interest. Note that all data are reported as parts per million (mg/kg).

Table 2: Statistical Summary for Whole-Rock Chemistry (Whole-Rock Analysis). All data in mg/L

	Count	Non-Detects	Max	Min	Mean	Median	Std Dev	5%	10%	25%	75%	90%	95%
Ag	36	16	2.7	0.3	0.689	0.7	0.49	0.3	0.3	0.3	0.83	1.15	1.5
Al	36	0	71200	18500	39383	37700	11331	22000	28100	31700	43625	53900	60475
As	36	9	66	1.5	13.6	6.5	17.2	1.5	1.5	2.625	13.3	39.5	48.5
Ba	36	0	1110	60	248	180	224	82.5	115	140	222.5	460	740
Be	36	0	4.6	2	2.622	2.6	0.55	2	2	2.2	3	3.15	3.35
Ca	36	0	236000	18800	100572	103000	43818	21425	50200	78675	123000	141500	172000
Cd	36	7	7	0.5	2.1	2	1.56	0.5	0.5	1	2.25	3.5	6
Co	36	32	90	25	29.4	25	13.5	25	25	25	25	37.5	60
Cr	36	8	250	25	82.2	85	47.6	25	25	50	100	140	145
Cu	36	10	340	25	99.2	100	70.8	25	25	25	130	165	220
Fe	36	0	179000	11700	47344	39250	30517	18675	25200	32450	47775	78300	105250
Hg	36	4	0.0427	0.00074	0.008	0.0057	0.0087	0.0009	0.0015	0.003	0.009	0.02	0.02
K	36	0	67000	4000	20500	18000	11644	6000	8500	15750	23500	30000	39750
Li	36	17	90	20	35.8	40	18.2	20	20	20	50	50	72.5
Mg	36	0	52000	5000	36111	37500	11185	15750	20500	31000	44000	48000	51000
Mn	36	0	6260	230	740	455	987	270	280	340	778	1130	1303
Mo	36	36	50	50	50	50	0.0	50	50	50	50	50	50
Na	36	2	38000	500	6500	5000	7319	875	1000	2750	6250	14000	17000
Ni	36	9	170	20	64.7	60	36.6	20	20	42.5	80	100	117.5
P	36	29	4700	250	510	250	811	250	250	250	250	750	1625
Pb	36	0	355	3	27.778	8.5	65.6	4	4.5	7	12.5	44	111
S	36	1	5.82	0.005	1.73	1.45	1.2	0.48	0.77	1.1	1.9	2.97	3.9
Sb	36	36	2.5	2.5	2.5	2.5	0.0	2.5	2.5	2.5	2.5	2.5	2.5
Se	36	9	10	0.5	2.9	3	2.4	0.5	0.5	0.875	3.25	5.5	7.75
Si	36	0	690000	288000	439111	428000	80391	338250	364500	389250	480500	526000	572250
Sr	36	0	340	90	167.2	150	65	90	100	120	212.5	250	295
Tl	36	28	2	0.5	0.69	0.5	0.43	0.5	0.5	0.5	0.5	1	2
U	36	3	9	0.5	4.04	4	2.0	0.5	1.5	3	5	7	8
V	36	3	310	15	153	165	69.5	15	50	110	192.5	220	243
Zn	36	0	650	70	251	240	135	97.5	120	168	282.5	350	613

4.5 Leachable Metals (Net Acid Generation Test)

The Net Acid Generation (NAG) test, which involves the oxidation of sulfides by excess hydrogen peroxide (H_2O_2) for rock crushed to < 75 µm, produces an aqueous solution after the oxidation of sulfides and any neutralization provided by the rock matrix itself has occurred. Hydrogen peroxide is a stronger oxidant than is O_2, so it is used in the test to accelerate oxidation of sulfide. The volume of effluent is sufficient that it can be analyzed chemically. This test gives an early indication of what, if any, metals and metalloids would potentially report to infiltration if sulfides oxidized in the LBNE cavern complex rock under ambient weathering conditions. Anions were also measured to determine how much sulfate would be produced if the sulfides fully oxidized. Note that the solution to solid ratio for the NAG test is very high, 100:1 (because its original and major purpose is to ensure that all available sulfides oxidize). This means that the absolute concentrations of effluents may not relate 1:1 to concentrations that would arise from ambient weathering. However, the concentrations are entirely relevant to scoping risks that arise as samples weather and metals or metalloids are released because they provide estimates of the total metals release due directly to sulfide oxidation. Under the slow reaction kinetics of natural weathering, the observed concentrations in effluents would be analogous to the tested effluents for rapid (4-24 hour) reactions with H_2O_2 at a higher water-to-rock ratio. At the least, it allows one to distinguish between soluble and insoluble fractions of the total metals from the Whole-Rock Chemistry (Table 2).

All 36 samples were analyzed under the NAG protocol. Table 3 presents a statistical summary for solution chemistry from the NAG tests, and laboratory reports are provided in Attachment 2. None of the 36 samples exhibited net acid generation, indicating that each rock sample contains an excess of acid neutralizing capacity over acid generating potential. The NAG pH, measured after the oxidation process had run to completion, ranged from 7.0 to 11.8, further demonstrating that any acidity produced due to sulfide oxidation is more than offset by the dissolution of acid neutralizing minerals. There were no analytes in NAG leachate that exceeded EPA Maximum Contaminant Levels. Although the tests are not intended to provide results that are equivalent to a site-specific evaluation of surface-water conditions in light of actual engineered disposal at the Gilt Edge site, the mean/median values are close to aquatic life standards for metals/metalloids. For example, the median values for As, Cu and Zn are 0.1 ug/L, 5 ug/L, and 5 ug/L, respectively.

Table 3: Statistical Summary of NAG Effluent Chemistries (mg/L)

Element	Count	Non-detects	Max	Min	Mean	Median	Std Dev	5%	10%	25%	75%	90%	95%
Ag	38	37	0.00006	0.000025	0.000026	0.000025	0.0000056	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025
Al	38	13	1.24	0.015	0.1854	0.055	0.312	0.015	0.015	0.015	0.1625	0.516	1.0545
Alkalinity-Total	38	0	348	6	55.3	28.5	71.37	10.55	12	16	59.5	113.7	233.25
As	38	33	0.0008	0.0001	0.000153	0.0001	0.00016	0.0001	0.0001	0.0001	0.0001	0.00023	0.00053
Ba	38	0	0.226	0.003	0.0309	0.015	0.04697	0.00385	0.004	0.005	0.02775	0.0732	0.1447
Be	38	38	0.000025	0.000025	0.000025	0.000025	1.69E-20	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025
Ca	38	0	182	27	81.3	69.35	40.1	32.74	37.84	48.8	108.75	144.3	147.5
Cd	38	36	0.0003	0.0001	0.000111	0.0001	0.000045	0.0001	0.0001	0.0001	0.0001	0.0001	0.00013
Cl	38	19	8	0.25	0.8118	0.375	1.5537	0.25	0.25	0.25	0.675	0.83	1.84
Co	38	36	0.03	0.005	0.00579	0.005	0.0041	0.005	0.005	0.005	0.005	0.005	0.00575
CO_3	38	6	91	1	27.2	15.5	26.78	1	1	3	45.5	69.6	76.35
Cr	38	31	0.04	0.005	0.0070	0.005	0.00613	0.005	0.005	0.005	0.005	0.01	0.0115
Cu	38	38	0.005	0.005	0.005	0.005	1.73E-18	0.005	0.005	0.005	0.005	0.005	0.005
F	38	0	1.89	0.08	0.2876	0.21	0.294	0.0985	0.124	0.1525	0.295	0.489	0.5775
Fe	38	38	0.01	0.01	0.01	0.01	3.5E-18	0.01	0.01	0.01	0.01	0.01	0.01
HCO_3	38	17	69	1	8	5	12.25	1	1	1	10	20.3	25.3
Hg	38	38	0.0001	0.0001	0.0001	0.0001	6.78E-20	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
K	38	0	56	1.5	19.04	11.65	17.558	2.555	2.87	3.725	36.475	43.91	49.83
Li	38	31	0.021	0.004	0.0054	0.004	0.004	0.004	0.004	0.004	0.004	0.009	0.0102
Mg	38	5	74.2	0.1	5.2474	0.65	13.190	0.1	0.1	0.3	2.575	14.71	20.81
Mn	38	35	1.17	0.0025	0.0345	0.0025	0.187	0.0025	0.0025	0.0025	0.0025	0.0025	0.02
Mo	38	4	0.2	0.01	0.0742	0.07	0.047	0.01	0.017	0.04	0.1	0.126	0.18
$NO_3 + NO_2$	38	0	1.06	0.06	0.2034	0.11	0.225	0.07	0.087	0.1	0.1775	0.399	0.598
Na	38	0	3	0.4	1.09	0.85	0.716	0.4	0.4	0.5	1.525	2.22	2.615
Ni	38	37	0.078	0.004	0.0059	0.004	0.012	0.004	0.004	0.004	0.004	0.004	0.004
OH	38	26	257	1	20.6	1	54.01	1	1	1	8.25	38.8	159.3
P	38	38	0.05	0.05	0.05	0.05	2.08E-17	0.05	0.05	0.05	0.05	0.05	0.05
Pb	38	32	0.0003	0.00005	0.0000697	0.00005	5.20E-05	0.00005	0.00005	0.00005	0.00005	0.0001	0.0002
Sb	38	24	0.002	0.0002	0.000671	0.0005	0.00052	0.0002	0.0002	0.0002	0.0009	0.0015	0.001615
Se	38	0	0.0396	0.0002	0.01135	0.0099	0.00923	0.001085	0.00239	0.005175	0.01385	0.02591	0.02816
Si	38	0	17.7	1.2	6.12	4.45	4.44	1.285	1.9	2.45	8.45	11.87	16.195
SO_4	37	0	649	1.4	181.8	156	118.6	67.38	82.5	108	220	323.2	378.8
Tl	38	16	0.002	0.00005	0.000195	0.0001	0.000324	0.00005	0.00005	0.00005	0.0002	0.0004	0.00043
U	38	38	0.00005	0.00005	0.00005	0.00005	3.39E-20	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
V	38	8	0.058	0.0025	0.0149	0.0105	0.01259	0.0025	0.0025	0.00525	0.02	0.0343	0.0363
Zn	38	29	0.02	0.005	0.0078	0.005	0.00546	0.005	0.005	0.005	0.005	0.02	0.02
Leachate pH	38	30	11.8	7.00	9.52	9.5	1.058	8.05	8.4	8.825	10.075	10.73	11.515
NAG pH	36	31	10	7.5	8.83	8.8	0.558	7.95	8.05	8.6	9.3	9.45	9.65

4.6 Leachable Metals (Meteoric Water Mobility Procedure)

A subset of four samples was tested using the Meteoric Water Mobility Procedure (MWMP), which is used to evaluate the potential for certain constituents from a rock sample to be dissolved and mobilized by meteoric water (NDEP, 1990, 1996). The procedure consists of a single-pass column leach over a 24-hour period using a rock sample (100% -5 cm) to extraction fluid (influent) mass ratio of 1:1. The extraction fluid is deionized water. The MWMP tests were carried out by ACZ Laboratories. MWMP effluent data are shown on Table 4. The effluent pH of each sample is near neutral. In sample 14-3, arsenic at 0.0124 mg/L, exceeded the EPA MCL.

Selection of the samples to test in the MWMP protocol was based on criteria to obtain data on rocks that: 1) are representative of development rock to be excavated, and 2) are small in proportional volume with respect to bulk development rock characteristics but possess unique characteristics that might result in a disproportional contribution of ML/ARD. Samples 14-1, 14-3, and COMP were collected to meet the first criterion. Samples 14-1 and 14-3 consist entirely of drill core intervals that lie inside the future LBNE cavern complex. Sample COMP is a composite that is made up of rock types that match their proportional distribution in the overall drill core sampling program (i.e., 61% sericite-carbonate-quartz schist, 14% graphitic sericite-carbonate-quartz schist, 13% graphitic schist, 10% rhyolite, and 2% unaltered schist). Sample RHY consists entirely of rhyolite, and was selected to test the unique properties of that lithology, i.e., ubiquitous, disseminated sulfides with an apparent low concentration (relative to the metasedimentary rocks) of acid-neutralizing carbonate minerals. Because COMP was prepared from direct splits of the mass-weighted components, the sulfide content of COMP is also mass-weighted for the LBNE rock as a whole.

5 Discussion

5.1 Samples and Representativeness

The purpose of the LBNE Geochemical Investigation is to determine the nature and extent of risks of acid-rock drainage and metals leaching from the rocks to be excavated for the LBNE cavern complex at a level of detail necessary and sufficient for SURF management to select excavation and management options for the rock. The evaluation was completed with existing geologic and geochemical information and scoping-level tests. Were the purpose to develop a research-level, scholarly evaluation of the mineralogy and geochemistry of the Poorman unit across the mine site (or even just on the 4850 Level), a different field and analytical program would have been in order. Nonetheless, it is a worthwhile matter to inquire into the likely strength of inference that can be drawn from data derived from the samples actually collected.

Because the study emphasizes risk of acid-rock drainage and metals leaching, the focus was on obtaining materials that could appropriately characterize the nature of the sulfide and carbonate mineralization. The collected samples were proportioned to represent the best estimate of lithologic distributions of metasediments and rhyolite. By preparing careful splits of the component lithologies and mass-weighting the components to their observed frequencies in the cores, the sulfide and carbonate contents of the composited samples are considered to also be properly proportioned.

Some consulting engineers have proposed that there is a standard ratio of samples per ton of rock appropriate for adequate geochemical characterization. However, a perfectly homogeneous material can be characterized perfectly by one sample, regardless of tonnage. To formally assess “how many samples is enough”, one has to know the distribution(s) of the parameters of concern in the actual rock and one must also have a criterion for successful characterization. This is formally called a "power analysis", and well suited to manufacturing processes or quality control analysis, but it is not well suited to a multivariate analysis such as the geochemistry of rock, and least of all at the level of a due-diligence investigation.

Table 4: MWMP Effluent Chemistry Data (mg/L except pH in s.u.)

Element	14-1	14-3	RHY	COMP
Aluminum	0.08	0.1	0.09	0.1
Antimony	0.0025	0.0029	0.0024	0.0029
Arsenic	0.0008	0.0124	0.0089	0.0047
Barium	<0.003	0.028	0.026	0.02
Beryllium	<0.00005	<0.00005	<0.00005	<0.00005
Cadmium	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	8.8	18.2	13.6	48.9
Chromium	<0.01	<0.01	<0.01	<0.01
Cobalt	<0.01	<0.01	<0.01	<0.01
Copper	<0.01	<0.01	<0.01	<0.01
Iron	<0.02	<0.02	<0.02	<0.02
Lead	<0.0001	<0.0001	<0.0001	<0.0001
Lithium	0.011	0.01	0.009	0.013
Magnesium	4.2	5	3	6.6
Manganese	<0.005	<0.005	<0.005	<0.005
Mercury	<0.0002	<0.0002	<0.0002	<0.0002
Molybdenum	<0.02	<0.02	<0.02	<0.02
Nickel	<0.008	<0.008	<0.008	<0.008
Phosphorus	<0.1	<0.1	<0.1	<0.1
Potassium	4.8	3.3	2.5	20.5
Selenium	0.0014	0.0006	0.0003	0.0009
Silica	4.5	7	5.5	6.1
Silver	<0.00005	<0.00005	<0.00005	<0.00005
Sodium	7.4	13.8	10.4	20
Thallium	<0.0001	0.0006	0.0003	0.0001
Titanium	<0.005	<0.005	<0.005	0.008
Uranium	0.0005	0.0014	0.0006	0.0021
Vanadium	<0.005	<0.005	<0.005	<0.005
Zinc	<0.01	<0.01	<0.01	<0.01
Bicarbonate as CaCO3	40.8	31.3	29.9	26.5
Carbonate as CaCO3	<2	<2	<2	<2
Chloride	4.3	3.4	2.4	6
Fluoride	0.54	0.62	0.5	0.55
Hydroxide as CaCO3	<2	<2	<2	<2
Nitrate/Nitrite as N	0.07	0.07	0.04	0.08
Sulfate	15.8	58.1	39	176
Total Alkalinity	40.8	31.3	29.9	26.5
pH	6.8	6.6	6.6	6.6

Note: All concentrations in mg/L

In exploration geochemistry, there is a "rule of thumb" very widely used for the last 30 years that the mean of any parameter can be estimated adequately for exploration purposes with 30 samples. This is based on published research at the Geological Survey of Canada (Garrett, 1979; Stanley, 2010). Garrett's analysis is based on considering the standard error of the mean, which is a function of the square root of the number of samples. Our investigation used 36 samples, above the GSC criterion.

More detailed statistical analysis shows that the sample number desired actually is a function of two different factors: 1) The distribution of the population (estimated, for example using the standard deviation (or coefficient of variation), and 2) How precisely one wishes to estimate the "true" mean. [There also is an additional assumption, that one can invoke the Central Limit Theorem to treat the population distribution as normal (or transformable to normal, e.g., log-normal).] If there is a narrow range of values (small standard deviation and low coefficient of variation), one does not need as many samples for any degree of precision as would be needed if the distribution were broad. Furthermore, if one needs the mean to within ± 1% then more samples are needed than if values within ± 10% are desired, regardless of the distribution. It is helpful to know that, for most geochemical parameters under normal procedures in a commercial lab, the analytical precision (1σ) of the reported values is about ± 10% of the reported value. When close to detection limits, relative precision may easily go to 50 to 100%.

In this investigation there are a large number of parameters, and one expects the statistical distributions to range across those parameters. Therefore, the precision with which to estimate each parameter, given the total number of samples, also ranges. Without knowledge of the distribution *a priori*, there is no rigorous way to calculate the number of samples needed in advance, even if investigators or decision-makers have a prior view of the necessary precision.

For the purposes of scoping geochemical risk, fine tolerance to a given level of reliability, as one might in quality control for a manufacturing process, is not required. The central question of the study was the risk of ARD, which is addressed by large-scale distinctions (the neutralization potential ratio, the NNP, and/or the NAG pH). The traditional decision-criteria for these classifications are quite broad, and in the case of the LBNE cavern complex samples, the outcomes are confirmed by multiple independent measures. As such, the likelihood of misclassification is very low, even if the individual parameters that go into the classification schemes varied by ± 10% or more.

For the purposes of this geochemical investigation, from both practical geochemical experience of others and specific analysis of the results of this smaller study, there has been adequate sampling and analysis to reach programmatic decisions that are required to manage the excavated rock.

It should be noted that the drill core tested for this program has not been exposed to any nitrogen-based explosive reagents. The LBNE cavern, when developed, will include blasting, and there may be impacts from the blasting, and there could be soluble nitrates and nitrites in runoff from such blasted rocks. Because nitrates are highly soluble, their persistence will not be similar to the period over which water-rock interactions (including ARD) would be expected.

6 Risk of Acid Rock Drainage (ARD)

This study has evaluated ARD risk through three methods; a) the ratio of NP to MPA (using both Modified Sobek and Carbonate NP); b) the Net Neutralization Potential (NNP, again using both Modified Sobek and Carbonate NP); and c) the Net Acid Generation (NAG) Test. Each method is widely viewed to be highly conservative because each test maximizes the estimate for potential acid generation. Taken together, the test data produce five (5) different ways of estimating the likelihood of acid generation. Additionally, through the measurement (by direct titration) of net acid generated in the NAG test (if acidity is generated at all), one can calculate the capacity of the system to generate acidity. The consistency in predicting expected ARD outcome between the standard acid-base accounting tests and the NAG Test (Table 5) supports the inference (Section 4.3, page 12, above) that the sulfide-sulfur content has not been significantly underestimated. Low potential for net acidity is important, because low acid capacity may be easily offset either by excess neutralizing potential in the rocks, or by aqueous alkalinity in solutions along flow paths, or ultimately by very small additions of alkalinity in water treatment. The risk to the environment and the costs of treatment would be much higher if the rocks in the cavern complex had high capacities to generate acidity.

Table 5 tabulates the estimates of ARD risk by each method and includes the major results for the NAG tests. A NAG pH (the pH of the solution after full reaction) less than pH 4.5 indicates that there is titratable acidity, and the solution is judged to be Potentially Acid Forming (PAF). In this case the solution is titrated to pH 4.5 and then to pH 7, and the NAG value computed. NAG values < 25 mg $CaCO_3$/L are judged to be Low Capacity, values of 25 – 100 mg $CaCO_3$ are Moderate Capacity, and values > 100 mg $CaCO_3$/L are High Capacity. A NAG pH > 4.5, combined with NPR > 3 and NNP > 20 indicates a sample that is non-acid forming (NAF). The sample outcome is conservatively shown as “uncertain” when the test (ABA or NAG) cannot resolve the ARD risk. The last column in Table 5 presents Geochimica/SRK’s professional opinion of the most likely status, based on the available test data and understanding of site mineralogy, disposal conditions, hydrology and experience with mined sulfide rocks at more than 250 other mining projects around the world.

Data from the previous investigation (Geochimica, 2010) indicated that the rhyolites were the most likely source of ML/ARD during excavation of the LC-1 Complex rocks. For the present investigation, the NP_{Sobek} data from the four rhyolite samples show a $CaCO_3$ equivalent mass ranging from 295 to 665 kg $CaCO_3$/t of rock, which is analogous to a calcite fraction ranging from 29.5% to 66.5% of the rock mass. Contrast these data with the NP_{Carbon}, which indicates a $CaCO_3$ equivalent mass ranging from 7% to 27% of the rock mass. These data, in conjunction with the NAG test results which all produce neutral to alkaline solutions after allowing sulfides to rapidly oxidize, indicate that reactive silicate minerals such as chlorite and plagioclase feldspar will contribute to the overall acid neutralizing capacity of the rhyolite. This is also true of the metasediments, which Figure 5 demonstrates. The NP_{Sobek} exceeds the NP_{Carbon} in nearly all samples, in some cases significantly, demonstrating that contained silicate minerals are reactive and will contribute to acid neutralizing capacity across the entire distribution of LBNE cavern complex development rock. The mineralogical analyses with supplemental X-ray diffraction and scanning electron microscopy (Hansley, this report) show silicate minerals that are known to provide long-term neutralization potential (Jambor, 2003). It is sometimes considered that silicate provides neutralization only when the pH is < 4.5. This is not strictly so. The rates of reaction of alumino-silicate minerals to hydrolysis are pH dependent, so are faster at low pH (Whiote and Brantley, 1995). However, the net acid-base balance of solution-solid reactions depends not only on the kinetics of reactions, but also on the mass-action component of the irreversible reaction because acidity and alkalinity are capacity-based, not concentration or kinetic-rate, functions (Stumm and Morgan, 1996). Large solid-phase concentrations of slower-reacting (relative to dissolution rates of calcite) silicate minerals also will react with H^+ in solution to neutralize the aqueous system (Holland, 1978; 1984). Although the available carbonates are also of significant importance, The empirical results of the NAG and MWMP testing for this new LBNE project demonstrate that silicate neutralization can be achieved by the minerals of these rocks,

Table 5: Summary of ARD Risks by Multiple Tests (*m.Sobek* signifies Modified Sobek method)

Sample ID	NAG pH	NAG (kg H_2SO_4/t)	NPR (M.Sobek)	NPR (Carbon)	NNP (M.Sobek)	NNP (Carbon)	ARD Risk
STATION 1310	9.6	<1	10.8	7.8	472	327	NAF
STATION 1312	9.8	<1	6.6	5.1	331	241	NAF
STATION 1317	8.9	<1	35.9	4.5	578	58	NAF
SIX WINZE DOGHOUSE	8.8	<1	57.0	46.9	437	359	NAF
14-1: 34.40-38.57	7.5	<1	20.4	20.2	328	325	NAF
14-1: 137.75-141.52	8.6	<1	15.1	13.8	537	487	NAF
14-1: 258.85-263.15	8.7	<1	118.5	72.7	808	493	NAF
14-1: 355.67-359.60	8.8	<1	180	160	671	596	NAF
14-1: 446.0-450.0	8	<1	139.4	137.1	606	596	NAF
14-1: 580.70-585.10	8.6	<1	172.0	153.3	641	571	NAF
14-1: 600.33-605.13	8.2	<1	5.9	5.2	316	269	NAF
14-1: 791.0-795.0	9.4	<1	94.0	78.3	465	387	NAF
14-2: 32.0-37.0	7.8	<1	17.0	9.3	861	446	NAF
14-2: 142.0-148.3	9.1	<1	208	178	776	663	NAF
14-2: 234.6-240.3	8.1	<1	14.7	11.8	438	343	NAF
14-2: 261.66-267.0	8.2	<1	67.3	55.2	601	491	NAF
14-2: 298.10-304.20	8.6	<1	43.3	25.1	674	384	NAF
14-2: 358.0-365.0	8.8	<1	42.9	29.3	537	362	NAF
14-2: 388.0-393.50	9.3	<1	3296	3040	515	475	NAF
14-2: 401.0-407.0	9.3	<1	28.2	16.5	468	266	NAF
14-3: 35.0-41.2	9.4	<1	18.0	6.8	628	213	NAF
14-3: 174.50-181.0	10	<1	14.8	3.9	564	117	NAF
14-3: 275.0-281.2	9.3	<1	30.5	19.3	600	371	NAF
14-3: 379.10-384.2	9	<1	18.2	12.0	586	374	NAF
14-3: 492.8-498.9	9	<1	53.2	42.7	653	521	NAF
14-3: 500.0-505.16	8.9	<1	15.4	9.8	561	344	NAF
14-3: 510.83-516.23	8.8	<1	72.8	58.7	449	360	NAF
14-3: 545.0-550.0	9.2	<1	97.5	68.6	633	443	NAF
14-4: 4.4-9.4	9.5	<1	25.9	14.7	466	256	NAF
14-4: 83.7-89.4	9.3	<1	14.3	3.2	274	46	NAF
14-4: 202.1-209.45	8.7	<1	23.4	17.2	574	416	NAF
14-4: 320.0-324.52	8.8	<1	8.7	3.3	682	204	NAF
14-4: 413.0-417.9	8	<1	**2.6**	**2.7**	233	241	Uncertain
14-4: 480.5-485.33	8.9	<1	7.5	5.5	464	321	NAF
14-4: 545.4-549.7	8.3	<1	18.8	11.9	611	374	NAF
14-4: 573.0-578.0	8.7	<1	21.4	12.3	567	314	NAF

Note: NAF = Non-Acid Forming

Tables 1 and 5 show that overall there is a very low risk of ARD from development rock that will be excavated for the LBNE cavern complex. Geochimica/SRK conclude that a maximum of 3% of the rock in the cavern has even a slight potential for acid generation, based on the occurrence of one 1.5-meter interval of core sample in the total 51.1 meters of core sample that reports NPR_{Sobek} and

NPR_{Carbon} of less than 3.0. Given however that the NNP_{Sobek} and NNP_{Carbon} are well within the safe range (both are >200), even the conservative analysis classifies this rock as "uncertain." Also considering that the mean NPR_{Sobek} and NPR_{Carbon} of the total sample population are both greater than 100, this corresponds to an abundance of excess neutralizing capacity in the overall rock mass to counter the small quantity of acidity expected from this interval. Additionally, none of the rock samples has any acid generation potential based on the NAG protocol.

The mean value of sulfide sulfur across the sampled boreholes and additional discretionary samples for this LBNE Project on the 4850 Level is 0.93 wt%, with a wide dispersion (see also Table 1, where sulfide mineral abundances range from 0.01% to 4.54%). The entire suite of rocks, metasediments and rhyolite, has sufficient sulfide-sulfur that, if allowed to oxidize, one should expect to see dissolution and rising effluent TDS (mostly as sulfate). However, both the metasediments and rhyolite have NP greatly in excess over AP, and the neutral pH of the effluent is expected to favor sequestration and attenuation of the majority of trace metals that might mobilize.

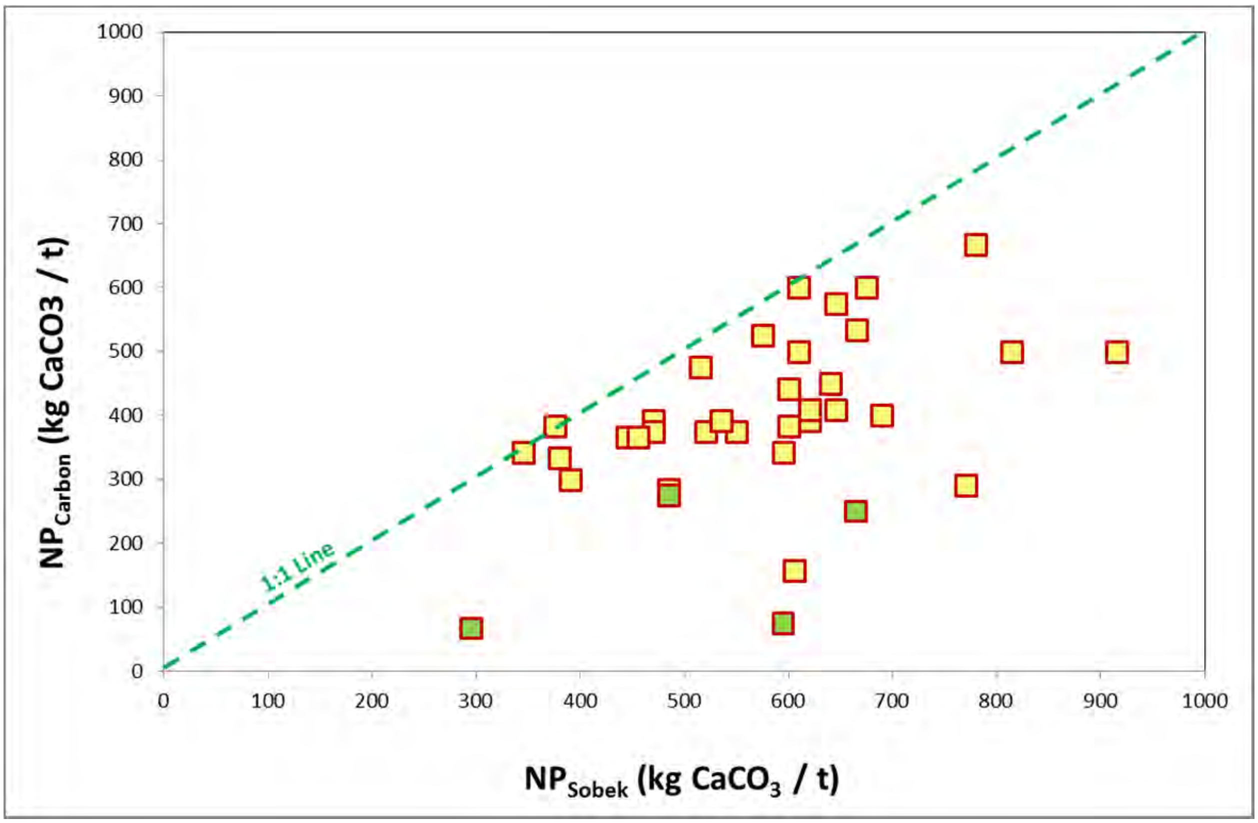

Figure 5: Comparison of NP Determined by Modified Sobek Method (NP_{Sobek}) versus NP Determined from Carbonate Concentration (NP_{Carbon}). Rhyolite samples shown as symbols with green fill.

6.1 Caveats with Respect to ARD Risk

There are two caveats with respect to using the static ABA data to estimate ARD risk for the rocks of the LBNE cavern complex. Firstly, the laboratory data for sulfur speciation show concentrations of sulfate-sulfur that are generally on the order of a few percent. The MPA is computed from sulfide-sulfur and is the difference of total- and sulfate-sulfur. Thus, the MPA values calculated here are lower than they would be if total-sulfur had been used. The MPA rational for using total sulfur less sulfate-sulfur is that most sulfates (anhydrite, barite, etc.) are not acid-generating minerals because the sulfur is already oxidized. However, iron-bearing hydroxysulfates such as jarosite are mildly acid-generating (compared to pyrite) and typically form as secondary salts from the oxidation of primary sulfides. These hydroxysulfates are stable at pHs < 4, are not likely present in the LBNE rocks, and neither jarosite nor alunite were identified during the petrographic observation and XRD analyses of this study (Hansley, 2014, Attachment 1). Discussion of the integrated water-quality risk including trace metals is presented in Section 8.2 below.

Secondly, the mineralogical examinations by detailed X-ray diffraction analysis show that calcite represents the majority of the total carbonate present in the rocks observed across the entire set of samples tested. The petrography indicates that the other carbonate minerals present are dolomite and possibly ankerite. These results are consistent with other mineralogical studies of Homestake Mine rocks conducted by Geochimica in prior geochemistry investigations at the site (Geochimica, 2010). Ankeritic carbonates do not provide long-term neutralization potential, and their presence must be recognized, if present, to properly assess ARD risk. Although the ankeritic carbonates will titrate with strong acid, producing a short-term neutralization, the Fe and Mn released in an oxidizing environment will hydrolyze (react with water) to release additional H^+, offsetting the total, long-term neutralization potential originally inferred by treating the carbonate as calcite in the ARD calculations. Because ankeritic carbonates are much less prominent in the LBNE samples than in the earlier studies (Hansley 2014, attachment 1), potential issues with long-term carbonate neutralization potential are not considered important in this study. The calcite and dolomite in the LBNE rocks are capable of buffering the pH and acidity in these materials, even if oxidation occurs. This is supported further by the results of the MWMP tests, showing pH >6.6 and bicarbonate alkalinity ranging from 26.5 to 40.8 mg/L in the effluents.

7 Evaluation of ARD Risks Given Caveats

One of the reasons for having the samples tested using the NAG procedure is that it offers an entirely independent basis for assessing ARD risk from that used in the standard Sobek-style tests. It makes no assumption about the form of sulfur, or about what minerals provide the empirical neutralization determined from the test. Either the sample, when exposed to a very strong oxidant, can consume the acidity (and leave the NAG pH > 4.5), or it cannot. As can be seen in Table 5, the NAG test results are consistent with the interpretation developed from the standard ABA tests, despite the uncertainties described above.

The Sulfate-sulfur test used in sulfur speciation for the standard ABA tests is straightforward, so there is confidence that the laboratory actually measured sulfates; effects from short-term dissolution of pyrrhotite are considered negligible. There are sulfates (as anhydrite) associated with the Tertiary hydrothermal events (Unzular et al., 1990). Although the acid-base accounting tests clearly show the presence of sulfates in the rock, the sulfate minerals are very fine grained and dispersed, and hard to identify optically in petrographic analysis. Based on the petrographic and X-ray diffraction analyses, the hydroxysulfates, if present at all, are a sufficiently small proportion of the total mass of the tested rock as to be present in the “noise” rather than as a distinguishable optical or X-ray signal.

The NAG test incorporates the actual, available neutralization potential of the carbonates, regardless of their mineralogy. Dissolved metals (Fe and Mn) from ankeritic carbonates should be oxidized and subject to hydrolysis because the test uses excess H_2O_2. Even when the pH of the NAG effluents was measured some days later (as part of the effluent chemistry analysis), there was no systematic increase in acidity that would indicate a kinetically-controlled hydrolysis.

Therefore, the NAG tests confirm the conclusions from the static ABA tests that the caveats should be considered, but that they do not change conclusions about ARD risk. Based on testing of these carefully selected and spatially distributed 36 samples from the LBNE cavern complex rocks:

- At least 97% of the tested rock is non-acid forming (NAF);
- Of the approximately 3% classified with uncertain acid drainage potential based on the Modified Sobek method, the NAG test reported a NAG pH of 8.0, a NAG effluent pH of 9.0[2], and a net acid generation below detection limit of 1.0 kg H_2SO_4/t; and
- The lone sample that reported NPR values < 3 (sample 14-4: 413.0-417.9), and upon which the conservative ARD conclusion is based, was a discretionary sample that was collected to intentionally target a strongly sulfidic-graphitic zone and test its characteristics. The zone should not be regarded as representative of a substantial portion of the LBNE cavern complex, but even this sample returned NPR ratios > 2.5, or far above the 1:1 ratio where there would be no factor of safety for acid generation.

[2] The NAGpH is the pH of the solution measured at the immediate end of the test period. The laboratory also re-tests the pH of the total effluent at a later date when it measures the solution chemistry. It is ordinary to see the pH of solutions change with time as the solution interacts with air.

8 Whole-Rock Chemistry and the Risk of Leachable Metals in Effluents

8.1 Whole-Rock Chemistry

The whole-rock chemistry and specifically the trace-metal content of the waste rock is a basic piece of geochemical information that is a standard part of all geochemical characterization studies, in a manner analogous to providing basic lithologic descriptions of samples. It also is relevant to the environmental fate of rock that is to be disposed, as bulk metals contents may limit some possible uses of a property where the public might be exposed by direct contact. Table 2 provides the detailed statistical distributions of total (i.e., solid-phase) metals and metalloids in the rock. Such values and their distributions need some context in order to determine whether they are elevated compared to ordinary, world-wide near-surface rocks. There has been a recent, very detailed investigation of the world-wide data for composition of rocks (Rudnick and Gao, 2005). The compilation includes data for average, worldwide composition of the upper continental crust among the other subsets of rocks. Comparison of the LBNE cavern complex rocks to the Rudnick and Gao data for average upper continental crust is provided in Table 6 which reveals the trace metals that are slightly (2-5 times, yellow), moderately (5 to 10 times, orange) and highly (>10 times, red) elevated with respect to average upper continental crust. The table also shows the calculations for the average, 75th percentile and 95th percentile of the LBNE cavern complex development rock data.

Table 6: Comparison of LBNE Cavern Complex Development Rock Whole-Rock Chemistry to Average Composition of Upper Continental Crust (parts per million (mg/kg); Rudnick and Gao (abbreviated R&G in Table), 2005)

Element	LBNE Mean	LBNE 75%	LBNE 95%	R&G Ave	Mean / R&G	75% / R&G	95% / R&G
Ag	0.689	0.825	1.5	0.053	13.00	15.57	28.30
Al	39383	43625	60475	81600	0.48	0.53	0.74
As	13.625	13.25	48.5	4.8	2.84	2.76	10.10
Ba	248	222.5	740	528	0.47	0.42	1.40
Be	2.622	3	3.35	2.1	1.25	1.43	1.60
Ca	100572	123000	172000	25700	3.91	4.79	6.69
Cd	2.097	2.25	6	0.09	23.30	25.00	66.67
Co	29.44	25	60	17.3	1.70	1.45	3.47
Cr	82.22	100	145	92	0.89	1.09	1.58
Cu	99.17	130	220	28	3.54	4.64	7.86
Fe	47344	47775	105250	39300	1.20	1.22	2.68
Hg	0.008	0.00878	0.024125	0.05	0.16	0.18	0.48
K	20500	23500	39750	23200	0.88	1.01	1.71
Li	35.833	50	72.5	24	1.49	2.08	3.02
Mg	36111	44000	51000	14100	2.56	3.12	3.62
Mn	740	777.5	1302.5	770	0.96	1.01	1.69
Mo	50	50	50	1.1	45.45	45.45	45.45
Na	6500	6250	17000	24200	0.27	0.26	0.70
Ni	64.72	80	117.5	47	1.38	1.70	2.50
P	510	250	1625	660	0.77	0.38	2.46
Pb	27.78	12.5	110.75	17	1.63	0.74	6.51
S (%)	1.73	1.89	3.905	0.0062	279	305	630
Sb	2.5	2.5	2.5	0.4	6.25	6.25	6.25
Se	2.931	3.25	7.75	0.09	32.56	36.11	86.11
Si	439111	480500	572250	311300	1.41	1.54	1.84
Sr	167.2	212.5	295	320	0.52	0.66	0.92
Tl	0.694	0.5	2	0.38	1.83	1.32	5.26
U	4.042	5	8	2.7	1.50	1.85	2.96
V	153.2	192.5	242.5	97	1.58	1.98	2.50
Zn	250.6	282.5	612.5	67	3.74	4.22	9.14

Note: All concentrations reported as ppm with exception of S which is reported as %

Ratio Ranges
>10
10>x>5
5>x>2

The trace metals that are highly enriched are Ag, Cd, Mo, and Se based on the average of the test results (it must be noted that all Mo values were below detection limit, but the detection limit is greater than ten times the R&G average for Mo). Sulfur, although not a metal, is highly enriched at the average level, consistent with the mineralogy of the samples and the static acid-base accounting data (Table 1). If one considers the 95th percentile of the LBNE samples (that is the highest end of all tested materials), there is only one additionally elevated trace element: Arsenic. Two trace metals exceed the crustal average by more than a factor of 50 at the 95th percentile concentration (Cd, Se). Moderately to slightly enriched trace elements, at any level of detection, include Ag, As, Cd, Co, Cu, Li, Mo, Ni, Pb, Sb, Se, Tl, U, V, and Zn. Most of those are elevated compared to the Rudnick and Gao averages by a slight amount (less than 5 times).

Because it is a parameter of special environmental significance, some additional information on selenium in these rocks is warranted. The sampling and analysis of the LBNE core and discretionary samples supports the hypothesis (T. Duex, personal communication) that there is a genetic association between solid-phase Se and graphite in the Poorman Formation rocks. The two samples with highest whole-rock selenium concentration (10 ppm) were discretionary samples collected in boreholes 14-1 and 14-4 in intervals that had been logged as graphitic and high-sulfide. Those logging characteristics were confirmed by the Project Geochemist, David Bird. It seems likely that elevated Se is associated with the original, highly reduced and sulfidic, depositional environment of the sediments that eventually became the Poorman Formation.

However, the world-wide crustal abundances, while a useful initial screen, do not provide great insight with respect to how the LBNE development rock might be managed. The rock, in any case, will be managed at either the Gilt Edge site or at the Homestake Open Cut. Therefore, it is important also to consider the whole-rock chemistry and trace metals to the local environment. The results for metals from this study of the core from the LBNE cavern rocks for metals are consistent with the known trace element composition of rocks around the north end of the Black Hills Uplift (Caddey et al., 1991). For example, there was a small tungsten mine with elevated silver near the Homestake operations, so an elevated Ag concentration is reasonable, and the “porphyry style” transition metals Cd, Cu, Co, Mo, and Zn. Selenium is known to be elevated in the district. Because these whole-rock analyses are comparable to the trace metals contents of rocks across the Black Hills, they would pose no greater risk to the public by direct exposure than would casual contact with other rocks in the district. It should be noted further that, based on public records of the site conditions, the rocks present at the Gilt Edge site release environmentally significant quantities of heavy metals including arsenic, cadmium, chromium, copper, lead, nickel, silver and zinc (EPA, 2014). The whole-rock chemistry of the LBNE cavern development rock would not be incrementally higher than the rocks and waste materials that need to be managed at the Gilt Edge site.

8.2 Dissolved Metals in Effluents from Weathered Rocks

It is unlikely that the general public will be exposed to the total metals present in the rock provided the development rock from the LBNE cavern complex is managed either at the Gilt Edge site or in the Homestake Open Cut. Provided proper rock management and dust control are available, the total metals are not bio-available in their solid-phase form in the development rock. For there to be a potential impact, the metals must be solubilized and migrate away from the disposal site in infiltration runoff. Therefore, the environmentally relevant measure is not total metals, but rather the dissolved metals that could move if the development rock weathers.

To assess the potential dissolution and transport of trace metals, this study elected to analyze the effluents from the aggressive oxidation of the rocks by the NAG procedure in addition to the MWMP leach test. These tests allow us to identify what metals and metalloids may be solubilized if the sulfides oxidize and the sulfuric acid reacts with the rest of the rock matrix. Results of the trace-metals analyses of the NAG effluents are presented in summary statistical form in Table 3, and the leachate data from the MWMP tests are presented in Table 4.

To evaluate trace elements that may be solubilized, it is conventional to consider the suite of metals and metalloids that are addressed by Primary (P) or Secondary (S) Federal water-quality criteria compared to the data for effluents from the NAG and MWMP leach tests of the LBNE cavern complex (Table 7). The drinking-water criteria are used here strictly to provide one possible benchmark. If the LBNE rock is taken to Gilt Edge, the State/EPA contractors will need to develop a specific management plan, and the engineering controls of that plan would determine the sorts of surface water or seepage flows that might be expected so that final Superfund-specific water quality criteria could be developed. Geochimica/SRK assume that in the Gilt Edge case there will be no uncontrolled discharge into the environment, but rather that water-rock interactions would be managed within engineering controls that are protective of human health and the environment. Were the rock to be disposed in the Homestake Open Cut, runoff and seepage would report to the underground workings and be managed through the pumping/water-treatment systems there.

A total of 38 analyses were run for NAG leachate (36 samples and two (2) replicates), plus 4 samples for MWMP leachate. Table 7 includes the number of samples for which results exceeded the method detection limit. For example, a "count" of 9 for arsenic means that only 9 of 42 samples had detectible arsenic; arsenic concentrations were below method detection limits in the other 33 samples. In contrast, barium, fluoride, and selenium all had a count of 42. The table then includes the maximum value, mean, median, 75th percentile and 95th percentile values of the samples that were quantified, and also the Federal water-quality primary maximum contaminant limit or secondary drinking water standard (designated as S). Note that if the count is less than 42, the apparent percentiles are skewed to high values compared to the whole set because non-detect samples are not included in the computation. Metals not shown had no values that exceeded detection limits or were not analyzed.

The highly favorable quality of these leachates is shown by the occurrence of only one value in all analyses that exceeds EPA primary MCLs or secondary standards, and that is an arsenic concentration of 0.0124 mg/L in MWMP test 14-3 (versus a criterion value of 0.010). The only constituent to exceed EPA secondary drinking water standards is manganese, which exceeded the 0.05 mg/L criterion in one sample (1.17 mg/L in NAG leachate of sample 14-1: 34.40-38.57), although it is important to note that Mn was detectable in only 3 of the 42 leach tests.

The NAG and MWMP effluents are laboratory leaching tests, not potential drinking waters, to which the MCL criteria relate. Because of the manner in which the test effluents are generated (rapidly and quantitatively oxidizing essentially all the sulfide in the sample, using a range of water-to-rock ratios from high (NAG) to low (MWMP)), they can be viewed as conservative surrogates for any real effluent, which would reflect only a small, partial dissolution of sulfides during an instant in time because of the kinetic rate controls on rock dissolution. On the other hand, the solution–solid ratio of the test is very high with respect to water – rock interactions in the ambient environment, probably more representative of runoff ratios than infiltration ratios. Therefore these values should not be taken as indicating that effluents from specific LBNE cavern complex rocks would exceed MCL or other environmental criteria, even at the 95th percentile concentrations. The NAG and MWMP effluent solutions do reflect oxidation of the sulfides in the rocks and secondary reaction of those products with the gangue mineralogy to neutralize locally produced acidity. Therefore, Geochimica/SRK consider that the NAG and MWMP effluent chemistries can be used to distinguish potentially mobile trace elements from those that are unlikely to be mobilized, and to judge whether the reasonable worst-case effluents are likely to be highly elevated with respect to potential water-quality outcomes of interest. Again, the MCL values are shown only as reference points to which the NAG effluents can be compared. When a decision on disposal is made, it will be necessary for the design engineers at the receiving facility to incorporate the specific disposal plans, engineering controls (e.g., covers to control infiltration and limit oxidation), and local hydraulic factors to meet their site-specific closure-design criteria. The current geochemical testing shows that the outcomes will be neutral to slightly alkaline, and will contain concentrations of metals and metalloids that are close to detection limits.

Table 7: NAG and MWMP Effluent Dissolved Metals vs. Water-Quality Criteria (mg/L). Total Samples = 42. Concentrations in mg/L. (S) signifies EPA secondary water quality standard.

Element	Count	Max	Mean	Median	75th %	95th %	Criterion
Antimony	28	0.0029	0.001193	0.0009	0.001525	0.00276	0.006
Arsenic	9	0.0124	0.003256	0.0008	0.0047	0.011	0.01
Barium	42	0.226	0.029774	0.017	0.02775	0.13905	2
Beryllium	0	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.004
Cadmium	2	0.0003	0.0003	0.0003	0.0003	0.0003	0.005
Chromium	7	0.04	0.015714	0.01	0.015	0.034	0.1
Fluoride	42	1.89	0.312857	0.22	0.3775	0.6175	4
Iron (S)	0	<0.02	<0.02	<0.02	<0.02	<0.02	0.3
Lead	6	0.0003	0.000167	0.00015	0.0002	0.000275	0.015
Manganese (S)	3	1.17	0.408	0.037	0.6035	1.0567	0.05
Mercury	0	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.002
Selenium	42	0.0396	0.010345	0.00775	0.013075	0.02659	0.05
Sulfate (S)	41	649	171	152	203	369	250
Thallium	26	0.002	0.000294	0.0002	0.0003	0.0006	0.0005
Uranium	4	0.0021	0.00115	0.001	0.001575	0.001995	0.03
Zinc (S)	9	0.02	0.016667	0.02	0.02	0.02	5

Note: Count = Number of results reported above method detection limit

From the water-quality perspective, one can consider that the results tabulated in Table 7 indicate that effluents are likely to have:

- Elevated (probably several hundred to perhaps 2,000 mg/L) TDS, based on sulfate and the necessity for sulfate to be balanced by cations of some kind, probably mostly Ca, Mg, and K in these rocks. This is entirely expected in rocks with high sulfide contents, even if they do not become acidic;
- Low to non-detect values for As (median 0.8 ug/L) and Se (median 7.75 ug/L); and
- In the small fraction (3%) of the samples that are uncertain with respect to acidic effluents (based on the Modified Sobek-ABA evaluation), trace elements might be released. However, the NAG tests for this sample predict neutral drainage, so the probability of trace-element release is considered small. The concentrations of most trace elements are either below detection or at levels that are of little concern. Cadmium (Cd), selenium (Se) and silver (Ag) are slightly enriched in the whole-rock analyses, and for that reason there is a slight possibility of release, although the MWMP effluents were all non-detect for those elements.

As discussed above, the observed concentrations are, in part a function of the specific experimental details of the MWMP testing procedures. Lower water-rock ratios would be expected if thick piles of LBNE waste were stacked in the vadose zone, and higher concentrations for some parameters might be seen in pore waters of such piles. However, not only is risk to water resources limited by the low release rates shown by this test program, but there are further geochemical protections present given the overall geochemistry of the LBNE materials. Many of the trace metals, if released, would be solubility-controlled by rapid neutralization in the high bulk neutralization potential (NP) of the rock mass. The re-precipitation of ferric iron derived from oxidation of pyrite or pyrrhotite will provide surface sorption sites that can effectively scavenge trace metals and metalloids (particularly arsenic).

However, some trace metals, such as nickel and zinc, are not subject to strong solubility control at pH values <9, and these may persist at low concentrations. It is assumed that proper engineering and hydrogeology will be conducted for potential disposal at Gilt Edge, to determine the water quality outcomes. Based on the available testing, the effluents will be neutral to slightly alkaline and have low, solubility-controlled concentrations. If disposed at the Homestake Open Cut, water would infiltrate to the underground workings and be managed by pumping and treatment with the other subsurface water. It is concluded that in both disposal cases, the natural geochemistry will limit risk and that proper engineering controls of surface waters and infiltration will protect other water uses.

9 Implications for Management of Cavern Development Rock

The development rock excavated from the LBNE cavern complex will be geochemically reactive during weathering if it is exposed to oxygen from the atmosphere and meteoric precipitation because of the sulfide content of the metasediments and the Tertiary felsite veinlets. However, for at least 97% of the rock likely to be excavated, the drainage should be neutral to moderately alkaline, and the uncertain acid-generating rocks are likely to produce very low acidities, if they actually are acid-generating at all. The static tests from this study and others indicate such effluents will have elevated levels of sulfate (potentially up to 1,000 mg/L) and TDS (potentially in the range of 2,000 mg/L), but the observed impacts to surface or groundwater would depend on the flux control through these rocks by the hydrogeology of the engineered disposal because other inputs will also contribute. Only about 3% of the rock is uncertain with respect to net acidity, but pH values should remain in the neutral range. Any locally generated acidity is expected to be rapidly neutralized by surrounding rock or by the alkalinity of waters contacted by the alkaline rocks. The apparent mobility of metals, except perhaps Mn, would be low. There is no indication that As, Se, or any trace elements for that matter, would be sufficiently elevated that special water treatment streams would be needed beyond those that exist at Homestake or that would be assumed for a Superfund site like Gilt Edge.

In contrast to the findings from the 2010 study, the Tertiary felsic (rhyolitic) rocks in the LBNE development rock do not indicate an elevated acid generation potential relative to the metasediments. There do not appear to be statistically significant differences between the metasediments and the rhyolite in terms of ARD or metals-leaching characteristics. The sulfur concentrations (and therefore MPA values) are comparable between the lithologies, and range from low to high for each lithology.

There is no geochemical need for engineering controls for the LBNE development rock because at least 97% of the rock is non-acid forming, the remaining small fraction (3%) is classified as uncertain with respect to acidity (based on one ABA test), and it is likely that the uncertain fraction will be in close communication with rock producing high alkalinities. Any engineering controls that are applied, for example to divert clean upgradient water and limit infiltration through disposed rock, would further reduce the low geochemical risk to beneficial uses of local waters. Between the intrinsically limited geochemical risks and the small proportional mass loading that this limited volume of uncertain rock could produce in any case, the impacts to waters at either the Gilt Edge or Open Cut sites will be *de minimus*.

10 Conclusions and Recommendations

10.1 General Conclusion

On an integrated basis across the entire mass of tested rock, Geochimica/SRK consider that that the ARD testing and the leachate values from the MWMP testing indicate low risk to water resources, especially in light of the potential benefits to the site closure derived from the available NP provided by the LBNE rocks.

10.2 The Program

1. 36 samples selected to represent spatial distribution, lithologic variation, and mineralogic variability of rocks from the LBNE 4850 level cavern complex, have been studied through detailed programs of petrography and static geochemical tests.
2. Testing has been completed by experienced professionals operating qualified laboratories using standard operating procedures for testing programs that are routinely used in regulatory assessments in the US and other countries. Quality assurance of their work was completed, as documented in the analytical reports.
3. The testing program was designed to evaluate the geochemical impacts related to extraction, disposal, and long-term storage of LBNE cavern complex development rock in one of two locations under consideration: 1) the Gilt Edge site, and 2) the Homestake Open Cut.
4. The complete set of analytical reports is appended to this report in Attachments.

10.3 Geochemical Conclusions

1. Based on geologic logs of the four coreholes, an estimated 90% of the development rock from the LBNE cavern complex will be Precambrian schist, primarily consisting of sericite-carbonate-quartz schist. About 27% of the schist is logged as graphitic (containing graphite at concentrations that can be identified visually). An estimated 10% of the rock mass consists of Tertiary intrusive rhyolite, occurring as thin dikes and stringers.
2. Both the schist and the rhyolite typically contain iron sulfide minerals (pyrite and pyrrhotite) that, if allowed to oxidize during weathering, will release trace metals in their structures and dissolved sulfate.
3. The schist characteristically has high neutralization potential associated with extensive development of carbonate layers and veins.
4. Initial visual inspection and hydrochloric acid fizz test indicated that the Tertiary rhyolites do not contain primary carbonate mineralization. However, the geochemical test data indicate elevated neutralization potential that is presumed to be present as reactive acid-neutralizing silicate minerals (e.g., chlorite, plagioclase feldspar) in addition to secondary carbonate veinlets and fracture fillings.
5. Many of the trace metals, if released, would be solubility-controlled by rapid neutralization in the high bulk neutralization potential (NP) of the rock mass. The re-precipitation of ferric iron

will provide surface sorption sites that can effectively scavenge trace metals and metalloids (particularly arsenic). However, some trace metals, such as nickel and zinc, are not subject to strong solubility control at pH values < 9, and these may persist at low concentrations. It is assumed that proper engineering and hydrogeology will be conducted for potential disposal at Gilt Edge, to determine the water quality outcomes. Based on the available testing, the effluents will be neutral to slightly alkaline and have low, solubility-controlled concentrations. If disposed at the Homestake Open Cut, water would infiltrate to the underground workings and be managed by pumping and treatment with the other subsurface water. It is concluded that in both disposal cases, the natural geochemistry will limit risk and that proper engineering controls of surface waters and infiltration will protect other water uses.

6. A minimum of 97 mass % of the total rock mass is expected to be non-acid forming. The remaining 3 mass % is conservatively classified as uncertain but based on the geochemical tests conducted is not expected to generate more than very low acidity and probably will not be acid generating at all because of the high net neutralization potential. The Tertiary rhyolites have a higher risk of acid rock drainage (ARD) than do the metasediments, but comprise a small and discontinuous volume of the total development rock.
7. Trace-metal releases are expected to be at the part per billion to tens of parts per billion levels, although weathering of all the development rock is expected to produce sulfate and total dissolved solids (TDS) on the order of 1,000 to 2,000 mg/L locally.
8. Arsenic (As) and selenium (Se) appear to be very minimally leachable (< 1 ug/L to 8 ug/L, respectively) from the LBNE cavern complex rocks even under aggressive oxidation. No special water-treatment implications arise from limited zones of such leaching in a much larger total mass of rock that is affecting the environment.
9. All NAG (net acid generation) tests show zero net acid generation and neutral effluent pH. These acid-base outcomes are reinforced by the observed pH values from MWMP testing.
10. Although sulfides, including pyrite and pyrrhotite, are locally abundant as observed in drill core, the carbonate content more than offsets the sulfide minerals from a bulk material standpoint.
11. A few rock sample intervals contain cadmium, selenium, and silver at concentrations significantly greater than average crustal abundance, although this has limited utility in the prediction of leachate concentrations.
12. MWMP leachate produced one arsenic concentration that exceeds EPA maximum contaminant levels. NAG leachate produced no analytes at concentrations exceeding EPA maximum contaminant levels. If the rock were to be disposed at Gilt Edge, the project engineers there would need to consider the effects of site-specific dumping plans, engineering controls (e.g., covers to control infiltration or diffusion of oxygen), along with site-specific hydrogeology in order to estimate specific water chemistries that could report to surface or ground waters. If disposed at the Homestake Open Cut, all drainage would report to the mine workings and be controlled by the existing pumping and treatment systems.

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12 Date and Signature Page

Signed on this 15th day of January, 2015.

Prepared by

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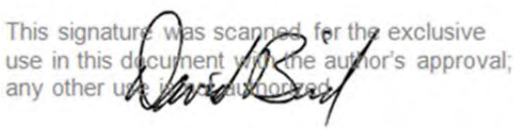

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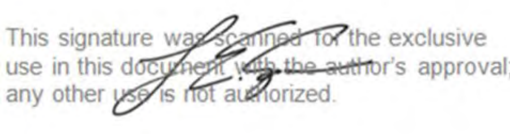

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted industry practices.

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APPENDIX E

Noise Modeling

APPENDIX E-1

Fermilab CadnaA Noise Modeling Report

Imagine the result

Fermi National Accelerator Laboratory

LBNE Noise Modeling Report

Long-Baseline Neutrino Experiment Project
Kane County, Batavia, Illinois

September 30, 2013

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Acoustical Project Scientist

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Long-Baseline Neutrino Experiment Project

LBNE Noise Modeling Report

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Date:
September 30, 2013

Tables

Figures

Appendices

1. Introduction and Summary

This technical noise modeling report provides backup for the noise modeling completed to analyze the potential noise impacts associated with the proposed Long-Baseline Neutrino Experiment (LBNE) Project at Fermi National Accelerator Laboratory (Fermilab). The project site is located within Kane County, City of Batavia, Illinois, on Fermilab property. The nearest sensitive receptors are single-family residences located to the west along Kirk Road and on Savannah Drive located to the south.

The analysis addresses the Proposed Action. The Proposed Action includes the construction of a beamline facility. The EA presents a detailed description of the Proposed Action and Alternative A.

Noise is a physical disturbance in a medium, such as air, that is capable of being detected by the human ear. Sound waves in air are caused by variations in pressure above and below the static value of atmospheric pressure. Sound is measured in units of decibels (dB) on a logarithmic scale. The "pitch" (high or low) of the sound is a description of frequency, which is measured in Hertz (Hz). Most common environmental sounds are composed of a composite of frequencies.

A normal human ear can usually detect sounds within frequencies from 20 Hz to about 20,000 Hz. However, humans are most sensitive to frequencies from 500 Hz to 4000Hz. Certain frequencies are given more "weight" during assessment because human hearing is not equally sensitive to all frequencies of sound. The dBA scale corresponds to the sensitivity range for human hearing. Noise levels capable of being heard by humans are measured in dBA. A noise level change of 3 dBA or less is barely perceptible to average human hearing and is considered "less than significant". However, a 5 dBA change in noise level is clearly noticeable and is considered to be "substantial". A 10 dBA change in noise level is considered a "significant impact" and is perceived as a doubling or halving of noise loudness, while a 20 dBA change is considered a "dramatic change" in loudness. The following table provides typical instantaneous noise levels of common activities in dBA.

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
Jet Fly-over at 1,000 feet	100	
Gas Lawn Mower at 3 feet	90	
Diesel Truck at 50 feet, at 50 miles per hour (mph)	80	Food Blender at 3 feet Garbage Disposal at 3 feet
Noisy Urban Area, Daytime Gas Lawn Mower at 100 feet	70	Vacuum Cleaner at 10 feet
Commercial Area Heavy Traffic at 300 feet	60	Normal Speech at 3 feet
Quiet Urban Daytime	50	Large Business Office, Dishwasher in Next Room
Quiet Urban Nighttime	40	Theater, Large Conference Room (Background)
Quiet Suburban Nighttime	30	Library
Quiet Rural Nighttime	20	Bedroom at Night
	10	Broadcast/Recording Studio (background level)
Lowest Threshold of Human Hearing	0	Lowest Threshold of Human Hearing

Source: Caltrans Technical Noise Supplement, October 1998

Sound from a source spreads out as it travels away from the source, and the sound pressure level diminishes with distance in accordance with the “inverse square law.” Individual sound sources are considered “point sources” when the distance from the source is large compared to the size of the source, for example: transformer bank, construction equipment, and turbines. Sound from a point source radiates hemispherically, which yields a 6 dB sound level reduction for each doubling of the distance from the source. If the sound source is quite long in one dimension, the source is considered a “line source”, for example: roadways and railroads. Sound from a line source radiates cylindrically, which typically yields a 3 dB sound level reduction for each doubling of the distance from the source.

In addition to distance attenuation, the air absorbs a certain amount of sound energy, and atmospheric effects (wind, temperature, precipitation), and terrain/vegetation effects also influence the sound propagation and attenuation over large distances from the source.

An individual’s sound exposure is valued based on a measurement of the noise that the individual experiences over a specified time interval. A sound level is a measurement of noise that occurs during a specified period of time. A continuous source of noise is rare for long periods of time and is typically not a characteristic of community noise. Community noise refers to outdoor noise in the vicinity of a community and most commonly originates from transportation vehicles or stationary mechanical equipment. A community noise environment varies continuously over time with respect to the contributing sources. Within a community, ambient noise levels gradually change throughout a typical day and the changes can be correlated to the increase and decrease of transportation noise or to the daytime/nighttime operation of stationary mechanical equipment. The variation in community noise throughout a day is also due to the addition of short-duration single-event noise sources, such as aircraft and sirens as well as various natural sources.

The metrics for evaluating the community noise environment are based on measurements of the noise exposure over a period of time in order to characterize and evaluate the cumulative noise impacts. These metrics are time-varying and are defined as statistical noise descriptors.

Construction activities could result in varying degrees of ground vibration, depending on the kind of equipment and operations involved, and the distances between the construction activities and the nearest sensitive receptors. The effects of ground borne vibrations generated from construction activities are typically imperceptible to an average human outside of the project site. However, high magnitude vibrations can result in damage to nearby structures within the immediate vicinity of the source.

2. Methodology and Equipment

2.1 Methodology

2.1.1 Noise Model Software

Modeling of the proposed Fermilab LBNE Project and surrounding community environment was accomplished using a noise model, CadnaA (Computer Aided Noise Abatement), developed by DataKustik for predicting noise impacts in a wide variety of conditions. CadnaA assists in the calculation, presentation, assessment, and mitigation of all types of environmental noise exposure conditions. All predicted noise impacts are based on the International Standards Organization (ISO) 9613 standard. The algorithm allows input of project information such as noise source data, sound barriers, intervening structures, ground absorption, and topography to create a detailed computer-aided drafting (CAD) model. Modeling input and results are provided in **Attachment A**.

2.1.2 Long-term Noise Monitoring Measurement

To document the existing noise conditions at the Fermilab LBNE Project, a 48-hour ambient noise monitoring measurement was conducted between Wednesday, February 27, 2013 and Friday, March 1, 2013. The field noise monitor was programmed to log data every 30-minutes during the continuous 48-hour time period. The microphone at the monitoring location was placed approximately 8 feet above the existing site grade. During the on-site ambient noise measurements, start and end times were recorded along with existing background noise sources to accurately account for the community noise environment (**Figure 1**).

2.1.3 Short-term Noise Measurements

To further document the existing noise levels at identified residential sensitive receptor locations a series of 1-hour equivalent sound level measurements (dBA Leq) was conducted during the daytime hours of Wednesday, February 27, 2013 and Friday, March 1, 2013. The microphones at all noise measurement locations were placed approximately 5 feet above ground level. During the ambient short-term noise measurements, start and end times were recorded, along with existing ambient noise sources to accurately account for the noise environment in the project area. The receptor locations are shown in **Figure 1** and listed in **Attachment A** (Table A-1).

2.2 Measurement Equipment

All of the following equipment was used to measure existing noise levels:

- Larson Davis Model 820 Sound Level Meter
- Larson Davis Model 824 Sound Level Meter
- Larson Davis Model CA200 Microphone Calibrator
- Hand-held global positioning system (GPS) unit, microphone with windscreen, tripods

The sound level meter was field-calibrated prior to and following the noise measurement to ensure accuracy. All sound level measurements conducted and presented in this report, in accordance with the regulations, were made with a sound level meter that conforms to the American National Standards Institute (ANSI) specifications for sound level meters ANSI SI.4-1983 (R2001). All instruments are maintained with National Bureau of Standards traceable calibrations per the manufacturers' standards.

3. Existing Environmental Setting

3.1 Existing Noise Environment

The Fermilab LBNE Project would be located on Fermilab property. The surrounding adjacent land uses include residential communities to the west, north, and east and industrial facilities to the north and south. Existing noise sources identified in proximity to the Fermilab property include vehicular traffic from Kirk Road to the west, as well as Butterfield Road to the south.

3.1.1 Noise Sensitive Receptors

Overall, the noise sensitive receptors in the area are single-family residences located to the west of Kirk Road and to the south along Savannah Drive. The nearest sensitive residential receptors potentially affected by the project are single-family residences to the west of Kirk Road located approximately 1,150 feet from the Proposed Action and approximately 240 feet from Alternative A. Single-family residences are also located on Savannah Road approximately 4,550 feet south from both the Proposed Action and Alternative A.

3.1.2 Long-term Noise Monitoring Measurements

A long-term 48-hour noise measurement was conducted along the western boundary of the Fermilab property (see Figure 3.9-1 of the EA) near Kirk Road to establish the ambient baseline noise level at the project site. The coordinates for the noise monitor location is noted in **Table 1** below.

Table 1 Long-term Noise Monitor Location

Receptor	Noise Measurement Location (Coordinates)
Noise Monitor Location	41°50'4.8"N, 88°16'42.1"W

The results from the 48-hour monitoring period are shown in **Table 2**. The noise monitoring data shows that daytime (7:00 a.m. to 9:00 p.m.) hourly noise levels range from 56.2 to 62.2 dBA Leq, and nighttime (9:00 p.m. to 7:00 a.m.) hourly noise levels range from 50.7 to 60.5 dBA Leq. The average Leq over the 48-hour noise monitoring period during the daytime was 60.3 dBA and during the nighttime was 55.9 dBA.

3.1.3 Short-term Noise Level Measurements

The results of the 1-hour ambient noise measurements conducted off-site near three potential noise sensitive receptor locations located adjacent to Kirk Road are presented in **Table 3**. These measurement locations represent 3 single-family residences located west of Kirk Road.

Table 2 Long-term Noise Monitor – Noise Monitoring Data Summary

Military Time	February 27 – 28, 2013 (dBA Leq)	February 28 – March 1, 2013 (dBA Leq)
12:00:00	60.1	59.4
13:00:00	60.1	59.9
14:00:00	60.7	61.0
15:00:00	61.1	60.9
16:00:00	61.5	61.0
17:00:00	61.3	60.1
18:00:00	59.4	58.8
19:00:00	57.9	57.2
20:00:00	57.5	56.2
21:00:00	56.2	55.9
22:00:00	56.1	55.8
23:00:00	53.8	54.2
0:00:00	53.5	52.3
1:00:00	51.8	51.3
2:00:00	50.8	50.7
3:00:00	54.9	52.2
4:00:00	55.9	55.4
5:00:00	58.6	58.1
6:00:00	60.5	60.3
7:00:00	61.3	61.2
8:00:00	61.3	61.2
9:00:00	60.0	60.3
10:00:00	59.6	60.2
11:00:00	60.0	62.2

Table 3 Short-term Noise Measurements on February 27, 2013 and March 1, 2013

Receptor	Noise Measurement Location (Coordinates)	Measurement Date	Measurement Time Interval	Daytime 1-hour Leq (dBA)
1	41°50'27.10"N, 88°16'44.88"W	March 1, 2013	12:25 – 13:25	62.4
2	41°49'44.1"N, 88°16'43.9"W	February 27, 2013	14:10 – 15:10	66.8
3	41°50'8.8"N, 88°16'45.6"W	March 1, 2013	10:30 – 11:30	67.5

The ambient noise measurement data provided in **Table 3** shows that daytime noise levels in the project area range from 62.4 to 67.5 dBA Leq.

4. Proposed Action Noise Modeling

4.1 Construction Noise

The construction of the Proposed Action would require the use of heavy earth moving equipment excavators, loaders and haul trucks. The Proposed Action would include transport and placement of excavated material to create a large embankment, construction of service buildings, assembly of beamline components, replacement of a cooling pond, and site preparation and restoration.

Construction would require substantial transport of excavated material and rock; however, these activities would all occur on-site at Fermilab. All the material for the embankment would be obtained from borrowed areas at Fermilab and any excess rock would be taken to existing stockpile areas on-site. It would also include transport of construction materials and beamline components to Fermilab.

The Proposed Action would include construction of the Near Detector approximately 150 feet east of Kirk Road and 780 feet west of the Absorber Hall. The Near Detector construction would include a deep mechanical soil excavation within a shaft (approximately 70 feet) followed by blasting of bedrock at depths below 70 feet. The Near Detector construction would also require construction of access shafts, equipment installation (within buildings), refilling the excavation, and site restoration. During construction of the Near Detector progresses, the source of noise would be located progressively deeper inside the shaft and less audible with time.

The noise analysis evaluated different construction phases proposed for the Proposed Action. The phases included:

- Construction of Embankment
- Excavation and Foundation Installation of Primary Beam Enclosure, Target Hall Complex Underground Enclosure, and Installation of Drilled Pilings
- Excavation of Absorber Hall Shaft and Underground Enclosure
- Service Building Construction (Primary Beamline Service Building, Target Hall Complex, Absorber Hall, and Near Detector)

The phased construction activities as well as the associated equipment are based on the construction equipment and workforce estimates provided by Fermilab engineers based on recent experience from the NuMI and Nova projects. Construction would require a variety of equipment operating at or near grade level. The blasting operations will occur approximately 70 feet below grade at the bedrock. **Table 4** identifies equipment type, quantity, utilization percentage, and noise level for each major type of construction equipment.

Table 4 Fermilab LBNE Proposed Action Construction Equipment

Phase	Equipment Type	Equipment Quantity	Utilization Percentage	Noise Source Level at 50 feet (dBA)
Construction of Embankment	Bulldozer	3	40	85
	Grader	3	40	85
	Water Truck	3	40	84
	Dump Truck	6	40	84
	Compactor	3	20	80
Excavation and Foundation Installation of Primary Beam Enclosure, Target Hall Complex Underground Enclosure, and Installation of Drilled Pilings	Drill Rig Truck	2	20	84
	Backhoe (trench)	1	40	80
	Concrete Truck	3	40	85
	Water Truck	3	40	84
	Flatbed Truck	2	40	84
	Grader	2	40	85
	Crane	1	20	85
	Scraper	1	40	85
	Bulldozer	2	40	85
	Excavator	2	40	85
	Dump Truck	3	40	84
Excavation of Absorber Hall and Near Detector Shafts and Underground Enclosure	Backhoe (trench)	5	40	80
	Concrete Truck	5	40	85
	Water Truck	4	40	84
	Flatbed Truck	3	40	84
	Grader	3	40	85
	Scraper	3	40	85
	Bulldozer	3	40	85
	Excavator	6	40	85
	Dump Truck	10	40	84
	Blasting (explosives)	4 per day	---*	94
Service Building Construction	Concrete Truck	4	40	85
	Flatbed Truck	4	40	84
	Dump Truck	2	40	84
	Welder	6	40	73
	Generator Set	6	40	82

Notes:
* Blasting was evaluated with a 5 second duration.
Source: FHWA 2009

Model input data for line sources and point sources are provided in **Attachment A** (Tables A-2 through A-11). The calculated noise impacts range from 39.8 dBA at the southern residential community to 70.9 dBA at the western residential community (**Table 5**). (Figure 3.9-2 of the EA depicts the modeled Proposed Action construction noise contours.) Although close to Kirk Road, much of the construction activity for the Near Detector (and Absorber) would be conducted within excavations that would attenuate much of the sound. The maximum increase in noise levels in Table 8 reflects the increase over ambient noise levels, including roadway traffic, aircraft, and residential/commercial noise sources.

4.2 Operational Noise

The primary noise source during Proposed Action operations would be from outdoor equipment including transformer and chiller units, HVAC (heating, ventilation and air conditioning) units, and ventilation of the service buildings. Potential outdoor sources for would include an outside chiller unit and 5,000 cfm HVAC unit associated with the Near Detector located approximately 150 feet from Kirk Road. The Absorber Hall would be located approximately 990 feet from Kirk Road and would have chiller units (2), transformer units (2), and a 2,400 cubic foot per minute (cfm) HVAC unit. The Target Hall would be located approximately 1,830 feet from Kirk Road and would have chiller units (3) and three rooftop HVAC units (50,000 cfm, 35,000 cfm, and 4,000 cfm). The Primary Beam Service Building would be approximately 2,530 feet from Kirk Road and would have transformer units (3), outside air fans (3), one rooftop ventilation fan and one 15,000 cfm rooftop HVAC unit.

Model input data for Proposed Action operations are provided in **Attachment A** (Table A-12). This analysis evaluated the operations of this mechanical equipment during a 24-hour period. It assumes all major stationary mechanical equipment would operate at 100 percent utilization during the 24-hour period. Noise emission data for the mechanical equipment was not readily available. Noise levels for the equipment were based on mechanical equipment similar to those proposed by Fermilab engineers. **Table 6** provides a summary of all major exterior mechanical equipment required for operations and the associated noise emission data.

Table 7 presents modeled operational noise levels (project only) for residential receptors. The highest predicted operational noise level would be 42.8 dBA Leq (see Figure 3.9-3 of the EA). The corresponding octave band noise level would be 36.8 dB at 2,000 Hz (**Table 8**).

Table 5 Modeled Proposed Action Construction Equipment Noise Levels at Receptor Locations

Sensitive Receptor	Receptor Location	Construction of Embankment	Construction Noise Impacts (dBA Leq)			
			Excavation, Foundations, Primary Beam Enclosure, Target Hall, and Drilled Pilings	Excavation of Absorber Hall and Near Detector Shafts and Underground Enclosures	Service Building Construction (4 Buildings)	Maximum Increase in Noise Levels (dB)[1]
1	Residential (Kirk Road near Pine Street)	44.5	47.5	52.5	48.6	0.4
2	Residential and Recreational (Kirk Road near Prairie Path)	51.5	52.4	56.2	51.8	0.4
3	Residential (Kirk Road near Giese Road)	50.9	56.0	65.6	64.4	2.2
4	Residential (Kirk Road directly west of Alternative A)	51.1	56.7	70.9	69.4	5.0[2]
5	Residential (near Savannah Road)	43.0	43.3	45.0	39.8	---

Notes:
dBA = A-weighted decibels
1 Increase based on the highest calculated construction noise level.
2 Ambient noise level based on data collected at monitoring location 3

Table 6 Fermilab LBNE Proposed Action Operational Noise Emission Data

Equipment Description	Quantity	Referenced Distance (feet)	Sound Pressure Level (dB) Octave Band Center Frequency (Hertz)								
			31.5	63	125	250	500	1000	2000	4000	8000
Transformer	5	5	50	52	56	76	72	55	43	36	32
Chiller	6	5	71	73	75	83	84	81	77	69	55
HVAC 15,000 cfm	1	---	---	97*	99*	92*	95*	92*	88*	82*	77*
HVAC 35,000 cfm	1	---	---	95*	101*	98*	95*	90*	86*	83*	77*
HVAC 50,000 cfm	1	---	---	101*	104*	105*	101*	99*	92*	88*	82*
HVAC 4,000 cfm	1	---	---	94*	89*	87*	83*	82*	78*	76*	68*
HVAC 2,400 cfm	1	---	---	84*	82*	78*	61*	64*	64*	56*	41*
HVAC 5,000 cfm	1	---	---	94*	89*	87*	83*	82*	78*	76*	68*
Outside Air Fan	3	---	---	84*	82*	78*	61*	64*	64*	56*	41*
Ventilating Fan	1	---	---	84*	82*	78*	61*	64*	64*	56*	41*

Notes:
--- = Not Applicable
* Sound Power Level (PWL)

Table 7 Fermilab LBNE Proposed Action Increase in Operational Noise Levels

Receptor	Receptor Location	Measured Daytime Noise Level (dBA Leq)	Calculated Noise Level (dBA Leq)	Combined Noise Level (dBA Leq)	Operational Noise Level Increase (dB)
1	Residential (near Pine Street)	62.4	28.2	62.4	0.0
2	Residential and Recreational (near Prairie Path)	66.8	31.5	66.8	0.0
3	Residential (near Giese Road)	67.5	35.0	67.5	0.0
4	Residential (Kirk Road directly west of Alternative A)	67.5*	42.8	67.5	0.0
5	Residential (near Savannah Road)	N/A	21.8	N/A	N/A

Notes:
dBA = A-weighted decibels
*Ambient noise level based on data collected at monitoring location 3

Table 8 Proposed Action Octave Band Noise Levels at the Residential Receptors

Receptor	Sound Pressure Level (dB) Octave Band Center Frequency (Hertz)									Leq (dBA)
	31.5	63	125	250	500	1000	2000	4000	8000	
1	14.0	28.6	29.2	26.9	26.1	25.3	14.2	0.0	0.0	28.2
2	16.4	31.2	32.7	29.8	29.0	28.6	19.0	0.0	0.0	31.5
3	28.8	36.0	34.5	31.5	31.3	32.6	25.3	6.8	0.0	35.0
4	28.4	40.9	38.4	35.4	38.7	39.0	36.8	27.7	8.6	42.8
5	5.3	25.0	26.0	23.2	21.2	16.6	2.3	0.0	0.0	21.8

Note:
dBA = A-weighted decibels

5. Vibration

5.1 Proposed Action Construction Vibration

Proposed Action construction would include the use of heavy equipment that would generate ground-borne vibrations. Possible sources of vibration may include excavators, dump trucks, backhoes, blasting (explosives), and other heavy construction equipment.

The construction vibration calculations are based on the FTA published vibration levels provided in **Table 9**.

Table 9 Vibration Source Levels for Construction Equipment

Equipment		PPV* at 25 feet (in/sec)	Approximate L_v ** at 25 feet
Clam shovel drop (slurry wall)		0.202	94
Hydromill (slurry wall)	In soil	0.008	66
	In rock	0.017	75
Vibratory Roller		0.210	94
Hoe Ram		0.089	87
Large Bulldozer		0.089	87
Caisson Drilling		0.089	87
Loaded Trucks		0.076	86
Jack Hammer		0.035	79
Small Bulldozer		0.003	58
Blasting (explosives)		1.518	112

Notes:
* Peak Particle Velocity
** RMS velocity in decibels (VdB) re 1 micro-inch/second

Excavation equipment would result in vibration levels of approximately 57.5 VdB at the nearest residential receptor west of Kirk Road. The Proposed Action would also incorporate blasting with up to approximately four events per day over several months for excavation at the Near Detector and Absorber Hall. Blasting would result in vibration levels of up to approximately 82.5 VdB at the nearest residential receptor west of Kirk Road. These vibration levels are summarized in **Table 10**.

Table 10 Fermilab LBNE Proposed Action Construction Vibration Impacts

Receptor	Receptor Location	Approximate Distance to Receptor (feet)	Calculated Vibration Level (VdB*)
1	Northwestern Residential Community (Short-term Measurement Location 1)	2,350	52.8
2	Southwestern Residential Community (Short-term Measurement Location 3)	2,000	54.9
3	Western Residential Community (Short-term Measurement Location 2)	550	71.7
4	Western Residential Community	240	82.5
5	Southern Residential Community	5,160	42.6

Notes:
* RMS velocity in decibels (VdB) re 1 micro-inch/second

6. References

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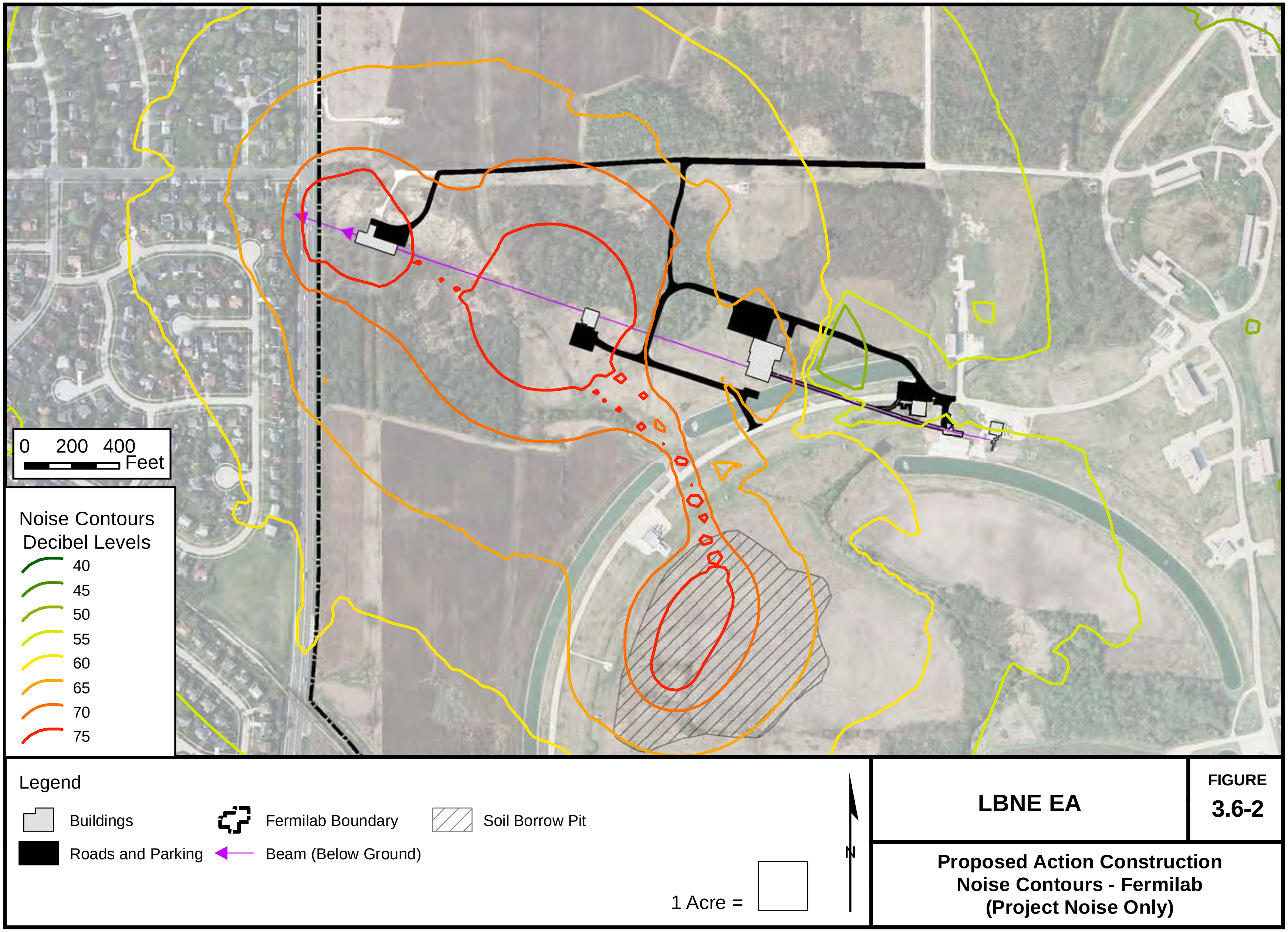
LBNE Noise Modeling

Fermilab Project

Figures

Absolute Scale - 1:7,200
1 inch = 600 feet



LBNE EA

FIGURE 3.6-2

Proposed Action Construction
Noise Contours - Fermilab
(Project Noise Only)

Absolute Scale - 1:12,000
1 inch = 1,000 feet

Legend

Fermilab Boundary
Beam (Below Ground)
Buildings
Construction Limits
Roads and Parking
Noise Monitor Locations

Absolute Frame

1 Acre =

0 500 1,000
Feet

N

LBNE EA

FIGURE
3.6-1

Noise Monitoring Locations
- Fermilab

ARCADIS

Attachment A

CadnaA Noise Model Data and Results

E-1: Proposed Action - Receptors

				Coordinates		
	Level Lr Day	Height		X	Y	Z
Name	(dBA)	(m)		(m)	(m)	(m)
Residential Receptor 1 (northwest)	44.5	1.52	r	28072.62	-30630.88	237.8
Residential Receptor 2 (southwest)	51.5	1.52	r	28142.61	-31961.8	232.07
Residential Receptor 3 (west)	50.9	1.52	r	28105.73	-31194	236.52
Residential Receptor 4 (west)	51.1	1.52	r	28117.15	-31334.37	234.75
Residential Receptor 5 (south)	43	1.52	r	28984.41	-32919.4	225.25
Noise Monitor Location	52.5	1.52	r	28219.43	-31317.55	232.13

E-2: Proposed Action Construction of Embankment - Line Sources

Name	ID	Result. PWL Day (dBA)	Result. PWL' Day (dBA)	Lw / Li Type	Value	Freq. (Hz)	Moving Pt. Src Number Day	Moving Pt. Src Speed (km/h)
Dump Truck 6 mobile	dump_truck	108.7	83.2	PWL-Pt	dump_truck	1000	4.6	16

E-3: Proposed Action Construction of Embankment - Point Sources

Name	ID	Result. PWL Day (dBA)	Lw / Li Type	Lw / Li Value	Operating Time Day (min)	Freq. (Hz)	Height (m)		Coordinates X (m)	Coordinates Y (m)	Coordinates Z (m)
Bulldozer 1	bulldozer	119.7	Lw	bulldozer	240	1000	2.44	r	28651.55	-31811.08	228.23
Bulldozer 2	bulldozer	119.7	Lw	bulldozer	240	1000	2.44	r	28616.77	-31889.55	227.98
Bulldozer 3	bulldozer	119.7	Lw	bulldozer	240	1000	2.44	r	28826.26	-31497.06	228.05
Grader 1	grader	119.7	Lw	grader	240	1000	2.44	r	28874.94	-31509.03	228.05
Grader 2	grader	119.7	Lw	grader	240	1000	2.44	r	28782.29	-31486.59	228.72
Grader 3	grader	119.7	Lw	grader	240	1000	2.44	r	28733.24	-31475.18	229.12
Water Truck 1	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28707.12	-31761.81	228.12
Water Truck 2	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28866.07	-31527.42	228.05
Water Truck 3	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28751.44	-31498.89	229.07
Compactor 1	compactor	114.7	Lw	compactor	120	1000	2.44	r	28915.15	-31521.52	228.05
Compactor 2	compactor	114.7	Lw	compactor	120	1000	2.44	r	28694.15	-31464.61	229.45
Compactor 3	compactor	114.7	Lw	compactor	120	1000	2.44	r	28805.79	-31512.23	228.43
Dump Truck 1	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28665.19	-31832.02	228.05
Dump Truck 2	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28893.25	-31524.84	228.05
Dump Truck 3	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28848.43	-31510.45	228.05
Dump Truck 4	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28781.88	-31500.09	228.83
Dump Truck 5	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28709.81	-31486.71	229.37

E-4: Proposed Action and Alternative A Excavation and Foundation Installation of Primary Beam Enclosure, Target Hall Complex Underground Enclosure, and Installation of Drilled Pilings - Line Sources

				Lw / Li			Moving Pt. Src	
Name	**ID**	**Result. PWL Day (dBA)**	**Result. PWL' Day (dBA)**	**Type**	**Value**	**Freq. (Hz)**	**Number Day**	**Speed (km/h)**
Dump Truck 3 mobile	dump_truck	108.6	84.6	PWL-Pt	dump_truck	1000	6.3	16

E-5: Proposed Action Excavation and Foundation Installation of Primary Beam Enclosure, Target Hall Complex Underground Enclosure, and Installation of Drilled Pilings - Point Sources

			Lw / Li		Operating Time Day (min)	Freq. (Hz)	Height		Coordinates		
Name	ID	Result. PWL Day (dBA)	Type	Value			(m)		X (m)	Y (m)	Z (m)
Concrete Truck 1	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28481.3	-31435.41	231.25
Concrete Truck 2	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28646.84	-31468.68	228.46
Concrete Truck 3	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28730.38	-31496.16	237.33
Drill Rig Truck 1	drillrig_truck	118.7	Lw	drillrig_truck	120	1000	2.44	r	28500.31	-31426.86	231.54
Drill Rig Truck 2	drillrig_truck	118.7	Lw	drillrig_truck	120	1000	2.44	r	28718.01	-31483.25	238.06
Backhoe trench	backhoe_trench	114.7	Lw	backhoe_trench	240	1000	2.44	r	28784.82	-31504.27	244.58
Water Truck 1	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28561.46	-31443.6	232.48
Water Truck 2	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28761.38	-31498.12	242.81
Water Truck 3	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28870.43	-31528.8	228.05
Flatbed Truck 1	water_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28830.97	-31477.63	232.67
Flatbed Truck 2	water_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28603.14	-31442.42	230.92
Grader 1	grader	119.7	Lw	grader	240	1000	2.44	r	28606.7	-31454.63	230.35
Grader 2	grader	119.7	Lw	grader	240	1000	2.44	r	28848.6	-31517.51	233.85
Crane	crane	119.7	Lw	crane	120	1000	2.44	r	28736.99	-31464.74	240.22
Scraper	scraper	119.7	Lw	scraper	240	1000	2.44	r	28808.64	-31510.21	239.98
Bulldozer 1	bulldozer	119.7	Lw	bulldozer	240	1000	2.44	r	28827.88	-31514.06	236.88
Bulldozer 2	bulldozer	119.7	Lw	bulldozer	240	1000	2.44	r	28680.49	-31473.67	233.16
Excavator 1	excavator	119.7	Lw	excavator	240	1000	2.44	r	28697.74	-31477.72	235.48
Excavator 2	excavator	119.7	Lw	excavator	240	1000	2.44	r	28589.75	-31449.25	231.37
Dump Truck 1	excavator	118.7	Lw	dump_truck	240	1000	2.44	r	28624.76	-31490.14	229.57
Dump Truck 2	excavator	118.7	Lw	dump_truck	240	1000	2.44	r	28812.94	-31540.42	231.64

E-6: Proposed Action Excavation of Absorber Hall Shaft and Underground Enclosure - Line Sources

Name	ID	Result. PWL Day (dBA)	Result. PWL' Day (dBA)	Lw / Li Type	Lw / Li Value	Freq. (Hz)	Moving Pt. Src Number Day	Moving Pt. Src Speed (km/h)
Dump Truck 6 mobile	dump_truck	108.7	82.6	PWL-Pt	dump_truck	1000	4	16

E-7: Proposed Action Excavation of Absorber Hall Shaft and Underground Enclosure - Point Sources

			Lw / Li		Operating		Height		Coordinates		
Name	ID	Result. PWL Day (dBA)	Type	Value	Time Day (min)	Freq. (Hz)	(m)		X (m)	Y (m)	Z (m)
Backhoe Trench 1	backhoe_trench	114.7	Lw	backhoe_trench	240	1000	2.44	r	28465.41	-31435.6	231.1
Backhoe Trench 2	backhoe_trench	114.7	Lw	backhoe_trench	240	1000	2.44	r	28470.14	-31410.39	228.11
Backhoe Trench 3	backhoe_trench	114.7	Lw	backhoe_trench	240	1000	2.44	r	28456.49	-31417.14	228.2
Concrete Truck 1	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28472.2	-31446.32	231.1
Concrete Truck 2	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28478.58	-31422.37	228.22
Concrete Truck 3	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28455.24	-31428.07	229.68
Water Truck 1	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28454.16	-31403.52	228.41
Water Truck 2	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28485.11	-31409.96	228.22
Water Truck 3	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28439.65	-31430.67	231.1
Blasting - explosives	blasting	128.7	Lw	blasting	0.17	1000	0.61	r	28466.89	-31419.37	204.88
Excavator 1	excavator	119.7	Lw	excavator	240	1000	2.44	r	28455.11	-31423.84	228.15
Excavator 2	excavator	119.7	Lw	excavator	240	1000	2.44	r	28460.97	-31409.77	228.06
Excavator 3	excavator	119.7	Lw	excavator	240	1000	2.44	r	28478.31	-31413.57	228.08
Excavator 4	excavator	119.7	Lw	excavator	240	1000	2.44	r	28476.86	-31430.4	228.33
Grader 1	grader	119.7	Lw	grader	240	1000	2.44	r	28461.09	-31433.53	231.1
Grader 2	grader	119.7	Lw	grader	240	1000	2.44	r	28452.11	-31452.76	231.1
Scraper 1	scraper	119.7	Lw	scraper	240	1000	2.44	r	28460.79	-31446.98	231.1
Scraper 2	scraper	119.7	Lw	scraper	240	1000	2.44	r	28469.86	-31436.64	231.1
Dump Truck 1	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28454.74	-31475.83	231.1
Dump Truck 2	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28430.62	-31438.43	231.1
Dump Truck 3	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28654.65	-31877.17	227.82
Dump Truck 4	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28664.76	-31840.93	228.05
Dump Truck 5	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28693.42	-31780.25	228.23
Bulldozer 1	bulldozer	119.7	Lw	bulldozer	240	1000	2.44	r	28678.25	-31809.75	228.05
Bulldozer 2	bulldozer	119.7	Lw	bulldozer	240	1000	2.44	r	28451.53	-31412.26	228.96
Flatbed Truck 1	flatbed_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28485.25	-31443.62	230.25
Flatbed Truck 2	flatbed_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28440.92	-31414.95	230.13

E-8: Proposed Action Excavation of Absorber Hall and Near Detector Shafts and Underground Enclosures - Line Sources

Name	ID	Result. PWL Day (dBA)	Result. PWL' Day (dBA)	Lw / Li Type	Lw / Li Value	Freq. (Hz)	Moving Pt. Src Number Day	Moving Pt. Src Speed (km/h)
Dump Truck 6 mobile	dump_truck	108.7	82.6	PWL-Pt	dump_truck	1000	4	16
Dump Truck 1 mobile - Alt A	dump_truck	108.6	80.6	PWL-Pt	dump_truck	1000	2.5	16

E-9: Proposed Action Excavation of Absorber Hall and Near Detector Shafts and Underground Enclosures - Point Sources

Name	ID	Result. PWL Day (dBA)	Lw / Li Type	Lw / Li Value	Operating Time Day (min)	Freq. (Hz)	Height (m)	Height	Coordinates X (m)	Coordinates Y (m)	Coordinates Z (m)
Backhoe Trench 1	backhoe_trench	114.7	Lw	backhoe_trench	240	1000	2.44	r	28465.41	-31435.6	231.1
Backhoe Trench 2	backhoe_trench	114.7	Lw	backhoe_trench	240	1000	2.44	r	28470.14	-31410.39	228.11
Backhoe Trench 3	backhoe_trench	114.7	Lw	backhoe_trench	240	1000	2.44	r	28456.49	-31417.14	228.2
Concrete Truck 1	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28472.2	-31446.32	231.1
Concrete Truck 2	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28478.58	-31422.37	228.22
Concrete Truck 3	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28455.24	-31428.07	229.68
Water Truck 1	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28454.16	-31403.52	228.41
Water Truck 2	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28485.11	-31409.96	228.22
Water Truck 3	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28439.65	-31430.67	231.1
Blasting - explosives	blasting	128.7	Lw	blasting	0.17	1000	0.61	r	28466.89	-31419.37	204.88
Excavator 1	excavator	119.7	Lw	excavator	240	1000	2.44	r	28455.11	-31423.84	228.15
Excavator 2	excavator	119.7	Lw	excavator	240	1000	2.44	r	28460.97	-31409.77	228.06
Excavator 3	excavator	119.7	Lw	excavator	240	1000	2.44	r	28478.31	-31413.57	228.08
Excavator 4	excavator	119.7	Lw	excavator	240	1000	2.44	r	28476.86	-31430.4	228.33
Grader 1	grader	119.7	Lw	grader	240	1000	2.44	r	28461.09	-31433.53	231.1
Grader 2	grader	119.7	Lw	grader	240	1000	2.44	r	28452.11	-31452.76	231.1
Scraper 1	scraper	119.7	Lw	scraper	240	1000	2.44	r	28460.79	-31446.98	231.1
Scraper 2	scraper	119.7	Lw	scraper	240	1000	2.44	r	28469.86	-31436.64	231.1
Dump Truck 1	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28454.74	-31475.83	231.1
Dump Truck 2	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28430.62	-31438.43	231.1
Dump Truck 3	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28654.65	-31877.17	227.82
Dump Truck 4	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28664.76	-31840.93	228.05
Dump Truck 5	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28693.42	-31780.25	228.23
Bulldozer 1	bulldozer	119.7	Lw	bulldozer	240	1000	2.44	r	28678.25	-31809.75	228.05
Bulldozer 2	bulldozer	119.7	Lw	bulldozer	240	1000	2.44	r	28451.53	-31412.26	228.96
Backhoe Trench 1 - Alt A	backhoe_trench	114.7	Lw	backhoe_trench	240	1000	2.44	r	28201.21	-31356.83	228.4
Backhoe Trench 2 - Alt A	backhoe_trench	114.7	Lw	backhoe_trench	240	1000	2.44	r	28190.91	-31333.44	228.58
Concrete Truck 1 - Alt A	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28205.04	-31341.62	228.19
Concrete Truck 2 - Alt A	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28195.96	-31330.49	229.04
Water Truck - Alt A	water_truck	118.7	Lw	water_truck	240	1000	2.44	r	28188.72	-31340.07	228.17
Flatbed Truck 1	flatbed_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28485.25	-31443.62	230.25
Flatbed Truck 2	flatbed_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28440.92	-31414.95	230.13
Flatbed Truck - Alt A	flatbed_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28210.99	-31331.66	230.14
Scraper - Alt A	scraper	119.7	Lw	scraper	240	1000	2.44	r	28218.52	-31345.08	228.19
Grader - Alt A	grader	119.7	Lw	grader	240	1000	2.44	r	28211.22	-31359.22	228.34
Bulldozer - Alt A	bulldozer	119.7	Lw	bulldozer	240	1000	2.44	r	28227.98	-31366.08	228.53
Excavator 1 - Alt A	bulldozer	119.7	Lw	excavator	240	1000	2.44	r	28194.34	-31355.1	228.42
Excavator 2 - Alt A	bulldozer	119.7	Lw	excavator	240	1000	2.44	r	28186.54	-31327.34	229.59
Blasting - explosives - Alt A	blasting	128.7	Lw	blasting	0.17	1000	2.44	r	28209.38	-31351.46	212.81
Dump Truck 2 - Alt A	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28234.02	-31352.41	228.79
Dump Truck 3 - Alt A	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28194.92	-31359.22	229.7
Dump Truck 4 - Alt A	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28172.34	-31334.47	231.14

E-10: Proposed Action Service Building Construction - Point Sources

Name	ID	Result. PWL Day (dBA)	Lw / Li Type	Lw / Li Value	Operating Time Day (min)	Freq. (Hz)	Height (m)		Coordinates X (m)	Coordinates Y (m)	Coordinates Z (m)
Concrete Truck 1	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28473.54	-31430.65	231.15
Concrete Truck 2	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28459.16	-31418.74	231.18
Dump Truck	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28486.68	-31441.55	231.26
Flatbed Truck 1	flatbed_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28487.66	-31430.82	231.34
Flatbed Truck 2	flatbed_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28490.42	-31420.31	231.46
Concrete Truck 3	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28471.35	-31415.38	231.25
Flatbed Truck 3	flatbed_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28441.51	-31416.24	231.13
Generator Set 1	generator_set	116.7	Lw	generator_set	240	1000	1.83	r	28456.29	-31427.3	230.49
Generator Set 2	generator_set	116.7	Lw	generator_set	240	1000	1.83	r	28457.09	-31412.03	230.61
Generator Set 3	generator_set	116.7	Lw	generator_set	240	1000	1.83	r	28476.36	-31412.24	230.72
Generator Set 4	generator_set	116.7	Lw	generator_set	240	1000	1.83	r	28478.68	-31426.46	230.64
Welder 1	welder	107.7	Lw	welder	240	1000	1.83	r	28454.35	-31425.3	230.5
Welder 2	welder	107.7	Lw	welder	240	1000	1.83	r	28457.93	-31409.61	230.63
Welder 3	welder	107.7	Lw	welder	240	1000	1.83	r	28478.47	-31412.98	230.74
Welder 4	welder	107.7	Lw	welder	240	1000	1.83	r	28479.11	-31424.81	230.66
Dump Truck - Alt A	dump_truck	118.7	Lw	dump_truck	240	1000	2.44	r	28227.12	-31366.39	233.31
Flatbed Truck - Alt A	flatbed_truck	118.7	Lw	flatbed_truck	240	1000	2.44	r	28200.55	-31330.44	233.49
Concrete Truck - Alt A	concrete_truck	119.7	Lw	concrete_truck	240	1000	2.44	r	28194.16	-31340.74	233.71
Generator Set 1 - Alt A	generator_set	116.7	Lw	generator_set	240	1000	1.83	r	28185.93	-31354.01	233.39
Generator Set 2 - Alt A	generator_set	116.7	Lw	generator_set	240	1000	1.83	r	28207.84	-31341.94	232.8
Welder 1 - Alt A	welder	107.7	Lw	welder	240	1000	1.83	r	28188.85	-31354.55	233.32
Welder 2 - Alt A	welder	107.7	Lw	welder	240	1000	1.83	r	28210.23	-31342.6	232.76

E-11: Proposed Action Operations - Point Sources

			Lw / Li		Height		Coordinates		
Name	ID	Result. PWL Day (dBA)	Type	Value	(m)		X (m)	Y (m)	Z (m)
Transformer 1 - LBNE 5	transformer1_LBNE5	85.9	Lw	transformer	1.83	r	28955.05	-31514.78	227.44
Transformer 2 - LBNE 5	transformer2_LBNE5	85.9	Lw	transformer	1.83	r	28954.74	-31518.88	227.44
Transformer 3 - LBNE 5	transformer3_LBNE5	85.9	Lw	transformer	1.83	r	28965.76	-31517.35	227.44
Outside Air Fan 1 - LBNE 5	OAF1_LBNE5	73	Lw	outside_airfans	1	r	28938.66	-31530.83	226.61
Outside Air Fan 2 - LBNE 5	OAF2_LBNE5	73	Lw	outside_airfans	1	r	28939.29	-31530.88	226.61
Outside Air Fan 3 - LBNE 5	OAF3_LBNE5	73	Lw	outside_airfans	1	r	28939.96	-31530.93	226.61
Ventilating Fan	ventfan_LBNE5	73	Lw	vent_fans	0.1	g	28947.01	-31515.71	229.37
HVAC 15000 cfm - LBNE 5	HVAC15000cfm_LBNE5	96.6	Lw	HVAC_15000cfm	1.52	g	28934.9	-31512.73	230.79
HVAC 50000 cfm - LBNE 20	HVAC50000cfm_LBNE20	103.4	Lw	HVAC_50000cfm	1.52	g	28725.79	-31452.74	249.66
HVAC 35000 cfm - LBNE 20	HVAC35000cfm_LBNE20	96.5	Lw	HVAC_35000cfm	1.52	g	28736.38	-31455.44	249.66
HVAC 4000 cfm - LBNE 20	HVAC4000cfm_LBNE20	86.9	Lw	HVAC_4000cfm	1.52	g	28746.6	-31458.16	249.66
Chiller 1 - LBNE 20	chiller1_LBNE20	95.6	Lw	chiller	1.83	r	28741.62	-31448.64	239.01
Chiller 2 - LBNE 20	chiller2_LBNE20	95.6	Lw	chiller	1.83	r	28743.97	-31449.23	239.26
Chiller 3 - LBNE 20	chiller3_LBNE20	95.6	Lw	chiller	1.83	r	28746.37	-31449.89	239.51
Transformer 2 - LBNE 30	transformer2_LBNE30	85.9	Lw	transformer	1.83	r	28457.35	-31412.17	230.61
Transformer 1 - LBNE 30	transformer1_LBNE30	85.9	Lw	transformer	1.83	r	28455.56	-31411.71	230.61
Chiller 1 - LBNE 30	chiller1_LBNE30	95.6	Lw	chiller	1.83	r	28454.07	-31417.92	230.55
Chiller 2 - LBNE 30	chiller2_LBNE30	95.6	Lw	chiller	1.83	r	28455.74	-31418.38	230.56
HVAC 2400 cfm - LBNE 30	HVAC2400cfm_LBNE30	73	Lw	HVAC_2400cfm	1.52	r	28454.53	-31423.11	230.2
Chiller - Near Detector	chiller_NearDetector	95.6	Lw	chiller	1.83	r	28203.63	-31357.5	233.06
HVAC 5000 cfm - Near Detector	HVAC5000_NearDetector	86.9	Lw	HVAC_5000cfm	1.52	r	28208.52	-31358.77	232.68

APPENDIX E-2

SURF CadnaA Noise Modeling Report

Technical Memo

Date:	Wednesday, March 11, 2015
Project:	LBNF Far Detector Site
To:	John Scheetz, SDSTA
From:	Brian Goss and Mike Parsons, PE
Subject:	CadnaA Noise Modeling Methodology for Proposed Action

HDR performed noise modeling to estimate noise levels during construction of the Proposed Action for the LBNF far detector site. SDSTA provided baseline noise monitoring data that was used to estimate current noise levels. This memorandum documents the methodology used for estimating construction noise levels. A separate effort was conducted to estimate noise from dump truck traffic for hauling rock removed from the 4850 level at the SURF site in Lead, South Dakota. The noise levels of the estimated dump truck traffic, and the methodology used to predict the noise levels, were documented in an HDR memorandum titled “TNM Dump Truck Analysis Methodology”, dated June 27, 2014.

Project related Leq noise levels for each construction phase were predicted using CadnaA (Computer Aided Noise Abatement). Leq is the equivalent steady-state sound level, which, in a stated period of time, contains the same acoustic energy as the time-varying sound level during the same time period, with Leq(h) being the hourly value of the Leq. CadnaA is a three-dimensional software-based acoustical analysis tool based on the ISO 9613 standard for outdoor noise propagation. The estimated noise levels accounted for multiple pieces of equipment generating noise during separate activities for each construction phase. The distance from construction activities varied at the different receptor locations, resulting in a variance of predicted noise levels depending on proximity to the closest receiver.

The noise modeling was performed by identifying three construction phases, the construction activities needed to accomplish the construction, the type of equipment anticipated to be used, the estimated hours per day and the time of day when the equipment would operate, and the noise generated by the equipment. HDR coordinated with SDSTA to identify the construction phases, activities, equipment, and operation parameters, and the CadnaA noise model used these equipment factors for calculating noise levels. Figures 1, 2, and 3 show the locations of noise receptors related to the various phases of construction and operation for the Proposed Action.

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Receptors were chosen to be near the areas where equipment would likely be operating. Receptors 1 – 35 (Figure 1) are related to activities at the SURF site. Receptors 36 – 49 (Figure 2) are related to the potential transportation of waste rock to the Gilt Edge Superfund site, and receptors 50 – 59 (Figure 3) are related to the potential transportation of waste rock to the Open Cut. SDSTA identified the locations of the noise receptors. Both disposal locations are under consideration and discussed in the EA.

The three main phases of surface construction for the Proposed Action at SURF are as follows:

1. **Site Preparation and Excavation**: This phase would include demolition of the Ross Boiler and site preparation for constructing one of the three alternative methods (e.g., railveyor, pipe conveyor, trucking) conveying rock excavated for the deep detector at the 4850 Level. The demolition of the Ross Boiler and the site preparation for the conveyance would not overlap in time.
2. **Buildings and Infrastructure**: This phase would include construction of the cryogenic support building and construction of one of the three conveyance alternative methods. The construction of the cryogen building and the rock conveyance system would not overlap.
3. **Detector Facility Excavation:** This phase includes operation of the rock crusher, and operation of one of the three conveyance alternative methods. Crushing and rock conveyance activities would overlap.

The CadnaA noise model was used to evaluate several construction scenarios to estimate noise levels and their potential effects on sensitive receptors. The noise modeling effort for the far site incorporated terrain for all the construction scenarios. The modeling of noise for operation of the enclosed rock crusher in Phase 3 accounted for attenuation of noise by the structure in which the rock crusher would be enclosed. Ground Borne Vibration (GBV) was estimated at key locations adjacent to where construction activities would be conducted using source levels and equations from the Federal Transit Administration (FTA) Transit Noise and Vibration Impact Assessment Manual.

In order to predict future noise levels, the modeling effort assumed equipment sources of noise and duration of their operation in order to calculate noise levels at any given receptor. Table E-2.1 shows the likely types and numbers of equipment that would

Table E-2.1 Equipment Used for Site Preparation and Construction of the Proposed Action

Activity	Equipment		Building Component
Phase 1[a]			
Demolition of Ross Boiler Building	Flatbed trucks (2) Backhoe (2)	Front-end Loader (2) Water Tanker (1)	NA
Site preparation for Rail/ Pipe Conveyor	Flatbed Trucks (2) Backhoe (2) Compactor (1)	Water tanker (1) Crane (1) Front-end loader (2)	NA
Site preparation for Truck Conveyor and Load-out	Flatbed Trucks (2) Backhoe (2) Compactor (1)	Water tanker (1) Crane (1) Front-end loader (2)	NA
Phase 2[b]			
Construction of Cryogenic Building[c]	Flatbed truck (2) Backhoe (2)	Compactor (1) Water tanker (2)	Foundation
	Crane (4) Front-end loader (2) Compressor (4)	Generator (4) Water tanker (2)	Structure
	Backhoe (2) Crane (2) Front-end loader (2)	Flatbed truck (2) Water tanker (2)	Utilities
Construction of Rail/Pipe Conveyor[c]	Flatbed truck (2) Backhoe (2)	Compactor (1) Water tanker (2)	Foundation
	Crane (4) Front-end loader (2) Compressor (4)	Generator (4) Water tanker (2)	Structure
	Backhoe (2) Crane (2) Front-end loader (2)	Flatbed truck (2) Water tanker (2)	Utilities
Construction of Truck Conveyor and Load-out[c]	Flatbed truck (2) Backhoe (2)	Compactor (1) Water tanker (2)	Foundation
	Crane (4) Front-end loader (2) Compressor (4)	Generator (4) Water tanker (2)	Structure
	Backhoe (2) Crane (2) Front-end loader (2)	Flatbed truck (2) Water tanker (2)	Utilities
Phase 3[d]			
Operation of the Ross Crusher	Crusher		NA
Operation of the Railveyor/ Pipe Conveyor	Railveyor drive units Rail cars		NA
Trucking	Conveyor (to truck load-out) Truck Load-out (on Kirk Road)		NA

Notes:

a Phase 1 would include site preparation for either the rail/conveyor or the truck conveyor and load out, but not both.

b Phase 2 would include construction of either the rail/conveyor or the truck conveyor and load out, but not both.

c The construction of the foundation, structure, and utilities would occur in sequence and not overlap.

d Phase 3 would involve either operation of the rail-conveyor alternative or the trucking alternative, but not both. Both alternatives would involve the crusher. Operation of the crusher would occur at the same time as either of the transportation alternatives.

be used for specific phases of the construction. Table E-2.2 shows source terms for all equipment that is anticipated to be used during the various phases of the project.

Table E-2.2. Source Equipment Sound Levels

Equipment	Sound Pressure Level	Sound Power Level (independent of distance)
At 50 feet		
Backhoe[a]	78.0	112.6
Compactor[a]	83.0	117.6
Compressor[a]	78.0	112.6
Concrete Truck[a]	80.0	114.6
Crane[a]	81.0	115.6
Drill Rig[a]	79.0	113.6
Dump Truck[a]	76.0	110.6
Flatbed Truck[a]	74.0	108.6
Front-end Loader[a]	79.0	113.6
Generator[a]	81.0	115.6
Grader[a]	85.0	119.6
Heavy duty Pick-up Truck[a]	75.0	109.6
Scraper[a]	84.0	118.6
Tanker Truck[a]	76.0	110.6
Water Tanker[a]	76.0	110.6
Rock Crusher[b,c]	88.9	123.5
Rail Cars[d,e]	82.0	116.6
At 10 meters		
Railveyor Drive Units[f]	69.0	99.9
Conveyor Drive Unit[g,h]	77.0	107.9
Truck Load-out[i,j]	87.0	117.9

Notes:
a Based on FHWA Construction Noise Handbook *RCNM Default Noise Emission Reference Levels*.
b Based on City of San Marcos, 5399/University Business Park Specific Plan (December 2006).
c The value for the crusher is for an open crusher, but the crusher at SURF is enclosed.
d FTA Transit Noise and Vibration Impact Assessment (May 2006).
e 2 trains, 655' long with 82 cars each traveling at 7.1 mph; a train passes a given point 3 times in an hour (one train would pass that oint twice, while the other only passses once).
f Information from Railveyor provided in an email from Sanford Lab on 3/21/2014.
g Construction Noise Database (Phase 3), NANR 174 (Revised September 2008).
h Table 1(b) http://archive.defra.gov.uk/environment/quality/noise/research/documents/noise-database-phase3.pdf.
i Construction Noise Database (Phase 3), NANR 174 (Revised September 2008).
j Table 1(b) http://archive.defra.gov.uk/environment/quality/noise/research/documents/noise-database-phase3.pdf.

If the rail or pipe conveyor alternatives were constructed, they would be developed along the same alignment previously used by Homestake for a pipe conveyor. Manufacturer noise data from the pipe conveyor and rail system providers indicate the rail system noise (from 70 to 76 dBA) is slightly greater than the pipe conveyor noise levels (from 66 to79 dBA at 1 meter) (Fantin 2013; Cohen 2013). Therefore, only the railveyor operating noise was estimated, as representative of the most conservative noise scenario.

Ambient (background) noise levels were measured during a 24-hour period during May, 2014. Ambient noise monitoring stations were selected to be representative of the project vicinity. Figure 4 shows the locations of all ambient noise monitoring locations and Table E-2.3 summarizes the results of the 24-hour monitoring study for each location. Results are shown as L_{eq} (equivalent continuous noise level) for daytime (7 am to 10 pm) and nighttime (10 pm to 7 am). L_{eq} is a standard measure of perceived noise levels that vary over time. The method results in a single value expressed in A-weighted decibels that takes into account the total sound energy over the time period of interest. A-weighting weights sound energy differently within different frequency bands to be more representative of the human range of frequencies.

Table E-2.4 shows CadnaA model results for Phase 1 activities. Tables E-2.5 through E-2.7 show estimated noise levels for activities during Phase 2. Table E.2-8 provides estimated noise levels for activities during Phase 3. As documented in the note at the end of Table E-2.1, there are alternatives included within each phase; thus, for any phase, only some of the alternatives would be performed. In addition, many of the impacts would be sequential rather than coincident.

In Tables E-2.4 through E-2.8, noise impacts from various activities tied to specific phases are examined by receptor locations. These five tables indicate the impact of various phases of construction on receptors. With one exception, all tables represent construction activities potentially occurring between 7 am to 10 pm. Table E-2.8 includes two sub-tables: Table E-2.8a for 7 am and 10 pm operation, and Table E-2.8b for 10 pm to 7 am operation. The rock crusher and conveyer system are the only equipment proposed for nighttime operation. The impacts are expressed in terms of the absolute noise level of the activity in combination with the existing background, and the increase in noise level expected over the existing background alone. In each table, data and receptors for which there is an increase in noise levels, over the existing background, are indicated by shading. For non-shaded receptors, no increase would be expected.

Another way of visualizing noise impacts from equipment operation is illustrated in Figures 5 through 12. Noise contours have been generated for different geographical areas (receptors) and for different phases of construction. Figures 5 through 7 address Phase 1 noise levels, Figures 8 through 10 represent Phase 2 noise levels, and Figures 11 and 12 apply to Phase 3 noise levels.

Table E-2.3. Noise Monitoring Data of Leq Day (7 a.m.-10 p.m.) and Night (10 p.m.-7 a.m.)

Time	Location							
	Ross Hoist	**Ross Dry**	**Open Cut**	**Sand Street**	**Kirk Bridge**	**385**	**Roundhouse**	**Gilt Edge**
7:00 a.m.	45.4	42.6	48.7	53	55.5	61.8	63.0	40.6
8:00 a.m.	50.8	41.4	48.8	53	55.3	62.6	63.9	43.6
9:00 a.m.	45.2	39.5	48.6	55	56.5	65.3	65.8	51.3
10:00 a.m.	66.3	43.5	48.6	56			65.0	39.5
11:00 a.m.	65.6	43.0	49.0	56			63.8	36.6
12:00 p.m.	46.4	39.2	50.0	55			67.7	73.6
1:00 p.m.	55.3	39.8	39.8	56			66.3	50.8
2:00 p.m.	46.0	59.7			57.1	66.3	64.4	55.9
3:00 p.m.	46.2	40.0	54.5		56.4	63.8	63.6	50.4
4:00 p.m.	45.2	40.1	57.7	58	54.9	64.4	64.0	41.2
5:00 p.m.	44.9	38.6	55.4	56	56.4	63.4	63.4	40.4
6:00 p.m.	43.7	40.1	47.6	51	56	62.9	61.7	37.9
7:00 p.m.	45.1	39.5	45.1	52	55.5	62.1	61.0	38.5
8:00 p.m.	44.1	40.0	44.5	50	55.5	59.5	59.4	36.1
9:00 p.m.	46.2	41.7	44.0	48	55.5	60.5	59.0	33.2
10:00 p.m.	43.5	43.5	45.5	45	55.7	57.0	57.2	35.8
11:00 p.m.	44.8	40.8	37.2	42	55.3	60.0	55.3	34.0
12:00 a.m.	47.3	40.3	39.6	43	55.4	50.4	53.3	30.2
1:00 a.m.	43.5	40.4	37.3	40	55.8	50.4	56.3	57.3
2:00 a.m.	43.4	39.7	37.7	39	55.4	45.7	54.0	47.5
3:00 a.m.	43.4	39.7	32.8	39	55.2	52.9	51.0	32.4
4:00 a.m.	45.2	41.6	40.9	46	56	56.5	51.8	36.3
5:00 a.m.	45.1	44.5	41.2	47	55.7	56.4	59.0	43.1
6:00 a.m.	47.3	45.0	44.6	50	55.4	61.5	61.9	41.6
Leq Average (7 a.m.-10 p.m.)	57.4	48.5	51.0	54.3	55.9	63.1	63.8	61.7
Leq Average (10 p.m.-7 a.m.)	45.3	42.0	40.0	45.0	55.5	56.7	56.8	49.0

Notes:
a Data table provided by SDSTA.

Table E-2.4 Proposed Action Construction Noise Levels Site Preparation and Excavation: Modeled Day Time Noise

Receptor	Leq (7am-10pm) (dBA)									
	Existing[a]	Ross Boiler Demolition	Total	Increase over Existing	Railveyor/ Pipe Conveyor Site Prep	Total	Increase over Existing	Truck Conveyor and Load Out Site Preparation	Total	Increase over Existing
1	56	39	56	0	19	56	0	49	56	1
2	56	37	56	0	20	56	0	57	59	4
3	57	57	60	3	32	57	0	49	58	1
4	57	58	60	3	32	57	0	50	58	1
5	57	59	61	4	33	57	0	49	58	1
6	57	59	61	4	33	57	0	48	58	1
7	57	54	59	2	38	57	0	54	59	2
8	49	47	51	2	38	49	0	54	55	6
9	49	42	50	1	36	49	0	55	56	7
10	54	21	54	0	62	62	8	23	54	0
11	54	22	54	0	63	63	9	23	54	0
12	54	22	54	0	65	65	11	24	54	0
13	54	22	54	0	63	63	9	24	54	0
14	54	22	54	0	63	63	9	24	54	0
15	54	22	54	0	63	63	9	23	54	0
16	54	22	54	0	63	63	9	23	54	0
17	54	22	54	0	62	62	8	23	54	0
18	54	21	54	0	61	62	8	23	54	0
19	54	22	54	0	61	62	8	23	54	0
20	54	22	54	0	63	63	9	23	54	0
21	54	22	54	0	64	64	10	23	54	0
22	54	21	54	0	59	60	6	23	54	0
23	51	21	51	0	59	60	9	22	51	0
24	51	20	51	0	58	59	8	22	51	0
25	51	20	51	0	60	60	9	23	51	0
26	51	20	51	0	57	58	7	23	51	0
27	51	22	51	0	61	61	10	24	51	0
28	51	21	51	0	59	60	9	25	51	0
29	51	21	51	0	58	59	8	25	51	0
30	51	21	51	0	57	58	7	25	51	0
31	51	21	51	0	57	58	7	25	51	0
32	51	20	51	0	56	57	6	25	51	0
33	51	20	51	0	56	57	6	25	51	0
34	56	30	56	0	23	56	0	56	58	2
35	56	25	56	0	27	56	0	32	56	0

Note:
a Existing noise levels estimated from noise monitoring done throughout the project area

Table E-2.5 Construction of Cryogen Building: Modeled Day Time Noise

Receptor	Leq (7am-10pm) (dBA)									
	Existing[a]	FOUNDATION	Total	Increase over Existing	STRUCTURE	Total	Increase over Existing	UTILITIES	Total	Increase over Existing
1	56	41	56	0	47	56	1	43	56	0
2	56	39	56	0	45	56	0	41	56	0
3	57	58	60	3	63	64	7	60	62	5
4	57	58	60	3	64	65	8	60	62	5
5	57	59	61	4	65	65	8	61	63	6
6	57	59	61	4	65	66	9	61	63	6
7	57	55	59	2	60	62	5	57	60	3
8	49	46	51	2	52	54	5	49	52	3
9	49	41	50	1	47	51	2	44	50	1
10	54	22	54	0	27	54	0	24	54	0
11	54	22	54	0	27	54	0	24	54	0
12	54	22	54	0	28	54	0	24	54	0
13	54	22	54	0	28	54	0	24	54	0
14	54	22	54	0	28	54	0	24	54	0
15	54	22	54	0	27	54	0	24	54	0
16	54	22	54	0	27	54	0	24	54	0
17	54	22	54	0	27	54	0	24	54	0
18	54	22	54	0	27	54	0	24	54	0
19	54	22	54	0	27	54	0	24	54	0
20	54	22	54	0	28	54	0	24	54	0
21	54	22	54	0	28	54	0	24	54	0
22	54	21	54	0	27	54	0	23	54	0
23	51	21	51	0	26	51	0	23	51	0
24	51	20	51	0	26	51	0	22	51	0
25	51	20	51	0	26	51	0	23	51	0
26	51	20	51	0	25	51	0	22	51	0
27	51	21	51	0	27	51	0	24	51	0
28	51	21	51	0	27	51	0	24	51	0
29	51	21	51	0	27	51	0	24	51	0
30	51	21	51	0	27	51	0	24	51	0
31	51	20	51	0	26	51	0	23	51	0
32	51	20	51	0	26	51	0	23	51	0
33	51	20	51	0	26	51	0	22	51	0
34	56	30	56	0	36	56	0	32	56	0
35	56	25	56	0	31	56	0	27	56	0

Note:
a Existing noise levels estimated from noise monitoring done throughout the project area.

Table E-2.6 Construction of Railveyor/Pipe Conveyor: Modeled Day Time Noise

Receptor	Leq (7am-10pm) (dBA)									
	Existing[a]	FOUNDATION	Total	Increase over Existing	STRUCTURE	Total	Increase over Existing	UTILITIES	Total	Increase over Existing
1	56	18	56	0	24	56	0	22	56	0
2	56	18	56	0	24	56	0	20	56	0
3	57	29	57	0	36	57	0	35	57	0
4	57	29	57	0	36	57	0	35	57	0
5	57	30	57	0	38	57	0	37	57	0
6	57	29	57	0	37	57	0	36	57	0
7	57	37	57	0	42	57	0	39	57	0
8	49	35	49	0	42	50	1	39	49	0
9	49	36	49	0	41	50	1	39	49	0
10	54	56	58	4	65	65	11	63	64	10
11	54	56	58	4	65	65	11	64	65	11
12	54	59	60	6	66	66	12	67	67	13
13	54	58	59	5	64	64	10	64	64	10
14	54	58	60	6	63	64	10	62	63	9
15	54	58	59	5	63	63	9	61	62	8
16	54	58	59	5	63	63	9	61	61	7
17	54	58	60	6	63	64	10	59	60	6
18	54	59	60	6	64	64	10	59	60	6
19	54	59	60	6	65	65	11	58	60	6
20	54	61	62	8	69	69	15	59	60	6
21	54	61	62	8	70	70	16	60	61	7
22	54	57	59	5	62	62	8	56	58	4
23	51	57	58	7	62	62	11	56	58	7
24	51	55	56	5	61	61	10	56	57	6
25	51	59	59	8	64	64	13	60	60	9
26	51	56	57	6	61	61	10	57	58	7
27	51	61	62	11	67	67	16	63	63	12
28	51	59	60	9	64	65	14	61	61	10
29	51	58	59	8	63	64	13	60	60	9
30	51	57	58	7	62	62	11	58	59	8
31	51	56	57	6	61	62	11	57	58	7
32	51	55	56	5	60	61	10	57	58	7
33	51	54	56	5	60	60	9	56	57	6
34	56	20	56	0	26	56	0	22	56	0
35	56	24	56	0	31	56	0	27	56	0

Note:
a Existing noise levels estimated from noise monitoring done throughout the project area.

Table E-2.7 Construction of Truck Conveyor and Loadout: Modeled Day Time Noise

Receptor	Leq (7am-10pm) (dBA)									
	Existing[a]	FOUNDATION	Total	Increase over Existing	STRUCTURE	Total	Increase over Existing	UTILITIES	Total	Increase over Existing
1	56	47	56	1	63	63	8	49	57	1
2	56	58	60	4	53	57	2	59	61	5
3	57	44	57	0	50	58	1	46	57	0
4	57	44	57	0	50	58	1	46	57	0
5	57	45	57	0	50	58	1	48	57	0
6	57	46	57	0	51	58	1	48	58	1
7	57	50	58	1	55	59	2	53	58	1
8	49	50	53	4	55	56	7	53	54	5
9	49	51	53	4	58	59	10	55	56	7
10	54	21	54	0	26	54	0	23	54	0
11	54	21	54	0	26	54	0	23	54	0
12	54	21	54	0	27	54	0	23	54	0
13	54	21	54	0	27	54	0	23	54	0
14	54	21	54	0	27	54	0	23	54	0
15	54	21	54	0	27	54	0	23	54	0
16	54	21	54	0	26	54	0	23	54	0
17	54	21	54	0	26	54	0	23	54	0
18	54	20	54	0	26	54	0	23	54	0
19	54	20	54	0	26	54	0	23	54	0
20	54	21	54	0	26	54	0	23	54	0
21	54	21	54	0	26	54	0	23	54	0
22	54	20	54	0	26	54	0	22	54	0
23	51	20	51	0	25	51	0	22	51	0
24	51	19	51	0	25	51	0	21	51	0
25	51	20	51	0	25	51	0	22	51	0
26	51	20	51	0	26	51	0	23	51	0
27	51	21	51	0	27	51	0	24	51	0
28	51	21	51	0	27	51	0	24	51	0
29	51	21	51	0	27	51	0	24	51	0
30	51	22	51	0	27	51	0	24	51	0
31	51	22	51	0	27	51	0	24	51	0
32	51	22	51	0	27	51	0	24	51	0
33	51	22	51	0	27	51	0	24	51	0
34	56	49	57	1	56	59	3	53	57	2
35	56	29	56	0	35	56	0	31	56	0

Note:
a Existing noise levels estimated from noise monitoring done throughout the project area.

TableE-2.8a Proposed Action Noise Levels Operation of Rock Crusher and Conveyor System: Modeled Night Time Noise

Receptor	Leq (10pm-7am) (dBA)						
	Existing[a]	Rock Crusher & Railveyor/Pipe Conveyor	Total	Increase over Existing	Rock Crusher & Truck Conveyor and Load Out	Total	Increase over Existing
1	55	32	55	0	40	55	0
2	55	27	55	0	51	57	2
3	45	42	47	2	42	47	2
4	45	40	46	1	40	46	1
5	45	43	47	2	43	47	2
6	45	45	48	3	45	48	3
7	45	48	50	5	48	50	5
8	42	46	47	5	46	48	6
9	42	51	52	10	52	52	10
10	45	47	49	4	16	45	0
11	45	47	49	4	16	45	0
12	45	49	51	6	16	45	0
13	45	48	50	5	16	45	0
14	45	48	50	5	16	45	0
15	45	48	50	5	16	45	0
16	45	48	50	5	16	45	0
17	45	49	51	6	16	45	0
18	45	50	52	7	16	45	0
19	45	52	53	8	16	45	0
20	45	56	56	11	16	45	0
21	45	58	58	13	16	45	0
22	45	49	51	6	15	45	0
23	40	49	50	10	15	40	0
24	40	48	49	9	14	40	0
25	40	51	51	11	15	40	0
26	40	48	49	9	15	40	0
27	40	53	53	13	16	40	0
28	40	52	52	12	16	40	0
29	40	51	51	11	16	40	0
30	40	50	50	10	16	40	0
31	40	49	50	10	16	40	0
32	40	48	49	9	16	40	0
33	40	48	48	8	16	40	0
34	55	37	55	0	40	55	0
35	55	28	55	0	22	55	0

Note:
a Existing noise levels estimated from noise monitoring done throughout the project area.

TableE-2.8b Proposed Action Noise Levels Operation of Rock Crusher and Conveyor System: Modeled Day Time Noise

Receptor	Leq (7am-10pm) (dBA)						
	Existing[a]	Rock Crusher & Railveyor/Pipe Conveyor	Total	Increase over Existing	Rock Crusher & Truck Conveyor and Load Out	Total	Increase over Existing
1	56	32	56	0	40	56	0
2	56	27	56	0	51	57	1
3	57	42	57	0	42	57	0
4	57	40	57	0	40	57	0
5	57	43	57	0	43	57	0
6	57	45	57	0	45	57	0
7	57	48	58	1	48	58	1
8	49	46	51	2	46	51	2
9	49	51	53	4	52	54	5
10	54	47	55	1	16	54	0
11	54	47	55	1	16	54	0
12	54	49	55	1	16	54	0
13	54	48	55	1	16	54	0
14	54	48	55	1	16	54	0
15	54	48	55	1	16	54	0
16	54	48	55	1	16	54	0
17	54	49	55	1	16	54	0
18	54	50	56	2	16	54	0
19	54	52	56	2	16	54	0
20	54	56	58	4	16	54	0
21	54	58	59	5	16	54	0
22	54	49	55	1	15	54	0
23	51	49	53	2	15	51	0
24	51	48	53	2	14	51	0
25	51	51	54	3	15	51	0
26	51	48	53	2	15	51	0
27	51	53	55	4	16	51	0
28	51	52	54	3	16	51	0
29	51	51	54	3	16	51	0
30	51	50	53	2	16	51	0
31	51	49	53	2	16	51	0
32	51	48	53	2	16	51	0
33	51	48	53	2	16	51	0
34	56	37	56	0	40	56	0
35	56	28	56	0	22	56	0

Note:
a Existing noise levels estimated from noise monitoring done throughout the project area.

Tables E-2.9 and E-2.10 indicates the noise impacts for two alternative methods of disposing of excavated rock that differ from the rail-conveyor alternative directly to the Open Cut. The rock would be trucked to either the Gilt Edge Superfund Site or the Open Cut. Noise was modeled as a linear source for these alternatives for receptors indicated in Figures 2 and 3. The modeling takes into account the distance from the highway to each receptor in modeling the perceived noise impact. A description of the modeling methodology is documented in an HDR memorandum titled "TNM Dump Truck Analysis Methodology", dated June 27, 2014.

Table E-2.9 Approximate Noise Levels at Receptor Locations (Gilt Edge Option)

Receptor	Distance from Roadway Centerline (feet)	Existing Noise Level Leq (dBA)[a]	Dump Truck Noise Level Leq (dBA)	Overall Combined Noise Level Leq (dBA)	Increase Over Existing dBA
36	45	56	59	61	5
37	65	56	57	59	3
38	55	56	58	60	4
39	85	59	55	60	1
40	70	59	56	61	2
41	60	59	57	61	2
42	45	59	59	62	3
43	255	59	48	59	0
44	200	43	50	50	7
45	210	43	49	50	7
46	205	43	49	50	7
47	80	43	55	55	12
48	180	43	50	51	8
49	300	43	47	48	5

Note:
a Existing noise levels estimated from noise monitoring conducted throughout the project area in May 2014.

Table E-2.10 Approximate Noise Levels at Receptor Locations (Open Cut Option)

Receptor	Distance from Roadway Centerline (feet)	Existing Noise Level Leq (dBA)[a]	Dump Truck Noise Level Leq (dBA)	Overall Combined Noise Level Leq (dBA)	Increase Over Existing dBA
50	55	60	58	62	2
51	60	60	58	62	2
52	150	60	51	61	1
53	30	60	62	64	4
54	150	60	51	61	1
55	55	60	58	62	2
56	70	60	56	62	2
57	120	60	53	61	1
58	60	60	58	62	2
59	75	60	56	61	1

Note:
a Existing noise levels estimated from noise monitoring conducted throughout the project area in May 2014.

FIGURES

APPENDIX F

Air Emissions Calculations

APPENDIX F-1

Fermilab Air Emissions Calculations

Table F1-1 Summary of Annual Emissions for Fermilab Project

Year	Emissions (short tons/year)						CO_2e Emissions (metric tons/year)		
	CO	NO_X	PM_{10}	$PM_{2.5}$	SO_2	VOC	Direct	Indirect	Total
Proposed Action Construction									
2017	43.28	89.84	38.99	13.53	28.62	7.52	17,013	2,304	19,318
2018	42.81	90.50	42.36	14.40	28.71	7.52	17,195	2,310	19,505
2019	38.12	83.73	19.42	11.13	26.64	6.81	15,945	1,932	17,877
2020	40.68	87.92	26.01	12.23	27.96	7.25	16,757	2,315	19,072
2021	40.44	88.88	23.92	11.76	28.39	7.26	16,931	2,319	19,250
2022	39.77	88.51	23.88	11.73	28.30	7.19	16,879	2,312	19,191
2023	38.31	85.93	22.57	11.28	27.53	6.96	16,378	2,273	18,651
Max Proposed Action Construction Emissions	43.28	90.50	42.36	14.40	28.71	7.52	17,195	2,319	19,505
Proposed Action Operational Period									
2024 - 2044	7.76E-01	5.04E-01	4.94E-02	4.76E-02	4.07E-03	5.66E-02	635	54,101	54,736

Table F1-2 Project Schedule

		Activity / Parameter / Equipment	Units	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	2017 Total
1	**Surface**		--													--
	A.)	**Project Infrastructure**	--													--
	1.) Civil/Site (Three Segments)		--													--
		a.) Segment 1	--													--
		b.) Segment 2	--													--
		c.) Segment 3	--													--
	B.)	**LBNE 5**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**LBNE 20**	--													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	D.)	**LBNE 30**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	E.)	**LBNE 40**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
2	**Underground**		--													--
	A.)	**Extraction Enclosure**	--													--
		1.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	B.)	**Absorber Hall**	--													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**Primary Beam Enclosure**	--													--
		1.) Civil/Site	--													--
		2.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	D.)	**Decay Pipe**	--													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
	E.)	**NND Hall**	--													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--

Notes:

Schedule represents range of months during which each activity may occur based on information provided by Fermilab. Project infrastructure activities are assumed to occur from 2017 through the end of the project.

Table F1-2 Project Schedule

		Activity / Parameter / Equipment	Units	Calendar 2018												2018 Total
				Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	
1	**Surface**		--													--
	A.)	**Project Infrastructure**	--													--
	1.) Civil/Site (Three Segments)		--													--
		a.) Segment 1	--													--
		b.) Segment 2	--													--
		c.) Segment 3	--													--
	B.)	**LBNE 5**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**LBNE 20**	--													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	D.)	**LBNE 30**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	E.)	**LBNE 40**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
2	**Underground**		--													--
	A.)	**Extraction Enclosure**	--													--
		1.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	B.)	**Absorber Hall**	--													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**Primary Beam Enclosure**	--													--
		1.) Civil/Site	--													--
		2.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	D.)	**Decay Pipe**	--													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
	E.)	**NND Hall**	--													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--

Notes:

Schedule represents range of months during which each activity may occur based on information provided by Fermilab. Project infrastructure activities are assumed to occur from 2017 through the end of the project.

Table F1-2 Project Schedule

	Activity / Parameter / Equipment		Units	Calendar 2019 Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	2019 Total
1	**Surface**		**--**													--
	A.)	**Project Infrastructure**	**--**													--
	1.) Civil/Site (Three Segments)		--													--
		a.) Segment 1	--													--
		b.) Segment 2	--													--
		c.) Segment 3	--													--
	B.)	**LBNE 5**	**--**													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**LBNE 20**	**--**													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	D.)	**LBNE 30**	**--**													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	E.)	**LBNE 40**	**--**													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
2	**Underground**		**--**													--
	A.)	**Extraction Enclosure**	**--**													--
		1.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	B.)	**Absorber Hall**	**--**													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**Primary Beam Enclosure**	**--**													--
		1.) Civil/Site	--													--
		2.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	D.)	**Decay Pipe**	**--**													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
	E.)	**NND Hall**	**--**													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--

Notes:
Schedule represents range of months during which each activity may occur based on information provided by Fermilab. Project infrastructure activities are assumed to occur from 2017 through the end of the project.

Table F1-2 Project Schedule

		Activity / Parameter / Equipment	Units	Calendar 2020 Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	2020 Total
1	**Surface**		--													--
	A.)	**Project Infrastructure**	--													--
	1.) Civil/Site (Three Segments)		--													--
		a.) Segment 1	--													--
		b.) Segment 2	--													--
		c.) Segment 3	--													--
	B.)	**LBNE 5**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**LBNE 20**	--													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	D.)	**LBNE 30**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	E.)	**LBNE 40**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
2	**Underground**		--													--
	A.)	**Extraction Enclosure**	--													--
		1.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	B.)	**Absorber Hall**	--													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**Primary Beam Enclosure**	--													--
		1.) Civil/Site	--													--
		2.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	D.)	**Decay Pipe**	--													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
	E.)	**NND Hall**	--													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--

Notes:

Schedule represents range of months during which each activity may occur based on information provided by Fermilab. Project infrastructure activities are assumed to occur from 2017 through the end of the project.

Table F1-2 Project Schedule

		Activity / Parameter / Equipment	Units	Calendar 2021 Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	2021 Total
1	**Surface**		--													--
	A.)	**Project Infrastructure**	--													--
	1.) Civil/Site (Three Segments)		--													--
		a.) Segment 1	--													--
		b.) Segment 2	--													--
		c.) Segment 3	--													--
	B.)	**LBNE 5**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**LBNE 20**	--													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	D.)	**LBNE 30**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	E.)	**LBNE 40**	--													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
2	**Underground**		--													--
	A.)	**Extraction Enclosure**	--													--
		1.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	B.)	**Absorber Hall**	--													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**Primary Beam Enclosure**	--													--
		1.) Civil/Site	--													--
		2.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	D.)	**Decay Pipe**	--													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
	E.)	**NND Hall**	--													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--

Notes:
Schedule represents range of months during which each activity may occur based on information provided by Fermilab. Project infrastructure activities are assumed to occur from 2017 through the end of the project.

Table F1-2 Project Schedule

		Activity / Parameter / Equipment	Units	Calendar 2022 Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	2022 Total
1	**Surface**		**--**													--
	A.)	**Project Infrastructure**	**--**													--
	1.) Civil/Site (Three Segments)		--													--
		a.) Segment 1	--													--
		b.) Segment 2	--													--
		c.) Segment 3	--													--
	B.)	**LBNE 5**	**--**													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**LBNE 20**	**--**													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	D.)	**LBNE 30**	**--**													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	E.)	**LBNE 40**	**--**													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
2	**Underground**		**--**													--
	A.)	**Extraction Enclosure**	**--**													--
		1.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	B.)	**Absorber Hall**	**--**													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**Primary Beam Enclosure**	**--**													--
		1.) Civil/Site	--													--
		2.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	D.)	**Decay Pipe**	**--**													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
	E.)	**NND Hall**	**--**													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--

Notes:

Schedule represents range of months during which each activity may occur based on information provided by Fermilab. Project infrastructure activities are assumed to occur from 2017 through the end of the project.

Table F1-2 Project Schedule

		Activity / Parameter / Equipment	Units	Calendar 2023												2023 Total
				Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	
1	**Surface**		**--**													--
	A.)	**Project Infrastructure**	**--**													--
	1.) Civil/Site (Three Segments)		--													--
		a.) Segment 1	--													--
		b.) Segment 2	--													--
		c.) Segment 3	--													--
	B.)	**LBNE 5**	**--**													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**LBNE 20**	**--**													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	D.)	**LBNE 30**	**--**													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	E.)	**LBNE 40**	**--**													--
		1.a) Civil/Site	--													--
		1.b) Civil/Site	--													--
		2.) Structural	--													--
		3.) MEP	--													--
2	**Underground**		**--**													--
	A.)	**Extraction Enclosure**	**--**													--
		1.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	B.)	**Absorber Hall**	**--**													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--
	C.)	**Primary Beam Enclosure**	**--**													--
		1.) Civil/Site	--													--
		2.) Excavation	--													--
		3.) Structural	--													--
		4.) MEP	--													--
	D.)	**Decay Pipe**	**--**													--
		1.a) Excavation	--													--
		1.b) Excavation	--													--
		2.) Structural	--													--
	E.)	**NND Hall**	**--**													--
		1.) Excavation	--													--
		2.) Structural	--													--
		3.) MEP	--													--

Notes:

Schedule represents range of months during which each activity may occur based on information provided by Fermilab. Project infrastructure activities are assumed to occur from 2017 through the end of the project.

Table F1-3 General Schedule Assumptions

Parameter	Units	Calendar 2017												2017 Total
Max Days in Month	day/mo	31	28	31	30	31	30	31	31	30	31	30	31	--
Days Without Construction[a]	day/mo	5	4	4	5	4	4	5	4	4	5	4	5	--
Days of Construction	day/mo	26	24	27	25	27	26	26	27	26	26	26	26	--
Max Construction Hours in Month[b]	hr/mo	260	240	270	250	270	260	260	270	260	260	260	260	--

Notes:

a Represents number of Sundays in the month. Although construction activities would be performed during a 5-day work week, emissions were calculated assuming six days per week to capture any potential weekend construction that may occur. For months with no planned construction, the days without construction equal the max days in month.

b Equipment was assumed to operate for 10 hours per day of construction.

Table F1-3 General Schedule Assumptions

Parameter	Units	Calendar 2018												2018 Total
Max Days in Month	day/mo	31	28	31	30	31	30	31	31	30	31	30	31	--
Days Without Construction[a]	day/mo	4	4	4	5	4	4	5	4	5	4	4	5	--
Days of Construction	day/mo	27	24	27	25	27	26	26	27	25	27	26	26	--
Max Construction Hours in Month[b]	hr/mo	270	240	270	250	270	260	260	270	250	270	260	260	--

Notes:

a Represents number of Sundays in the month. Although construction activities would be performed during a 5-day work week, emissions were calculated assuming six days per week to capture any potential weekend construction that may occur. For months with no planned construction, the days without construction equal the max days in month.

b Equipment was assumed to operate for 10 hours per day of construction.

Table F1-3 General Schedule Assumptions

Parameter	Units	Calendar 2019												2019 Total
Max Days in Month	day/mo	31	28	31	30	31	30	31	31	30	31	30	31	--
Days Without Construction[a]	day/mo	4	4	5	4	4	5	4	4	5	4	4	5	--
Days of Construction	day/mo	27	24	26	26	27	25	27	27	25	27	26	26	--
Max Construction Hours in Month[b]	hr/mo	270	240	260	260	270	250	270	270	250	270	260	260	--

Notes:

a Represents number of Sundays in the month. Although construction activities would be performed during a 5-day work week, emissions were calculated assuming six days per week to capture any potential weekend construction that may occur. For months with no planned construction, the days without construction equal the max days in month.

b Equipment was assumed to operate for 10 hours per day of construction.

Table F1-3 General Schedule Assumptions

Parameter	Units	Calendar 2020												2020 Total
Max Days in Month	day/mo	31	29	31	30	31	30	31	31	30	31	30	31	--
Days Without Construction[a]	day/mo	4	4	5	4	5	4	4	5	4	4	5	4	--
Days of Construction	day/mo	27	25	26	26	26	26	27	26	26	27	25	27	--
Max Construction Hours in Month[b]	hr/mo	270	250	260	260	260	260	270	260	260	270	250	270	--

Notes:

a Represents number of Sundays in the month. Although construction activities would be performed during a 5-day work week, emissions were calculated assuming six days per week to capture any potential weekend construction that may occur. For months with no planned construction, the days without construction equal the max days in month.

b Equipment was assumed to operate for 10 hours per day of construction.

Table F1-3 General Schedule Assumptions

Parameter	Units	Calendar 2021												2021 Total
Max Days in Month	day/mo	31	28	31	30	31	30	31	31	30	31	30	31	--
Days Without Construction[a]	day/mo	5	4	4	4	5	4	4	5	4	5	4	4	--
Days of Construction	day/mo	26	24	27	26	26	26	27	26	26	26	26	27	--
Max Construction Hours in Month[b]	hr/mo	260	240	270	260	260	260	270	260	260	260	260	270	--

Notes:

a Represents number of Sundays in the month. Although construction activities would be performed during a 5-day work week, emissions were calculated assuming six days per week to capture any potential weekend construction that may occur. For months with no planned construction, the days without construction equal the max days in month.

b Equipment was assumed to operate for 10 hours per day of construction.

Table F1-3 General Schedule Assumptions

Parameter	Units	Calendar 2022												2022 Total
Max Days in Month	day/mo	31	27	31	30	31	30	31	31	30	31	30	31	--
Days Without Construction[a]	day/mo	5	4	4	4	5	4	5	4	4	5	4	4	--
Days of Construction	day/mo	26	23	27	26	26	26	26	27	26	26	26	27	--
Max Construction Hours in Month[b]	hr/mo	260	230	270	260	260	260	260	270	260	260	260	270	--

Notes:

a Represents number of Sundays in the month. Although construction activities would be performed during a 5-day work week, emissions were calculated assuming six days per week to capture any potential weekend construction that may occur. For months with no planned construction, the days without construction equal the max days in month.

b Equipment was assumed to operate for 10 hours per day of construction.

Table F1-3 General Schedule Assumptions

Parameter	Units	Calendar 2023												2023 Total
Max Days in Month	day/mo	31	26	31	30	31	30	31	31	30	31	30	31	--
Days Without Construction[a]	day/mo	5	4	4	5	4	4	5	4	4	5	4	5	--
Days of Construction	day/mo	26	22	27	25	27	26	26	27	26	26	26	26	--
Max Construction Hours in Month[b]	hr/mo	260	220	270	250	270	260	260	270	260	260	260	260	--

Notes:

a Represents number of Sundays in the month. Although construction activities would be performed during a 5-day work week, emissions were calculated assuming six days per week to capture any potential weekend construction that may occur. For months with no planned construction, the days without construction equal the max days in month.

b Equipment was assumed to operate for 10 hours per day of construction.

Table F1-4 Types of Activities for Proposed Action[a]

Activity	Units	Calendar 2017												2017 Total
Excavation	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Civil/Site	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Structural	--	N	N	N	N	N	N	N	N	N	N	N	N	--
MEP	--	N	N	N	N	N	N	N	N	N	N	N	N	--
Soil Movement	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--

Notes:

a Based on project schedule in Table F1-2 above.

Table F1-4 Types of Activities for Proposed Action[a]

Activity	Units	Calendar 2018												2018 Total
Excavation	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Civil/Site	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Structural	--	N	N	N	N	N	N	N	N	N	N	N	N	--
MEP	--	N	N	N	N	N	N	N	N	N	N	N	N	--
Soil Movement	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--

Notes:

a Based on project schedule in Table F1-2 above.

Table F1-4 Types of Activities for Proposed Action[a]

Activity	Units	Calendar 2019												2019 Total
Excavation	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Civil/Site	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Structural	--	N	N	N	N	N	N	N	N	N	N	N	N	--
MEP	--	N	N	N	N	N	N	N	N	N	N	N	N	--
Soil Movement	--	N	N	N	N	N	N	N	N	N	N	N	N	--

Notes:

a Based on project schedule in Table F1-2 above.

Table F1-4 Types of Activities for Proposed Action[a]

Activity	Units	Calendar 2020												2020 Total
Excavation	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Civil/Site	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Structural	--	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	--
MEP	--	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	--
Soil Movement	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--

Notes:

a Based on project schedule in Table F1-2 above.

Table F1-4 Types of Activities for Proposed Action[a]

Activity	Units	Calendar 2021												2021 Total
Excavation	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Civil/Site	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Structural	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
MEP	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Soil Movement	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--

Notes:

a Based on project schedule in Table F1-2 above.

Table F1-4 Types of Activities for Proposed Action[a]

Activity	Units	Calendar 2022												2022 Total
Excavation	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Civil/Site	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Structural	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
MEP	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Soil Movement	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--

Notes:

a Based on project schedule in Table F1-2 above.

Table F1-4 Types of Activities for Proposed Action[a]

Activity	Units	Calendar 2023												2023 Total
Excavation	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--
Civil/Site	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	--
Structural	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	--
MEP	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	--
Soil Movement	--	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	--

Notes:

a Based on project schedule in Table F1-2 above.

Table F1-5 Construction Equipment Hours of Operation for Proposed Action[a]

Equipment	Units	Calendar 2017												2017 Total
Bulldozers	hr/mo/unit	260	240	270	250	270	260	260	270	260	260	260	260	**3,120**
Backhoes	hr/mo/unit	260	240	270	250	270	260	260	270	260	260	260	260	**3,120**
Bobcats	hr/mo/unit	260	240	270	250	270	260	260	270	260	260	260	260	**3,120**
Rollers/Compactors	hr/mo/unit	260	240	270	250	270	260	260	270	260	260	260	260	**3,120**
Scrapers (Pans)	hr/mo/unit	260	240	270	250	270	260	260	270	260	260	260	260	**3,120**
Grader (Blade)	hr/mo/unit	260	240	270	250	270	260	260	270	260	260	260	260	**3,120**
Water Trucks	hr/mo/unit	260	240	270	250	270	260	260	270	260	260	260	260	**3,120**
Asphalt Paver	hr/mo/unit	65	60	67.5	62.5	67.5	65	65	67.5	65	65	65	65	**780**
Gradall	hr/mo/unit	156	144	162	150	162	156	156	162	156	156	156	156	**1,872**
Mobile Crane (Large)	hr/mo/unit	130	120	135	125	135	130	130	135	130	130	130	130	**1,560**
Mobile Crane (Truck)	hr/mo/unit	260	240	270	250	270	260	260	270	260	260	260	260	**3,120**
Dewatering Pumps	hr/mo/unit	260	240	270	250	270	260	260	270	260	260	260	260	**3,120**
Soil Dump Trucks[b]	hr/mo total	425	425	425	425	425	425	425	425	425	425	425	425	**5,100**

Notes:

a Based on max construction hours per month and equipment utilization factors in Table F1-9.

b Soil dump truck operating hours calculated based on amounts of soil to be moved provided in Table F1-10 and the following parameters:

15	cubic yards/trip
3	miles/trip
10	miles/hr

Table F1-5 Construction Equipment Hours of Operation for

Equipment	Units	Calendar 2018												2018 Total
Bulldozers	hr/mo/unit	270	240	270	250	270	260	260	270	250	270	260	260	**3,130**
Backhoes	hr/mo/unit	270	240	270	250	270	260	260	270	250	270	260	260	**3,130**
Bobcats	hr/mo/unit	270	240	270	250	270	260	260	270	250	270	260	260	**3,130**
Rollers/Compactors	hr/mo/unit	270	240	270	250	270	260	260	270	250	270	260	260	**3,130**
Scrapers (Pans)	hr/mo/unit	270	240	270	250	270	260	260	270	250	270	260	260	**3,130**
Grader (Blade)	hr/mo/unit	270	240	270	250	270	260	260	270	250	270	260	260	**3,130**
Water Trucks	hr/mo/unit	270	240	270	250	270	260	260	270	250	270	260	260	**3,130**
Asphalt Paver	hr/mo/unit	67.5	60	67.5	62.5	67.5	65	65	67.5	62.5	67.5	65	65	**783**
Gradall	hr/mo/unit	162	144	162	150	162	156	156	162	150	162	156	156	**1,878**
Mobile Crane (Large)	hr/mo/unit	135	120	135	125	135	130	130	135	125	135	130	130	**1,565**
Mobile Crane (Truck)	hr/mo/unit	270	240	270	250	270	260	260	270	250	270	260	260	**3,130**
Dewatering Pumps	hr/mo/unit	270	240	270	250	270	260	260	270	250	270	260	260	**3,130**
Soil Dump Trucks[b]	hr/mo total	425	425	425	425	425	425	425	425	425	425	425	425	**5,100**

Notes:

a Based on max construction hours per month and equipment utilization factors in Table F1-9.

b Soil dump truck operating hours calculated based on amounts of soil to be moved provided in Table F1-10 and the following parameters:

15 cubic yards/trip
3 miles/trip
10 miles/hr

Table F1-5 Construction Equipment Hours of Operation for

Equipment	Units	Calendar 2019												2019 Total
Bulldozers	hr/mo/unit	270	240	260	260	270	250	270	270	250	270	260	260	**3,130**
Backhoes	hr/mo/unit	270	240	260	260	270	250	270	270	250	270	260	260	**3,130**
Bobcats	hr/mo/unit	270	240	260	260	270	250	270	270	250	270	260	260	**3,130**
Rollers/Compactors	hr/mo/unit	270	240	260	260	270	250	270	270	250	270	260	260	**3,130**
Scrapers (Pans)	hr/mo/unit	270	240	260	260	270	250	270	270	250	270	260	260	**3,130**
Grader (Blade)	hr/mo/unit	270	240	260	260	270	250	270	270	250	270	260	260	**3,130**
Water Trucks	hr/mo/unit	270	240	260	260	270	250	270	270	250	270	260	260	**3,130**
Asphalt Paver	hr/mo/unit	67.5	60	65	65	67.5	62.5	67.5	67.5	62.5	67.5	65	65	**783**
Gradall	hr/mo/unit	162	144	156	156	162	150	162	162	150	162	156	156	**1,878**
Mobile Crane (Large)	hr/mo/unit	135	120	130	130	135	125	135	135	125	135	130	130	**1,565**
Mobile Crane (Truck)	hr/mo/unit	270	240	260	260	270	250	270	270	250	270	260	260	**3,130**
Dewatering Pumps	hr/mo/unit	270	240	260	260	270	250	270	270	250	270	260	260	**3,130**
Soil Dump Trucks[b]	hr/mo total	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Notes:

a Based on max construction hours per month and equipment utilization factors in Table F1-9.

b Soil dump truck operating hours calculated based on amounts of soil to be moved provided in Table F1-10 and the following parameters:

15 cubic yards/trip
3 miles/trip
10 miles/hr

Table F1-5 Construction Equipment Hours of Operation for

Equipment	Units	Calendar 2020												2020 Total
Bulldozers	hr/mo/unit	270	250	260	260	260	260	270	260	260	270	250	270	**3,140**
Backhoes	hr/mo/unit	270	250	260	260	260	260	270	260	260	270	250	270	**3,140**
Bobcats	hr/mo/unit	270	250	260	260	260	260	270	260	260	270	250	270	**3,140**
Rollers/Compactors	hr/mo/unit	270	250	260	260	260	260	270	260	260	270	250	270	**3,140**
Scrapers (Pans)	hr/mo/unit	270	250	260	260	260	260	270	260	260	270	250	270	**3,140**
Grader (Blade)	hr/mo/unit	270	250	260	260	260	260	270	260	260	270	250	270	**3,140**
Water Trucks	hr/mo/unit	270	250	260	260	260	260	270	260	260	270	250	270	**3,140**
Asphalt Paver	hr/mo/unit	67.5	62.5	65	65	65	65	67.5	65	65	67.5	62.5	67.5	**785**
Gradall	hr/mo/unit	162	150	156	156	156	156	162	156	156	162	150	162	**1,884**
Mobile Crane (Large)	hr/mo/unit	135	125	130	130	130	260	270	260	260	270	250	270	**2,490**
Mobile Crane (Truck)	hr/mo/unit	270	250	260	260	260	260	270	260	260	270	250	270	**3,140**
Dewatering Pumps	hr/mo/unit	270	250	260	260	260	260	270	260	260	270	250	270	**3,140**
Soil Dump Trucks[b]	hr/mo total	100	100	100	100	100	100	100	100	100	100	100	100	**1,200**

Notes:

a Based on max construction hours per month and equipment utilization factors in Table F1-9.

b Soil dump truck operating hours calculated based on amounts of soil to be moved provided in Table F1-10 and the following parameters:

15 cubic yards/trip
3 miles/trip
10 miles/hr

Table F1-5 Construction Equipment Hours of Operation for

Equipment	Units	Calendar 2021												2021 Total
Bulldozers	hr/mo/unit	260	240	270	260	260	260	270	260	260	260	260	270	**3,130**
Backhoes	hr/mo/unit	260	240	270	260	260	260	270	260	260	260	260	270	**3,130**
Bobcats	hr/mo/unit	260	240	270	260	260	260	270	260	260	260	260	270	**3,130**
Rollers/Compactors	hr/mo/unit	260	240	270	260	260	260	270	260	260	260	260	270	**3,130**
Scrapers (Pans)	hr/mo/unit	260	240	270	260	260	260	270	260	260	260	260	270	**3,130**
Grader (Blade)	hr/mo/unit	260	240	270	260	260	260	270	260	260	260	260	270	**3,130**
Water Trucks	hr/mo/unit	260	240	270	260	260	260	270	260	260	260	260	270	**3,130**
Asphalt Paver	hr/mo/unit	65	60	67.5	65	65	65	67.5	65	65	65	65	67.5	**783**
Gradall	hr/mo/unit	156	144	162	156	156	156	162	156	156	156	156	162	**1,878**
Mobile Crane (Large)	hr/mo/unit	260	240	270	260	260	260	270	260	260	260	260	270	**3,130**
Mobile Crane (Truck)	hr/mo/unit	260	240	270	260	260	260	270	260	260	260	260	270	**3,130**
Dewatering Pumps	hr/mo/unit	260	240	270	260	260	260	270	260	260	260	260	270	**3,130**
Soil Dump Trucks[b]	hr/mo total	100	100	100	100	100	100	100	100	100	100	100	100	**1,200**

Notes:

a Based on max construction hours per month and equipment utilization factors in Table F1-9.

b Soil dump truck operating hours calculated based on amounts of soil to be moved provided in Table F1-10 and the following parameters:

15 cubic yards/trip
3 miles/trip
10 miles/hr

Table F1-5 Construction Equipment Hours of Operation for

Equipment	Units	Calendar 2022												2022 Total
Bulldozers	hr/mo/unit	260	230	270	260	260	260	260	270	260	260	260	270	**3,120**
Backhoes	hr/mo/unit	260	230	270	260	260	260	260	270	260	260	260	270	**3,120**
Bobcats	hr/mo/unit	260	230	270	260	260	260	260	270	260	260	260	270	**3,120**
Rollers/Compactors	hr/mo/unit	260	230	270	260	260	260	260	270	260	260	260	270	**3,120**
Scrapers (Pans)	hr/mo/unit	260	230	270	260	260	260	260	270	260	260	260	270	**3,120**
Grader (Blade)	hr/mo/unit	260	230	270	260	260	260	260	270	260	260	260	270	**3,120**
Water Trucks	hr/mo/unit	260	230	270	260	260	260	260	270	260	260	260	270	**3,120**
Asphalt Paver	hr/mo/unit	65	57.5	67.5	65	65	65	65	67.5	65	65	65	67.5	**780**
Gradall	hr/mo/unit	156	138	162	156	156	156	156	162	156	156	156	162	**1,872**
Mobile Crane (Large)	hr/mo/unit	260	230	270	260	260	260	260	270	260	260	260	270	**3,120**
Mobile Crane (Truck)	hr/mo/unit	260	230	270	260	260	260	260	270	260	260	260	270	**3,120**
Dewatering Pumps	hr/mo/unit	260	230	270	260	260	260	260	270	260	260	260	270	**3,120**
Soil Dump Trucks[b]	hr/mo total	100	100	100	100	100	100	100	100	100	100	100	100	**1,200**

Notes:

a Based on max construction hours per month and equipment utilization factors in Table F1-9.

b Soil dump truck operating hours calculated based on amounts of soil to be moved provided in Table F1-10 and the following parameters:

15 cubic yards/trip
3 miles/trip
10 miles/hr

Table F1-5 Construction Equipment Hours of Operation for

Equipment	Units	Calendar 2023												2023 Total
Bulldozers	hr/mo/unit	260	220	270	250	270	260	260	270	260	260	260	260	**3,100**
Backhoes	hr/mo/unit	260	220	270	250	270	260	260	270	260	260	260	260	**3,100**
Bobcats	hr/mo/unit	260	220	270	250	270	260	260	270	260	260	260	260	**3,100**
Rollers/Compactors	hr/mo/unit	260	220	270	250	270	260	260	270	260	260	260	260	**3,100**
Scrapers (Pans)	hr/mo/unit	260	220	270	250	270	260	260	270	260	260	260	260	**3,100**
Grader (Blade)	hr/mo/unit	260	220	270	250	270	260	260	270	260	260	260	260	**3,100**
Water Trucks	hr/mo/unit	260	220	270	250	270	260	260	270	260	260	260	260	**3,100**
Asphalt Paver	hr/mo/unit	65	55	67.5	62.5	67.5	65	65	67.5	65	65	0	0	**645**
Gradall	hr/mo/unit	156	132	162	150	162	156	156	162	156	156	130	130	**1,808**
Mobile Crane (Large)	hr/mo/unit	260	220	270	250	270	260	260	270	260	260	0	0	**2,580**
Mobile Crane (Truck)	hr/mo/unit	260	220	270	250	270	260	260	270	260	260	65	65	**2,710**
Dewatering Pumps	hr/mo/unit	260	220	270	250	270	260	260	270	260	260	260	260	**3,100**
Soil Dump Trucks[b]	hr/mo total	100	100	100	100	100	100	100	100	100	100	100	100	**1,200**

Notes:

a Based on max construction hours per month and equipment utilization factors in Table F1-9.

b Soil dump truck operating hours calculated based on amounts of soil to be moved provided in Table F1-10 and the following parameters:

15	cubic yards/trip
3	miles/trip
10	miles/hr

Table F1-6 Construction Equipment Horsepower Hours for Proposed Action[a]

Equipment	Units	Calendar 2017												2017 Total
Bulldozers	bhp/mo total	322,400	297,600	334,800	310,000	334,800	322,400	322,400	334,800	322,400	322,400	322,400	322,400	**3,868,800**
Backhoes	bhp/mo total	170,040	156,960	176,580	163,500	176,580	170,040	170,040	176,580	170,040	170,040	170,040	170,040	**2,040,480**
Bobcats	bhp/mo total	117,000	108,000	121,500	112,500	121,500	117,000	117,000	121,500	117,000	117,000	117,000	117,000	**1,404,000**
Rollers/Compactors	bhp/mo total	390,000	360,000	405,000	375,000	405,000	390,000	390,000	405,000	390,000	390,000	390,000	390,000	**4,680,000**
Scrapers (Pans)	bhp/mo total	634,920	586,080	659,340	610,500	659,340	634,920	634,920	659,340	634,920	634,920	634,920	634,920	**7,619,040**
Grader (Blade)	bhp/mo total	77,220	71,280	80,190	74,250	80,190	77,220	77,220	80,190	77,220	77,220	77,220	77,220	**926,640**
Water Trucks	bhp/mo total	171,600	158,400	178,200	165,000	178,200	171,600	171,600	178,200	171,600	171,600	171,600	171,600	**2,059,200**
Asphalt Paver	bhp/mo total	11,310	10,440	11,745	10,875	11,745	11,310	11,310	11,745	11,310	11,310	11,310	11,310	**135,720**
Gradall	bhp/mo total	25,896	23,904	26,892	24,900	26,892	25,896	25,896	26,892	25,896	25,896	25,896	25,896	**310,752**
Mobile Crane (Large)	bhp/mo total	117,000	108,000	121,500	112,500	121,500	117,000	117,000	121,500	117,000	117,000	117,000	117,000	**1,404,000**
Mobile Crane (Truck)	bhp/mo total	111,800	103,200	116,100	107,500	116,100	111,800	111,800	116,100	111,800	111,800	111,800	111,800	**1,341,600**
Dewatering Pumps	bhp/mo total	305,760	282,240	317,520	294,000	317,520	305,760	305,760	317,520	305,760	305,760	305,760	305,760	**3,669,120**
Soil Dump Trucks[b]	bhp/mo total	192,100	192,100	192,100	192,100	192,100	192,100	192,100	192,100	192,100	192,100	192,100	192,100	**2,305,200**

Notes:

a Based on hours of operation per unit in Table F1-5 above and number of units and unit capacity in Table F1-9.

b Soil dump truck horsepower-hour totals based on total hours of operation in Table F1-5 above and unit capacity in Table F1-9.

Table F1-6 Construction Equipment Horsepower Hours for I

Equipment	Units	Calendar 2018												2018 Total
Bulldozers	bhp/mo total	334,800	297,600	334,800	310,000	334,800	322,400	322,400	334,800	310,000	334,800	322,400	322,400	**3,881,200**
Backhoes	bhp/mo total	176,580	156,960	176,580	163,500	176,580	170,040	170,040	176,580	163,500	176,580	170,040	170,040	**2,047,020**
Bobcats	bhp/mo total	121,500	108,000	121,500	112,500	121,500	117,000	117,000	121,500	112,500	121,500	117,000	117,000	**1,408,500**
Rollers/Compactors	bhp/mo total	405,000	360,000	405,000	375,000	405,000	390,000	390,000	405,000	375,000	405,000	390,000	390,000	**4,695,000**
Scrapers (Pans)	bhp/mo total	659,340	586,080	659,340	610,500	659,340	634,920	634,920	659,340	610,500	659,340	634,920	634,920	**7,643,460**
Grader (Blade)	bhp/mo total	80,190	71,280	80,190	74,250	80,190	77,220	77,220	80,190	74,250	80,190	77,220	77,220	**929,610**
Water Trucks	bhp/mo total	178,200	158,400	178,200	165,000	178,200	171,600	171,600	178,200	165,000	178,200	171,600	171,600	**2,065,800**
Asphalt Paver	bhp/mo total	11,745	10,440	11,745	10,875	11,745	11,310	11,310	11,745	10,875	11,745	11,310	11,310	**136,155**
Gradall	bhp/mo total	26,892	23,904	26,892	24,900	26,892	25,896	25,896	26,892	24,900	26,892	25,896	25,896	**311,748**
Mobile Crane (Large)	bhp/mo total	121,500	108,000	121,500	112,500	121,500	117,000	117,000	121,500	112,500	121,500	117,000	117,000	**1,408,500**
Mobile Crane (Truck)	bhp/mo total	116,100	103,200	116,100	107,500	116,100	111,800	111,800	116,100	107,500	116,100	111,800	111,800	**1,345,900**
Dewatering Pumps	bhp/mo total	317,520	282,240	317,520	294,000	317,520	305,760	305,760	317,520	294,000	317,520	305,760	305,760	**3,680,880**
Soil Dump Trucks[b]	bhp/mo total	192,100	192,100	192,100	192,100	192,100	192,100	192,100	192,100	192,100	192,100	192,100	192,100	**2,305,200**

Notes:

a Based on hours of operation per unit in Table F1-5 above and number of units and unit capacity in Table F1-9.

b Soil dump truck horsepower-hour totals based on total hours of operation in Table F1-5 above and unit capacity in Table F1-9.

Table F1-6 Construction Equipment Horsepower Hours for I

Equipment	Units	Calendar 2019												2019 Total
Bulldozers	bhp/mo total	334,800	297,600	322,400	322,400	334,800	310,000	334,800	334,800	310,000	334,800	322,400	322,400	**3,881,200**
Backhoes	bhp/mo total	176,580	156,960	170,040	170,040	176,580	163,500	176,580	176,580	163,500	176,580	170,040	170,040	**2,047,020**
Bobcats	bhp/mo total	121,500	108,000	117,000	117,000	121,500	112,500	121,500	121,500	112,500	121,500	117,000	117,000	**1,408,500**
Rollers/Compactors	bhp/mo total	405,000	360,000	390,000	390,000	405,000	375,000	405,000	405,000	375,000	405,000	390,000	390,000	**4,695,000**
Scrapers (Pans)	bhp/mo total	659,340	586,080	634,920	634,920	659,340	610,500	659,340	659,340	610,500	659,340	634,920	634,920	**7,643,460**
Grader (Blade)	bhp/mo total	80,190	71,280	77,220	77,220	80,190	74,250	80,190	80,190	74,250	80,190	77,220	77,220	**929,610**
Water Trucks	bhp/mo total	178,200	158,400	171,600	171,600	178,200	165,000	178,200	178,200	165,000	178,200	171,600	171,600	**2,065,800**
Asphalt Paver	bhp/mo total	11,745	10,440	11,310	11,310	11,745	10,875	11,745	11,745	10,875	11,745	11,310	11,310	**136,155**
Gradall	bhp/mo total	26,892	23,904	25,896	25,896	26,892	24,900	26,892	26,892	24,900	26,892	25,896	25,896	**311,748**
Mobile Crane (Large)	bhp/mo total	121,500	108,000	117,000	117,000	121,500	112,500	121,500	121,500	112,500	121,500	117,000	117,000	**1,408,500**
Mobile Crane (Truck)	bhp/mo total	116,100	103,200	111,800	111,800	116,100	107,500	116,100	116,100	107,500	116,100	111,800	111,800	**1,345,900**
Dewatering Pumps	bhp/mo total	317,520	282,240	305,760	305,760	317,520	294,000	317,520	317,520	294,000	317,520	305,760	305,760	**3,680,880**
Soil Dump Trucks[b]	bhp/mo total	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Notes:

a Based on hours of operation per unit in Table F1-5 above and number of units and unit capacity in Table F1-9.

b Soil dump truck horsepower-hour totals based on total hours of operation in Table F1-5 above and unit capacity in Table F1-9.

Table F1-6 Construction Equipment Horsepower Hours for I

Equipment	Units	Calendar 2020												2020 Total
Bulldozers	bhp/mo total	334,800	310,000	322,400	322,400	322,400	322,400	334,800	322,400	322,400	334,800	310,000	334,800	**3,893,600**
Backhoes	bhp/mo total	176,580	163,500	170,040	170,040	170,040	170,040	176,580	170,040	170,040	176,580	163,500	176,580	**2,053,560**
Bobcats	bhp/mo total	121,500	112,500	117,000	117,000	117,000	117,000	121,500	117,000	117,000	121,500	112,500	121,500	**1,413,000**
Rollers/Compactors	bhp/mo total	405,000	375,000	390,000	390,000	390,000	390,000	405,000	390,000	390,000	405,000	375,000	405,000	**4,710,000**
Scrapers (Pans)	bhp/mo total	659,340	610,500	634,920	634,920	634,920	634,920	659,340	634,920	634,920	659,340	610,500	659,340	**7,667,880**
Grader (Blade)	bhp/mo total	80,190	74,250	77,220	77,220	77,220	77,220	80,190	77,220	77,220	80,190	74,250	80,190	**932,580**
Water Trucks	bhp/mo total	178,200	165,000	171,600	171,600	171,600	171,600	178,200	171,600	171,600	178,200	165,000	178,200	**2,072,400**
Asphalt Paver	bhp/mo total	11,745	10,875	11,310	11,310	11,310	11,310	11,745	11,310	11,310	11,745	10,875	11,745	**136,590**
Gradall	bhp/mo total	26,892	24,900	25,896	25,896	25,896	25,896	26,892	25,896	25,896	26,892	24,900	26,892	**312,744**
Mobile Crane (Large)	bhp/mo total	121,500	112,500	117,000	117,000	117,000	234,000	243,000	234,000	234,000	243,000	225,000	243,000	**2,241,000**
Mobile Crane (Truck)	bhp/mo total	116,100	107,500	111,800	111,800	111,800	111,800	116,100	111,800	111,800	116,100	107,500	116,100	**1,350,200**
Dewatering Pumps	bhp/mo total	317,520	294,000	305,760	305,760	305,760	305,760	317,520	305,760	305,760	317,520	294,000	317,520	**3,692,640**
Soil Dump Trucks[b]	bhp/mo total	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	**542,400**

Notes:

a Based on hours of operation per unit in Table F1-5 above and number of units and unit capacity in Table F1-9.

b Soil dump truck horsepower-hour totals based on total hours of operation in Table F1-5 above and unit capacity in Table F1-9.

Table F1-6 Construction Equipment Horsepower Hours for I

Equipment	Units	Calendar 2021												2021 Total
Bulldozers	bhp/mo total	322,400	297,600	334,800	322,400	322,400	322,400	334,800	322,400	322,400	322,400	322,400	334,800	**3,881,200**
Backhoes	bhp/mo total	170,040	156,960	176,580	170,040	170,040	170,040	176,580	170,040	170,040	170,040	170,040	176,580	**2,047,020**
Bobcats	bhp/mo total	117,000	108,000	121,500	117,000	117,000	117,000	121,500	117,000	117,000	117,000	117,000	121,500	**1,408,500**
Rollers/Compactors	bhp/mo total	390,000	360,000	405,000	390,000	390,000	390,000	405,000	390,000	390,000	390,000	390,000	405,000	**4,695,000**
Scrapers (Pans)	bhp/mo total	634,920	586,080	659,340	634,920	634,920	634,920	659,340	634,920	634,920	634,920	634,920	659,340	**7,643,460**
Grader (Blade)	bhp/mo total	77,220	71,280	80,190	77,220	77,220	77,220	80,190	77,220	77,220	77,220	77,220	80,190	**929,610**
Water Trucks	bhp/mo total	171,600	158,400	178,200	171,600	171,600	171,600	178,200	171,600	171,600	171,600	171,600	178,200	**2,065,800**
Asphalt Paver	bhp/mo total	11,310	10,440	11,745	11,310	11,310	11,310	11,745	11,310	11,310	11,310	11,310	11,745	**136,155**
Gradall	bhp/mo total	25,896	23,904	26,892	25,896	25,896	25,896	26,892	25,896	25,896	25,896	25,896	26,892	**311,748**
Mobile Crane (Large)	bhp/mo total	234,000	216,000	243,000	234,000	234,000	234,000	243,000	234,000	234,000	234,000	234,000	243,000	**2,817,000**
Mobile Crane (Truck)	bhp/mo total	111,800	103,200	116,100	111,800	111,800	111,800	116,100	111,800	111,800	111,800	111,800	116,100	**1,345,900**
Dewatering Pumps	bhp/mo total	305,760	282,240	317,520	305,760	305,760	305,760	317,520	305,760	305,760	305,760	305,760	317,520	**3,680,880**
Soil Dump Trucks[b]	bhp/mo total	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	**542,400**

Notes:

a Based on hours of operation per unit in Table F1-5 above and number of units and unit capacity in Table F1-9.

b Soil dump truck horsepower-hour totals based on total hours of operation in Table F1-5 above and unit capacity in Table F1-9.

Table F1-6 Construction Equipment Horsepower Hours for I

Equipment	Units	Calendar 2022												2022 Total
Bulldozers	bhp/mo total	322,400	285,200	334,800	322,400	322,400	322,400	322,400	334,800	322,400	322,400	322,400	334,800	**3,868,800**
Backhoes	bhp/mo total	170,040	150,420	176,580	170,040	170,040	170,040	170,040	176,580	170,040	170,040	170,040	176,580	**2,040,480**
Bobcats	bhp/mo total	117,000	103,500	121,500	117,000	117,000	117,000	117,000	121,500	117,000	117,000	117,000	121,500	**1,404,000**
Rollers/Compactors	bhp/mo total	390,000	345,000	405,000	390,000	390,000	390,000	390,000	405,000	390,000	390,000	390,000	405,000	**4,680,000**
Scrapers (Pans)	bhp/mo total	634,920	561,660	659,340	634,920	634,920	634,920	634,920	659,340	634,920	634,920	634,920	659,340	**7,619,040**
Grader (Blade)	bhp/mo total	77,220	68,310	80,190	77,220	77,220	77,220	77,220	80,190	77,220	77,220	77,220	80,190	**926,640**
Water Trucks	bhp/mo total	171,600	151,800	178,200	171,600	171,600	171,600	171,600	178,200	171,600	171,600	171,600	178,200	**2,059,200**
Asphalt Paver	bhp/mo total	11,310	10,005	11,745	11,310	11,310	11,310	11,310	11,745	11,310	11,310	11,310	11,745	**135,720**
Gradall	bhp/mo total	25,896	22,908	26,892	25,896	25,896	25,896	25,896	26,892	25,896	25,896	25,896	26,892	**310,752**
Mobile Crane (Large)	bhp/mo total	234,000	207,000	243,000	234,000	234,000	234,000	234,000	243,000	234,000	234,000	234,000	243,000	**2,808,000**
Mobile Crane (Truck)	bhp/mo total	111,800	98,900	116,100	111,800	111,800	111,800	111,800	116,100	111,800	111,800	111,800	116,100	**1,341,600**
Dewatering Pumps	bhp/mo total	305,760	270,480	317,520	305,760	305,760	305,760	305,760	317,520	305,760	305,760	305,760	317,520	**3,669,120**
Soil Dump Trucks[b]	bhp/mo total	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	**542,400**

Notes:

a Based on hours of operation per unit in Table F1-5 above and number of units and unit capacity in Table F1-9.

b Soil dump truck horsepower-hour totals based on total hours of operation in Table F1-5 above and unit capacity in Table F1-9.

Table F1-6 Construction Equipment Horsepower Hours for I

Equipment	Units	Calendar 2023												2023 Total
Bulldozers	bhp/mo total	322,400	272,800	334,800	310,000	334,800	322,400	322,400	334,800	322,400	322,400	322,400	322,400	**3,844,000**
Backhoes	bhp/mo total	170,040	143,880	176,580	163,500	176,580	170,040	170,040	176,580	170,040	170,040	170,040	170,040	**2,027,400**
Bobcats	bhp/mo total	117,000	99,000	121,500	112,500	121,500	117,000	117,000	121,500	117,000	117,000	117,000	117,000	**1,395,000**
Rollers/Compactors	bhp/mo total	390,000	330,000	405,000	375,000	405,000	390,000	390,000	405,000	390,000	390,000	390,000	390,000	**4,650,000**
Scrapers (Pans)	bhp/mo total	634,920	537,240	659,340	610,500	659,340	634,920	634,920	659,340	634,920	634,920	634,920	634,920	**7,570,200**
Grader (Blade)	bhp/mo total	77,220	65,340	80,190	74,250	80,190	77,220	77,220	80,190	77,220	77,220	77,220	77,220	**920,700**
Water Trucks	bhp/mo total	171,600	145,200	178,200	165,000	178,200	171,600	171,600	178,200	171,600	171,600	171,600	171,600	**2,046,000**
Asphalt Paver	bhp/mo total	11,310	9,570	11,745	10,875	11,745	11,310	11,310	11,745	11,310	11,310	0	0	**112,230**
Gradall	bhp/mo total	25,896	21,912	26,892	24,900	26,892	25,896	25,896	26,892	25,896	25,896	21,580	21,580	**300,128**
Mobile Crane (Large)	bhp/mo total	234,000	198,000	243,000	225,000	243,000	234,000	234,000	243,000	234,000	234,000	0	0	**2,322,000**
Mobile Crane (Truck)	bhp/mo total	111,800	94,600	116,100	107,500	116,100	111,800	111,800	116,100	111,800	111,800	27,950	27,950	**1,165,300**
Dewatering Pumps	bhp/mo total	305,760	258,720	317,520	294,000	317,520	305,760	305,760	317,520	305,760	305,760	305,760	305,760	**3,645,600**
Soil Dump Trucks[b]	bhp/mo total	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	45,200	**542,400**

Notes:

a Based on hours of operation per unit in Table F1-5 above and number of units and unit capacity in Table F1-9.

b Soil dump truck horsepower-hour totals based on total hours of operation in Table F1-5 above and unit capacity in Table F1-9.

Table F1-7 Construction Worker Off-site Vehicle Travel for Proposed Action[a]

Equipment	Units	Calendar 2017												2017 Total
Bulldozers	VMT/mo	31,200	28,800	32,400	30,000	32,400	31,200	31,200	32,400	31,200	31,200	31,200	31,200	**374,400**
Backhoes	VMT/mo	46,800	43,200	48,600	45,000	48,600	46,800	46,800	48,600	46,800	46,800	46,800	46,800	**561,600**
Bobcats	VMT/mo	46,800	43,200	48,600	45,000	48,600	46,800	46,800	48,600	46,800	46,800	46,800	46,800	**561,600**
Rollers/Compactors	VMT/mo	46,800	43,200	48,600	45,000	48,600	46,800	46,800	48,600	46,800	46,800	46,800	46,800	**561,600**
Scrapers (Pans)	VMT/mo	46,800	43,200	48,600	45,000	48,600	46,800	46,800	48,600	46,800	46,800	46,800	46,800	**561,600**
Grader (Blade)	VMT/mo	7,800	7,200	8,100	7,500	8,100	7,800	7,800	8,100	7,800	7,800	7,800	7,800	**93,600**
Water Trucks	VMT/mo	15,600	14,400	16,200	15,000	16,200	15,600	15,600	16,200	15,600	15,600	15,600	15,600	**187,200**
Asphalt Paver	VMT/mo	7,800	7,200	8,100	7,500	8,100	7,800	7,800	8,100	7,800	7,800	7,800	7,800	**93,600**
Gradall	VMT/mo	7,800	7,200	8,100	7,500	8,100	7,800	7,800	8,100	7,800	7,800	7,800	7,800	**93,600**
Mobile Crane (Large)	VMT/mo	15,600	14,400	16,200	15,000	16,200	15,600	15,600	16,200	15,600	15,600	15,600	15,600	**187,200**
Mobile Crane (Truck)	VMT/mo	15,600	14,400	16,200	15,000	16,200	15,600	15,600	16,200	15,600	15,600	15,600	15,600	**187,200**
Dewatering Pumps	VMT/mo	31,200	28,800	32,400	30,000	32,400	31,200	31,200	32,400	31,200	31,200	31,200	31,200	**374,400**
Soil Dump Trucks	VMT/mo	62,400	57,600	64,800	60,000	64,800	62,400	62,400	64,800	62,400	62,400	62,400	62,400	**748,800**

Notes:

a Number of trips assumes 10 construction workers required for each piece of construction equipment listed and that each worker makes 1 x 30-mile trip per day on passenger/light-duty vehicles.

Table F1-7 Construction Worker Off-site Vehicle Travel for

Equipment	Units	Calendar 2018												2018 Total
Bulldozers	VMT/mo	32,400	28,800	32,400	30,000	32,400	31,200	31,200	32,400	30,000	32,400	31,200	31,200	**375,600**
Backhoes	VMT/mo	48,600	43,200	48,600	45,000	48,600	46,800	46,800	48,600	45,000	48,600	46,800	46,800	**563,400**
Bobcats	VMT/mo	48,600	43,200	48,600	45,000	48,600	46,800	46,800	48,600	45,000	48,600	46,800	46,800	**563,400**
Rollers/Compactors	VMT/mo	48,600	43,200	48,600	45,000	48,600	46,800	46,800	48,600	45,000	48,600	46,800	46,800	**563,400**
Scrapers (Pans)	VMT/mo	48,600	43,200	48,600	45,000	48,600	46,800	46,800	48,600	45,000	48,600	46,800	46,800	**563,400**
Grader (Blade)	VMT/mo	8,100	7,200	8,100	7,500	8,100	7,800	7,800	8,100	7,500	8,100	7,800	7,800	**93,900**
Water Trucks	VMT/mo	16,200	14,400	16,200	15,000	16,200	15,600	15,600	16,200	15,000	16,200	15,600	15,600	**187,800**
Asphalt Paver	VMT/mo	8,100	7,200	8,100	7,500	8,100	7,800	7,800	8,100	7,500	8,100	7,800	7,800	**93,900**
Gradall	VMT/mo	8,100	7,200	8,100	7,500	8,100	7,800	7,800	8,100	7,500	8,100	7,800	7,800	**93,900**
Mobile Crane (Large)	VMT/mo	16,200	14,400	16,200	15,000	16,200	15,600	15,600	16,200	15,000	16,200	15,600	15,600	**187,800**
Mobile Crane (Truck)	VMT/mo	16,200	14,400	16,200	15,000	16,200	15,600	15,600	16,200	15,000	16,200	15,600	15,600	**187,800**
Dewatering Pumps	VMT/mo	32,400	28,800	32,400	30,000	32,400	31,200	31,200	32,400	30,000	32,400	31,200	31,200	**375,600**
Soil Dump Trucks	VMT/mo	64,800	57,600	64,800	60,000	64,800	62,400	62,400	64,800	60,000	64,800	62,400	62,400	**751,200**

Notes:

a Number of trips assumes 10 construction workers required for each piece of construction equipment listed and that each worker makes 1 x 30-mile trip per day on passenger/light-duty vehicles.

Table F1-7 Construction Worker Off-site Vehicle Travel for

Equipment	Units	Calendar 2019												2019 Total
Bulldozers	VMT/mo	32,400	28,800	31,200	31,200	32,400	30,000	32,400	32,400	30,000	32,400	31,200	31,200	**375,600**
Backhoes	VMT/mo	48,600	43,200	46,800	46,800	48,600	45,000	48,600	48,600	45,000	48,600	46,800	46,800	**563,400**
Bobcats	VMT/mo	48,600	43,200	46,800	46,800	48,600	45,000	48,600	48,600	45,000	48,600	46,800	46,800	**563,400**
Rollers/Compactors	VMT/mo	48,600	43,200	46,800	46,800	48,600	45,000	48,600	48,600	45,000	48,600	46,800	46,800	**563,400**
Scrapers (Pans)	VMT/mo	48,600	43,200	46,800	46,800	48,600	45,000	48,600	48,600	45,000	48,600	46,800	46,800	**563,400**
Grader (Blade)	VMT/mo	8,100	7,200	7,800	7,800	8,100	7,500	8,100	8,100	7,500	8,100	7,800	7,800	**93,900**
Water Trucks	VMT/mo	16,200	14,400	15,600	15,600	16,200	15,000	16,200	16,200	15,000	16,200	15,600	15,600	**187,800**
Asphalt Paver	VMT/mo	8,100	7,200	7,800	7,800	8,100	7,500	8,100	8,100	7,500	8,100	7,800	7,800	**93,900**
Gradall	VMT/mo	8,100	7,200	7,800	7,800	8,100	7,500	8,100	8,100	7,500	8,100	7,800	7,800	**93,900**
Mobile Crane (Large)	VMT/mo	16,200	14,400	15,600	15,600	16,200	15,000	16,200	16,200	15,000	16,200	15,600	15,600	**187,800**
Mobile Crane (Truck)	VMT/mo	16,200	14,400	15,600	15,600	16,200	15,000	16,200	16,200	15,000	16,200	15,600	15,600	**187,800**
Dewatering Pumps	VMT/mo	32,400	28,800	31,200	31,200	32,400	30,000	32,400	32,400	30,000	32,400	31,200	31,200	**375,600**
Soil Dump Trucks	VMT/mo	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Notes:

a Number of trips assumes 10 construction workers required for each piece of construction equipment listed and that each worker makes 1 x 30-mile trip per day on passenger/light-duty vehicles.

Table F1-7 Construction Worker Off-site Vehicle Travel for

Equipment	Units	Calendar 2020												2020 Total
Bulldozers	VMT/mo	32,400	30,000	31,200	31,200	31,200	31,200	32,400	31,200	31,200	32,400	30,000	32,400	**376,800**
Backhoes	VMT/mo	48,600	45,000	46,800	46,800	46,800	46,800	48,600	46,800	46,800	48,600	45,000	48,600	**565,200**
Bobcats	VMT/mo	48,600	45,000	46,800	46,800	46,800	46,800	48,600	46,800	46,800	48,600	45,000	48,600	**565,200**
Rollers/Compactors	VMT/mo	48,600	45,000	46,800	46,800	46,800	46,800	48,600	46,800	46,800	48,600	45,000	48,600	**565,200**
Scrapers (Pans)	VMT/mo	48,600	45,000	46,800	46,800	46,800	46,800	48,600	46,800	46,800	48,600	45,000	48,600	**565,200**
Grader (Blade)	VMT/mo	8,100	7,500	7,800	7,800	7,800	7,800	8,100	7,800	7,800	8,100	7,500	8,100	**94,200**
Water Trucks	VMT/mo	16,200	15,000	15,600	15,600	15,600	15,600	16,200	15,600	15,600	16,200	15,000	16,200	**188,400**
Asphalt Paver	VMT/mo	8,100	7,500	7,800	7,800	7,800	7,800	8,100	7,800	7,800	8,100	7,500	8,100	**94,200**
Gradall	VMT/mo	8,100	7,500	7,800	7,800	7,800	7,800	8,100	7,800	7,800	8,100	7,500	8,100	**94,200**
Mobile Crane (Large)	VMT/mo	16,200	15,000	15,600	15,600	15,600	15,600	16,200	15,600	15,600	16,200	15,000	16,200	**188,400**
Mobile Crane (Truck)	VMT/mo	16,200	15,000	15,600	15,600	15,600	15,600	16,200	15,600	15,600	16,200	15,000	16,200	**188,400**
Dewatering Pumps	VMT/mo	32,400	30,000	31,200	31,200	31,200	31,200	32,400	31,200	31,200	32,400	30,000	32,400	**376,800**
Soil Dump Trucks	VMT/mo	64,800	60,000	62,400	62,400	62,400	62,400	64,800	62,400	62,400	64,800	60,000	64,800	**753,600**

Notes:

a Number of trips assumes 10 construction workers required for each piece of construction equipment listed and that each worker makes 1 x 30-mile trip per day on passenger/light-duty vehicles.

Table F1-7 Construction Worker Off-site Vehicle Travel for

Equipment	Units	Calendar 2021												2021 Total
Bulldozers	VMT/mo	31,200	28,800	32,400	31,200	31,200	31,200	32,400	31,200	31,200	31,200	31,200	32,400	**375,600**
Backhoes	VMT/mo	46,800	43,200	48,600	46,800	46,800	46,800	48,600	46,800	46,800	46,800	46,800	48,600	**563,400**
Bobcats	VMT/mo	46,800	43,200	48,600	46,800	46,800	46,800	48,600	46,800	46,800	46,800	46,800	48,600	**563,400**
Rollers/Compactors	VMT/mo	46,800	43,200	48,600	46,800	46,800	46,800	48,600	46,800	46,800	46,800	46,800	48,600	**563,400**
Scrapers (Pans)	VMT/mo	46,800	43,200	48,600	46,800	46,800	46,800	48,600	46,800	46,800	46,800	46,800	48,600	**563,400**
Grader (Blade)	VMT/mo	7,800	7,200	8,100	7,800	7,800	7,800	8,100	7,800	7,800	7,800	7,800	8,100	**93,900**
Water Trucks	VMT/mo	15,600	14,400	16,200	15,600	15,600	15,600	16,200	15,600	15,600	15,600	15,600	16,200	**187,800**
Asphalt Paver	VMT/mo	7,800	7,200	8,100	7,800	7,800	7,800	8,100	7,800	7,800	7,800	7,800	8,100	**93,900**
Gradall	VMT/mo	7,800	7,200	8,100	7,800	7,800	7,800	8,100	7,800	7,800	7,800	7,800	8,100	**93,900**
Mobile Crane (Large)	VMT/mo	15,600	14,400	16,200	15,600	15,600	15,600	16,200	15,600	15,600	15,600	15,600	16,200	**187,800**
Mobile Crane (Truck)	VMT/mo	15,600	14,400	16,200	15,600	15,600	15,600	16,200	15,600	15,600	15,600	15,600	16,200	**187,800**
Dewatering Pumps	VMT/mo	31,200	28,800	32,400	31,200	31,200	31,200	32,400	31,200	31,200	31,200	31,200	32,400	**375,600**
Soil Dump Trucks	VMT/mo	62,400	57,600	64,800	62,400	62,400	62,400	64,800	62,400	62,400	62,400	62,400	64,800	**751,200**

Notes:

a Number of trips assumes 10 construction workers required for each piece of construction equipment listed and that each worker makes 1 x 30-mile trip per day on passenger/light-duty vehicles.

Table F1-7 Construction Worker Off-site Vehicle Travel for

Equipment	Units	Calendar 2022												2022 Total
Bulldozers	VMT/mo	31,200	27,600	32,400	31,200	31,200	31,200	31,200	32,400	31,200	31,200	31,200	32,400	**374,400**
Backhoes	VMT/mo	46,800	41,400	48,600	46,800	46,800	46,800	46,800	48,600	46,800	46,800	46,800	48,600	**561,600**
Bobcats	VMT/mo	46,800	41,400	48,600	46,800	46,800	46,800	46,800	48,600	46,800	46,800	46,800	48,600	**561,600**
Rollers/Compactors	VMT/mo	46,800	41,400	48,600	46,800	46,800	46,800	46,800	48,600	46,800	46,800	46,800	48,600	**561,600**
Scrapers (Pans)	VMT/mo	46,800	41,400	48,600	46,800	46,800	46,800	46,800	48,600	46,800	46,800	46,800	48,600	**561,600**
Grader (Blade)	VMT/mo	7,800	6,900	8,100	7,800	7,800	7,800	7,800	8,100	7,800	7,800	7,800	8,100	**93,600**
Water Trucks	VMT/mo	15,600	13,800	16,200	15,600	15,600	15,600	15,600	16,200	15,600	15,600	15,600	16,200	**187,200**
Asphalt Paver	VMT/mo	7,800	6,900	8,100	7,800	7,800	7,800	7,800	8,100	7,800	7,800	7,800	8,100	**93,600**
Gradall	VMT/mo	7,800	6,900	8,100	7,800	7,800	7,800	7,800	8,100	7,800	7,800	7,800	8,100	**93,600**
Mobile Crane (Large)	VMT/mo	15,600	13,800	16,200	15,600	15,600	15,600	15,600	16,200	15,600	15,600	15,600	16,200	**187,200**
Mobile Crane (Truck)	VMT/mo	15,600	13,800	16,200	15,600	15,600	15,600	15,600	16,200	15,600	15,600	15,600	16,200	**187,200**
Dewatering Pumps	VMT/mo	31,200	27,600	32,400	31,200	31,200	31,200	31,200	32,400	31,200	31,200	31,200	32,400	**374,400**
Soil Dump Trucks	VMT/mo	62,400	55,200	64,800	62,400	62,400	62,400	62,400	64,800	62,400	62,400	62,400	64,800	**748,800**

Notes:

a Number of trips assumes 10 construction workers required for each piece of construction equipment listed and that each worker makes 1 x 30-mile trip per day on passenger/light-duty vehicles.

Table F1-7 Construction Worker Off-site Vehicle Travel for

Equipment	Units	Calendar 2023												2023 Total
Bulldozers	VMT/mo	31,200	26,400	32,400	30,000	32,400	31,200	31,200	32,400	31,200	31,200	31,200	31,200	**372,000**
Backhoes	VMT/mo	46,800	39,600	48,600	45,000	48,600	46,800	46,800	48,600	46,800	46,800	46,800	46,800	**558,000**
Bobcats	VMT/mo	46,800	39,600	48,600	45,000	48,600	46,800	46,800	48,600	46,800	46,800	46,800	46,800	**558,000**
Rollers/Compactors	VMT/mo	46,800	39,600	48,600	45,000	48,600	46,800	46,800	48,600	46,800	46,800	46,800	46,800	**558,000**
Scrapers (Pans)	VMT/mo	46,800	39,600	48,600	45,000	48,600	46,800	46,800	48,600	46,800	46,800	46,800	46,800	**558,000**
Grader (Blade)	VMT/mo	7,800	6,600	8,100	7,500	8,100	7,800	7,800	8,100	7,800	7,800	7,800	7,800	**93,000**
Water Trucks	VMT/mo	15,600	13,200	16,200	15,000	16,200	15,600	15,600	16,200	15,600	15,600	15,600	15,600	**186,000**
Asphalt Paver	VMT/mo	7,800	6,600	8,100	7,500	8,100	7,800	7,800	8,100	7,800	7,800	0	0	**77,400**
Gradall	VMT/mo	7,800	6,600	8,100	7,500	8,100	7,800	7,800	8,100	7,800	7,800	7,800	7,800	**93,000**
Mobile Crane (Large)	VMT/mo	15,600	13,200	16,200	15,000	16,200	15,600	15,600	16,200	15,600	15,600	0	0	**154,800**
Mobile Crane (Truck)	VMT/mo	15,600	13,200	16,200	15,000	16,200	15,600	15,600	16,200	15,600	15,600	15,600	15,600	**186,000**
Dewatering Pumps	VMT/mo	31,200	26,400	32,400	30,000	32,400	31,200	31,200	32,400	31,200	31,200	31,200	31,200	**372,000**
Soil Dump Trucks	VMT/mo	62,400	52,800	64,800	60,000	64,800	62,400	62,400	64,800	62,400	62,400	62,400	62,400	**744,000**

Notes:

a Number of trips assumes 10 construction workers required for each piece of construction equipment listed and that each worker makes 1 x 30-mile trip per day on passenger/light-duty vehicles.

Table F1-8 Construction Equipment Unpaved Road Onsite Travel for Proposed Action[a]

Equipment	Units	Calendar 2017												2017 Total
Bulldozers	VMT/mo	26	24	27	25	27	26	26	27	26	26	26	26	**312**
Backhoes	VMT/mo	39	36	41	38	41	39	39	41	39	39	39	39	**468**
Bobcats	VMT/mo	39	36	41	38	41	39	39	41	39	39	39	39	**468**
Rollers/Compactors	VMT/mo	39	36	41	38	41	39	39	41	39	39	39	39	**468**
Scrapers (Pans)	VMT/mo	39	36	41	38	41	39	39	41	39	39	39	39	**468**
Grader (Blade)	VMT/mo	7	6	7	6	7	7	7	7	7	7	7	7	**78**
Water Trucks	VMT/mo	13	12	14	13	14	13	13	14	13	13	13	13	**156**
Asphalt Paver	VMT/mo	7	6	7	6	7	7	7	7	7	7	7	7	**78**
Gradall	VMT/mo	7	6	7	6	7	7	7	7	7	7	7	7	**78**
Mobile Crane (Large)	VMT/mo	13	12	14	13	14	13	13	14	13	13	13	13	**156**
Mobile Crane (Truck)	VMT/mo	13	12	14	13	14	13	13	14	13	13	13	13	**156**
Dewatering Pumps	VMT/mo	26	24	27	25	27	26	26	27	26	26	26	26	**312**
Soil Dump Trucks[b]	VMT/mo	4,250	4,250	4,250	4,250	4,250	4,250	4,250	4,250	4,250	4,250	4,250	4,250	**51,000**

Notes:

a Each piece of construction equipment is assumed to make 1 trip per day of operation with a distance of 0.25 miles.

b See assumptions in Table F1-5, footnote b.

Table F1-8 Construction Equipment Unpaved Road Onsite T

Equipment	Units	Calendar 2018												2018 Total
Bulldozers	VMT/mo	27	24	27	25	27	26	26	27	25	27	26	26	**313**
Backhoes	VMT/mo	41	36	41	38	41	39	39	41	38	41	39	39	**470**
Bobcats	VMT/mo	41	36	41	38	41	39	39	41	38	41	39	39	**470**
Rollers/Compactors	VMT/mo	41	36	41	38	41	39	39	41	38	41	39	39	**470**
Scrapers (Pans)	VMT/mo	41	36	41	38	41	39	39	41	38	41	39	39	**470**
Grader (Blade)	VMT/mo	7	6	7	6	7	7	7	7	6	7	7	7	**78**
Water Trucks	VMT/mo	14	12	14	13	14	13	13	14	13	14	13	13	**157**
Asphalt Paver	VMT/mo	7	6	7	6	7	7	7	7	6	7	7	7	**78**
Gradall	VMT/mo	7	6	7	6	7	7	7	7	6	7	7	7	**78**
Mobile Crane (Large)	VMT/mo	14	12	14	13	14	13	13	14	13	14	13	13	**157**
Mobile Crane (Truck)	VMT/mo	14	12	14	13	14	13	13	14	13	14	13	13	**157**
Dewatering Pumps	VMT/mo	27	24	27	25	27	26	26	27	25	27	26	26	**313**
Soil Dump Trucks[b]	VMT/mo	4,250	4,250	4,250	4,250	4,250	4,250	4,250	4,250	4,250	4,250	4,250	4,250	**51,000**

Notes:

a Each piece of construction equipment is assumed to make 1 trip per day of operation with a distance of 0.25 miles.

b See assumptions in Table F1-5, footnote b.

Table F1-8 Construction Equipment Unpaved Road Onsite T

Equipment	Units	Calendar 2019												2019 Total
Bulldozers	VMT/mo	27	24	26	26	27	25	27	27	25	27	26	26	**313**
Backhoes	VMT/mo	41	36	39	39	41	38	41	41	38	41	39	39	**470**
Bobcats	VMT/mo	41	36	39	39	41	38	41	41	38	41	39	39	**470**
Rollers/Compactors	VMT/mo	41	36	39	39	41	38	41	41	38	41	39	39	**470**
Scrapers (Pans)	VMT/mo	41	36	39	39	41	38	41	41	38	41	39	39	**470**
Grader (Blade)	VMT/mo	7	6	7	7	7	6	7	7	6	7	7	7	**78**
Water Trucks	VMT/mo	14	12	13	13	14	13	14	14	13	14	13	13	**157**
Asphalt Paver	VMT/mo	7	6	7	7	7	6	7	7	6	7	7	7	**78**
Gradall	VMT/mo	7	6	7	7	7	6	7	7	6	7	7	7	**78**
Mobile Crane (Large)	VMT/mo	14	12	13	13	14	13	14	14	13	14	13	13	**157**
Mobile Crane (Truck)	VMT/mo	14	12	13	13	14	13	14	14	13	14	13	13	**157**
Dewatering Pumps	VMT/mo	27	24	26	26	27	25	27	27	25	27	26	26	**313**
Soil Dump Trucks[b]	VMT/mo	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Notes:

a Each piece of construction equipment is assumed to make 1 trip per day of operation with a distance of 0.25 miles.

b See assumptions in Table F1-5, footnote b.

Table F1-8 Construction Equipment Unpaved Road Onsite T

Equipment	Units	Calendar 2020												2020 Total
Bulldozers	VMT/mo	27	25	26	26	26	26	27	26	26	27	25	27	**314**
Backhoes	VMT/mo	41	38	39	39	39	39	41	39	39	41	38	41	**471**
Bobcats	VMT/mo	41	38	39	39	39	39	41	39	39	41	38	41	**471**
Rollers/Compactors	VMT/mo	41	38	39	39	39	39	41	39	39	41	38	41	**471**
Scrapers (Pans)	VMT/mo	41	38	39	39	39	39	41	39	39	41	38	41	**471**
Grader (Blade)	VMT/mo	7	6	7	7	7	7	7	7	7	7	6	7	**79**
Water Trucks	VMT/mo	14	13	13	13	13	13	14	13	13	14	13	14	**157**
Asphalt Paver	VMT/mo	7	6	7	7	7	7	7	7	7	7	6	7	**79**
Gradall	VMT/mo	7	6	7	7	7	7	7	7	7	7	6	7	**79**
Mobile Crane (Large)	VMT/mo	14	13	13	13	13	13	14	13	13	14	13	14	**157**
Mobile Crane (Truck)	VMT/mo	14	13	13	13	13	13	14	13	13	14	13	14	**157**
Dewatering Pumps	VMT/mo	27	25	26	26	26	26	27	26	26	27	25	27	**314**
Soil Dump Trucks[b]	VMT/mo	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	**12,000**

Notes:

a Each piece of construction equipment is assumed to make 1 trip per day of operation with a distance of 0.25 miles.

b See assumptions in Table F1-5, footnote b.

Table F1-8 Construction Equipment Unpaved Road Onsite T

Equipment	Units	Calendar 2021												2021 Total
Bulldozers	VMT/mo	26	24	27	26	26	26	27	26	26	26	26	27	**313**
Backhoes	VMT/mo	39	36	41	39	39	39	41	39	39	39	39	41	**470**
Bobcats	VMT/mo	39	36	41	39	39	39	41	39	39	39	39	41	**470**
Rollers/Compactors	VMT/mo	39	36	41	39	39	39	41	39	39	39	39	41	**470**
Scrapers (Pans)	VMT/mo	39	36	41	39	39	39	41	39	39	39	39	41	**470**
Grader (Blade)	VMT/mo	7	6	7	7	7	7	7	7	7	7	7	7	**78**
Water Trucks	VMT/mo	13	12	14	13	13	13	14	13	13	13	13	14	**157**
Asphalt Paver	VMT/mo	7	6	7	7	7	7	7	7	7	7	7	7	**78**
Gradall	VMT/mo	7	6	7	7	7	7	7	7	7	7	7	7	**78**
Mobile Crane (Large)	VMT/mo	13	12	14	13	13	13	14	13	13	13	13	14	**157**
Mobile Crane (Truck)	VMT/mo	13	12	14	13	13	13	14	13	13	13	13	14	**157**
Dewatering Pumps	VMT/mo	26	24	27	26	26	26	27	26	26	26	26	27	**313**
Soil Dump Trucks[b]	VMT/mo	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	**12,000**

Notes:

a Each piece of construction equipment is assumed to make 1 trip per day of operation with a distance of 0.25 miles.

b See assumptions in Table F1-5, footnote b.

Table F1-8 Construction Equipment Unpaved Road Onsite T

Equipment	Units	Calendar 2022												2022 Total
Bulldozers	VMT/mo	26	23	27	26	26	26	26	27	26	26	26	27	**312**
Backhoes	VMT/mo	39	35	41	39	39	39	39	41	39	39	39	41	**468**
Bobcats	VMT/mo	39	35	41	39	39	39	39	41	39	39	39	41	**468**
Rollers/Compactors	VMT/mo	39	35	41	39	39	39	39	41	39	39	39	41	**468**
Scrapers (Pans)	VMT/mo	39	35	41	39	39	39	39	41	39	39	39	41	**468**
Grader (Blade)	VMT/mo	7	6	7	7	7	7	7	7	7	7	7	7	**78**
Water Trucks	VMT/mo	13	12	14	13	13	13	13	14	13	13	13	14	**156**
Asphalt Paver	VMT/mo	7	6	7	7	7	7	7	7	7	7	7	7	**78**
Gradall	VMT/mo	7	6	7	7	7	7	7	7	7	7	7	7	**78**
Mobile Crane (Large)	VMT/mo	13	12	14	13	13	13	13	14	13	13	13	14	**156**
Mobile Crane (Truck)	VMT/mo	13	12	14	13	13	13	13	14	13	13	13	14	**156**
Dewatering Pumps	VMT/mo	26	23	27	26	26	26	26	27	26	26	26	27	**312**
Soil Dump Trucks[b]	VMT/mo	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	**12,000**

Notes:

a Each piece of construction equipment is assumed to make 1 trip per day of operation with a distance of 0.25 miles.

b See assumptions in Table F1-5, footnote b.

Table F1-8 Construction Equipment Unpaved Road Onsite T

Equipment	Units	Calendar 2023												2023 Total
Bulldozers	VMT/mo	26	22	27	25	27	26	26	27	26	26	26	26	**310**
Backhoes	VMT/mo	39	33	41	38	41	39	39	41	39	39	39	39	**465**
Bobcats	VMT/mo	39	33	41	38	41	39	39	41	39	39	39	39	**465**
Rollers/Compactors	VMT/mo	39	33	41	38	41	39	39	41	39	39	39	39	**465**
Scrapers (Pans)	VMT/mo	39	33	41	38	41	39	39	41	39	39	39	39	**465**
Grader (Blade)	VMT/mo	7	6	7	6	7	7	7	7	7	7	7	7	**78**
Water Trucks	VMT/mo	13	11	14	13	14	13	13	14	13	13	13	13	**155**
Asphalt Paver	VMT/mo	7	6	7	6	7	7	7	7	7	7	0	0	**65**
Gradall	VMT/mo	7	6	7	6	7	7	7	7	7	7	7	7	**78**
Mobile Crane (Large)	VMT/mo	13	11	14	13	14	13	13	14	13	13	0	0	**129**
Mobile Crane (Truck)	VMT/mo	13	11	14	13	14	13	13	14	13	13	13	13	**155**
Dewatering Pumps	VMT/mo	26	22	27	25	27	26	26	27	26	26	26	26	**310**
Soil Dump Trucks[b]	VMT/mo	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	**12,000**

Notes:

a Each piece of construction equipment is assumed to make 1 trip per day of operation with a distance of 0.25 miles.

b See assumptions in Table F1-5, footnote b.

Table F1-9 Construction Equipment Inventory and Utilization

Equipment	# units	Capacity hp/unit[a]	Utilization[b]			
			Excavation	Civil/Site	Structural	MEP
Bulldozers	4	310	100%	25%	0%	0%
Backhoes	6	109	100%	25%	10%	10%
Bobcats	6	75	100%	100%	100%	100%
Rollers/Compactors	6	250	100%	10%	0%	0%
Scrapers (Pans)	6	407	100%	10%	0%	0%
Grader (Blade)	1	297	100%	25%	0%	0%
Water Trucks	2	330	100%	25%	0%	0%
Asphalt Paver	1	174	0%	25%	0%	0%
Gradall	1	166	50%	10%	0%	0%
Mobile Crane (Large)	2	450	0%	50%	100%	25%
Mobile Crane (Truck)	2	215	25%	75%	100%	100%
Dewatering Pumps	4	294	100%	100%	100%	100%
Soil Dump Trucks	8	452	100%	0%	0%	0%

Notes:

[a] Based on typical sizes for mid-range equipment.

[b] Represents utilization of construction equipment for different phases. Based on information provided to ARCADIS on 11/25/2013. Soil dump trucks operate during excavation phases only.

Table F1-10 Emission Calculation Inputs for Supply Trucks and Topsoil and Borrow Material Handling

Activity				Year	Paved Road Travel						Material Drops[c]	
					Supply Trucks (Onsite)[a]			Supply Trucks (Offsite)[b]			Soil	
EA Option	Location	Area	Activity Type		# trips	mi/trip	mi/yr	# trips	mi/trip	mi/yr	cy	ton
PROP	SURF	Proj. Inf.	Civil/Site	2017	1120	2.0	2,239	1,120	30	33,585		
PROP	SURF	Proj. Inf.	Civil/Site	2018	1120	2.0	2,239	1,120	30	33,585		
PROP	SURF	Proj. Inf.	Civil/Site	2019	1120	2.0	2,239	1,120	30	33,585		
PROP	SURF	Proj. Inf.	Civil/Site	2020	1120	2.0	2,239	1,120	30	33,585		
PROP	SURF	Proj. Inf.	Civil/Site	2021	1120	2.0	2,239	1,120	30	33,585		
PROP	SURF	Proj. Inf.	Civil/Site	2022	1120	2.0	2,239	1,120	30	33,585		
PROP	SURF	Proj. Inf.	Civil/Site	2023	933	2.0	1,866	933	30	27,988		
PROP	SURF	LBNE5	Civil/Site	2017	0	2.0	0	0	30	0		
PROP	SURF	LBNE5	Civil/Site	2018	6	2.0	13	6	30	188		
PROP	SURF	LBNE5	Civil/Site	2019	13	2.0	25	13	30	376		
PROP	SURF	LBNE5	Civil/Site	2020	9	2.0	19	9	30	282		
PROP	SURF	LBNE5	Civil/Site	2021	0	2.0	0	0	30	0		
PROP	SURF	LBNE5	Civil/Site	2022	0	2.0	0	0	30	0		
PROP	SURF	LBNE5	Civil/Site	2023	0	2.0	0	0	30	0		
PROP	SURF	LBNE5	Structural	2017	0	2.0	0	0	30	0		
PROP	SURF	LBNE5	Structural	2018	0	2.0	0	0	30	0		
PROP	SURF	LBNE5	Structural	2019	0	2.0	0	0	30	0		
PROP	SURF	LBNE5	Structural	2020	3	2.0	6	3	30	94		
PROP	SURF	LBNE5	Structural	2021	6	2.0	13	6	30	188		
PROP	SURF	LBNE5	Structural	2022	6	2.0	13	6	30	188		
PROP	SURF	LBNE5	Structural	2023	3	2.0	6	3	30	94		
PROP	SURF	LBNE20	Excavation	2018	1330	2.0	2,660	1,330	30	39,900		
PROP	SURF	LBNE20	Excavation	2019	45	2.0	91	45	30	1,358		
PROP	SURF	LBNE20	Excavation	2020	34	2.0	68	34	30	1,018		
PROP	SURF	LBNE20	Excavation	2021	0	2.0	0	0	30	0		
PROP	SURF	LBNE20	Excavation	2022	0	2.0	0	0	30	0		
PROP	SURF	LBNE20	Excavation	2023	0	2.0	0	0	30	0		
PROP	SURF	LBNE20	Structural	2019	0	2.0	0	0	30	0		
PROP	SURF	LBNE20	Structural	2020	23	2.0	45	23	30	679		
PROP	SURF	LBNE20	Structural	2021	45	2.0	91	45	30	1,358		
PROP	SURF	LBNE20	Structural	2022	45	2.0	91	45	30	1,358		
PROP	SURF	LBNE20	Structural	2023	23	2.0	45	23	30	679		
PROP	SURF	LBNE30	Civil/Site	2017	0	2.0	0	0	30	0		
PROP	SURF	LBNE30	Civil/Site	2018	22	2.0	44	22	30	660		
PROP	SURF	LBNE30	Civil/Site	2019	44	2.0	88	44	30	1,320		
PROP	SURF	LBNE30	Civil/Site	2020	33	2.0	66	33	30	990		
PROP	SURF	LBNE30	Civil/Site	2021	0	2.0	0	0	30	0		
PROP	SURF	LBNE30	Civil/Site	2022	0	2.0	0	0	30	0		
PROP	SURF	LBNE30	Civil/Site	2023	0	2.0	0	0	30	0		
PROP	SURF	LBNE30	Structural	2017	0	2.0	0	0	30	0		
PROP	SURF	LBNE30	Structural	2018	0	2.0	0	0	30	0		
PROP	SURF	LBNE30	Structural	2019	0	2.0	0	0	30	0		

Table F1-10 Emission Calculation Inputs for Supply Trucks and Topso

Activity				Year	Diesel Combustion Emissions			Other Construction Activities	
					Supply Trucks[a,b]			Scraper Topsoil Unloading[d]	
EA Option	Location	Area	Activity Type		# trips	mi/trip	mi/yr	cy	ton
PROP	SURF	Proj. Inf.	Civil/Site	2017	1120	32	35,824		
PROP	SURF	Proj. Inf.	Civil/Site	2018	1120	32	35,824		
PROP	SURF	Proj. Inf.	Civil/Site	2019	1120	32	35,824		
PROP	SURF	Proj. Inf.	Civil/Site	2020	1120	32	35,824		
PROP	SURF	Proj. Inf.	Civil/Site	2021	1120	32	35,824		
PROP	SURF	Proj. Inf.	Civil/Site	2022	1120	32	35,824		
PROP	SURF	Proj. Inf.	Civil/Site	2023	933	32	29,854		
PROP	SURF	LBNE5	Civil/Site	2017	0	32	0		
PROP	SURF	LBNE5	Civil/Site	2018	6	32	201		
PROP	SURF	LBNE5	Civil/Site	2019	13	32	401		
PROP	SURF	LBNE5	Civil/Site	2020	9	32	301		
PROP	SURF	LBNE5	Civil/Site	2021	0	32	0		
PROP	SURF	LBNE5	Civil/Site	2022	0	32	0		
PROP	SURF	LBNE5	Civil/Site	2023	0	32	0		
PROP	SURF	LBNE5	Structural	2017	0	32	0		
PROP	SURF	LBNE5	Structural	2018	0	32	0		
PROP	SURF	LBNE5	Structural	2019	0	32	0		
PROP	SURF	LBNE5	Structural	2020	3	32	100		
PROP	SURF	LBNE5	Structural	2021	6	32	201		
PROP	SURF	LBNE5	Structural	2022	6	32	201		
PROP	SURF	LBNE5	Structural	2023	3	32	100		
PROP	SURF	LBNE20	Excavation	2018	1330	32	42,560		
PROP	SURF	LBNE20	Excavation	2019	45	32	1,448		
PROP	SURF	LBNE20	Excavation	2020	34	32	1,086		
PROP	SURF	LBNE20	Excavation	2021	0	32	0		
PROP	SURF	LBNE20	Excavation	2022	0	32	0		
PROP	SURF	LBNE20	Excavation	2023	0	32	0		
PROP	SURF	LBNE20	Structural	2019	0	32	0		
PROP	SURF	LBNE20	Structural	2020	23	32	724		
PROP	SURF	LBNE20	Structural	2021	45	32	1,448		
PROP	SURF	LBNE20	Structural	2022	45	32	1,448		
PROP	SURF	LBNE20	Structural	2023	23	32	724		
PROP	SURF	LBNE30	Civil/Site	2017	0	32	0		
PROP	SURF	LBNE30	Civil/Site	2018	22	32	704		
PROP	SURF	LBNE30	Civil/Site	2019	44	32	1,408		
PROP	SURF	LBNE30	Civil/Site	2020	33	32	1,056		
PROP	SURF	LBNE30	Civil/Site	2021	0	32	0		
PROP	SURF	LBNE30	Civil/Site	2022	0	32	0		
PROP	SURF	LBNE30	Civil/Site	2023	0	32	0		
PROP	SURF	LBNE30	Structural	2017	0	32	0		
PROP	SURF	LBNE30	Structural	2018	0	32	0		
PROP	SURF	LBNE30	Structural	2019	0	32	0		

Table F1-10 Emission Calculation Inputs for Supply Trucks and Topsoil and Borrow Material Handling

Activity				Year	Paved Road Travel						Material Drops[c]	
					Supply Trucks (Onsite)[a]			Supply Trucks (Offsite)[b]			Soil	
EA Option	Location	Area	Activity Type		# trips	mi/trip	mi/yr	# trips	mi/trip	mi/yr	cy	ton
PROP	SURF	LBNE30	Structural	2020	11	2.0	22	11	30	330		
PROP	SURF	LBNE30	Structural	2021	22	2.0	44	22	30	660		
PROP	SURF	LBNE30	Structural	2022	22	2.0	44	22	30	660		
PROP	SURF	LBNE30	Structural	2023	11	2.0	22	11	30	330		
PROP	UNDERG	Absorber Hall	Structural	2020	482	2.0	964	482	30	14,460		
PROP	UNDERG	PBE	Civil/Site	2017	92	2.0	184	92	30	2,762		
PROP	UNDERG	PBE	Civil/Site	2018	0	2.0	0	0	30	0		
PROP	UNDERG	PBE	Civil/Site	2019	0	2.0	0	0	30	0		
PROP	UNDERG	PBE	Civil/Site	2020	0	2.0	0	0	30	0		
PROP	UNDERG	PBE	Civil/Site	2021	0	2.0	0	0	30	0		
PROP	UNDERG	PBE	Civil/Site	2022	0	2.0	0	0	30	0		
PROP	UNDERG	PBE	Civil/Site	2023	0	2.0	0	0	30	0		
PROP	UNDERG	PBE	Excavation	2017	92	2.0	184	92	30	2,762	255,000	344,250
PROP	UNDERG	PBE	Excavation	2018	92	2.0	184	92	30	2,762	255,000	344,250
PROP	UNDERG	PBE	Structural	2019	0	2.0	0	0	30	0		
PROP	UNDERG	PBE	Structural	2020	54	2.0	107	54	30	1,611		
PROP	UNDERG	PBE	Structural	2021	92	2.0	184	92	30	2,762		
PROP	UNDERG	PBE	Structural	2022	92	2.0	184	92	30	2,762		
PROP	UNDERG	PBE	Structural	2023	46	2.0	92	46	30	1,381		
PROP	UNDERG	Decay Pipe	Excavation	2017	0	2.0	0	0	30	0		
PROP	UNDERG	Decay Pipe	Excavation	2018	876	2.0	1,753	876	30	26,288		
PROP	UNDERG	Decay Pipe	Excavation	2019	1753	2.0	3,505	1,753	30	52,576		
PROP	UNDERG	Decay Pipe	Excavation	2020	1314	2.0	2,629	1,314	30	39,432		
PROP	UNDERG	Decay Pipe	Excavation	2021	0	2.0	0	0	30	0		
PROP	UNDERG	Decay Pipe	Excavation	2022	0	2.0	0	0	30	0		
PROP	UNDERG	Decay Pipe	Excavation	2023	0	2.0	0	0	30	0		
PROP	UNDERG	Decay Pipe	Structural	2017	0	2.0	0	0	30	0		
PROP	UNDERG	Decay Pipe	Structural	2018	0	2.0	0	0	30	0		
PROP	UNDERG	Decay Pipe	Structural	2019	0	2.0	0	0	30	0		
PROP	UNDERG	Decay Pipe	Structural	2020	438	2.0	876	438	30	13,144		
PROP	UNDERG	Decay Pipe	Structural	2021	876	2.0	1,753	876	30	26,288		
PROP	UNDERG	Decay Pipe	Structural	2022	876	2.0	1,753	876	30	26,288		
PROP	UNDERG	Decay Pipe	Structural	2023	438	2.0	876	438	30	13,144		

Table F1-10 Emission Calculation Inputs for Supply Trucks and Topso

Activity				Year	Diesel Combustion Emissions			Other Construction Activities	
					Supply Trucks[a,b]			Scraper Topsoil Unloading[d]	
EA Option	Location	Area	Activity Type		# trips	mi/trip	mi/yr	cy	ton
PROP	SURF	LBNE30	Structural	2020	11	32	352		
PROP	SURF	LBNE30	Structural	2021	22	32	704		
PROP	SURF	LBNE30	Structural	2022	22	32	704		
PROP	SURF	LBNE30	Structural	2023	11	32	352		
PROP	UNDERG	Absorber Hall	Structural	2020	482	32	15,424		
PROP	UNDERG	PBE	Civil/Site	2017	92	32	2,946		
PROP	UNDERG	PBE	Civil/Site	2018	0	32	0		
PROP	UNDERG	PBE	Civil/Site	2019	0	32	0		
PROP	UNDERG	PBE	Civil/Site	2020	0	32	0		
PROP	UNDERG	PBE	Civil/Site	2021	0	32	0		
PROP	UNDERG	PBE	Civil/Site	2022	0	32	0		
PROP	UNDERG	PBE	Civil/Site	2023	0	32	0		
PROP	UNDERG	PBE	Excavation	2017	92	32	2,946	11,500	17,078
PROP	UNDERG	PBE	Excavation	2018	92	32	2,946	11,500	17,078
PROP	UNDERG	PBE	Structural	2019	0	32	0		
PROP	UNDERG	PBE	Structural	2020	54	32	1,718		
PROP	UNDERG	PBE	Structural	2021	92	32	2,946		
PROP	UNDERG	PBE	Structural	2022	92	32	2,946		
PROP	UNDERG	PBE	Structural	2023	46	32	1,473		
PROP	UNDERG	Decay Pipe	Excavation	2017	0	32	0		
PROP	UNDERG	Decay Pipe	Excavation	2018	876	32	28,041		
PROP	UNDERG	Decay Pipe	Excavation	2019	1753	32	56,081		
PROP	UNDERG	Decay Pipe	Excavation	2020	1314	32	42,061		
PROP	UNDERG	Decay Pipe	Excavation	2021	0	32	0		
PROP	UNDERG	Decay Pipe	Excavation	2022	0	32	0		
PROP	UNDERG	Decay Pipe	Excavation	2023	0	32	0		
PROP	UNDERG	Decay Pipe	Structural	2017	0	32	0		
PROP	UNDERG	Decay Pipe	Structural	2018	0	32	0		
PROP	UNDERG	Decay Pipe	Structural	2019	0	32	0		
PROP	UNDERG	Decay Pipe	Structural	2020	438	32	14,020		
PROP	UNDERG	Decay Pipe	Structural	2021	876	32	28,041		
PROP	UNDERG	Decay Pipe	Structural	2022	876	32	28,041		
PROP	UNDERG	Decay Pipe	Structural	2023	438	32	14,020		

Table F1-10 Emission Calculation Inputs for Supply Trucks and Topsoil and Borrow Material Handling

Activity				Year	Paved Road Travel						Material Drops[c]	
					Supply Trucks (Onsite)[a]			Supply Trucks (Offsite)[b]			Soil	
EA Option	Location	Area	Activity Type		# trips	mi/trip	mi/yr	# trips	mi/trip	mi/yr	cy	ton
PROP	SURF	LBNE38	Civil/Site	2017	0	2.0	0	0	30	0		
PROP	SURF	LBNE39	Civil/Site	2018	0	2.0	0	0	30	0		
PROP	SURF	LBNE40	Civil/Site	2019	13	2.0	25	13	30	376		
PROP	SURF	LBNE40	Civil/Site	2020	21	2.0	43	21	30	644		
PROP	SURF	LBNE40	Civil/Site	2021	5	2.0	11	5	30	161		
PROP	SURF	LBNE40	Civil/Site	2022	0	2.0	0	0	30	0		
PROP	SURF	LBNE40	Civil/Site	2023	0	2.0	0	0	30	0		
PROP	SURF	LBNE40	Structural	2017	0	2.0	0	0	30	0		
PROP	SURF	LBNE40	Structural	2018	0	2.0	0	0	30	0		
PROP	SURF	LBNE40	Structural	2019	0	2.0	0	0	30	0		
PROP	SURF	LBNE40	Structural	2020	0	2.0	0	0	30	0		
PROP	SURF	LBNE40	Structural	2021	0	2.0	0	0	30	0		
PROP	SURF	LBNE40	Structural	2022	3	2.0	5	3	30	81		
PROP	SURF	LBNE40	Structural	2023	9	2.0	18	9	30	268		
PROP	UNDERG	NND Hall	Excavation	2017	0	2.0	0	0	30	0		
PROP	UNDERG	NND Hall	Excavation	2018	0	2.0	0	0	30	0		
PROP	UNDERG	NND Hall	Excavation	2019	23	2.0	45	23	30	679		
PROP	UNDERG	NND Hall	Excavation	2020	39	2.0	78	39	30	1,165	60,000	81,000
PROP	UNDERG	NND Hall	Excavation	2021	39	2.0	78	39	30	1,165	60,000	81,000
PROP	UNDERG	NND Hall	Excavation	2022	39	2.0	78	39	30	1,165	60,000	81,000
PROP	UNDERG	NND Hall	Excavation	2023	39	2.0	78	39	30	1,165	60,000	81,000
PROP	UNDERG	NND Hall	Structural	2017	0	2.0	0	0	30	0		
PROP	UNDERG	NND Hall	Structural	2018	0	2.0	0	0	30	0		
PROP	UNDERG	NND Hall	Structural	2019	0	2.0	0	0	30	0		
PROP	UNDERG	NND Hall	Structural	2020	0	2.0	0	0	30	0		
PROP	UNDERG	NND Hall	Structural	2021	0	2.0	0	0	30	0		
PROP	UNDERG	NND Hall	Structural	2022	10	2.0	19	10	30	291		
PROP	UNDERG	NND Hall	Structural	2023	32	2.0	65	32	30	971		

Notes:

[a] Number of trips based on truck information provided to ARCADIS on June 13, 2013. Equipment was assumed to travel 2 miles per trip on-site.

[b] Number of trips based on truck information provided to ARCADIS on June 13, 2013. Equipment was assumed to travel 30 miles per trip offsite.

[c] Based on projected amounts of soil to be moved by trucks specified below, and an average soil density of 100 pounds per cubic foot.

90,000 cubic yards for the new pond (2017 and 2018)
345,000 cubic yards for the borrow pit (2017 and 2018)
75,000 cubic yards for roads, utilities, creek relocation, etc. (2017 and 2018)
240,000 cubic yards for the beam line enclosure construction (2020 through 2023)

[d] Based on projected 23000 cubic yards of topsoil stripped in 2017 and 2018 and an average soil density of 110 pounds per cubic foot.

Table F1-10 Emission Calculation Inputs for Supply Trucks and Topso

Activity				Year	Diesel Combustion Emissions			Other Construction Activities	
					Supply Trucks[a,b]			Scraper Topsoil Unloading[d]	
EA Option	Location	Area	Activity Type		# trips	mi/trip	mi/yr	cy	ton
PROP	SURF	LBNE38	Civil/Site	2017	0	32	0		
PROP	SURF	LBNE39	Civil/Site	2018	0	32	0		
PROP	SURF	LBNE40	Civil/Site	2019	13	32	401		
PROP	SURF	LBNE40	Civil/Site	2020	21	32	687		
PROP	SURF	LBNE40	Civil/Site	2021	5	32	172		
PROP	SURF	LBNE40	Civil/Site	2022	0	32	0		
PROP	SURF	LBNE40	Civil/Site	2023	0	32	0		
PROP	SURF	LBNE40	Structural	2017	0	32	0		
PROP	SURF	LBNE40	Structural	2018	0	32	0		
PROP	SURF	LBNE40	Structural	2019	0	32	0		
PROP	SURF	LBNE40	Structural	2020	0	32	0		
PROP	SURF	LBNE40	Structural	2021	0	32	0		
PROP	SURF	LBNE40	Structural	2022	3	32	86		
PROP	SURF	LBNE40	Structural	2023	9	32	286		
PROP	UNDERG	NND Hall	Excavation	2017	0	32	0		
PROP	UNDERG	NND Hall	Excavation	2018	0	32	0		
PROP	UNDERG	NND Hall	Excavation	2019	23	32	725		
PROP	UNDERG	NND Hall	Excavation	2020	39	32	1,242		
PROP	UNDERG	NND Hall	Excavation	2021	39	32	1,242		
PROP	UNDERG	NND Hall	Excavation	2022	39	32	1,242		
PROP	UNDERG	NND Hall	Excavation	2023	39	32	1,242		
PROP	UNDERG	NND Hall	Structural	2017	0	32	0		
PROP	UNDERG	NND Hall	Structural	2018	0	32	0		
PROP	UNDERG	NND Hall	Structural	2019	0	32	0		
PROP	UNDERG	NND Hall	Structural	2020	0	32	0		
PROP	UNDERG	NND Hall	Structural	2021	0	32	0		
PROP	UNDERG	NND Hall	Structural	2022	10	32	311		
PROP	UNDERG	NND Hall	Structural	2023	32	32	1,035		

Notes:

[a] Number of trips based on truck information provided to ARCADIS on June 13, 2013. Equipment was assumed to travel 2 miles per trip on-site.

[b] Number of trips based on truck information provided to ARCADIS on June 13, 2013. Equipment was assumed to travel 30 miles per trip offsite.

[c] Based on projected amounts of soil to be moved by trucks specified below, and an average soil density of 100 pounds per cubic foot.

90,000 cubic yards for the new pond (2017 and 2018)
345,000 cubic yards for the borrow pit (2017 and 2018)
75,000 cubic yards for roads, utilities, creek relocation, etc. (2017 and 2018)
240,000 cubic yards for the beam line enclosure construction (2020 through 2023)

[d] Based on projected 23000 cubic yards of topsoil stripped in 2017 and 2018 and an average soil density of 110 pounds per cubic foot.

Table F1-11 Paved Road Emissions from On-site Travel

Year	Total Vehicle Miles Traveled[a] (VMT/yr)	Average Vehicle Weight (tons)	Emission Factor[b] (lb/VMT)		Emissions (ton/yr)	
			PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Proposed Action						
2017	2,607	25	1.29	0.32	1.68	0.41
2018	6,892	25	1.29	0.32	4.43	1.09
2019	6,018	25	1.29	0.32	3.87	0.95
2020	7,162	25	1.29	0.32	4.60	1.13
2021	4,411	25	1.29	0.32	2.84	0.70
2022	4,425	25	1.29	0.32	2.84	0.70
2023	3,068	25	1.29	0.32	1.97	0.48

Notes:

[a] See Table F1-10.

[b] Emission factor based on AP-42 Section 13.2.1 Equation 2, an assumed control efficiency of 50% provided by road watering, and parameters in tables above and below.

$E = k * sL^{0.91} * W^{1.02} * (1 - P / 4N) * (1 - 50\%)$ AP-42 Section 13.2.1 (January 2011)

E = emission factor (units of k)
k = particle size multiplier (g/VKT, g/VMT, or lb/VMT)
sL = road surface silt loading (g/m^2)
W = average vehicle weight (tons)
P = Number of days with at least 0.01 in of precipitation (from AP-42 Figure 13.2.1-2)
N = Number of days in averaging period (365 for annual)

Table F1-12 Paved Road Emission Factor Calculation Parameters

Parameter	Values	Units
PM_{10} particle size multiplier (k)[a]	0.0022	lb/VMT
$PM_{2.5}$ particle size multiplier (k)[a]	0.00054	lb/VMT
Silt Loading (sL)[b]	70	g/m^2
Number of wet days (P)[c]	120	days

Notes:

[a] Particle size multipliers obtained from AP-42.

[b] Silt loading obtained from AP-42 Table 13.2.1-3 for paved roads at sand and gravel processing facilities.

[c] Number of wet days obtained from AP-42 Figure 13.2.1-2 based on site location.

Table F1-13 Paved Road Emissions from Offsite Supply Truck Travel

Year	Total Vehicle Miles Traveled[a] (VMT/yr)	Average Vehicle Weight (tons)	Emission Factor[b] (lb/VMT)		Emissions (ton/yr)	
			PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Proposed Action						
2017	39,109	25	1.69E-02	4.15E-03	0.33	0.08
2018	103,383	25	1.69E-02	4.15E-03	0.87	0.21
2019	90,270	25	1.69E-02	4.15E-03	0.76	0.19
2020	107,435	25	1.69E-02	4.15E-03	0.91	0.22
2021	66,167	25	1.69E-02	4.15E-03	0.56	0.14
2022	66,377	25	1.69E-02	4.15E-03	0.56	0.14
2023	46,019	25	1.69E-02	4.15E-03	0.39	0.10

Notes:

[a] See Table F1-10.

[b] Emission factor based on AP-42 Section 13.2.1 Equation 2 and parameters in tables above and below.

$E = k * sL^{0.91} * W^{1.02} * (1 - P / 4N)$ AP-42 Section 13.2.1 (January 2011)

E = emission factor (units of k)
k = particle size multiplier (g/VKT, g/VMT, or lb/VMT)
sL = road surface silt loading (g/m^2)
W = average vehicle weight (tons)
P = Number of days with at least 0.01 in of precipitation (from AP-42 Figure 13.2.1-2)
N = Number of days in averaging period (365 for annual)

Table F1-14 Paved Road Emission Factor Calculation Parameters

Parameter	Values	Units
PM_{10} particle size multiplier (k)[a]	0.0022	lb/VMT
$PM_{2.5}$ particle size multiplier (k)[a]	0.00054	lb/VMT
Ubiquitous Baseline Silt Loading (sL)[b]	0.2	g/m^2
Winter Baseline Multiplier[c]	3	--
Operations During Wintertime[d]	20%	%
Calculated Silt Loading (sL)[e]	0.28	g/m^2
Number of wet days (P)[f]	120	days

Notes:

[a] Particle size multipliers obtained from AP-42.

[b] Obtained from AP-42 Table 13.2.1-2 for medium volume (500 to 5,000 ADT) public roads.

[c] Obtained from AP-42 Table 13.2.1-2 for medium volume (500 to 5,000 ADT) public roads.

[d] Approximate percent of civil/site, excavation, and structural operations during wintertime.

[e] Calculated silt loading based on ubiquitous baseline, winter baseline, and percent of operations during wintertime.

[f] Number of wet days obtained from AP-42 Figure 13.2.1-2 based on site location.

Table F1-15 Paved Road Emissions from Offsite Construction Worker Vehicle Travel

Year	Total Vehicle Miles Traveled[a] (VMT/yr)	Average Vehicle Weight (tons)	Emission Factor[b] (lb/VMT)		Emissions (ton/yr)	
			PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Proposed Action						
2017	4,586,400	2	1.29E-03	3.16E-04	2.95	0.72
2018	4,601,100	2	1.29E-03	3.16E-04	2.96	0.73
2019	3,849,900	2	1.29E-03	3.16E-04	2.47	0.61
2020	4,615,800	2	1.29E-03	3.16E-04	2.97	0.73
2021	4,601,100	2	1.29E-03	3.16E-04	2.96	0.73
2022	4,586,400	2	1.29E-03	3.16E-04	2.95	0.72
2023	4,510,200	2	1.29E-03	3.16E-04	2.90	0.71

Notes:

[a] See Tables F1-7 and F1-12.

[b] Emission factor based on AP-42 Section 13.2.1 Equation 2 and parameters in tables above and below.

$E = k * sL^{0.91} * W^{1.02} * (1 - P / 4N)$ AP-42 Section 13.2.1 (January 2011)

E = emission factor (units of k)
k = particle size multiplier (g/VKT, g/VMT, or lb/VMT)
sL = road surface silt loading (g/m^2)
W = average vehicle weight (tons)
P = Number of days with at least 0.01 in of precipitation (from AP-42 Figure 13.2.
N = Number of days in averaging period (365 for annual)

Table F-16 Paved Road Emission Factor Calculation Parameters

Parameter	Values	Units
PM_{10} particle size multiplier (k)[a]	0.0022	lb/VMT
$PM_{2.5}$ particle size multiplier (k)[a]	0.00054	lb/VMT
Ubiquitous Baseline Silt Loading (sL)[b]	0.2	g/m^2
Winter Baseline Multiplier[c]	3	--
Operations During Wintertime[d]	20%	%
Calculated Silt Loading (sL)[e]	0.28	g/m^2
Number of wet days (P)[f]	120	days

Notes:

[a] Particle size multipliers obtained from AP-42.

[b] Obtained from AP-42 Table 13.2.1-2 for medium volume (500 to 5,000 ADT) public roads.

[c] Obtained from AP-42 Table 13.2.1-2 for medium volume (500 to 5,000 ADT) public roads.

[d] Approximate percent of civil/site, excavation, and structural operations during wintertime.

[e] Calculated silt loading based on ubiquitous baseline, winter baseline, and percent of operations during wintertime.

[f] Number of wet days obtained from AP-42 Figure 13.2.1-2 based on site location.

Table F1-17 Unpaved Road Emissions from Onsite Travel

Year	Total Vehicle Miles Traveled[a] (VMT/yr)	Average Vehicle Weight (tons)	Emission Factor[b] (lb/VMT)		Emissions (ton/yr)	
			PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Proposed Action						
2017	54,198	25	0.82	0.08	22.09	2.21
2018	54,208	25	0.82	0.08	22.09	2.21
2019	3,208	25	0.82	0.08	1.31	0.13
2020	15,219	25	0.82	0.08	6.20	0.62
2021	15,208	25	0.82	0.08	6.20	0.62
2022	15,198	25	0.82	0.08	6.19	0.62
2023	15,139	25	0.82	0.08	6.17	0.62

Notes:

[a] See Tables F1-8 and F1-13.

[b] Emission factor based on AP-42 Section 13.2.2 Equation 1a & Equation 2 for unpaved surfaces at industrial sites, an assumed control efficiency of 50% from watering, and parameters in tables above and below.

$E = k * (s/12)^a * (W/3)^b * [(365 - P)/365] * (1 - 50\%)$ AP-42 Section 13.2.2 (November 2006)

E = emission factor (lb/VMT)
k = particle size multiplier (lb/VMT)
s = surface material silt content (%)
W = average vehicle weight (tons)
a = empirical constant (adimensionless)
b = empirical constant (adimensionless)
P = Number of days with at least 0.01 in of precipitation (from AP-42 Figure 13.2.2-1)

Table F1-18 Unpaved Road Emission Factor Calculation Parameters

Parameter	Values	Units
PM_{10} particle size multiplier (k)[a]	1.5	lb/VMT
$PM_{2.5}$ particle size multiplier (k)[a]	0.15	lb/VMT
a[a]	0.9	--
b[a]	0.45	--
Silt Content (s)[b]	7.1	%
Number of wet days (P)[c]	120	days

Notes:

[a] Particle size multipliers and empirical constants obtained from AP-42 Table 13.2.2-2.

[b] Silt loading obtained from AP-42 Table 13.2.2-1 for material storage areas at sand and gravel processing facilities.

[c] Number of wet days obtained from AP-42 Figure 13.2.1-2 based on site location.

Table F1-19 Material Drops

Year	Average Throughput[a]	Emission Factor[b] (lb/ton)		Emissions (ton/yr)	
	ton/yr	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Proposed Action					
2017	344,250	4.62E-04	6.99E-05	7.95E-02	1.20E-02
2018	344,250	4.62E-04	6.99E-05	7.95E-02	1.20E-02
2019	0	4.62E-04	6.99E-05	0.00E+00	0.00E+00
2020	81,000	4.62E-04	6.99E-05	1.87E-02	2.83E-03
2021	81,000	4.62E-04	6.99E-05	1.87E-02	2.83E-03
2022	81,000	4.62E-04	6.99E-05	1.87E-02	2.83E-03
2023	81,000	4.62E-04	6.99E-05	1.87E-02	2.83E-03

Notes:

a See Table F1-10.

b Emission factor for material drop emissions based on AP-42, Section 13.2.4 equation 1 and parameters provided in tables above and below.

$E = k * 0.0032 * (U / 5)^{1.3} / (M / 2)^{1.4}$

AP-42 Section 13.2.4 (November 2006)

E = emission factor (lb/ton)

k = particle size multiplier (dimensionless)

U = mean wind speed (mph)

M = material moisture content (%)

Table F1-20 Material Drop Emission Factor Calculation Parameters

Parameter[a]	Values
PM_{10} particle size multiplier (k)[a]	0.35
$PM_{2.5}$ particle size multiplier (k)[a]	0.053
Mean wind speed (U)[b] (mph)	9
Moisture Content (M)[c] (%)	6.5

Notes:

a Particle size multipliers obtained from AP-42.

b Wind speed represents average 2012 wind speed for Chicago, IL obtained from http://www.wunderground.com/history

c Assumed the average of range of observed surface moisture content values reported in AP-42 Table 13.2.2-3 for unpaved industrial roads. These surfaces are expected to dry quickly than other areas because of traffic-enhanced natural evaporation and, therefore, the selection of this moisture content is expected to be conservative.

Table F1-21 Diesel Combustion Emissions from Supply Trucks

Year	Total Vehicle Miles Traveled[a] (VMT/yr)	Emissions[b]													
		CO		NO_X		PM_{10}		$PM_{2.5}$		SO_2		VOC		CO_2	
		Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	metric tons/yr
Proposed Action															
2017	41,716	6.51E-03	1.36E-01	1.69E-02	3.53E-01	8.49E-04	1.77E-02	6.97E-04	1.45E-02	4.03E-05	8.41E-04	1.45E-03	3.03E-02	4.21	79.66
2018	110,275	6.05E-03	3.33E-01	1.53E-02	8.42E-01	7.68E-04	4.23E-02	6.24E-04	3.44E-02	3.93E-05	2.17E-03	1.32E-03	7.26E-02	4.21	210.54
2019	96,288	5.65E-03	2.72E-01	1.39E-02	6.69E-01	7.02E-04	3.38E-02	5.61E-04	2.70E-02	4.03E-05	1.94E-03	1.20E-03	5.79E-02	4.21	183.78
2020	114,597	5.32E-03	3.05E-01	1.27E-02	7.30E-01	6.46E-04	3.70E-02	5.09E-04	2.92E-02	3.96E-05	2.27E-03	1.11E-03	6.34E-02	4.21	218.67
2021	70,578	5.04E-03	1.78E-01	1.18E-02	4.16E-01	5.94E-04	2.10E-02	4.63E-04	1.63E-02	4.03E-05	1.42E-03	1.03E-03	3.64E-02	4.22	134.97
2022	70,802	4.79E-03	1.70E-01	1.10E-02	3.89E-01	5.54E-04	1.96E-02	4.26E-04	1.51E-02	4.11E-05	1.45E-03	9.61E-04	3.40E-02	4.22	135.41
2023	49,087	4.58E-03	1.12E-01	1.03E-02	2.53E-01	5.21E-04	1.28E-02	3.96E-04	9.72E-03	4.01E-05	9.84E-04	9.02E-04	2.21E-02	4.22	93.87

Notes:

[a] See Table F1-10.

[b] Emission factors based on highest EMFAC2007 (version 2.3) for heavy-heavy-duty diesel trucks provided by the South Coast Air Quality Management District..

Table F1-22 Combustion Emissions from Construction Worker Vehicles

Year	Total Vehicle Miles Traveled[a] (VMT/yr)	Emissions[b]													
		CO		NO_X		PM_{10}		$PM_{2.5}$		SO_2		VOC		CO_2	
		Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	tons/yr	Emission Factor (lb/VMT)	metric tons/yr
Proposed Action															
2017	4,586,400	5.38E-03	12.33	5.13E-04	1.18	9.45E-05	2.17E-01	6.19E-05	1.42E-01	1.08E-05	2.48E-02	6.01E-04	1.38	1.11	2,304.21
2018	4,601,100	5.03E-03	11.57	4.73E-04	1.09	9.49E-05	2.18E-01	6.23E-05	1.43E-01	1.07E-05	2.46E-02	5.72E-04	1.32	1.11	2,310.08
2019	3,849,900	4.72E-03	9.08	4.37E-04	0.84	9.52E-05	1.83E-01	6.26E-05	1.20E-01	1.07E-05	2.06E-02	5.47E-04	1.05	1.11	1,931.65
2020	4,615,800	4.44E-03	10.25	4.05E-04	0.93	9.55E-05	2.20E-01	6.28E-05	1.45E-01	1.07E-05	2.48E-02	5.25E-04	1.21	1.11	2,314.97
2021	4,601,100	4.21E-03	9.69	3.78E-04	0.87	9.64E-05	2.22E-01	6.36E-05	1.46E-01	1.07E-05	2.47E-02	5.06E-04	1.16	1.11	2,319.05
2022	4,586,400	3.98E-03	9.12	3.51E-04	0.81	9.66E-05	2.22E-01	6.39E-05	1.47E-01	1.07E-05	2.46E-02	4.87E-04	1.12	1.11	2,311.76
2023	4,510,200	3.78E-03	8.51	3.29E-04	0.74	9.68E-05	2.18E-01	6.40E-05	1.44E-01	1.07E-05	2.41E-02	4.69E-04	1.06	1.11	2,273.33

Notes:

[a] See Tables F1-7 and F1-12.

[b] Emission factors based on highest EMFAC2007 (version 2.3) for passenger/light-duty vehicles provided by the South Coast Air Quality Management District..

Table F1-23 Diesel Combustion Emissions from Soil Dump Trucks

Year	Total Rating[a] (hp-hr/yr)	Emissions[b]													
		CO		NO_X		PM_{10}		$PM_{2.5}$		SO_2		HC		CO_2	
		Emission Factor (g/hp-hr)	tons/yr	Emission Factor (g/hp-hr)	tons/yr	Emission Factor (g/hp-hr)	tons/yr	Emission Factor (g/hp-hr)	tons/yr	Emission Factor (g/hp-hr)	tons/yr	Emission Factor (g/hp-hr)	tons/yr	Emission Factor (g/hp-hr)	metric tons/yr
Proposed Action															
2017	2,305,200	0.8425	2.14	2.50	6.35	0.15	0.38	0.15	0.37	0.8128	2.07	0.1669	0.42	530.5	1,223
2018	2,305,200	0.8425	2.14	2.50	6.35	0.15	0.38	0.15	0.37	0.8128	2.07	0.1669	0.42	530.5	1,223
2019	0	0.8425	0.00	2.50	0.00	0.15	0.00	0.15	0.00	0.8128	0.00	0.1669	0.00	530.5	0
2020	542,400	0.8425	0.50	2.50	1.49	0.15	0.09	0.15	0.09	0.8128	0.49	0.1669	0.10	530.5	288
2021	542,400	0.8425	0.50	2.50	1.49	0.15	0.09	0.15	0.09	0.8128	0.49	0.1669	0.10	530.5	288
2022	542,400	0.8425	0.50	2.50	1.49	0.15	0.09	0.15	0.09	0.8128	0.49	0.1669	0.10	530.5	288
2023	542,400	0.8425	0.50	2.50	1.49	0.15	0.09	0.15	0.09	0.8128	0.49	0.1669	0.10	530.5	288

Notes:

[a] See Tables F1-6 and F1-11.

[b] Emission factors for SO_2, hydrocarbons (HC), CO, NO_X, and PM from EPA-420-R-10-018, Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling--Compression Ignition, July 2010. Engines assumed to be Tier 3 (model years 2006 through 2010). $PM_{2.5}$ = 97% PM_{10}.

Table F1-24 Diesel Combustion Emissions from Construction Equipment

Year	Total Rating[a] (hp-hr/yr)	Emissions[b,] CO Emission Factor (g/hp-hr)	CO tons/yr	NO_X Emission Factor (g/hp-hr)	NO_X tons/yr	PM_{10} Emission Factor (g/hp-hr)	PM_{10} tons/yr	$PM_{2.5}$ Emission Factor (g/hp-hr)	$PM_{2.5}$ tons/yr	SO_2 Emission Factor (g/hp-hr)	SO_2 tons/yr	HC Emission Factor (g/hp-hr)	HC tons/yr	CO_2 Emission Factor (g/hp-hr)	CO_2 metric tons/yr
Proposed Action															
2017	**29,459,352**		**28.67**		**81.96**		**5.14**		**4.99**		**26.53**		**5.69**		**15,710.78**
2018	**29,553,773**		**28.76**		**82.22**		**5.16**		**5.00**		**26.62**		**5.71**		**15,761.13**
2019	**29,553,773**		**28.76**		**82.22**		**5.16**		**5.00**		**26.62**		**5.71**		**15,761.13**
2020	**30,476,194**		**29.62**		**84.76**		**5.31**		**5.15**		**27.45**		**5.88**		**16,250.74**
2021	**30,962,273**		**30.07**		**86.10**		**5.39**		**5.23**		**27.88**		**5.96**		**16,508.35**
2022	**30,863,352**		**29.97**		**85.82**		**5.37**		**5.21**		**27.79**		**5.95**		**16,455.60**
2023	**29,998,558**		**29.18**		**83.44**		**5.23**		**5.07**		**27.02**		**5.78**		**15,996.31**

Notes:

[a] See Tables F1-6 and F1-11.

[b] Emission based on emission factors in table below.

Table F1-25 Diesel Engine Emission Factors

Equipment	Emission Factors[a] (g/hp-hr) CO	NO_X	PM_{10}	$PM_{2.5}$	SO_2	HC	CO_2	BSFC (lb/hp-hr)	HP Category
Bull dozers	0.8425	2.50	0.15	0.15	0.8128	0.1669	530.5	0.367	300-600
Backhoes	0.8667	2.50	0.22	0.21	0.8127	0.1836	530.5	0.367	100-175
Bobcats	2.3655	3.00	0.20	0.19	0.9036	0.1836	589.8	0.408	75-100
Rollers/Compactors	0.7475	2.50	0.15	0.15	0.8127	0.1836	530.5	0.367	175-300
Scrapers (Pans)	0.8425	2.50	0.15	0.15	0.8128	0.1669	530.5	0.367	300-600
Grader (Blade)	0.7475	2.50	0.15	0.15	0.8127	0.1836	530.5	0.367	175-300
Water Trucks	0.8425	2.50	0.15	0.15	0.8128	0.1669	530.5	0.367	300-600
Asphalt Paver	0.8667	2.50	0.22	0.21	0.8127	0.1836	530.5	0.367	100-175
Gradall	0.8667	2.50	0.22	0.21	0.8127	0.1836	530.5	0.367	100-175
Mobile Crane (Large)	0.8425	2.50	0.15	0.15	0.8128	0.1669	530.5	0.367	300-600
Mobile Crane (Truck)	0.7475	2.50	0.15	0.15	0.8127	0.1836	530.5	0.367	175-300
Dewatering Pumps	0.7475	2.50	0.15	0.15	0.8127	0.1836	530.5	0.367	175-300

Notes:

[a] Emission factors for SO_2, hydrocarbons (HC), CO, NO_X, and PM from EPA-420-R-10-018, Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling--Compression Ignition, July 2010. Engines assumed to be Tier 3 (ca. 2009 model years). $PM_{2.5}$ = 97% PM_{10}.

Table F1-26 Bulldozing Emissions

Year	Hours per Year[a]	Emission Factor[b] (lb/hr)		Emissions (ton/yr)	
		PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Proposed Action					
2017	12,480	0.52	0.28	3.22	1.72
2018	12,520	0.52	0.28	3.23	1.73
2019	12,520	0.52	0.28	3.23	1.73
2020	12,560	0.52	0.28	3.24	1.73
2021	12,520	0.52	0.28	3.23	1.73
2022	12,480	0.52	0.28	3.22	1.72
2023	12,400	0.52	0.28	3.20	1.71

Notes:

[a] Based on Table F1-5 hours of operation per unit and Table F1-9 number of units.

[b] Emission factors based on AP-42 Table 11.9-1 equations and scaling factors for overburnden bulldozing, as recommended in AP-42 Section Table 13.2.3-1 for general land clearing, bulldozing, and compacting activities, and a control efficiency of 50% provided by watering.

$E_{PM10} = 1.0 * s^{1.5} / M^{1.4} * 0.75 * (1 - 50\%)$

$E_{PM2.5} = 5.7 * s^{1.2} / M^{1.3} * 0.105 * (1 - 50\%)$

E_i = emission factor of pollutant i (lb/hr)

s = material silt content (%)

M = material moisture content (%)

Table F1-27 Bulldozing Emission Factor Calculation Parameters

Parameter	Values	Units
Silt Content (s)[a]	7.1	%
Moisture Content (M)[b] (%)	6.5	%

Notes:

[a] Silt loading obtained from AP-42 Table 13.2.2-1 for material storage areas at sand and gravel processing facilities.

[b] Assumed the average of range of observed surface moisture content values reported in AP-42 Table 13.2.2-3 for unpaved industrial roads. These surfaces are expected to dry more quickly than other areas because of traffic-enhanced natural evaporation and, therefore, the selection of this moisture content is expected to be conservative.

Table F1-28 Topsoil Scraping Emissions

Year	Total Vehicle Miles Traveled (VMT/yr)[a]	Amount of Topsoil[b] (ton/yr)	Topsoil Removal Emission Factor[c] (lb/VMT)		Topsoil Unloading Emission Factor[d] (lb/ton)		Emissions (ton/yr)	
			PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Proposed Action								
2017	468	17,078	10.1	10.1	0.058	0.058	2.86	2.86
2018	470	17,078	10.1	10.1	0.058	0.058	2.87	2.87
2019	470	0	10.1	10.1	0.058	0.058	2.37	2.37
2020	471	0	10.1	10.1	0.058	0.058	2.38	2.38
2021	470	0	10.1	10.1	0.058	0.058	2.37	2.37
2022	468	0	10.1	10.1	0.058	0.058	2.36	2.36
2023	465	0	10.1	10.1	0.058	0.058	2.35	2.35

Notes:

[a] See Tables F1-8 and F1-13.

[b] See Table F1-10.

[c] Emission factor from AP-42, Table 13.2.3-1 assuming a control efficiency of 50% for the top soil removal provided by watering. Conservatively assumes TSP = PM_{10} = $PM_{2.5}$.

[d] Emission factor from AP-42, Table 11.9-4 as recommended in AP-42, Table 13.2.3-1 for scrapers removing topsoil. Conservatively assumes TSP = PM_{10} = $PM_{2.5}$.

Table F1-29 Grading Emissions

Year	Total Vehicle Miles Traveled (VMT/yr)[a]	Emission Factor[b] (lb/hr)		Emissions (ton/yr)	
		PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Proposed Action					
2017	78	0.77	0.08	0.03	0.003
2018	78	0.77	0.08	0.03	0.003
2019	78	0.77	0.08	0.03	0.003
2020	79	0.77	0.08	0.03	0.003
2021	78	0.77	0.08	0.03	0.003
2022	78	0.77	0.08	0.03	0.003
2023	78	0.77	0.08	0.03	0.003

Notes:

a See Tables F1-8 and F1-13.

b Emission factors based on AP-42 Table 11.9-1 equations and scaling factors for grading, as recommended in AP-42 Section Table 13.2.3-1, and a control efficiency of 50% provided by watering.

$E_{PM10} = 0.051 * s^2 * 0.60 * (1 - 50\%)$

$E_{PM2.5} = 0.040 * s^{2.5} * 0.031 * (1 - 50\%)$

E_i = emission factor of pollutant i (lb/VMT)

s = material silt content (%)

Table F1-30 Grading Emission Factor Calculation Parameters

Parameter	Values	Units
Silt Content (s)[a]	7.1	%

Notes:

a Silt content obtained from AP-42 Table 13.2.2-1 for material storage areas at sand and gravel processing facilities.

Table F1-31 Construction Days per Year

Year	Days of Construction
2017 Total	312
2018 Total	313
2019 Total	313
2020 Total	314
2021 Total	313
2022 Total	312

Table F1-32 Indirect Emissions from Fermilab Worker Commutes During Operational Perioc

Total Vehicle Miles Traveled[a] (VMT/yr)	CO		NO_X		PM_{10}		$PM_{2.5}$		SO_2		VOC		CO_2e	
	Emission Factor[b] (lb/VMT)	tons/yr	Emission Factor[b] (lb/VMT)	tons/yr	Emission Factor[b] (lb/VMT)	tons/yr	Emission Factor[b] (lb/VMT)	tons/yr	Emission Factor[b] (lb/VMT)	tons/yr	Emission Factor[b] (lb/VMT)	tons/yr	Emission Factor[b] (lb/VMT)	metric tons/yr
109,500	3.59E-03	0.20	3.07E-04	0.02	9.68E-05	0.01	6.41E-05	0.00	1.08E-05	0.00	4.51E-04	0.02	1.11	55.21

Notes:

[a] Assumes 10 researchers and that each researcher will make one 30-mile trip per day on passenger/light-duty vehicles for 365 days per year.

[b] Emission factors based on highest EMFAC2007 (version 2.3) for passenger/light-duty vehicles provided by the South Coast Air Quality Management District for year 2024.

Table F1-33 Indirect Greenhouse Gas Emissions from Generation of Electricity for Proposed Action During Operational Perioc

Annual Electricity Use[a] (MWh/yr)	CO_2		CH_4		N_2O		CO_2e
	Emission Factor[b] (lb/MWh)	tons/yr	Emission Factor[b] (lb/GWh)	tons/yr	Emission Factor[b] (lb/GWh)	tons/yr	metric tons/yr
78,840	1,503.47	59,266.79	18.20	0.72	24.75	0.98	54,045.95

Notes:

[a] Based on an estimated electricity use of 9 MW and 8760 hours of operation per year.

[b] Emission factors obtained from USEPA's "eGRID 9th edition Version 1.0 Year 2010 GHG Annual Output Emission Rates" for the RFC West subregion.

Table F1-34 Direct Emissions from Natural Gas Space Heating During Operational Period

Space Heating Requirement[a] (MMBtu/hr)	CO		NO_X		PM_{10}		$PM_{2.5}$		SO_2		VOC		CO_2		Methane		N_2O		CO_2e
	Emission Factor[b] ($lb/10^6$ cf)	tons/yr[c]	Emission Factor[b] ($lb/10^6$ cf)	tons/yr[c]	Emission Factor[b] ($lb/10^6$ cf)	tons/yr[c]	Emission Factor[b] ($lb/10^6$ cf)	tons/yr[c]	Emission Factor[b] ($lb/10^6$ cf)	tons/yr[c]	Emission Factor[b] ($lb/10^6$ cf)	tons/yr[c]	Emission Factor[b] ($lb/10^6$ cf)	tons/yr[c]	Emission Factor[b] ($lb/10^6$ cf)	tons/yr[c]	Emission Factor[b] ($lb/10^6$ cf)	tons/yr[c]	metric tons/yr
2.7	100	#DIV/0!	84	#DIV/0!	7.60	#DIV/0!	7.60	#DIV/0!	0.60	#DIV/0!	5.50	#DIV/0!	120,000	#DIV/0!	2.30	#DIV/0!	2.20E+00	#DIV/0!	#DIV/0!

Notes:

[a] Calculated using the Calculator.net BTU calculator conservatively assuming a 60,000-square-foot space with a 12-foot height and normal insulation, temperature increase of 75 degrees Fahrenheit (cold winter regions), and a natural gas furnace efficiency of 80%.

[b] Emissions factors from AP-42 Section 1.4 for small uncontrolled boilers (under 100 MMBtu/hr)

[c] Assumes a natural gas higher heating value of Btu/scf and that the heater would be running at full capacity for 0% of the year.

APPENDIX F-2

SURF Air Emissions Calculations

Appendix F2, Table F-1

Emission Summary By Year for the Proposed Action, Gilt Edge Truck Haul

Totals Emissions by Year	CO (tons)	NOx (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	Sox (tons)	VOC (tons)	CO_2 (metric tons)
2017	0.416	0.985	3.722	0.698	0.005	0.171	451.360
2018	7.069	10.406	10.653	3.094	0.042	1.718	4649.443
2019	4.418	10.485	252.977	28.160	0.049	1.614	4704.657
2020	5.654	8.624	179.606	20.113	0.037	1.355	3714.973
2021	3.546	6.095	11.337	3.020	0.020	0.900	2431.296
2022	2.888	1.222	9.723	2.427	0.007	0.277	478.075
2023	3.664	0.702	1.574	0.414	0.006	0.263	374.872
2024-2044	0.105	0.366	32.259	7.918	0.021	0.105	18.941
Total	27.761	38.885	501.851	65.844	0.186	6.402	16,823.618

Appendix F2, Table F-1a

Emission Summary For On-site Construction Equipment, Employee Commute, and off Site Truck Traffic- Gilt Edge Truck Haul

Construction Equipment Exhaust	CO (tons)	Nox (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	SOx (tons)	VOC (tons)	CO_2 (tons)
Construction Equipment Exhaust 2017[1]	0.416	0.985	0.074	0.071	0.005	0.171	410.328
Construction Equipment Exhaust 2018[1]	7.069	10.406	0.662	0.642	0.042	1.718	4226.766
Construction Equipment Exhaust 2019[1]	4.418	10.485	0.689	0.668	0.049	1.614	4276.961
Construction Equipment Exhaust 2020[1]	5.654	8.624	0.509	0.493	0.037	1.355	3377.248
Construction Equipment Exhaust 2021[1]	3.546	6.095	0.328	0.318	0.020	0.900	2210.269
Construction Equipment Exhaust 2022[1]	2.888	1.222	0.057	0.055	0.007	0.277	434.614
Construction Equipment Exhaust 2023[1]	3.664	0.702	0.039	0.037	0.006	0.263	340.792

[1] From Appendix F, Table F-2

Appendix F2, Table F-1b

ission Summary for Off-Site Fugative Emissions, Gilt Edge Truck H

Year	PM_{10} (tons)	$PM_{2.5}$ (tons)
Fugitive Emissions Roads 2017[2]	3.648	0.626
Fugitive Emissions Roads 2018[2]	9.991	2.452
Fugitive Emissions Roads 2019[2]	252.288	27.492
Fugitive Emissions Roads 2020[2]	179.097	19.619
Fugitive Emissions Roads 2021[2]	11.009	2.702
Fugitive Emissions Roads 2022[2]	9.667	2.373
Fugitive Emissions Roads 2023[2]	1.534	0.377
Fugitive Emissions Roads 2022-2044[2]	32.259	7.918

[2] From Appendix F, Table F-3

Appendix F, Table F-2

On Site Construction Equipment Emissions for the Proposed Action Gilt Edge Truck Haul and Employee Commute and Truck Traffic[1]

Year	PM_{10} (tons)	$PM_{2.5}$ (tons)	NOX (tons)	SOX (tons)	VOC (tons)	CO (tons)	CO_2 (tons)
2017	0.074	0.071	0.985	0.005	0.171	0.416	410.328
2018	0.662	0.642	10.406	0.042	1.718	7.069	4226.766
2019	0.689	0.668	10.485	0.049	1.614	4.418	4276.961
2020	0.509	0.493	8.624	0.037	1.355	5.654	3377.248
2021	0.328	0.318	6.095	0.020	0.900	3.546	2210.269
2022	0.057	0.055	1.222	0.007	0.277	2.888	434.614
2023	0.039	0.037	0.702	0.006	0.263	3.664	340.792
2024-2044			0.366	0.021	0.105	0.105	17.219

[1] From Appendix F, Table F-2a and Table F-2d

Appendix F, Table F-2a

On site Construction Equipment Monthly Emissions Breakdown

									PM$_{10}$			PM$_{2.5}$			NOx			SOx			VOC			CO			CO$_2$		
Offroad Vehicles, Equipment (Surface and Undeground)	***SCC***	**Fuel Type**	**HP**	**Hour of Ops per Unit (hr/day)**	**Pieces of Equipment**	**Hours of Ops per Eqpt (hr/day)**	**Load Factor[c]**	**Operation Duration (months)**	**EF g/hp-hr[c]**	**Emissions lbs/month**	**Total Emissions lbs**	**EF g/hp-hr[c]**	**Emissions lbs/month**	**Total Emissions lbs**	**EF g/hp-hr[c]**	**Emissions lbs/month**	**Total Emissions lbs**	**EF g/hp-hr[c]**	**Emissions lbs/month**	**Total Emissions lbs**	**EF g/hp-hr[c]**	**Emissions lbs/month**	**Total Emissions lbs**	**EF g/hp-hr[c]**	**Emissions lbs/month**	**Total Emissions lbs**	**EF g/hp-hr[c]**	**Emissions lbs/month**	**Total Emissions tons**
Surface Construction (year)																													
Grader (2017)	2270002048	Diesel	200	8	2	16	0.59	3	0.029	3.580	10.74	0.028	3.473	10.42	0.649	81.025	243.08	0.004	0.452	1.36	0.145	18.047	54.14	0.196	24.532	73.59	536.393	66978	100.47
Compactor (2017)	2270002081	Diesel	250	6	2	12	0.43	3	0.087	7.436	22.31	0.085	7.213	21.64	1.333	113.711	341.13	0.004	0.335	1.01	0.171	14.563	43.69	0.452	38.592	115.77	536.318	45757	68.64
Backhoe (2017)	2270002066	Diesel	300	8	2	16	0.21	3	0.254	16.909	50.73	0.246	16.402	49.21	2.587	172.450	517.35	0.005	0.325	0.98	0.420	28.006	84.02	1.344	89.615	268.84	625.291	41686	62.53
Scraper (2017)	2270002018	Diesel	200	8	2	16	0.59	3	0.032	3.996	11.99	0.031	3.876	11.63	0.696	86.905	260.72	0.004	0.455	1.36	0.146	18.234	54.70	0.212	26.438	79.31	536.389	66978	100.47
Water Tanker (Grading) (2017)	2270002051	Diesel	225	2	1	2	0.59	3	0.012	0.210	0.63	0.012	0.204	0.61	0.322	5.653	16.96	0.004	0.062	0.19	0.139	2.445	7.34	0.121	2.118	6.35	536.409	9419	14.13
Backhoe (Foundation) (2017)	2270002066	Diesel	300	8	2	16	0.21	4	0.254	16.909	67.64	0.246	16.402	65.61	2.587	172.450	689.80	0.005	0.325	1.30	0.420	28.006	112.02	1.344	89.615	358.46	625.291	41686	83.37
										49.041			47.569			632.195			1.954			109.302			270.909			272504	
Compactor (2018)	2270002081	Diesel	250	6	1	6	0.43	4	0.087	3.718	14.87	0.085	3.606	14.43	1.333	56.856	227.42	0.004	0.168	0.67	0.171	7.281	29.13	0.452	19.296	77.18	536.318	22879	45.76
Water Tanker (Foundation) (2018)	2270002051	Diesel	225	8	2	16	0.59	4	0.012	1.683	6.73	0.012	1.632	6.53	0.322	45.225	180.90	0.004	0.496	1.98	0.139	19.561	78.25	0.121	16.943	67.77	536.409	75353	150.71
Crane (Structure) (2018)	2270002045	Diesel	230	8	4	32	0.43	7	0.042	8.858	62.01	0.041	8.592	60.15	1.016	212.565	1487.95	0.004	0.783	5.48	0.156	32.561	227.92	0.216	45.134	315.94	530.574	111056	388.69
Frontend Loader (Structure) (2018)	2270002060	Diesel	190	6	2	12	0.59	7	0.052	4.665	32.65	0.051	4.525	31.67	0.945	84.101	588.71	0.004	0.334	2.34	0.155	13.751	96.26	0.302	26.856	187.99	536.365	47719	167.02
Compressor (2018)	2265006015	Gasoline	50	8	4	32	0.56	7	0.069	4.078	28.55	0.063	3.752	26.27	1.456	86.258	603.81	0.013	0.759	5.31	0.775	45.954	321.68	14.868	881.045	6167.32	702.068	41604	145.61
Generators (2018)	2270006005	Diesel	250	8	4	32	0.43	7	0.150	34.172	239.21	0.146	33.149	232.04	2.892	657.895	4605.27	0.004	0.965	6.75	0.272	61.781	432.47	0.727	165.502	1158.52	530.232	120635	422.22
Water Tanker (Structure) (2018)	2270002051	Diesel	225	8	2	16	0.59	7	0.012	1.683	11.78	0.012	1.632	11.43	0.322	45.225	316.57	0.004	0.496	3.47	0.139	19.561	136.93	0.121	16.943	118.60	536.409	75353	263.73
Backhoe (Utilities) (2018)	2270002066	Diesel	300	8	2	16	0.21	1	0.254	16.909	16.91	0.246	16.402	16.40	2.587	172.450	172.45	0.005	0.325	0.33	0.420	28.006	28.01	1.344	89.615	89.61	625.291	41686	20.84
Crane (Utilities) (2018)	2270002045	Diesel	230	8	2	16	0.43	1	0.042	4.429	4.43	0.041	4.296	4.30	1.016	106.282	106.28	0.004	0.391	0.39	0.156	16.280	16.28	0.216	22.567	22.57	530.574	55528	27.76
Frontend Loader (Utilities) (2018)	2270002060	Diesel	190	8	2	16	0.59	1	0.052	6.219	6.22	0.051	6.033	6.03	0.945	112.134	112.13	0.004	0.445	0.44	0.155	18.335	18.33	0.302	35.808	35.81	536.365	63626	31.81
Water Tanker (Utilities) (2018)	2270002051	Diesel	225	8	2	16	0.59	1	0.012	1.683	1.68	0.012	1.632	1.63	0.322	45.225	45.22	0.004	0.496	0.50	0.139	19.561	19.56	0.121	16.943	16.94	536.409	75353	37.68
Skid Steer Loader (2018)	2270002072	Diesel	75	10	4	40	0.21	7	0.624	25.988	181.91	0.605	25.208	176.46	4.652	193.829	1356.80	0.006	0.238	1.66	0.840	35.013	245.09	4.264	177.667	1243.67	693.498	28896	101.14
Water Tanker (Foundation) (2018)	2270002051	Diesel	225	8	2	16	0.59	7	0.012	1.683	11.78	0.012	1.632	11.43	0.322	45.225	316.57	0.004	0.496	3.47	0.139	19.561	136.93	0.121	16.943	118.60	536.409	75353	263.73
										115.769			112.094			1863.271			6.390			337.207			1531.261			835039	
Cavern Excavation Phase (year)																													
Drill Rig (2018, 2019 2020)	2270002033	Electric	250	20	2	40	0.43	24	0.000	0.000	0.00	0.000	0.000	0.00	0.000	0.000	0.00	0.000	0.000	0.00	0.000	0.000	0.00	0.000	0.000	0.00	0.000	0	0.00
Frontend Loader (2018, 2019 2020)	2270002060	Diesel	190	20	4	80	0.59	24	0.052	31.097	746.34	0.051	30.166	723.99	0.945	560.672	13456.13	0.004	2.224	53.38	0.155	91.673	2200.15	0.302	179.040	4296.95	536.365	318130	3817.56
Skid Steer Loader (2018, 2019 2020)	2270002072	Diesel	75	20	4	80	0.21	24	0.624	51.975	1247.40	0.605	50.417	1210.00	4.652	387.658	9303.80	0.006	0.475	11.40	0.840	70.025	1680.60	4.264	355.333	8528.00	693.498	57792	693.50
Crane (2018, 2019 2020)	2270002045	Diesel	230	20	2	40	0.43	24	0.042	11.073	265.74	0.041	10.740	257.77	1.016	265.706	6376.95	0.004	0.979	23.48	0.156	40.701	976.82	0.216	56.417	1354.02	530.574	138819	1665.83
Rock Crusher (2018, 2019 2020)	2270002054	Diesel	400	10	2	20	0.43	24	0.083	18.929	454.30	0.081	18.360	440.65	1.929	438.919	10534.04	0.004	0.910	21.84	0.171	38.859	932.62	0.512	116.487	2795.68	530.525	120701	1448.42
Water Tanker (Excavation) (2018, 2019, 2020)	2270002051	Diesel	225	8	2	16	0.59	24	0.012	1.683	40.39	0.012	1.632	39.18	0.322	45.225	1085.40	0.004	0.496	11.90	0.139	19.561	469.47	0.121	16.943	406.63	536.409	75353	904.23
										114.76			111.32			1698.18			5.08			260.82			724.22			710794.86	
Cavern Outfitting (year)																													
Crane (Structure) (2020, 2021)	2270002045	Diesel	230	8	4	32	0.43	8	0.042	8.858	70.86	0.041	8.592	68.74	1.016	212.565	1700.52	0.004	0.783	6.26	0.156	32.561	260.48	0.216	45.134	361.07	530.574	111056	444.22
Frontend Loader (structure) (2020, 2021)	2270002060	Diesel	190	8	2	16	0.59	8	0.052	6.219	49.76	0.051	6.033	48.27	0.945	112.134	897.08	0.004	0.445	3.56	0.155	18.335	146.68	0.302	35.808	286.46	536.365	63626	254.50
Compressor (Structure) (2020, 2021)	2265006015	Gasoline	50	8	4	32	0.56	8	0.069	4.078	32.63	0.063	3.752	30.02	1.456	86.258	690.07	0.013	0.759	6.07	0.775	45.954	367.63	14.868	881.045	7048.36	702.068	41604	166.42
Generators (Structure) (2020, 2021)	2270006005	Diesel	250	8	4	32	0.43	8	0.150	34.172	273.38	0.146	33.149	265.19	2.892	657.895	5263.16	0.004	0.965	7.72	0.272	61.781	494.25	0.727	165.502	1324.02	530.232	120635	482.54
Water Tanker (Structure) (2020, 2021)	2270002051	Diesel	225	8	2	16	0.59	8	0.012	1.683	13.46	0.012	1.632	13.06	0.322	45.225	361.80	0.004	0.496	3.97	0.139	19.561	156.49	0.121	16.943	135.54	536.409	75353	301.41
Crane (Cryostats) (2021, 2022)	2270002045	Diesel	230	8	4	32	0.43	9	0.042	8.858	79.72	0.041	8.592	77.33	1.016	212.565	1913.08	0.004	0.783	7.05	0.156	32.561	293.05	0.216	45.134	406.21	530.574	111056	499.75
Generators (Cryostats) (2021, 2022)	2270006005	Diesel	250	8	4	32	0.43	9	0.150	34.172	307.55	0.146	33.149	298.34	2.892	657.895	5921.06	0.004	0.965	8.68	0.272	61.781	556.03	0.727	165.502	1489.52	530.232	120635	542.86
Compressor (Cryostats) 2021, 2022, 2023)	2265006015	Gasoline	50	8	4	32	0.56	14	0.069	4.078	57.10	0.063	3.752	52.53	1.456	86.258	1207.62	0.013	0.759	10.63	0.775	45.954	643.35	14.868	881.045	12334.63	702.068	41604	291.23
Water Tanker (Cryostats) (2021, 2022)	2270002051	Diesel	225	8	2	16	0.59	9	0.012	1.683	15.15	0.012	1.632	14.69	0.322	45.225	407.02	0.004	0.496	4.46	0.139	19.561	176.05	0.121	16.943	152.49	536.409	75353	339.09
Backhoe (Utilities) (2023)	2270002066	Diesel	300	8	2	16	0.21	2	0.254	16.909	33.82	0.246	16.402	32.80	2.587	172.450	344.90	0.005	0.325	0.65	0.420	28.006	56.01	1.344	89.615	179.23	625.291	41686	41.69
Crane (Utilities) (2023)	2270002045	Diesel	230	8	2	16	0.43	2	0.042	4.429	8.86	0.041	4.296	8.59	1.016	106.282	212.56	0.004	0.391	0.78	0.156	16.280	32.56	0.216	22.567	45.13	530.574	55528	55.53
Water Tanker (Utilities) (2023)	2270002051	Diesel	225	8	2	16	0.59	2	0.012	1.683	3.37	0.012	1.632	3.26	0.322	45.225	90.45	0.004	0.496	0.99	0.139	19.561	39.12	0.121	16.943	33.89	536.409	75353	75.35

Notes:

[a] Vehicle speed is the assumed average speed during vehicle's operating hours.

[b] Emission factors for onroad construction vehicles obtained from EPA's MOBILE62 model which assumes a representative engine fleet mix for the respective year of analysis.

[c] Load factor and emission factors for offroad vehicles obtained from EPA's NONROAD model which assumes a representative engine fleet mix for the respective year of analysis.

Appendix F, Table F-2b
Emissions Associated with Employee Commuting to and from SURF (excluding PM_{10} and $PM_{2.5}$)

	Fuel Type	HP	Number of Cars	Hours of Ops per Eqpt (hr/day)	Load Factor	Operation Duration (months)	NOx Emissions[1] (lbs.)	SOx Emissions[1] (lbs.)	VOC Emissions[1] (lbs.)	CO Emissions[1] (lbs.)	CO_2 Emissions[1] (lbs.)
2017	gasoline	150	20	1	0.5	5	5.452	0.029	7.434	3.449	540.000
	gasoline	150	25	1	0.5	1	1.363	0.007	1.859	0.862	135.000
2018	gasoline	150	20	1	0.5	3	3.271	0.018	4.460	2.070	324.000
	gasoline	150	60	1	0.5	6	19.625	0.105	26.762	12.417	1944.000
2019	gasoline	150	60	1	0.5	12	39.251	0.211	53.525	24.835	3888.000
2020	gasoline	150	60	1	0.5	6	19.625	0.105	26.762	12.417	1944.000
	gasoline	150	50	1	0.5	6	16.355	0.088	22.302	10.348	1620.000
2021	gasoline	150	50	1	0.5	12	32.709	0.176	44.604	20.696	3240.000
2022	gasoline	150	50	1	0.5	12	32.709	0.176	44.604	20.696	3240.000
2023	gasoline	150	50	1	0.5	6	16.355	0.088	22.302	10.348	1620.000
	gasoline	150	9	1	0.5	6	2.944	0.016	4.014	1.863	291.600
2024-2044	gasoline	150	9	1	0.5	240	117.753	0.632	160.574	74.504	11664.000

[1] USEPA 1991

Emission Factors for Cars[1]

Emission Factor (NOx) (grams/hp-hr)	2.423E-05
Emission Factor (CO) (grams/hp-hr)	1.533E-05
Emission Factor (SOx) (grams/hp-hr)	1.300E-07
Emssion Factor (VOC) (grams/hp-hr)	3.304E-05
Emission Factor (CO_2) (grams/hp-hr)	2.400E-03

Source USEPA, 1991, AP-42

Emission Factors for Trucks[2]

Emission Factor (NOx) (grams/hp-hr)	6.828E-05
Emission Factor (CO) (grams/hp-hr)	1.498E-05
Emission Factor (SOx) (grams/hp-hr)	4.515E-06
Emssion Factor (VOC) (grams/hp-hr)	5.441E-06
Emission Factor (CO_2) (grams/hp-hr)	2.530E-03

Source: USEPA 1991, AP-42

Appendix F, Table F-2c
Emissions Associated with Off-Site Truck Traffic to SURF (excluding PM_{10} and $PM_{2.5}$)

	Fuel Type	HP	Number of Trucks	Hours of Ops per Eqpt (hr/day)	Load Factor[c]	Operation Duration (months)	NOx Emissions[2] (lbs.)	SOx Emissions[2] (lbs.)	VOC Emissions[2] (lbs.)	CO Emissions[2] (lbs.)	CO[2] Emissions[2] (lbs.)
2017	Diesel	500	6	5	0.5	1	15.36	1.02	1.22	3.37	569.34
	Diesel	500	4	5	0.5	5	51.21	3.39	4.08	11.23	1897.80
2018	Diesel	500	4	5	0.5	3	30.73	2.03	2.45	6.74	1138.68
	Diesel	500	2	5	0.5	6	30.73	2.03	2.45	6.74	1138.68
	Diesel	500	8	10	0.5	6	245.82	16.25	19.59	53.92	9109.44
2019	Diesel	500	2	5	0.5	12	61.45	4.06	4.90	13.48	2277.36
	Diesel	500	8	10	0.5	12	491.63	32.51	39.18	107.84	18218.88
2020	Diesel	500	2	5	0.5	12	61.45	4.06	4.90	13.48	2277.36
	Diesel	500	8	10	0.5	6	245.82	16.25	19.59	53.92	9109.44
	Diesel	500	2	5	0.5	6	30.73	2.03	2.45	6.74	1138.68
2021	Diesel	500	2	5	0.5	12	61.45	4.06	4.90	13.48	2277.36
2022	Diesel	500	2	5	0.5	12	61.45	4.06	4.90	13.48	2277.36
2023	Diesel	500	2	5	0.5	6	30.73	2.03	2.45	6.74	1138.68
	Diesel	500	1	5	0.5	6	15.36	1.02	1.22	3.37	569.34
2024-2044	Diesel	500	1	5	0.5	240	614.54	40.64	48.97	134.80	22773.60

Emission Factors for Cars[1]

Emission Factor (NOx) (grams/hp-hr)	2.423E-05
Emission Factor (CO) (grams/hp-hr)	1.533E-05
Emission Factor (SOx) (grams/hp-hr)	1.300E-07
Emssion Factor (VOC) (grams/hp-hr)	3.304E-05
Emission Factor (CO_2) (grams/hp-hr)	2.400E-03

Source USEPA, 1991, AP-42

Emission Factors for Trucks[2]

Emission Factor (NOx) (grams/hp-hr)	6.828E-05
Emission Factor (CO) (grams/hp-hr)	1.498E-05
Emission Factor (SOx) (grams/hp-hr)	4.515E-06
Emssion Factor (VOC) (grams/hp-hr)	5.441E-06
Emission Factor (CO_2) (grams/hp-hr)	2.530E-03

Source: USEPA 1991, AP-42

Appendix F, Table F-2d
Total Emissions Associated with Employee Commute and Truck Traffic

Year	NOx (pounds)	SOx (pounds)	VOC (pounds)	CO (pounds)	CO_2 (pounds)
2017	73	4	15	19	3142
2018	330	20	56	82	13655
2019	592	37	98	146	24384
2020	374	23	76	97	16089
2021	94	4	50	34	5517
2022	94	4	50	34	5517
2023	65	3	30	22	3620
2024-2044	732	41	210	209	34438

Appendix F, Table F-3:

PM_{10} and $PM_{2.5}$ Calculations for Off-Site Vehicle Miles (Paved and Unpaved) for the Proposed Action Gilt Edge Truck Haul

Paved Roads Fugitive Dust by Year (pounds per year)

Year	GMT[1]	PM_{10}[2]	$PM_{2.5}$[2]
2017	117240	3598	883
2018	651151	19982	4905
2019	1014098	31120	7639
2020	766036	23508	5770
2021	717500	22018	5404
2022	630000	19333	4745
2023	100000	3069	753
2024-2044	2102400	64517	15836

[1] From Appenidx F, Table 3b, (below)

[2] From emission equations below times milage

Unpaved Roads Dust by Year (pounds per year)

Year	GMT[1]	PM_{10}[2]	$PM_{2.5}$[2]
2017	1370	3698	370
2018	0	0	0
2019	258208	473456	47346
2020	182527	334686	33468.6
2021	0	0.0	0.0
2022	0	0.0	0.0
2023	0	0.0	0.0

Total PM_{10} and $PM_{2.5}$ Dust Per Year1 (tons/year)

Year	PM_{10}	$PM_{2.5}$
2017	3.648	0.626
2018	9.991	2.452
2019	252.288	27.492
2020	179.097	19.619
2021	11.009	2.702
2022	9.667	2.373
2023	1.534	0.377
2022-2044	32.259	7.918

[1] Data insereted into Appendix F-1 Summary Table

$E = k\,(sL)^{0.91} \times (W)^{1.02}$

(equation for Paved Roads PM10 and PM2.5

	PM_{10}	$PM_{2.5}$
k=	0.0022	0.00054
sL=	0.4	0.4
W=	30	30

$E = k\,(s/12)^{a}(W/30)^{b}$

(equation forUnpaved Roads PM10 and PM2.5

	PM_{10}	$PM_{2.5}$
k=	1.5	0.15
a=	0.9	0.9
b=	0.45	0.45
s=	15	15
W=	30	30

Road Type	**(lb/VMT)**	
	PM_{10}	**$PM_{2.5}$**
Paved	0.031	0.008
Unpaved	1.834	0.183

Equations obtained from AP-42 Chapter 13.2.1 (1/11) and Chapter 13.2.2 (11/06)

Appendix F, Table F-3a

Total Vehicle Miles Traveled By Construction Phase (Proposed Action for Gilt Edge Rock Truck Haul)[1]

Year	Boiler Demo (miles)	Cryogen Building Construction (miles)	Truck Conveyor & LO (miles)	Cavern Construction/ Outfitting (miles	LAr LN Delivery (miles)	Trucking to Gilt Edge (miles)	Tucking to Open Cut (miles)	Rail/Pipe Conveyor Construction (miles)	Total For Trucking to Gilt Edge (miles)
2017	5510	12800	12800	87500					118610
2018		44800	44800	525000		86750	52437	54444	701350
2019				525000		347000	209750	190556	872000
2020				525000		266250	157313		791250
2021				525000	192500				717500
2022				437500	192500				630000
2023					100000				100000
2022-2044									

[1] From Transportation Section

Appendix F, Table F-3b

Total Vehicle Miles Traveled By Construction Phase (Proposed Action for Gilt Edge Rock Truck Haul) - Paved and Unpaved Road Breakdown[1]

Year	Boiler Demo (miles)	Cryogen Building Construction (miles)	Truck Conveyor & LO (miles)	Cavern Construction/ Outfitting (miles	LAr LN Delivery (miles)	Trucking to Gilt Edge (miles)	Tucking to Open Cut (miles)	Rail/Pipe Conveyor Construction (miles)	Trucking to Gilt Edge (miles)
2017 (paved)	5420	12800	11520	87500					117240
2017 (unpaved)	90		1280						1370
2018 (paved)		44800	40320	525000		41031	38369	49000	651151
2018 (unpaved)			4480			45719	14068	5444	50199
2019 (paved)				525000		164122	153476	171500	1014098
2019 (unpaved)						182878	56274	19056	258208
2020 (paved)				525000		125929	115107		766036
2020 (unpaved)						140321	42206		182527
2021 (paved)				525000	192500				717500
2021 (unpaved)									0
2022 (paved)				437500	192500				630000
2022 (unpaved)									0
2023 (paved)					100000				100000
2023 (unpaved)									0

[1] From Appendix F, Table F-3a

Notes:

1. Haul road emissions from the following vehicle types: site pickups, dump trucks, concrete trucks, flatbed trucks, tanker trucks, etc.
2. Assumes trucks operate on roads for duration of construction.

Alternative A Emssion Calculations (assuming the Gilt Edge Truck Haul)

Assumptions:

186,480 Truck (rock haul miles)   52.7% on unpaved roads (3.9/7.4) and 47.3% on paved roads

48,384 Employee commuter miles all on paved roads for truck haul and Load-out

487,000 Truck delivery miles all on paved roads (5 trucks per day over 21 months)

50 employees working undeground and commuting

Appendix F, Table F-4

Alternative A, Summary Off-Site Fugitive Emissions for Gilt Edge Truck Haul

Year	PM_{10} (tons)	$PM_{2.5}$ (tons)	NOx (tons)	SOx (tons)	VOC (tons)	CO (tons)	CO_2 (metric tons)
2020	77.849	77.827	8.462	0.899	1.705	3.773	4926.390
2021	77.637	38.926	4.748	0.966	1.149	2.438	2913.695
Total	155.486	116.753	13.210	1.864	2.854	6.212	8624.093

Appendix F, Table F-4a

Alternative A- PM_{10} and $PM_{2.5}$ Asscociated with the Rock Truck Haul on Paved and Unpaved Roads

Year	Trucking to Gilt Edge Paved (pounds)	Trucking to Gilt Edge Unpaved (pounds)	Employee Commute (paved) (pounds)	Truck Deliveries (paved) (pounds)	Total Paved (pounds)	Total Unpaved (pounds)	PM_{10} (paved) (pounds)	PM_{10} (unpaved) (pounds)	$PM_{2.5}$ (paved) (pounds)	$PM_{2.5}$ (unpaved) (pounds)	Total PM_{10} (pounds)	Total $PM_{2.5}$ (pounds)
2020	74100	82568	36000	218333	110100	82568	3379	151399	829	15140	154777	15969
2021	37050	41282	18,144	436667	55194	41,282	1694	75696	416	7570	77389	7985

$E = k\,(sL)^{0.91} \times (W)^{1.02}$

(equation for Paved Roads PM_{10} and $PM_{2.5}$

	PM_{10}	$PM_{2.5}$
k=	0.0022	0.00054
sL=	0.4	0.4
W=	30	30

$E = k\,(s/12)^{a}(W/30)^{b}$

(equation forUnpaved Roads PM_{10} and $PM_{2.5}$)

	PM_{10}	$PM_{2.5}$
k=	1.5	0.15
a=	0.9	0.9
b=	0.45	0.45
s=	15	15
W=	30	30

Appendix F, Table F-4b

Alternative A: Monthly Excavation Emissions and Fugative Emissions

					PM10			PM2.5			NOx			SOx			VOC			CO			CO2	
	Avg Distance of Travel	Pieces of Equipment	Total Miles Traveled per day	Operation Duration (months)	EF g/veh-mi[b]	Emissions lbs/month	Total Emissions lbs	EF g/veh-mi[b]	Emissions lbs/month	Total Emissions lbs	EF g/veh-mi[b]	Emissions lbs/month	Total Emissions lbs	EF g/veh-mi[b]	Emissions lbs/month	Total Emissions lbs	EF g/veh-mi[b]	Emissions lbs/month	Total Emissions lbs	EF g/veh-mi[b]	Emissions lbs/month	Total Emissions lbs	EF g/veh-mi[b]	Emissions lbs/month
Truck Supply	224	5	1120	21	0.0532	3.9407	82.76	0.0348	2.5778	54.13	1.550	114.815	2411.11	0.0126	0.9333	19.60	0.889	65.852	1382.89	1.655	122.59	2574.44	1351.5	100111
Empoyees Commute	32	50	1600	9	0.0247	2.6138	23.52	0.0112	1.1852	10.67	0.455	48.148	433.33	0.0068	0.7196	6.48	0.227	24.021	216.19	0.375	39.68	357.14	785.3	83101
Rock Haul trucks	14.8	75	1110	9							0.524	491.105		0.004	291.018		0.141	132.048		0.195	182.881		536.404	502347
Rock Haul Employees	32	9	288	9							0.455	8.667		0.0068	0.1295		0.227	4.324		0.375	7.14		785.3	14958
Construction Equip	from const. exhaust deep sheet			9		146.889			142.483			2157.925			6.713			342.115			905.514			941613.149
Total pounds/month						153.443			146.246			2820.660			299.513			568.360			1257.813			1642129.884