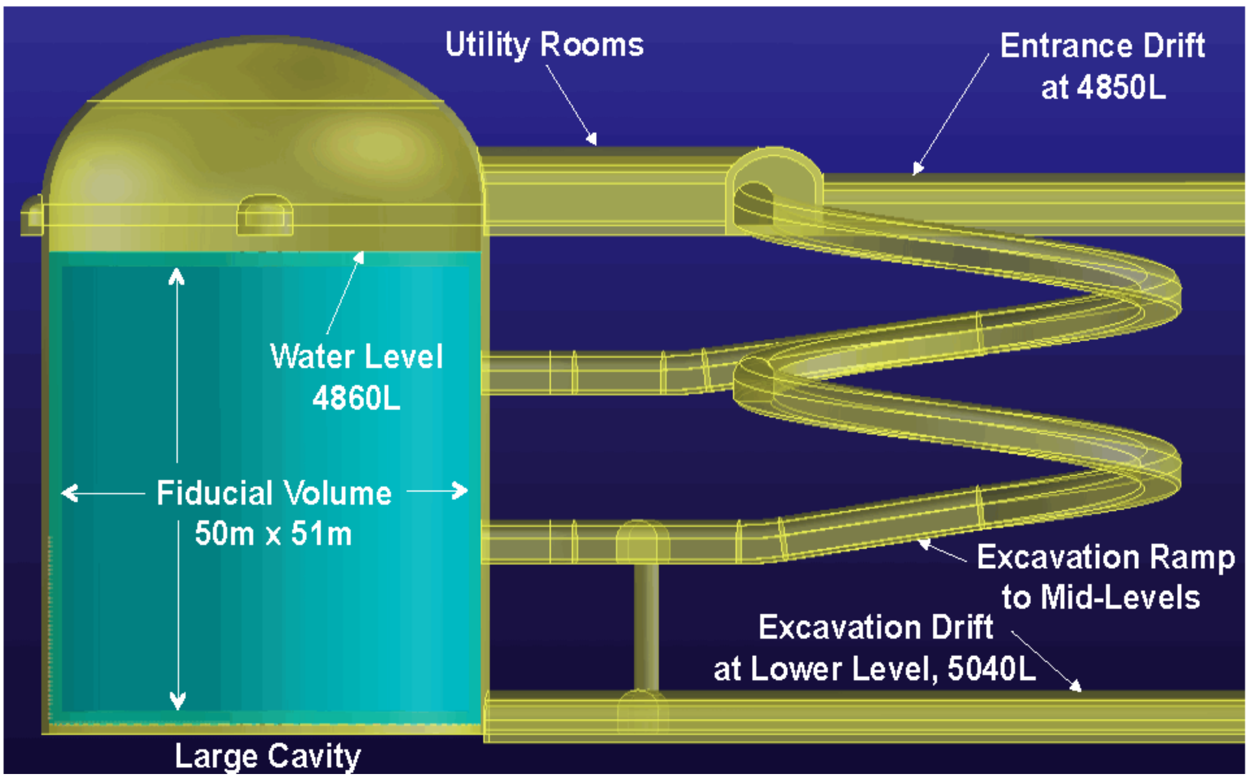
Long-Baseline Neutrino Experiment (LBNE) Project

Conceptual Design Report

Volume 4: The LBNE Water Cherenkov Detector

April 9, 2012



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A.1 Introduction

The goal of the LBNE Project is to explore physics beyond the Standard Model including the mass spectrum of the neutrinos and their properties by aiming an intense proton beam created at the Fermilab Main Injector at neutrino detectors more than 1,200 kilometers away. The preferred physics location for LBNE far detector is the Sanford Underground Laboratory at Homestake (Sanford Laboratory) in Lead, South Dakota. This site was selected as part of a National Science Foundation effort to create a deep underground science and engineering laboratory. This process is discussed further in the *LBNE Alternatives Analysis*[**?**], where the scientific reasons for this location are detailed.

The Sanford Laboratory is located at the site of the former Homestake Gold Mine, which is no longer an active mine. It is now being repurposed and modified to accommodate underground science. There are extensive underground workings that provide access to a depth of 8,000 ft.

The reference conceptual design for the far detector is a 200-kton water Cherenkov detector (WCD). The mass quoted is the fiducial mass of the detector — the volume over which the behavior of the detector is well understood at a size that meets the physics requirements. Excavated space for the detector will be larger than the fiducial volume. The WCD is designed to be constructed at 4850L of the facility between the Ross and Yates Shafts (see Figure A–1).

The existing Sanford Laboratory has many underground spaces, some of which can be utilized by LBNE for the WCD detector. However, significant work is required to provide the space and infrastructure support needed for the experiment installation and operation. The scope of the underground facilities required for the WCD includes new excavated spaces at 4850L for the detector, utility spaces for experimental equipment, utility spaces for facility equipment, drifts for access, Areas of Refuge (AoR) for emergencies, as well as construction-required spaces. Underground infrastructure provided by Conventional Facilities for the experiment includes power to experimental equipment, cooling systems and cyber infrastructure. Underground infrastructure for the facility includes domestic (potable) water, industrial water for

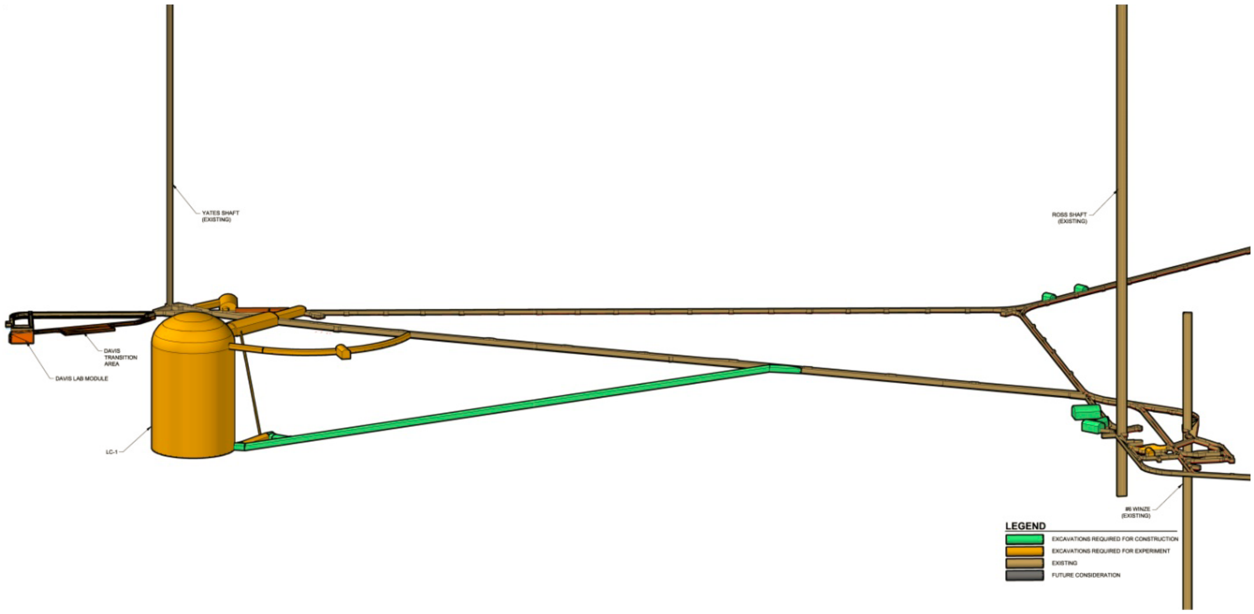

Figure A–1: Location of Water Cherenkov Detector at 4850L. (Golder Associates)

process and fire suppression, fire detection and alarm, normal and standby power systems, sump pump drainage system for native and leak water around the detector, water drainage to the facility-wide pump discharge system, compressed air and cyber infrastructure for communications and security.

In addition to providing new spaces and infrastructure underground, Conventional Facilities will enlarge and provide infrastructure in some existing spaces for WCD use, such as the West Access Drift. Examples of existing infrastructure that require upgrades to meet LBNE needs include rehabilitation of the Ross and Yates Shafts.

The existing Sanford Laboratory has many surface buildings and utilities, some of which can be utilized for WCD. The scope of the above ground work for Conventional Facilities includes that work necessary for LBNE, and not for the general rehabilitation of buildings on the site, which remains the responsibility of the Sanford Laboratory. Buildings that will be upgraded for WCD include repurposing of the Yates Crusher Building for the WCD water fill and purification system. The Yates and Ross Headframes and Hoist Buildings will receive structural, architectural, and electrical improvements. Electrical substations and distribution will be upgraded to increase power and provide standby capability for life safety. Additional surface scope includes a small control room in an existing building and temporary experimental installation office space in trailers. No new buildings will be constructed as part of the WCD Conventional Facilities.

A.1.1 Participants

The Far Detector is planned to be located at the Sanford Laboratory site, which is managed by the South Dakota Science and Technology Authority (SDSTA). The design and construction of LBNE Far Site Conventional Facilities will be executed in conjunction with Sanford Laboratory staff.

The LBNE Project Conventional Facilities is managed by the Work Breakdown Structure (WBS) Level 2 Conventional Facilities Manager. The supporting team includes a WBS Level 3 Manager for Conventional Facilities at Far Site, who works directly with the Sanford Laboratory engineering staff. The Level 3 Far Site Manager is also the LBNE Project liaison with the WCD subproject to ensure the detector requirements are met and is responsible for all LBNE scope at the Far Site. Management of the Sanford Laboratory and the organizational relationship between it and the LBNE Project and Fermilab were in the process of being determined when this section was written.

To date, Sanford Laboratory has utilized a team of in-house facility engineers to oversee multiple engineering design and construction consultants. Design consultants have specific areas of expertise in excavation, rock support, fire/life safety, electrical power distribution, cyber infrastructure, cooling with chilled water and heating/ventilation systems. Design consultants for LBNE's Conceptual Design were: HDR for surface facilities, Arup, USA for underground infrastructure and Golder Associates for excavation. Interaction between Sanford Laboratory facility engineers, LBNE Far Site design teams, and design consultants was done via weekly telephone conferences, periodic design interface workshops and electronic mail. The Sanford Laboratory facility engineers coordinated all information between design consultants to assure that design efforts remain on track.

For the LBNE Conceptual Design phase, the McCarthy Kiewit Joint Venture (MK) performed as the construction manager for pre-construction services. MK reviewed the consultant designs for constructibility and provided independent estimates of cost and schedule. MK also provided guidance on packaging of design components for contracting as part of the Far Site conventional facility acquisition strategy.

A.1.2 Codes and Standards

Conventional facilities to be constructed at the Far Site shall be designed and constructed in conformance with the Sanford Laboratory ESH Standards[**?**] especially the latest edition of the following codes and standards:

- Applicable Federal Code of Federal Regulations (CFR), Executive Orders, and DOE Requirements

- 2009 International Building Code
- Sanford Underground Laboratory Subterranean Design Criteria, EHS-1000-L3-05
- "Fire Protection/Life Safety Assessment for the Conceptual Design of the Far Site of the Long Baseline Neutrino Experiment (LBNE)", a preliminary assessment dated October 11, 2011, by Aon/Schirmer Engineering
- The Occupational Health and Safety Act of 1970 (OSHA)
- Mine Safety and Health Administration (MSHA)
- NFPA 101, Life Safety Code
- NFPA 520, Standard on Subterranean Spaces, 2005 Edition
- NFPA 72, National Fire Alarm Code
- American Concrete Institute (ACI) 318
- American Institute of Steel Construction Manual, 14^{th} Edition
- ASHRAE 90.1-2007, Energy Standard for Buildings
- ASHRAE 62, Indoor Air Quality
- 2009 National Electrical Code
- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Material (ASTM)
- American National Standards Institute (ANSI)
- National Institute of Standards & Technology (NIST)
- Insulated Cable Engineers Association (ICEA)
- Institute of Electrical and Electronics Engineers (IEEE)
- National Electrical Manufacturers Association (NEMA)
- American Society of Plumbing Engineers (ASPE)
- American Water Works Association (AWWA)
- American Society of Sanitary Engineering (ASSE)
- American Gas Association (AGA)
- National Sanitation Foundation (NSF)
- Federal American's with Disabilities Act (ADA) along with State of South Dakota ADA amendments. These requirements shall only be applied to those facilities which are located at the ground surface and accessible to the public.

A.2 Existing Site Conditions

The SDSTA currently operates and maintains Sanford Laboratory at Homestake in Lead, South Dakota. The Sanford Laboratory property comprises 186 acres on the surface and 7,700 acres underground. The Sanford Laboratory Surface Campus includes approximately 253,000 gross square feet of existing structures. Using a combination of private funds through T. Denny Sanford, South Dakota Legislature-appropriated funding, and a federal Department of Housing and Urban Development Grant, the SDSTA has made significant progress in stabilizing and rehabilitating the Sanford Laboratory facility to provide for safe access and prepare the site for new laboratory construction. These efforts have included dewatering of the underground facility and mitigating and reducing risks independent of the former Deep Underground Science and Engineering Laboratory (DUSEL) efforts and funding.

The Sanford Laboratory site has been well-characterized through work performed by the DUSEL Project for the National Science Foundation (NSF). The following sections are excerpted from the DUSEL *Preliminary Design Report* (PDR)[**?**], primarily Volume 5, and are used with permission in this and other sections of this CDR. They are edited to include only information as it is relevant to the development of the LBNE Project. The research supporting this work took place in whole or in part at the Sanford Laboratory at Homestake in Lead, South Dakota. Funding for the DUSEL PDR and project development was provided by the National Science Foundation through Cooperative Agreements PHY-0717003 and PHY-0940801. The assistance of the Sanford Laboratory at Homestake and its personnel in providing physical access and general logistical and technical support is acknowledged.

The following figures provide a context for the Sanford Laboratory site. Figure A–2 illustrates Sanford Laboratory's location within the region as a part of the northern Black Hills of South Dakota. Figure A–3 outlines the Sanford Laboratory site in relationship to the city of Lead, South Dakota, and points out various significant features of Lead including the surrounding property that still remains under the ownership of Barrick Gold Corporation*. Finally, Figures A–4 and A–5 provide perspectives of the Sanford Laboratory Campus from a surface and aerial view of the property and its surroundings. These views illustrate the varied topography found throughout the site.

A.2.1 Existing Site Conditions

The existing facility conditions were assessed as part of the DUSEL Preliminary Design and documented in the DUSEL PDR, Section 5.2.4, which is excerpted below. The portions of

*Barrick Gold Corporation (Barrick) operated the former Homestake Gold Mine in Lead, SD and when they closed the mine operations, a portion of the land was donated to the state of South Dakota and the use of the property is governed by the Property Donation Agreement (PDA) between Barrick and the state of South Dakota. The state of South Dakota manages the development of the now Sanford Laboratory site through the South Dakota Science and Technology Authority (SDSTA).

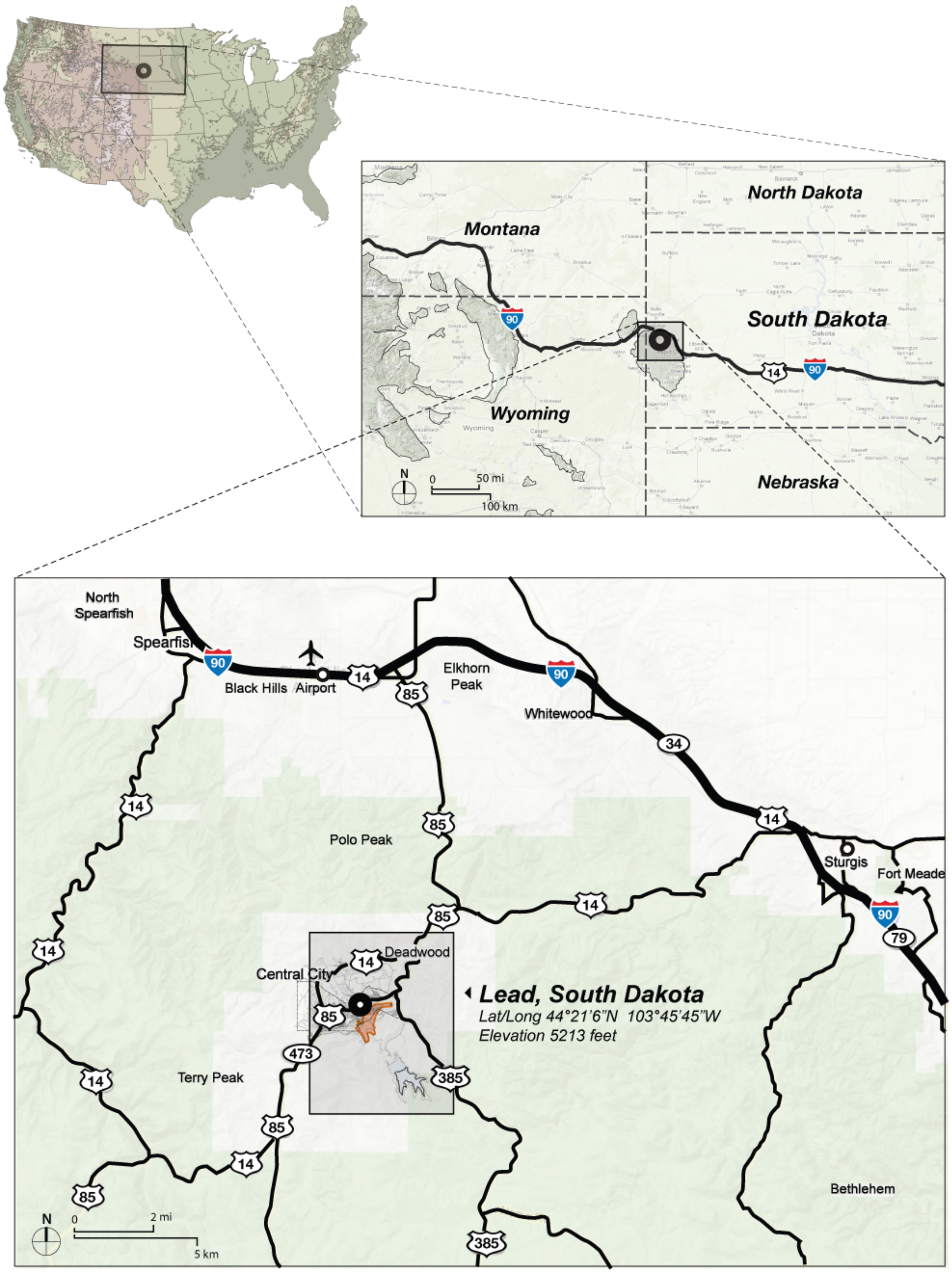

Figure A–2: Regional Context showing the city of Lead, South Dakota. (Dangermond Keane Architecture, Courtesy Sanford Laboratory)

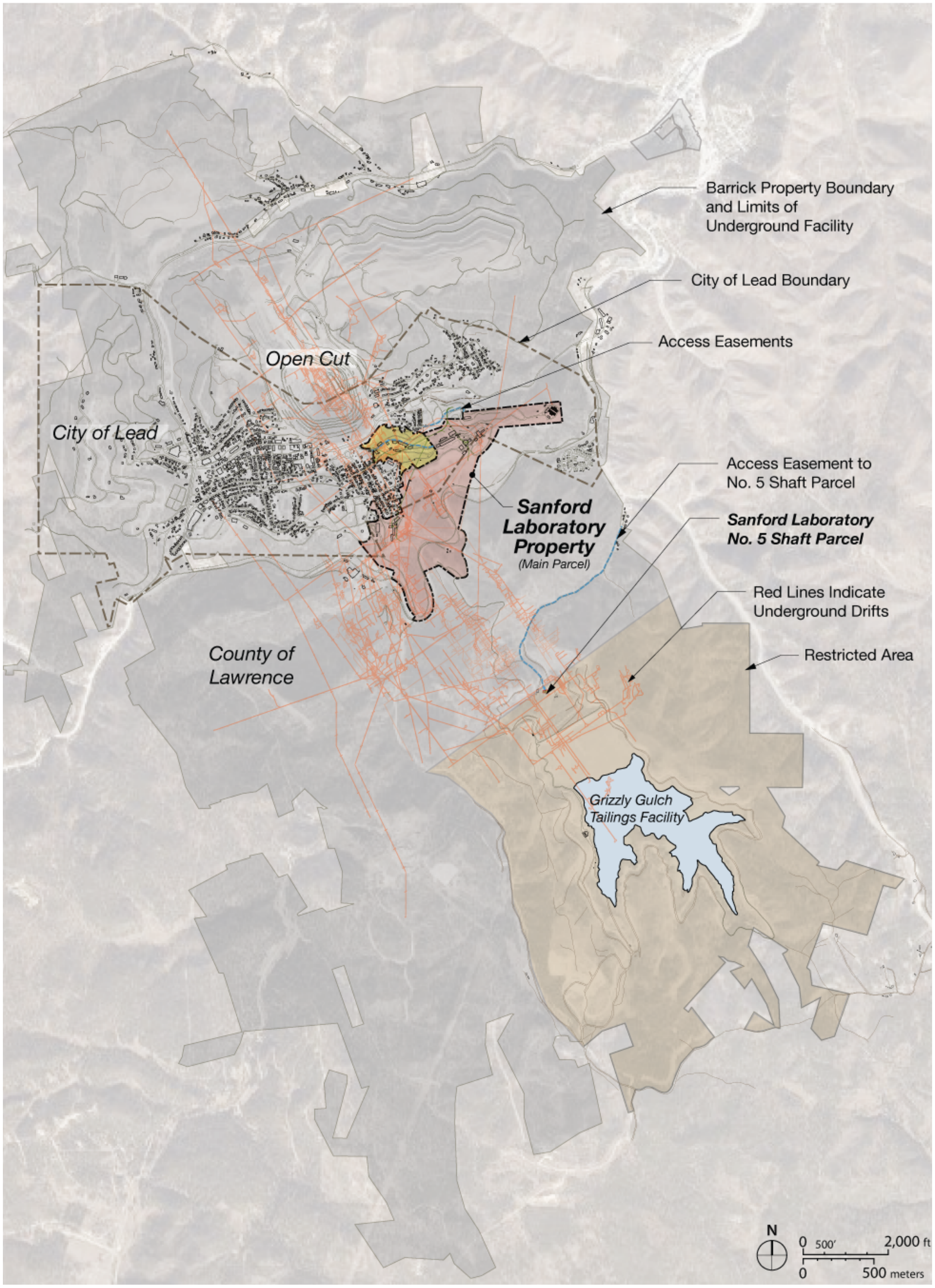

Figure A–3: Sanford Laboratory Campus shown in the context of the city of Lead, South Dakota, and the property remaining under ownership of Barrick. Area shown in yellow is a potential future expansion of the SDSTA property. (Dangermond Keane Architecture, Courtesy of Sanford Laboratory)

Figure A–4: Sanford Laboratory Yates Campus shown on the left and Kirk Canyon to the right. (Courtesy of Sanford Laboratory)

Figure A–5: Aerial view of Sanford Laboratory (boundary in red) and the adjacent city of Lead. (Dangermond Keane Architecture, Courtesy of Sanford Laboratory)

DUSEL's assessment included here have been edited to reflect current activities and to reference only that portion of the assessment that are pertinent to the LBNE Project. References to the DUSEL Project are from that time, and are now considered historic.

A.2.1.1 Existing Facilities and Site Assessment

Site and facility assessments were performed during DUSEL's Preliminary Design phase by HDR CUH2A to evaluate the condition of existing facilities and structures on the Yates, and Ross Campuses. The assessments reviewed the condition of buildings proposed for continuing present use, new use, or potential demolition. Building assessments were performed in the categories of architectural, structural, mechanical/ electrical/plumbing (MEP), civil, environmental, and historic. Site assessments looked at the categories that included civil, landscape, environmental, and historic. Facility-wide utilities such as electrical, steam distribution lines, water, and sewer systems were also assessed. The assessment evaluation was completed in three phases. The detailed reports are included in the appendices of the DUSEL PDR as noted and are titled:

- Phase I Report, Site Assessment for Surface Facilities and Campus Infrastructure to Support Laboratory Construction and Operations (DUSEL PDR Appendix 5.E)
- Phase II Site and Surface Facility Assessment Project Report (DUSEL PDR Appendix 5.F)
- Phase II Roof Framing Assessment (DUSEL PDR Appendix 5.G)

The site and facility assessments outlined above were performed during DUSEL's Preliminary Design as listed above and include a review of the following:

- Buildings proposed for reuse were evaluated for preliminary architectural and full structural, environmental, and historic assessments.
- Buildings proposed for demolition were evaluated for preliminary historic assessments.
- Preliminary MEP assessments were performed on the Ross Substation, #5 Shaft fan, Oro Hondo fan, Oro Hondo substation, and general site utilities for the Ross, Yates, and Ellison Campuses.
- The Waste Water Treatment Plant received preliminary architectural and structural assessments and a full MEP assessment.
- Preliminary civil assessments of the Kirk Portal site and Kirk to Ross access road were also completed.

A.2.1.2 Building Assessment Results

Results of the building assessment work, as detailed in the three reports referenced above, show that the buildings on the Ross and Yates Campuses were architecturally and structurally generally suitable for reuse or continued use with some upgrades or modifications.

A.2.1.2.1 Site Civil Assessment

Results of the civil assessment found in the Phase I Report, Site Assessment for Surface Facilities and Campus Infrastructure to Support Laboratory Construction and Operations (DUSEL PDR Appendix 5.E) and Phase II Site and Facility Assessment, Project Report (DUSEL PDR Appendix 5.F) showed the following results:

- Water and sewer utilities on both the Ross and Yates Campuses need replacement.
- Roadway and parking lot surfaces need replacement and regrading. Drainage ways and steep slopes need maintenance.
- Retaining walls and transportation structures are in useable condition, with some maintenance, except for two failing retaining walls.
- Retaining walls and transportation structures need maintenance in the form of drainage improvements and minor repairs to section loss due to rust and erosion.
- Existing fencing and guardrails are a very inconsistent pattern of chain link, wood, and steel; much of the fencing is deteriorating or collapsed.
- Abandoned equipment/scrap-metal piles around the sites represent traffic and health hazards.
- Pedestrian and traffic separation is poorly defined.
- Existing traffic signs are faded and do not meet *Manual of Uniform Traffic Control Devices* standards.

The Civil Site Assessment recommendations can be found in DUSEL PDR Appendix 5.E (Section 4, Page 4(1) of the Phase I Report, Site Assessment for Surface Facilities and Campus Infrastructure to Support Laboratory Construction and Operations); and DUSEL PDR Appendix 5.F (Section 2, Page (2.1) — 39 of the Phase II Site and Facility Assessment Project Report). All items that would cause immediate concern for the health and safety of onsite personnel have been addressed by the SDSTA by removing, repairing, or isolating the concerns.

A.2.1.2.2 Landscape Assessment

The landscape assessment, found in DUSEL PDR Appendix 5.E (Phase I Report, Site Assessment for Surface Facilities and Campus Infrastructure to Support Laboratory Construction and Operations); and DUSEL PDR Appendix 5.F (Phase II Site and Surface Facility Assessment Project Report) noted many of the same items as the site civil assessment: drainage issues, erosion concerns, abandoned equipment, and scrap metal. Soil conditions were noted as well as rock escarpments and soil stability concerns.

A.2.1.2.3 Site MEP Assessment

The site assessments, detailed in DUSEL PDR Appendix 5.E (Phase I Report, Site Assessment for Surface Facilities and Campus Infrastructure to Support Laboratory Construction and Operations); and DUSEL PDR Appendix 5.F (Phase II Site and Surface Facility Assessment Project Report) found the electrical distribution condition to range from fair to excellent, depending on the age of the equipment. The Ross Campus recommendations generally consisted of upgrades to increase reliability. The Yates Campus recommendations call for a new substation to replace the old abandoned East Substation if significant loads are added to this campus.

The assessments also evaluated the natural gas and steam distribution systems. Natural gas is provided to the site at three locations and appears to have the capacity required to meet surface needs as they are currently understood. However, the natural gas supply is an interruptible supply (non-firm) and thus cannot be guaranteed. Either an upgrade to Montana-Dakota Utilities (MDU, local natural gas supplier) supply lines (outside the scope of this Project) or an alternate fuel/heating source will be needed to meet the surface needs. The steam boiler systems have been dismantled and should not be reused. The existing components represent placeholders for routing for new distribution if steam is re-employed.

The site telecommunications service currently is provided by Knology Inc., Rapid City, South Dakota, and a fiber-optic data connection is from the South Dakota Research, Education and Economic Development (REED) Network (see DUSEL PDR Chapter 5.5, Cyber Infrastructure Systems Design, for details on these service providers). Both services are quite new and have historically been very reliable. The site distribution system is a mix of copper and fiber, copper being quite old and fiber very new. The Ross and Yates Campus' recommendations are to increase reliability as the campuses are developed.

A.2.1.2.4 Environmental Assessment

The environmental assessment, found in DUSEL PDR Appendix 5.F (*Phase II Site and Surface Facility Assessment Project Report)* looked for contamination from lead-based paint

(LBP); polychlorinated biphenyls (PCBs) contained in electrical equipment, lubrication oils, and hydraulics; asbestos-containing building materials; heavy metals; the historic presence of petroleum hydrocarbons and chlorinated solvents; molds; historic uncontrolled discharges of domestic sewage; industrial wastewater; and storm-water runoff. Environmental results showed some LBPs in various locations across both the Ross and Yates Campuses. No PCB concentrations above Environmental Protection Agency (EPA) regulatory standards were encountered, and no heavy metals above EPA regulatory standards were found.

A.2.1.2.5 Historic Assessment

The former Homestake Gold Mine site is a major component of the Lead Historic District. Most of the DUSEL Campus is within the historic district; thus, work on the DUSEL site must conform to the National Historic Preservation Act of 1966, as Amended. These standards recognize that historic buildings and sites must change with time if they are to meet contemporary needs but that alterations to meet these needs can be done in a manner that is sensitive to the historic property. Figure A–6 is a historic photograph showing the former Homestake Mining Company milling operation and components of the Yates Campus.

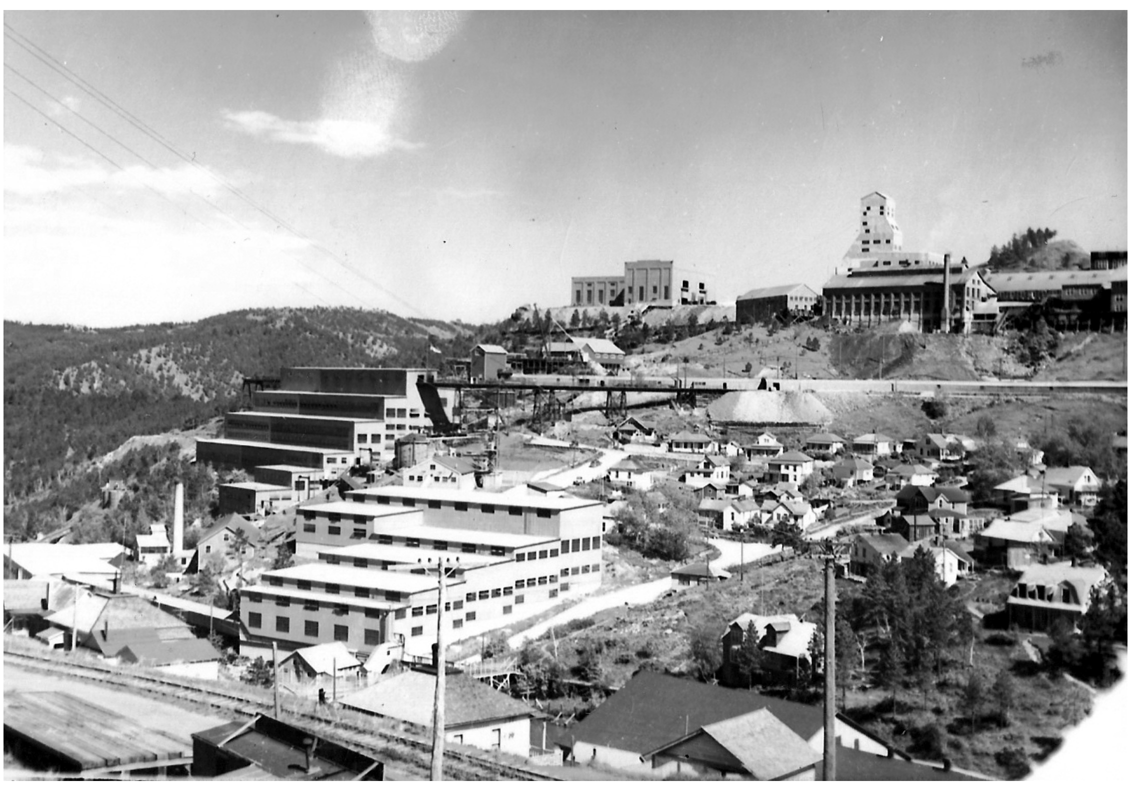

Figure A–6: Historic photo of milling operation, Yates Headframe, Hoist and Foundry. (Courtesy Homestake Adams Research and Cultural Center)

Figure A–7 shows the boundaries of the Lead historic district.

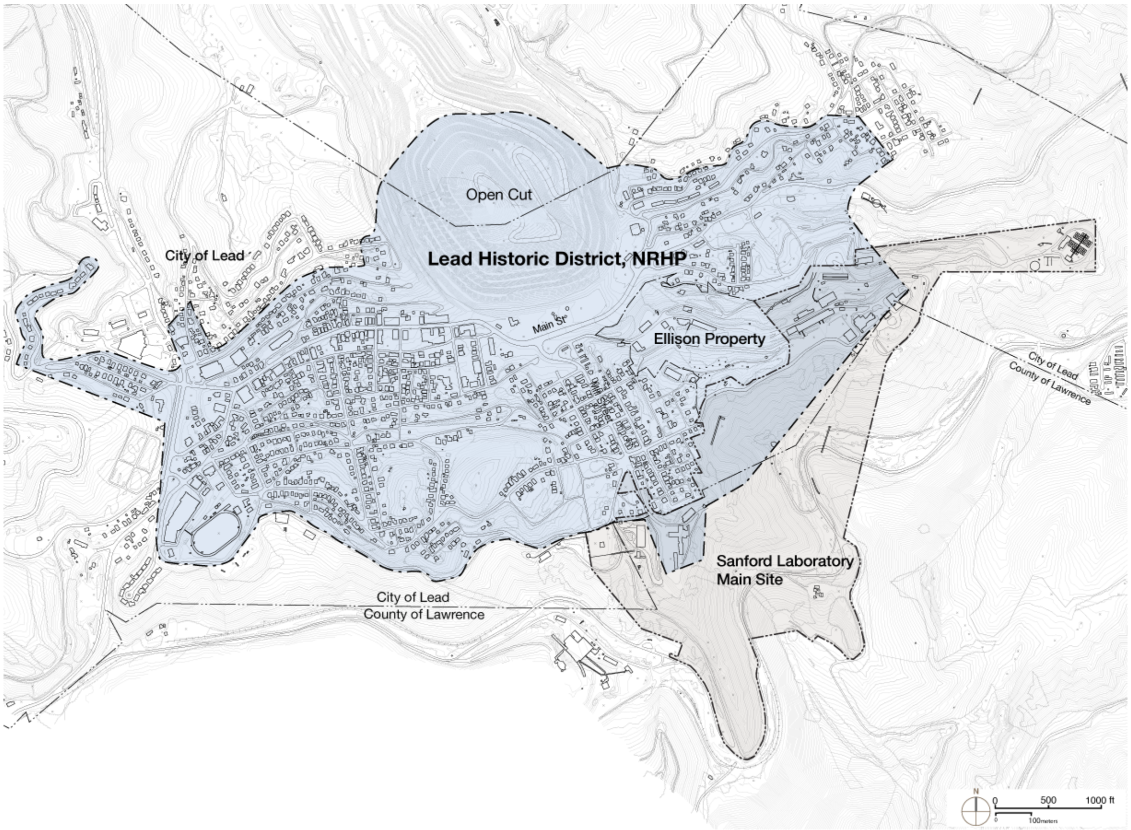

Figure A–7: Map of Lead Historic District. (Dangermond Keane Architecture, Courtesy of Sanford Laboratory)

The historic assessment consisted of the full assessment of 10 transcendent and eight support buildings. Transcendent buildings have the most significant historic value and represent an operation that was unique or limited to the site. Support buildings represented a function or activity that, although performed on the site, could have been done off site. Of the 10 transcendent buildings, nine were deemed to have significant historic value while one held only moderate historic value. Seven of the support buildings held moderate historic value, while the eighth has only limited historic value. Sixteen other buildings received a preliminary historic assessment. Two were deemed to have significant historic value, 13 held moderate historic value, and the last was deemed to be of limited historic value.

To assist the DUSEL Project in understanding the historic requirements for the Project, a meeting was held with the South Dakota State Historic Preservation Office (SD SHPO) in June 2010. The DUSEL team provided a Project overview for the SD SHPO staff and took a site tour so the SHPO staff could develop an understanding of the Project. The SD SHPO staff members were pleased, for the most part, with the direction the design team was taking for the Project. SD SHPO provided recommendations to DUSEL for documentation and preservation options that will need to be addressed during Final Design to meet mitigation requirements for any facilities that may ultimately be removed. LBNE is not currently planning to remove any existing structures.

It should be noted that the historic assessment prepared for this portion of the overall site assessment is not the formal historic assessment that will be required to comply with the National Environmental Policy Act (NEPA) strategy.

See section A.3.2.1 for additional information about the LBNE NEPA strategy.[†]

The entire historic assessment process and results can be viewed in DUSEL PDR Appendix 5.E (Phase I Report, Site Assessment for Surface Facilities and Campus Infrastructure to Support Laboratory Construction and Operations), and DUSEL PDR Appendix 5.F (Phase II Site and Surface Facility Assessment Project Report).

A.2.2 Geology and Existing Excavations

The accessible underground mine workings at the Homestake mine are extensive. Over the life of the former gold mine some 360 miles of drifts (tunnels) were mined and shafts and winzes sunk to gain access to depths in excess of 8,000 feet. A number of underground workings are being refurbished by Sanford Laboratory and new experiments are being developed at 4850L, the same level as proposed for LBNE WCD facilities. Geotechnical investigations and initial geotechnical analyses have been completed for the DUSEL Preliminary Design and are described in detail in the DUSEL PDR. Below are summaries of some of the work completed to date that is applicable to LBNE as excerpted from the DUSEL *Preliminary Design Report*, *Chapter 5.3* and edited to include only information as it is relevant to the development of the LBNE Project.

A.2.2.1 Geologic Setting

The Sanford Laboratory is sited within a metamorphic complex containing the Poorman, Homestake, Ellison and Northwestern Formations (oldest to youngest), which are sedimentary and volcanic in origin. An amphibolite unit (Yates Member) is present at the base of the Poorman Formation. The Yates Member is the preferred host rock for the LBNE excavations at 4850L. The layout adopted on 4850L attempts to maximize the amount of WCD excavation work performed in the Yates Member amphibolite rock.

[†] For clarity, this discussion of NEPA activities was developed for this Conceptual Design Report and inserted into this section of text which is largely copied from the DUSEL Preliminary Design Report. Discussions on NEPA were not included in the text of the DUSEL Preliminary Design Report.

A.2.2.2 Rock Mass Characterization

One of the goals of the geotechnical investigations performed to date by the DUSEL Project was to provide information for the excavation and stabilization of an alternative large cavity for a WCD supporting the Long Baseline Neutrino Experiment (LBNE). Characterization of the rock mass (see DUSEL PDR Sections 5.3.2 and 5.3.3) was accomplished through a program of mapping existing drifts and rooms in the vicinity of planned excavations, drilling and geotechnical logging of rock core samples, and laboratory measurements of the properties of those samples.

As part of the Preliminary Design process, the DUSEL Project engaged two advisory boards to provide expert review of the geotechnical investigation and excavation design efforts. The Geotechnical Advisory Committee (GAC) was an internal committee that focused primarily on geotechnical investigation and analysis. The Large Cavity Advisory Board (LCAB) was an internal high-level board that focused on geotechnical investigations and excavation design of the WCD cavity in support of the LBNE Project. The Geotechnical Engineering Services contract, which was used to execute geotechnical investigations, was reviewed by the GAC and the LCAB and included the following scope of work:

- The mapping program included drift mapping at the 300L and 4850L and 4,400 ft (1,340 m) of existing drifts mapped in detail and 2,600 ft (793 m) of newly excavated drifts and large openings mapped in detail (Davis Campus, Transition Area, and associated connecting drifts).
- The drilling program included the completion of nine new holes totaling 5,399 ft (1,646 m) of HQ (4-inch drill producing 2.5 inch core) diamond core drilling, which incorporated continuous logging, continuous core orientation, detailed geotechnical and geological logging, full depth continuous televiewer imaging, and initial groundwater monitoring.
- The in situ stress measurement program included stress measurements in three locations; two sites in amphibolite and one site in rhyolite for the total of eight measurements (six in amphibolite and two in rhyolite).
- The laboratory testing program included uniaxial compressive strength tests (80 samples that incorporated elastic constants and failure criteria), indirect tensile strength tests (40 samples), triaxial compressive strength tests (63 samples), and direct shear strength of discontinuities (36 samples).

Geotechnical investigations were initiated by DUSEL in January 2009 and executed by RESPEC Inc., with Golder Associates and Lachel Felice & Associates (LFA) as their main subcontractors. The initial scope was modified to include the addition of a 100 kTon water Cherenkov detector. The scope was further modified, resulting in the requirement for the potential to include up to two 100 kton WCDs into the DUSEL Preliminary Design effort. In mid-2010, the DUSEL Preliminary Design scope was narrowed to one WCD.

In mid-2009, an initial geotechnical program was executed by DUSEL, first on the 300L, then on 4850L of the Homestake site. This program included site mapping, reconnaissance level geotechnical drilling and core logging, in situ stress measurements, optical and acoustic televiewer logging, numerical modeling, laboratory testing, initial surveying, and generation of a three dimensional (3D) Geological and Geotechnical Model. Additional tasks added in 2010 included characterization of ground vibrations from blasting associated with the Davis Campus excavation activities, and groundwater monitoring. A *Geotechnical Engineering Summary Report* (DUSEL PDR Appendix 5.H) was completed in March 2010, which recommended additional drilling and mapping to address data gaps and reduce uncertainty in the characterization of the rock mass that would be important for future phases of design. All of the geologic, geotechnical, and hydrogeologic information collected has been used to advance the Conceptual Design of the WCD at 4850L.

Based on these site investigations and the recommendations of the LCAB, the single 100 kton WCD has increased in size resulting in the 200 kTon WCD that was considered during LBNE Conceptual Design.

The geotechnical site investigations area on 4850L, showing bore holes, in situ measurement stations, and planned cavities within the triangle of drifts between the Ross and Yates Shafts, is presented in Figure A–8. Note that only one core (hole J) was collected in the Poorman formation, as this was not the intended rock formation to be used at the time of the investigation.

Since their formation, the host rock units have been subject to periods of significant structural deformation. Deformations during the Precambrian era lead to the development of complex fold patterns, and local shear zones. Brittle deformations that took place during the Tertiary era resulted in the development of joint sets, veining, faulting and the intrusion of dikes[**?**]. Tertiary rhyolite dikes cross-cut the Precambrian rock units across the former mine site, from surface (open cut) to the deepest development levels (>8,000 ft). In the areas of 4850L observed and investigated to date, these dikes are commonplace. Rhyolite is estimated to constitute some 40% of the rock volume in the area of the proposed campus. Faulting and veining have also been observed within the host rock mass[**?**,**?**].

The in situ stress levels at various levels of the Sanford Laboratory underground facility have been measured on a number of occasions. The major principle stress, at depth, is sub-vertical. Recent measurements on 4850L report a range of vertical stress values, from 22 to 61 MPa (3.2 to 8.8 ksi) (average 44 Mpa / 6.4 ksi). Measured intermediate: major and minor: major stress ratios were reported to be 0.6 to 0.8 and 0.5 to 0.7 respectively. For further details, see Golder's Geotechnical Engineering Services[**?**].

The intact hard metamorphic rocks are generally of low primary hydrologic conductivity.

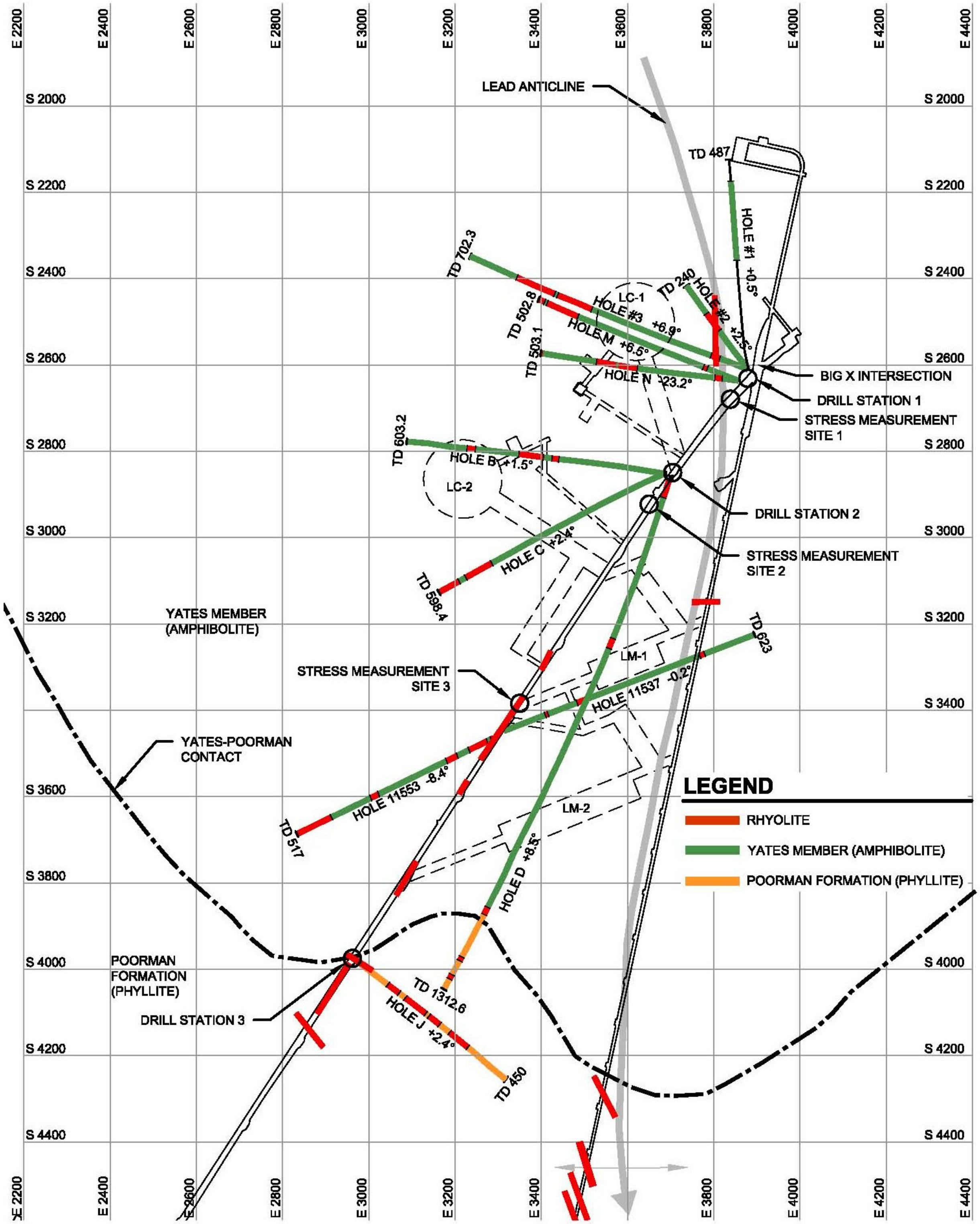

Figure A–8: General geologic map at 4850L and location of drill holes. (Golder Associates, Courtesy Sanford Laboratory)

During historic mine operations most water inflows were observed to be local and typically attributed to secondary permeability[**?**]. A recent evaluation by Golder[**?**] estimates the typical inflow rate of about 1–2 gallons per minute per mile of underground workings. Some additional flow may be anticipated in the upper workings where fractures may be generally more weathered, open and directly connected to the surface and/or the Open Cut.

A.2.2.3 Geologic Conclusions

The recovery of rock cores, plus geologic mapping, was performed to determine if discontinuities in the rock mass exist that would cause difficulties in the construction and maintenance of planned excavations. In general, the proposed locations of the excavations do not appear to be complicated by geologic structures that cause undue difficulties for construction. This information, along with measurement of in situ stresses, allowed initial numerical modeling[**?**] of the stresses associated with the anticipated excavations. 2D and 3D numerical modeling was then used to design ground support systems that will ensure that the large cavity, in particular, remains stable. The excavation design, which is influenced by anticipated methods of excavation and sequence of excavation, is described in the Golder Associates Conceptual Design Report[**?**], followed by the means by which the excavations will be monitored to ensure their long-term stability.

The overall analysis of the work indicates that the rock in the proposed location of the WCD is of good quality for the purposes of the LBNE Project, that preliminary numerical modeling shows that a large cavern of the size envisioned can be constructed, and that a workable excavation design has been developed.

A.3 The Facility Layout

The Sanford Laboratory property of 186 acres consists of steep terrain and man-made cuts dating from its mining history. There are approximately 50 buildings and associated site infrastructure in various states of repair. A select few of these buildings and the main utilities are needed by the WCD experiment and will be upgraded and rehabilitated as necessary. HDR prepared a conceptual design for surface facility improvements for WCD[**?**]. This section summarizes the work done by HDR and utilizes information from that report.

A layout of the overall Sanford Laboratory architectural site plan for the LBNE Project is found in Figure A–9.

The Yates Campus contains the main Sanford Laboratory Administration building and will be the location of WCD experiment installation and operations. Layout of surface facilities in the vicinity of the Yates Shaft is shown in Figure A–10.

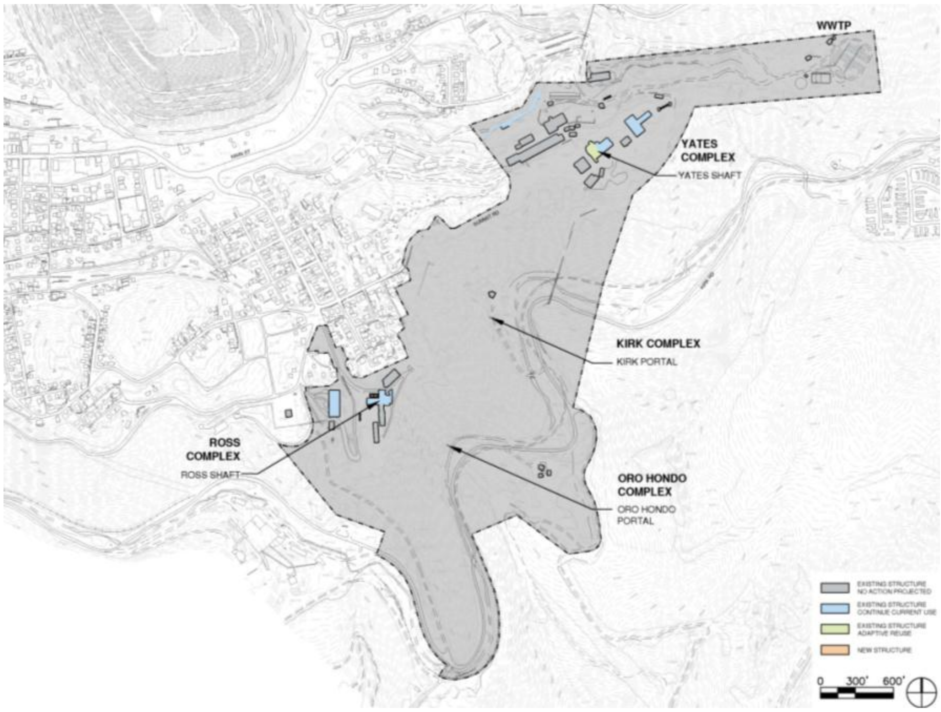

Figure A–9: Architectural site plan. (HDR)

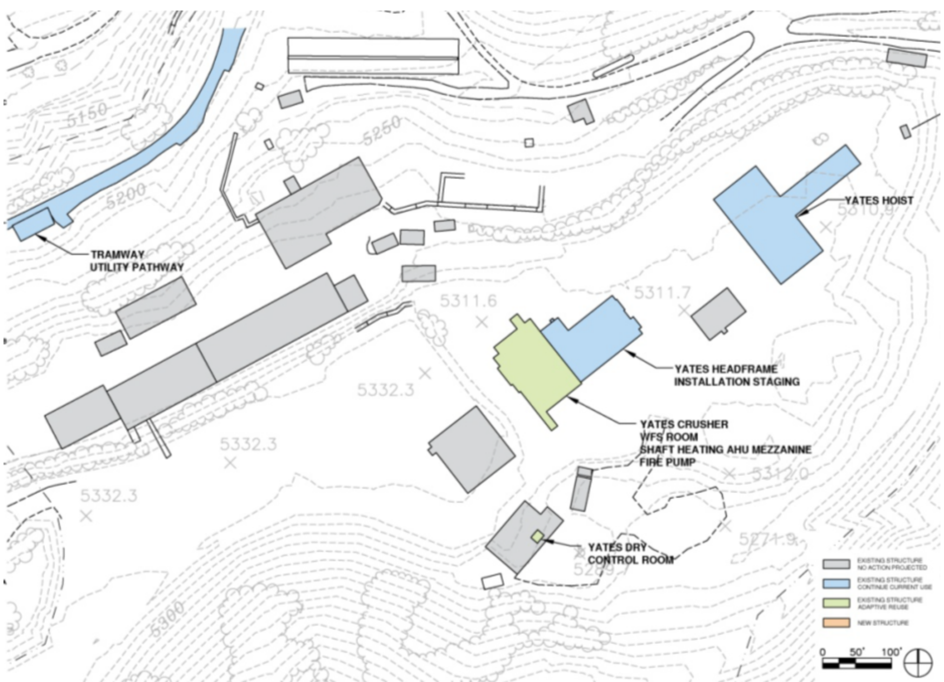

Figure A–10: Yates Campus architectural site plan. (HDR)

The Ross Campus will house the facility construction operations as well as continue to house the Sanford Laboratory maintenance and operations functions. Layout of surface facilities in the vicinity of the Ross Shaft is shown in Figure A–11.

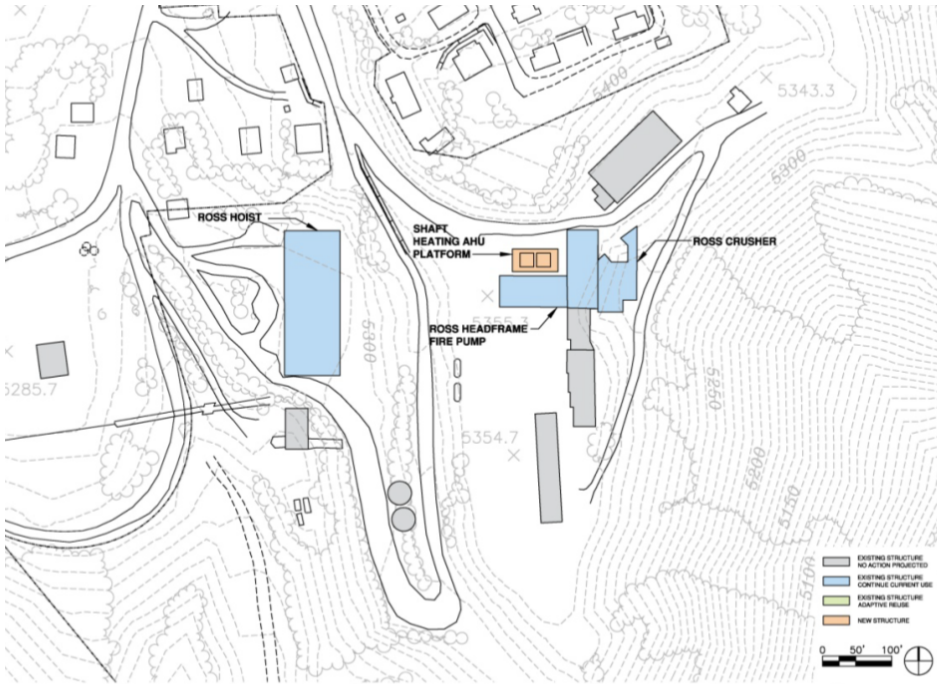

Figure A–11: Ross Campus architectural site plan. (HDR)

A.3.1 Surface Infrastructure

Surface infrastructure includes surface structures such as retaining walls and parking lots, as well as utilities to service both buildings and underground areas. Existing infrastructure requires both rehabilitation as well as upgrading to meet code requirements and WCD experiment needs. The experimental[**?**] and facility[**?**] requirements were documented.

A.3.1.1 Roads and Access

No new roads or parking lots are required for WCD at the Yates Campus. An analysis was performed to confirm that large delivery trucks could drive up Summit Street and turn around on the Yates Campus. Six existing retaining walls need upgrades to strengthen and stabilize them on this sloped site. Site drainage improvements are needed to adjust grades and ensure that storm water is diverted properly.

No new roads or parking lots are required for WCD at the Ross Campus.

A.3.1.2 Electrical Infrastructure

Power for the experiment and new facilities underground will be fed from the Yates Shaft. Underground life safety loads will be powered from the Yates Shaft standby power. Both the Ross and Yates Campuses will provide standby power generators for surface life safety needs, including fire pumps, hoists, and shaft heating and ventilation equipment. Standby power will also be added to the existing Oro Hondo substation for exhaust ventilation. Emergency power, defined by National Fire Protection Agency (NFPA) codes as "critical for life support" will be provided by 90 minute battery backed uninterruptible power supply (UPS) connected downstream of the standby power system. Figure A–12 indicates the location of electrical infrastructure work at Sanford Laboratory. Power requirements for the WCD experiment

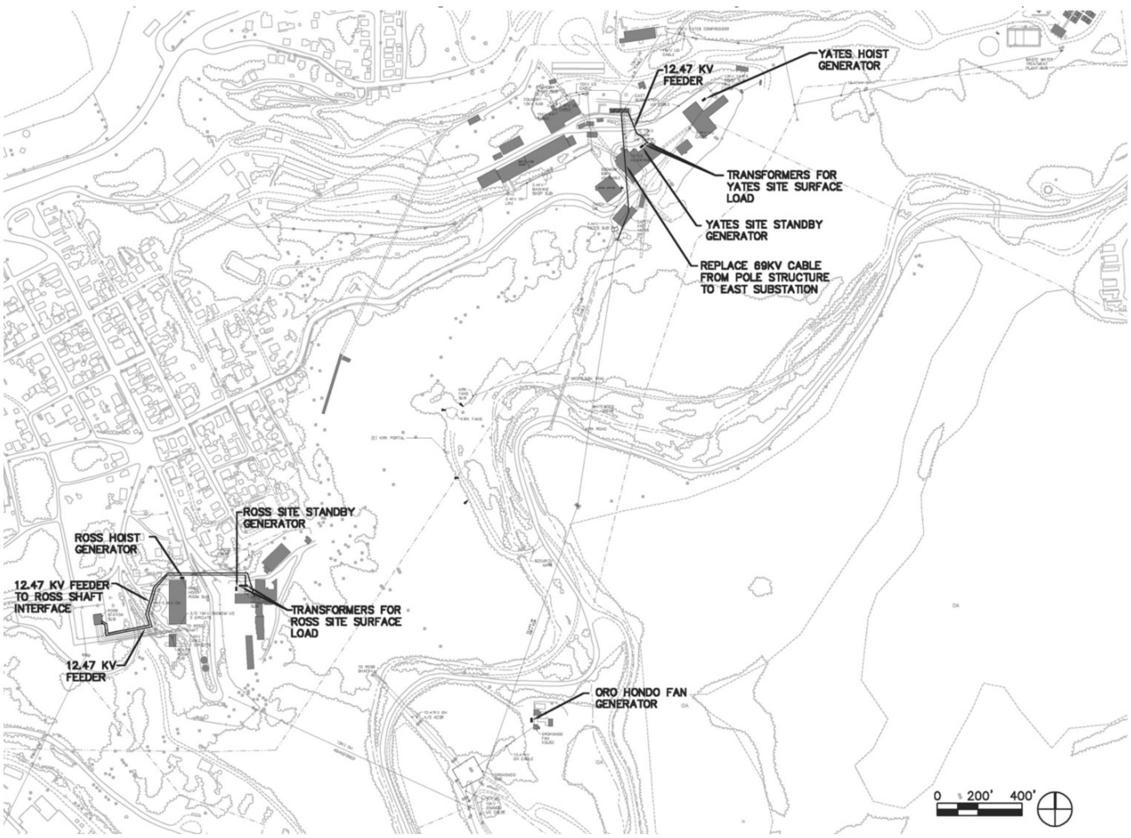

Figure A–12: Supply power for WCD at 4850L. (HDR)

and facility is shown in Tables A–1 and A–2 and summarized below in Table A–3. Note: Loads shown are only connected loads. Generator size is based on the starting and running loads of the equipment served.

New primary power feeder will be provided from the East Substation to the new surface load

Table A–1: Electrical load table: underground and Ross surface. (HDR)

Item: Underground Loads	QTY	Elec. Connected Load (KW)	Unit	Total Elec. Load (KW)	Stand-by Power (Y/N)	Remarks
Detector Loads						
LC Water (PMT-HV)	1	3	KW	3	N	Based on 8/12/11 Table 1-200
LC-Deck	1	138	KW	138	N	Based on 8/12/11 Table 1-200
LC-Balcony	1	88	KW	88	N	Based on 8/12/11 Table 1-200
Crane	1	6	KW	6	N	
Total Estimated Detector Power		235	KW	235		
With 20% Uncertainty Factor		282	KW	282		20% based on LBNE requirements
Infrastructure Loads						
Detector Lighting – assuming 1w/sq.ft.	1	32	KW	32	Y	
Drift Lighting – assuming .5w/sq.ft.	1	45	KW	45	Y	
Exhaust Fans	1	63.4	KW	63.4	N	
Water System	1	351	KW	351	N	Based on 8/12/11 Table 1-200
Sump Pump @ 5117L for Experiment	1	127	KW	127	N	Based on 8/12/11 Table 1-200
Sump Pump for 4850L drainage system	1	75	KW	75	N	
Utilities in Drift	1	694	KW	694	N	Based on 8/12/11 Table 1-200
AoRs –anticipate total load	1	76	KW	76	N	Based on DUSEL PDR AoR info
Fire Alarm	1	2	KW	2	Y	
Communication	1	12.5	KW	12.5	Y	
Security (future place holder)	1	12.5	KW	12.5	Y	
Total Infrastructure Power		1490.4	KW	1490		
Infrastructure Power w/20% Spare factor		1788.5	KW	1788		
Total Load – Detector + Infrastructure			KW	2070		Includes 20% spare factor
Total Load KVA assuming .9 Power Factor			KVA	2301		

UGI Stand-by generator Load reported as: 225 KW

Facility Surface Electrical Loads						
Ross Site Surface Equipment	**QTY**	**Elec. Load (EA)**	**Unit**	**Total Elec. Load (KVA)**	**Stand-by Power (Y/N)**	**Remarks**
Shaft Heating AHU	2	200	HP	184	Y	One unit will operate.
Fire Pump	2	100	HP	92	Y	One unit will operate.
Emergency lighting / Life Safety	1	15	KVA	15	Y	
System Controls	1	3	KVA	3	Y	
Total Estimated Normal Power Load (KVA)				294		
Total Estimated Stand-by Power Load (KVA)				294		
Total Estimated Normal Power Load (KVA) + 20% Uncertainty Factor				353		

Table A–2: Electrical load: Yates and Oro Hondo surface . (HDR)

Facility Surface Electrical Loads						
Yates Site Surface Equipment	**QTY**	**Elec. Load (EA)**	**Unit**	**Total Elec. Load (KVA)**	**Stand-by Power (Y/N)**	**Remarks**
Shaft Heating AHU	3	200	HP	369	Y	Two units will operate.
Fire Pump	2	100	HP	92	Y	One unit will operate.
Emergency lighting / Life Safety	1	15	KVA	15	Y	
System Controls	1	3	KVA	3	Y	
Water Purification System	1	350	KW	389	N	
Waste Lift Station (Duplex)	1	5	HP	5	N	
Total Estimated Normal Power Load (KVA)				873		Includes stand-by loads under normal conditions.
Total Estimated Stand-by Power Load (KVA)				479		
Total Estimated Normal Power Load (KVA) + 20% Uncertainty Factor				1048		

Facility Surface Electrical Loads						
Oro Hondo Site Surface Equipment	**QTY**	**Elec. Load (EA)**	**Unit**	**Total Elec. Load (KVA)**	**Stand-by Power (Y/N)**	**Remarks**
Oro Hondo Exhaust Fan (main)	1	3000	HP	3000	N	Normal power already provided.
Oro Hondo Exhaust Fan (stand-by)	1	350	HP	350	Y	Normal power already provided.
Total Estimated Normal Power Load (KVA)				0		Excluding Oro Hondo Exhaust Fans
Total Estimated Stand-by Power Load (KW)				315		
Total Estimated Normal Power Load (KVA) + 20% Uncertainty Factor				0		

Table A–3: Electrical load summary

Ross Campus summary		
Normal Power load (UGI and surface)	2654	KVA
standby Power load (UGI and surface)	490	KW
20% uncertainty Factor	98	KW
Total standby Power load (UGI and surface)	588	KW
Yates Campus summary		
Normal Power load (UGI and surface)	1048	KVA
standby Power load (UGI and surface)	656	KW
20% uncertainty Factor	131	KW
Total standby Power load (UGI and surface)	787	KW
Oro Hondo summary		
Normal Power load (UGI and surface)	0	KVA
standby Power load (surface)	315	KW
20% uncertainty Factor	63	KW
Total standby Power load (surface)	378	KW

transformer (for power to ventilation fans, fire pumps, water purification system, etc.). The below grade portion of the existing feeder cable from the Oro Hondo Substation to the East Substation (presently routed through the Yates Tramway Drift) has experienced problems in the past and will require replacement. The existing East Substation has capacity for the additional WCD Experiment surface loads, but will require rehabilitation to preserve the option of adding of gadolinium to the detector water and increasing science capability. This rehabilitation will involve the reinstatement of the substation feeder to its original voltage level of 69 KV and the addition of a new 1500 kVA, 12.47 kV: 480V/277V pad-mounted transformer with integral loadbreak switch. The secondary conductors from the transformer will feed a new 2000 A, 480V/277V main switchboard, MSB, located on the ground level of the Yates Crusher building.[‡]

Standby power at the Yates Campus will be provided for life safety considerations, none is required for the experiment. Two generators will be provided, one for the Yates Hoist and one for surface and underground life safety loads. The generator for the latter will feed 12.47 kV power to medium voltage switchgear from which one feeder will serve the Yates Shaft underground loads, and another feeder will serve a 750 kVA, 12.47 kV: 480V/277V pad-mounted transformer for the surface loads. An 1200 A, 480V/277V emergency switchboard (ESB) will be located in the Yates Crusher building. The ESB will feed three automatic transfer switches, one dedicated to standby power for the Yates Shaft ventilation air handing units (AHUs), one dedicated to the surface life safety loads, and one dedicated for the fire pump.

The Ross Campus normal power feeder will be provided from the existing Ross Substation to the new 750 kVA, 12.47 kV: 480V/277V pad-mounted transformer with integral loadbreak switch. The secondary conductors from the transformer will feed a new 1600 A, 480V/277V main switchboard (MSB) located within the Ross Headframe Building. Power from the MSB will be distributed to the Ross Shaft ventilation AHUs. New primary power feeder will be provided from the Ross Substation to the Ross Shaft collar at 480 V for interface with the underground infrastructure normal power.

Standby power for the surface Ross Shaft ventilation AHUs, fire pump, and associated equipment will be supplied from the Ross surface/underground life safety standby generator system. The generator will feed 12.47 kV power to medium voltage switchgear from which one feeder will serve the Ross Shaft underground life safety loads, and another feeder will serve a 500 kVA, 12.47 kV: 480V/277 volt pad-mounted transformer for the surface loads. A 800 A, 480V/277 volt emergency switchboard, ESB, will be located within the Ross Headframe Building. The ESB will feed three automatic transfer switches, one dedicated to standby power for the Ross Shaft ventilation AHUs, one dedicated to the surface life safety loads, and one dedicated for alternate source power to the fire pump.

[‡] Text of this paragraph excerpted from the HDR "WCD 4850L Final Report, Conceptual Design Report". September 30, 2011.

A.3.1.3 Cyber Infrastructure

On the overall site, communications infrastructure is required for voice/data communications, security, the facility management system, and the fire alarm system. The underground systems will be tied to the corresponding surface systems. Redundant underground communications will be provided through new backbone cables in both the Ross and Yates Shafts with connection at 4850L. The campus fiber and copper backbone network will be upgraded and extended to the existing Ross Hoist Building telecommunications closet and a new closet in the Yates Hoist Building. The Yates Campus will be the main IT source, with the Ross as backup. Surface network connection will be done through existing tunnels as much as practical. New routes will be created in ductbanks. Surface connections will include connection to the Yates Dry control and Yates Administration Building.

A.3.1.4 Mechanical and HVAC

Ventilation for the underground systems is provided by equipment at the Ross and Yates Campuses. New equipment is required to meet life safety codes. Heating of the supplied air is required to prevent ice formation in the shafts during cold weather. Air handling units (AHUs) are equipped with filtration, fans and indirect natural gas-fired furnace sections. All major system components will be provided with a standby unit utilizing an N+1 design approach. If one of the AHUs were to fail, the standby component will provide 100% redundancy.

The shaft ventilation system for the Yates Shaft is proposed to be located in the existing Yates Crusher Building on a new mezzanine above the WCD water fill system. The normal ventilation load for the Yates Shaft will be 200,000 cubic feet per minute (CFM). This volume corresponds with the minimum flow capacity of the existing Oro Hondo exhaust fan as well as the requirements for heat removal from the WCD experiment. This would be met by three AHUs, each sized at 100,000 CFM, permitting two units to meet the required capacity and one unit to act as standby should a unit fail or be shut down for maintenance. Should interim construction conditions require higher ventilation rates, the redundant AHU could be put into service and/or supplemental, heated, make-up air will be provided by the construction contractors. In order to provide some level of temperature control within the shaft the supply air temperature from the AHUs will be maintained at a minimum level of 45°F. No cooling will be provided.

A.3.1.5 Plumbing Systems

The existing Yates Campus has a network of aging water mains serving the site which is supplied from nearby city of Lead mains and water supply reservoir. To increase the reliability of the system and to provide fire protection, a new water main will be installed and connected to the existing mains to provide a looped water main. The looped system will serve the portion of the Yates Campus that will be used by the WCD 4850L Experiment. The water main will connect to an existing main west of the Upper Yates Parking Lot, run east along the south edge of this parking lot past the Administration and Sawmill buildings, turn north and reconnect to an existing water main to the west. This will also allow for simple connections of future water main improvements. A fire sprinkler main will be installed between the Yates Crusher and Yates Hoist Buildings. These improvements are shown in Figure A–13.

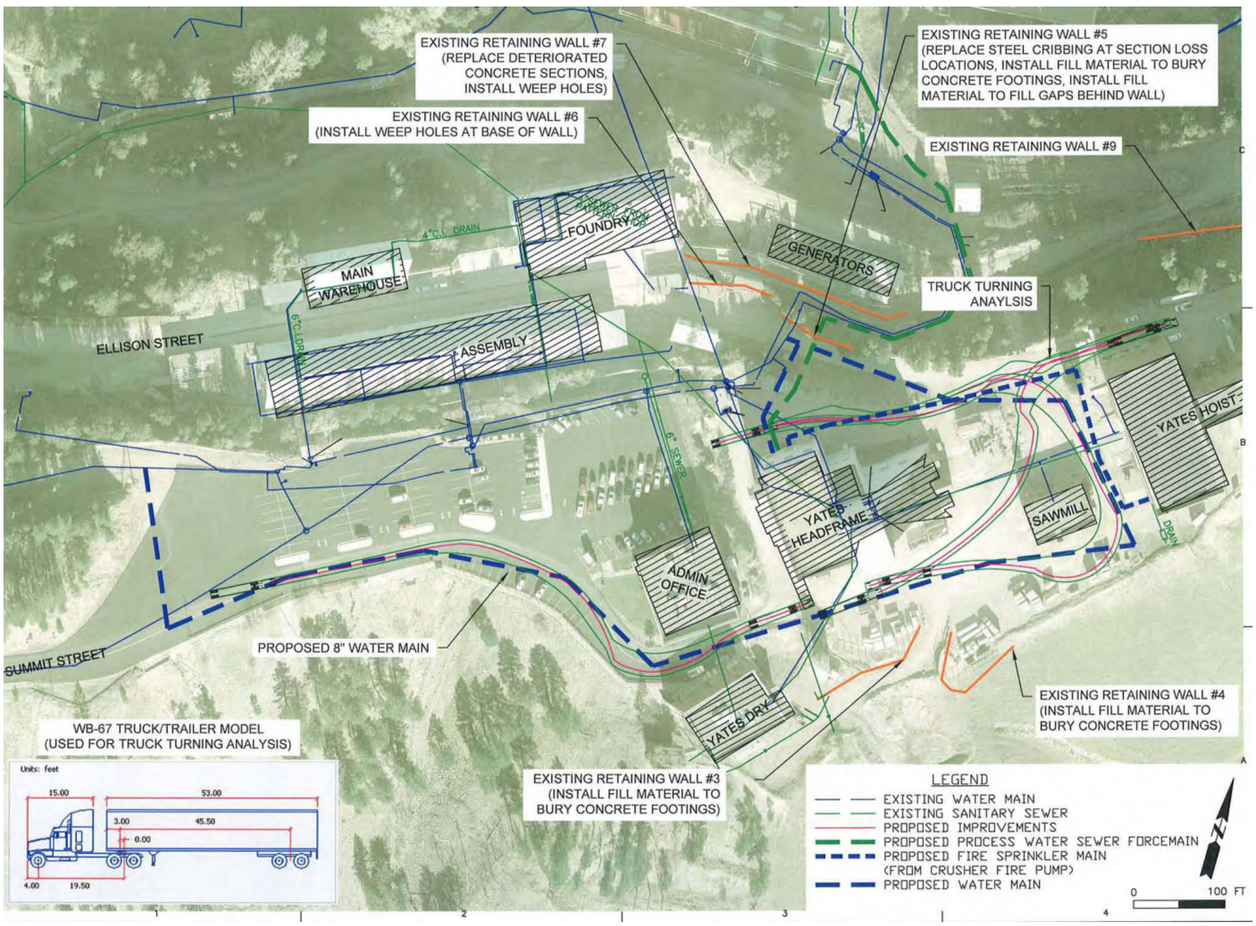

Figure A–13: Yates Campus civil site plan. (HDR)

The Ross Campus is also served by the city of Lead municipal system. New water main and fire hydrants will be installed at the site to ensure adequate fire protection. The new water main will be installed from the end of the existing main southeast of the LHD Warehouse (LHD stands for Load Haul Dump equipment used underground), then continued to the north along the west edge of the site, where it will eventually connect to the existing main north of the Ross Headframe Building. At the Ross Hoist Building, new fire hydrants will be connected to existing water mains serving the building. A fire sprinkler main will be installed between the Ross Headframe to the Ross Hoist Building. These improvements are shown on Figure A–14.

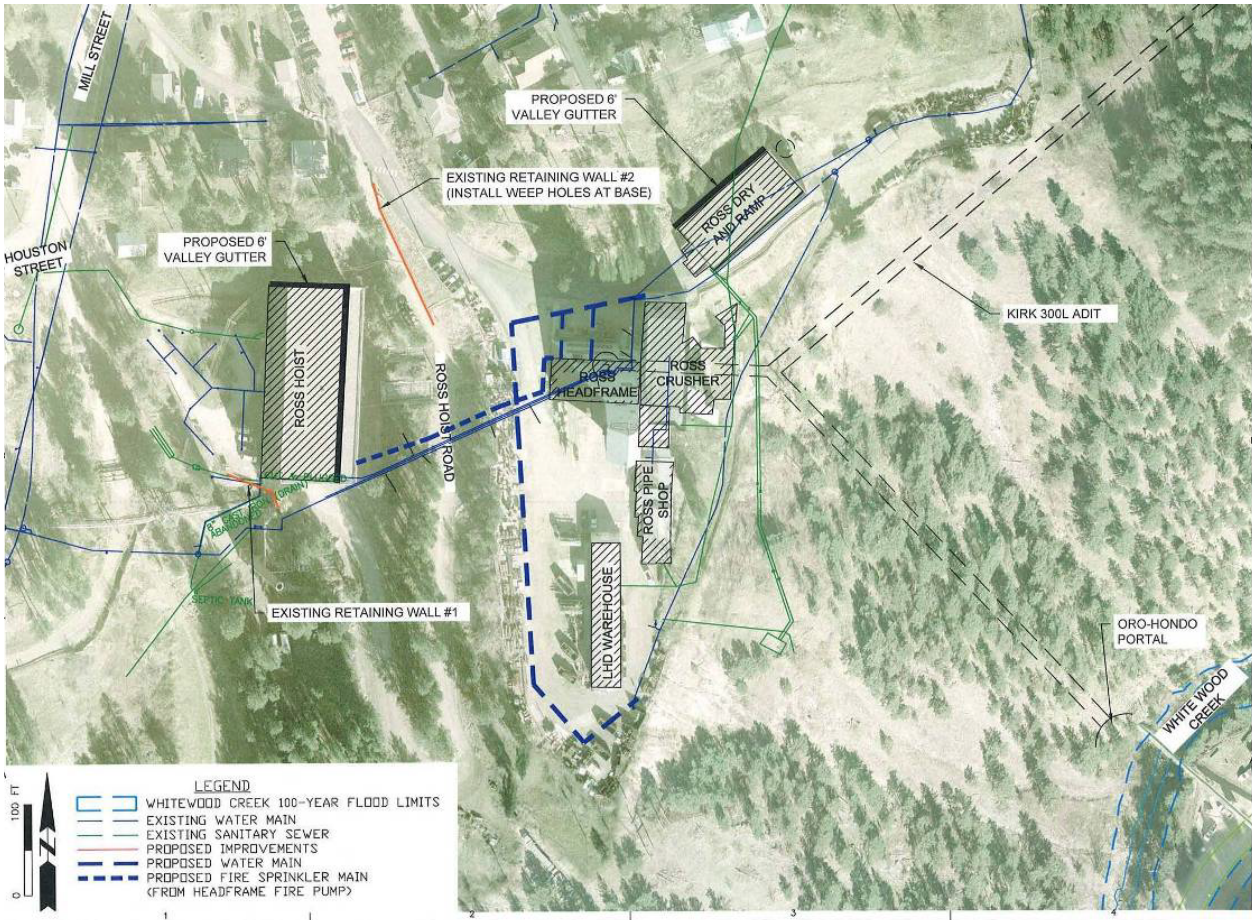

Figure A–14: Ross Campus civil site plan. (HDR)

A.3.1.5.1 Potable and Industrial Water Systems

The city of Lead provides two type of water to the site. Industrial water is provided from a mountain stream source several miles away directly to the site. This system was installed by the former Homestake Mining Company specifically for underground mining, and therefore it provides a reliable direct source of water. Potable water treats a side stream of the industrial water supply by filtering and adding fluorine and/or chlorine to the water.

Potable cold water will be provided to the Yates Shaft collar to serve the underground water requirements. Industrial cold water will be provided to serve all detector support systems that require an industrial water supply. The industrial cold water distribution system will be isolated from the potable water system by utilizing a reduced pressure backflow preventer

(RPBP). The potable and industrial cold water distribution piping will be galvanized steel pipe. Piping has been sized for a maximum velocity of 8 fps for the cold water.

The Ross Campus water system will supply an 8-inch industrial water into the Ross Headframe Building and up to the shaft collar in order to support the underground water needs, independent of the purified water needed to fill the WCD. The Yates Campus water system also will supply a maximum of 600 GPM of industrial water into the Yates Crusher Building to support the surface water purification plant. A 6-inch line will be provided to serve this load.

This purified water will be generated utilizing WCD-supplied pretreatment equipment located on the ground floor of the Yates Crusher Building. From this system, purified water will be supplied to the underground for additional polishing and purification utilizing WCD water systems. A single 4-inch, 316 L electro-polished stainless steel pipe will be routed from the Yates Crusher Building to the Yates Shaft collar. A plan view of this system is included as Figure A–15. The capacity of the shaft pipe has been specified by the WCD experiment.

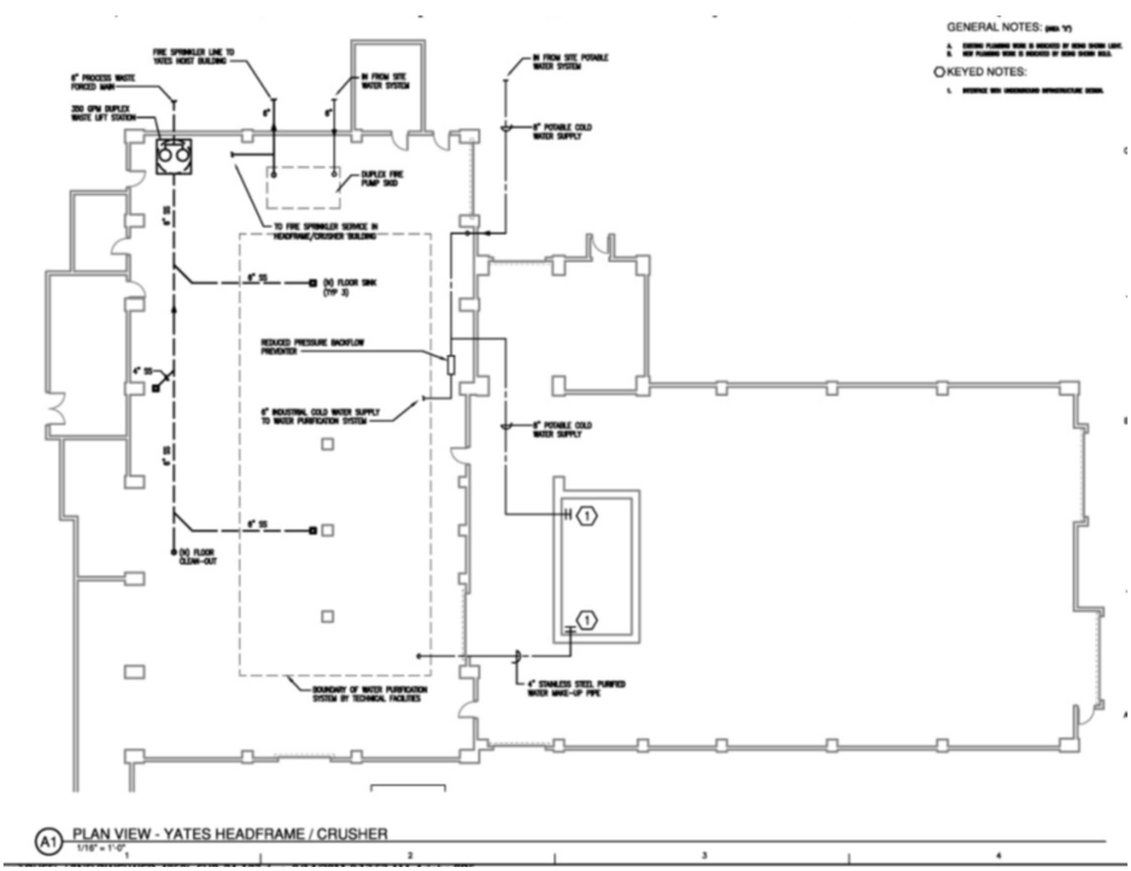

Figure A–15: Yates Headframe crusher building plumbing plan. (HDR)

A.3.1.5.2 Fire Protection Systems

All areas of the existing buildings will have full sprinkler coverage. The building fire protection system for the existing buildings will be supplied from the water distribution system on site. The system will be designed in accordance with NFPA-13 guidelines, with fire sprinkler hazard classifications selected to suit the building function. Underground laboratories will be supplied fire water from the existing gravity water distribution system. Fire water piping will be routed to the shaft collars for interface with the underground piping installation.

Given the relatively low water pressure available on the Yates and Ross Campuses, new fire pump systems will be provided to serve the taller structures at both campuses. Each system will include two 1,000-gallon per minute (GPM) electric fire pumps supplied with standby power. Systems will include all required accessories such as jockey pumps, flow test meters, flow test headers, controllers, etc. The Yates Campus system will be located in the Yates Crusher Building, while the Ross Campus system will reside in the Ross Headframe Building. New fire pumps will be UL/FM approved and fully compliant with NFPA 20. Piping for the sprinkler and standpipe systems will be Schedule 40 black steel with flanged, grooved or threaded fittings. Two fire pumps, each capable of 100% of the required flow, will be provided at each campus.

A.3.1.5.3 Process Waste System

A process waste and vent system will be added to the Yates Crusher Building to serve wastewater produced by WCD water purification system. The building system is anticipated to flow by gravity to a duplex, waste lift station installed in the Yates Crusher Building. From the lift station the waste will be pumped through a force main then flow to the existing site Waste Water Treatment Plant, which currently treats water from underground facility dewatering operations. No supplemental treatment is expected for process waste.

A.3.1.5.4 Gas Fuel System

Natural gas will be used as the primary fuel in the shaft ventilation systems, but dual fuel systems are required, since the Black Hills area is near the end of a natural gas pipeline from North Dakota. Service is reliable but is served on an interruptible basis for large loads during adverse weather conditions. Loads below approximately 2,500 MBH (thousands of BTU per hour) per customer are typically allowed to be served on a firm basis. The periods of interruption are typically one to several days.

Independent propane systems will be provided at both the Yates and Ross Campuses in order to serve the shaft heating systems, in the event of natural gas curtailment. Each system will be designed to provide five full days of backup fuel, assuming winter design conditions and normal ventilation airflow. Based on calculations, the Yates Campus will utilize a single 12,000-gallon propane tank, while the Ross Campus will utilize two 3,500-gallon propane tanks. Each system will be provided with an associated vaporizer unit.

Natural gas will be distributed to the heating, ventilation, and air conditioning (HVAC) mechanical equipment requiring natural gas. The low pressure gas shall be distributed inside the buildings at 7 inch to 11 inch water column. The primary design criteria use the 2009 International Plumbing Code and NFPA-54, including the applicable state and city amendments.

Natural gas and propane will be distributed within buildings in Schedule 40 black steel piping with black iron welded fittings. The natural gas and propane lines serving the facility will be sized for the current building program with an additional anticipated load of 20% for renovation flexibility.

A.3.2 Project-Wide Considerations

There are several project-wide considerations, many with environmental considerations that must also be considered. These are discussed below.

A.3.2.1 Environmental Protection

The LBNE Project will prepare designs and execute construction and operations of the WCD at the Far Site in accordance with all codes and standards to ensure adequate protection of the environment. The Sanford Laboratory codes and standards outline the requirements for work at the site.

The overall environmental impact of the LBNE Project will be evaluated and reviewed for conformance to applicable portions of the National Environmental Policy Act (NEPA).

Several specific environmental concerns will be addressed during the project. These are described in the subsections below.

A.3.2.1.1 Environmental Controls during Waste Rock Disposal

There are a number of components to the waste rock handling system, most of which are either underground or on SDSTA property. The most visible component of the system to the public is the surface pipe conveyor which conveys excavated material from the Yates Shaft overland to the Open Cut and is discussed further in Section A.6.8.

Several controls are included in the waste rock handling system design to protect both the equipment and the community. The existing belt magnet provides a first defense against belt damage due to rock bolts, loader bucket teeth, etc. Prior to the pipe conveyor rolling into the pipe configuration, an additional magnet followed by a metal detector will catch both ferrous and nonferrous metals and shut down the system before damage is done. A scale on this belt protects against over- or underloading the conveyor, preventing issues experienced with similar conveyors. Standard safety controls, including pull cords, drift switches, zero-speed switches, and guarding provide further protection for both the equipment and operators. A full building enclosure around the car dump, surge bin, and pipe conveyor feeding point will contain noise and spills, should they occur. The entire length of the pipe conveyor will be enclosed and fencing will be provided to eliminate public access. Figure A–16 shows a depiction of what the conveyor may look like as it passes over Main Street in Lead and into the Open Cut. A combination of dust collection and suppression will ensure that all

Figure A–16: Depiction of what the pipe conveyor will look like to the Lead, SD community. (SRK, Courtesy Sanford Laboratory)

environmental standards are met or exceeded. The Facility Management System will create interlocks to limit the potential for human error.

A.3.2.1.2 Waste Water Disposal Underground

To ensure environmental contaminants are not introduced into the lab-wide dewatering system, experimental space sumps will be required to be tested prior to discharge into the main drainage system. If contaminants are found, the experiment will be required to treat the water, or the water will be manually removed via tanks for proper disposal at the expense of the collaboration.

A.3.2.2 Safeguards and Security

A facilities security system shall be installed to provide a secure environment for the interior and the exterior of the facilities. To accomplish this, the security system will consist of the following:

- Closed Circuit Video Monitoring: A closed circuit video system to monitor security cameras at selected locations
- Card Access Control: An electronic access control system utilizing proximity card readers to control and record access to designated doors in the facility
- Intrusion Detection Alarms
- Security System Integration: The access control and video monitoring system shall be integrated into the Sanford Laboratory security monitoring system and monitored at the Command and Control Center.

A.3.2.3 Emergency Shelter Provisions

Required provision for occupant protection in the event of tornadoes or other extreme weather conditions may be incorporated into the design of the service buildings, if determined to be applicable. Guidelines established by the Federal Emergency Management Agency (FEMA) in publications TR-83A and TR-83B and referenced in Section 0111-2.5, DOE 6430.1A may, if determined to be applicable, be used to assess the design of the buildings to insure safe areas within the buildings for the protection of the occupants. These protected areas would also serve as dual-purpose spaces with regard to protection during a national emergency in accordance with the direction given in Section 0110-10, DOE 6430.1A.

FEMA guidelines indicate that protected areas are:

- on the lowest floor of a surface building
- in an interior space, avoiding spaces with glass partitions
- areas with short spans of the floor or roof structure are best; small rooms are usually safe, large rooms are to be avoided.

A.3.2.4 Energy Conservation

The DOE directive, Guiding Principles of High-Performance Building Design, is being assessed to determine applicability of how it may, or may not, be incorporated into the design of the LBNE Conventional Facilities. However, discussions are ongoing regarding the applicability of the guiding principles based on the ownership/stewardship of the Sanford Laboratory, the type and use of the facilities. If applicable, LBNE processes and each project element will be evaluated during design to reduce their impact on natural resources without sacrificing program objectives. The project design will incorporate maintainability, aesthetics, environmental justice, and program requirements as required to deliver a well-balanced project.

As applicable, elements of this project may be reviewed for energy conservation features that can be effectively incorporated into the overall building design. Energy conservation techniques and high efficiency equipment will be utilized wherever appropriate to minimize the total energy consumption.

A.3.2.5 DOE Space Allocation

The elimination of excess facility capacity is an ongoing effort at all DOE programs. Eliminating excess facilities (buildings) to offset new building construction (on a building square foot basis) frees up future budget resources for maintaining and recapitalizing DOE's remaining facilities.

The LBNE Near Site project has obtained a DOE Space Allocation/Space Bank waiver, meaning that there is sufficient elimination of excess facilities capacity elsewhere in DOE labs to offset the new LBNE building square footage. The ultimate applicability of these DOE requirements to the Far Site will be determined as the ownership/stewardship model of the Far Site is determined.

A.4 Surface Buildings

Surface facilities utilized for the WCD include those necessary for safe access and egress to the underground through the Ross and Yates Shafts, as well as that necessary for the WCD-provided water purification and fill system. Existing buildings will be rehabilitated to code-compliance and to provide for the needs of the experiment.

A.4.1 Ross Headframe and Hoist Buildings

The headframe and hoist buildings at the Ross Campus require exterior rehabilitation to provide a warm, usable shell. The Ross Headframe Building will be the main entry point for construction activities as well as the ongoing operations and maintenance functions. The Ross Hoist Building and Ross Headframe are pictured in Figures A–17 and A–18.

Figure A–17: Photo of Ross Hoist exterior. (HDR)

The rehabilitation work includes installation of fire suppression systems, improved lighting and heating, and miscellaneous plumbing and power upgrades.

A.4.1.1 Architectural

No architectural improvements are planned for the Ross Headframe and Hoist rooms. Some repairs are required for the metal sheathing of the headframe, and the brick for the hoist building requires tuckpointing.

Figure A–18: Photo of Ross Headframe. (HDR)

A.4.1.2 Structural

The Ross Headframe was designed and constructed in the 1930's. The design at that time did not take into consideration the potential for the shaft conveyance to over-travel and get pull against the sheave deck at the top of the headframe. If this occurs, a force equivalent to the breaking strength of the wire rope would be applied in the direction of the hoist room, substantially higher than the typical force in this direction. Current standards require that this load be included in the design of head frames. To address this deficiency in the design, internal reinforcement of the structure will be performed.

The Ross Hoist Building was evaluated during an early phase of design for the DUSEL Project. During this evaluation, the roof was found to have insufficient strength to meet 2009 International Building Code standards. A design for reinforcing this structure was funded by Sanford Laboratory and this roof will be repaired prior to the LBNE Conventional Facility project commencement.

A.4.1.3 Mechanical

The shaft heating system described in Section A.3.1.4 is the only mechanical upgrade associated with either the Ross Headframe or Ross Hoist building.

A.4.1.4 Electrical

The electrical systems in both the Ross Headframe and Hoist buildings will be upgraded as necessary to support fire suppression systems and ensure that these buildings are code compliant.

A.4.1.5 Plumbing

Plumbing modifications for the Ross Headframe and Hoist buildings are described in Section A.3.1.5 and are focused on providing fire protection and water supply for the underground.

A.4.1.6 ES&H

The Ross Headframe and Hoist buildings were investigated for potential environmental contaminants during the DUSEL Preliminary Design. These buildings are free from health concerns related to asbestos, lead based paints, or PCBs. Fire protection is the only upgrade required as described previously.

A.4.2 Ross Crusher Building

The existing Ross Crusher Building, as shown in Figure A–19, is a high bay space that contains rock crushing equipment that will be used for construction operations. The exterior of the building will be repaired to create a warm, usable shell. The upgrade of the existing crusher equipment is part of the waste rock handling work scope and not part of the building rehabilitation.

The rehabilitation work includes installation of fire suppression systems, improved lighting and heating, and miscellaneous plumbing and power upgrades.

A.4.3 Ross Dry

The Ross Dry building is in use by the Sanford Laboratory to provide office and meeting space in addition to men's and women's dry facilities. A portion of an existing meeting space within this building will be modified to allow the installation of a control room for facility control. The exterior of the Ross Dry is shown in Figure A–20.

Figure A–19: Photo of Ross Crusher exterior. (HDR)

Figure A–20: Photo of Ross Dry exterior. (HDR)

A.4.4 Yates Headframe and Hoist Building

The headframe and hoist buildings at the Yates Campus require exterior rehabilitation to provide a warm, usable shell. Since the Sanford Laboratory site is listed in the National Register of Historic Places, rehabilitation work will need to take into consideration appropriate standards and be coordinated with the State Historic Preservation Office. The Yates Headframe Building will be the main entry point for WCD experiment installation and operations, therefore staging of materials to be lowered underground will be done here. The Yates Headframe and Yates Hoist Buildings are pictured in Figure A–21 and A–22.

Figure A–21: Photo of Yates Headframe exterior. (HDR)

A.4.4.1 Civil

No civil improvements are anticipated for either the Yates Headframe or Yates Hoist buildings. New foundations will be installed by the Sanford Laboratory for a rope dog tower being installed in 2012. Additional civil foundation work may be identified for structural reinforcement of the headframe described in Section A.4.4.3.

Figure A–22: Photo of Yates Headframe interior. (HDR)

A.4.4.2 Architectural

The Yates Headframe and Hoist buildings are perhaps the most recognizable buildings in the area from a historical perspective. This requires enhanced sensitivity to historical preservation in these buildings. No significant modifications to the architecture of either building are planned.

A.4.4.3 Structural

During the DUSEL Preliminary Design, the Yates Headframe was assessed by G.L. Tiley to determine its capability to withstand a rope break load in the event that the conveyance became stuck at the top of the headframe with the hoist still operating. This assessment highlighted required structural reinforcement similar to that required for the Ross Headframe.

The Yates Hoist Building has been evaluated and minor roof strengthening is required in this building to meet current codes. A final design for this work has been provided to the Sanford Laboratory and construction will be completed prior to LBNE Conventional Facility project commencement.

A.4.4.4 Mechanical and Plumbing

The Yates Headframe will house two new mechanical/plumbing installations, fire pumps and the shaft heating system. The layout of these installations is shown in Figure A–23. In addition to this, a new water line will be installed to deliver water through the shaft to the underground spaces.

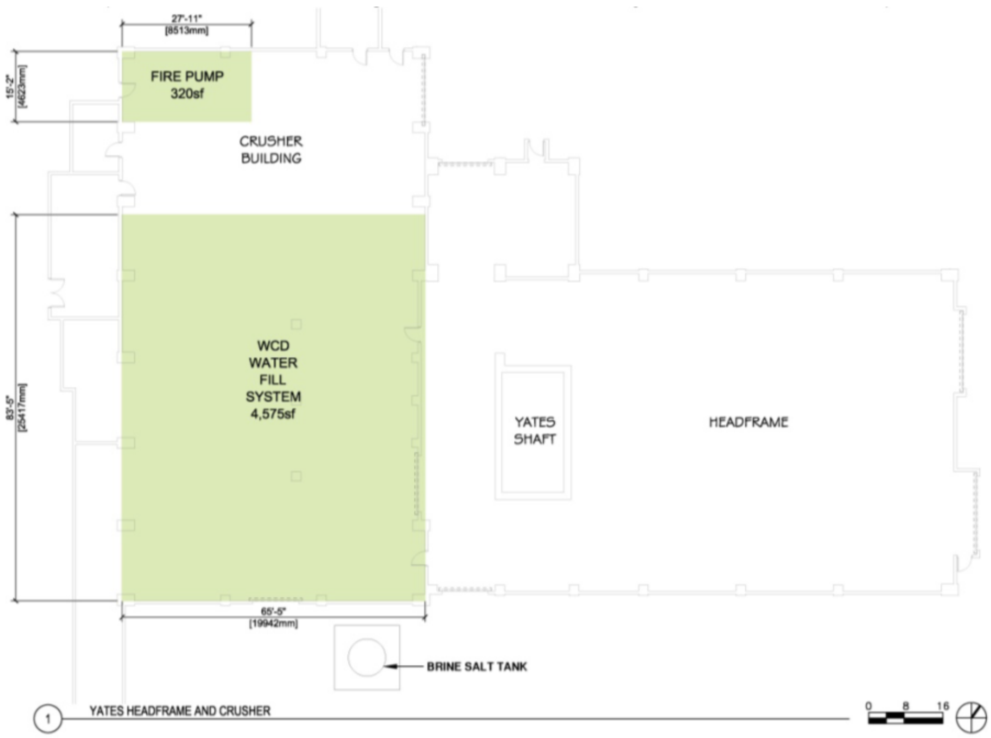

Figure A–23: Yates Headframe and Crusher architectural plan. (HDR)

A.4.4.5 Electrical

No significant electrical upgrades are required for either the Yates Headframe or Hoist buildings. System will be upgraded as necessary for code compliance, and new conductors and controls will be installed for the fire pumps and AHUs.

A.4.5 Yates Crusher Building

The water fill system will be housed in the Yates Crusher Building, which has adequate space for the fill system equipment. The water fill and purification system at the surface will be designed and provided by the experiment. The equipment requires 4,775 square feet and a 20 ft minimum inside height. Adjacent to the fill system will be an external 10,000-gallon brine tank that needs space for truck deliveries. The system will be served by the Lead municipal industrial (i.e. non potable) water supply to the Yates Campus, and the purified water will be routed down the Yates Shaft. In addition, the Yates Crusher Building will house the new fire pump for the Yates Campus as well as a new mezzanine on which new shaft heating equipment will be placed. The building will require a new floor infill at an existing floor pit, as well as upgrades to the exterior of the building to create a warm, usable interior. Layout of the building showing the water fill system is in Figure A–23. The interior of the building where the equipment would be placed is shown in Figure A–24.

Figure A–24: Photo of Yates Crusher interior. (HDR)

The rehabilitation work includes installation of a new roof, fire suppression systems, improved lighting and heating, and miscellaneous plumbing and power upgrades.

A.4.6 Yates Dry Building

The Yates Dry Building will house the WCD experiment and facility monitoring and control room. The experiment requires a 200-sf control room which can be easily housed in the existing Yates Dry, just to the south of the Yates Administration Building. Space will contain computer monitors and racks. Modest fit-out of this space will be required. Figure A–25 shows how the control room would fit into the existing Yates Dry on the upper level.

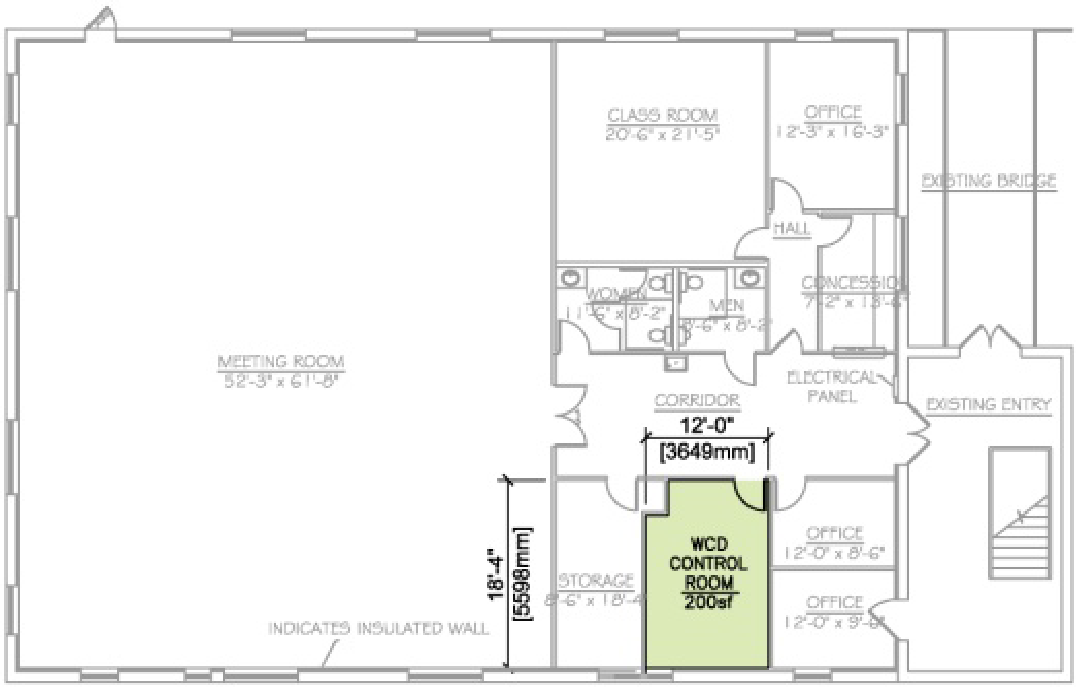

Figure A–25: Yates Dry architectural plan. (HDR)

A.4.7 Temporary Installation Offices

The WCD experiment requires 4,000 square feet of office space during experiment installation. As this is not a permanent space requirement, the current plan is to utilize temporary mobile office trailers that will be staged on the Upper Yates Parking Lot and will be provided for two years by Conventional Facilities. This will provide the greatest flexibility for site usage, and timing without placing an increased demand on the limited existing facilities, the project schedule, or construction sequencing.

A.5 Underground Excavation

The main excavated spaces necessary to support the WCD experiment are a combination of excavations required for the experiment and those believed to be required for constructability. Experimental spaces on 4850L include the detector cavern, two utility drifts, main access drift, secondary egress drift, AoR, plus a sump pit on 5117L. Spaces identified as likely necessary for the excavation subcontractor include a mucking drift from 4850L to 5117L and spaces near the Ross Shaft to enable waste rock handling. All spaces are identified on the Conceptual Design excavation drawings produced by Golder Associates in September 2011[?]. The spaces are pictured in Figures A–26 and A–27.

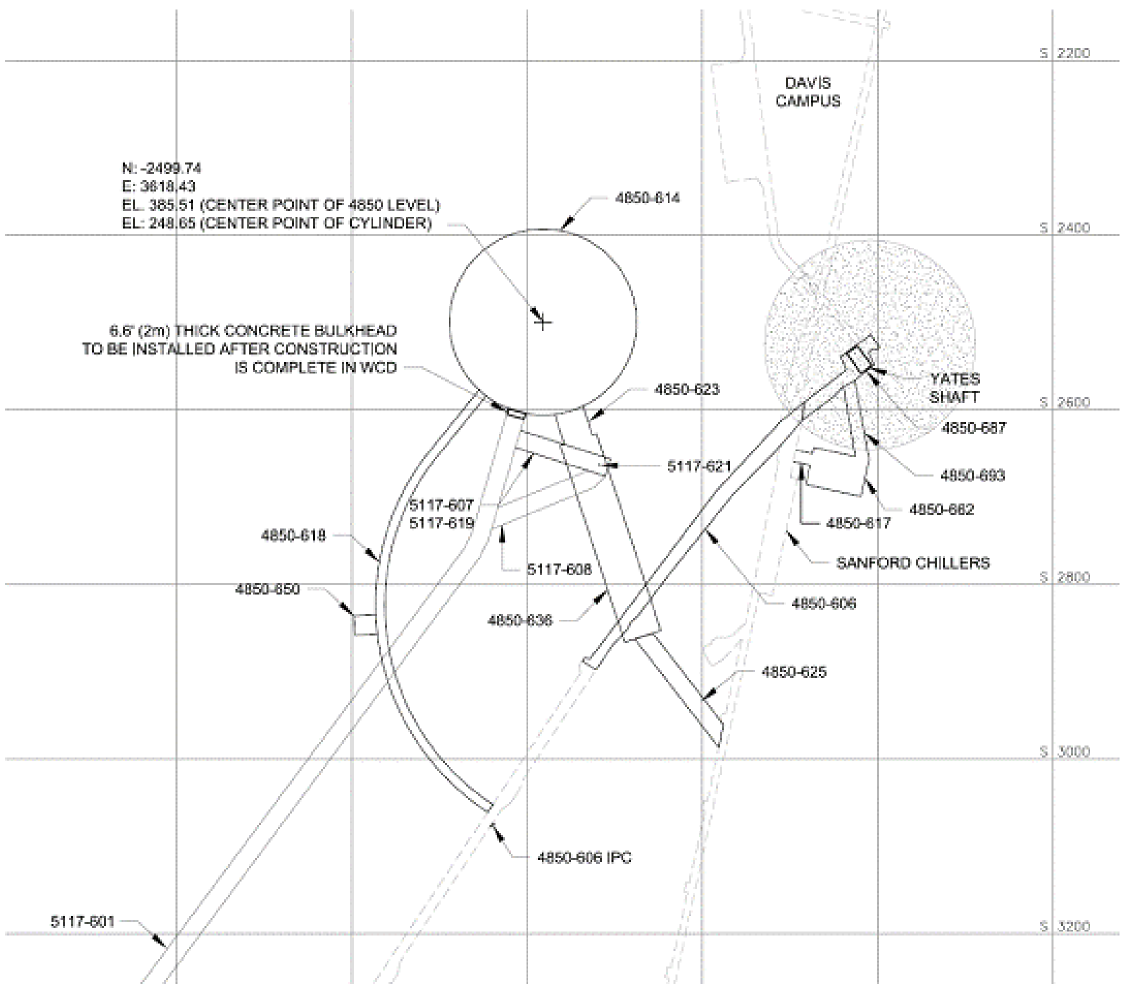

Figure A–26: Spaces required for WCD at 4850L and 5117L. (Golder Associates)

LBNE Conceptual Design is based on several geotechnical investigations conducted through the DUSEL Project by Golder Associates between 2008 and 2010 at the 4850L Campus. The geological/geotechnical characterization is taken from that work, which was for a larger scope at that time. The investigative work is summarized in the Golder Associates reference design report dated September 30, 2011[?].

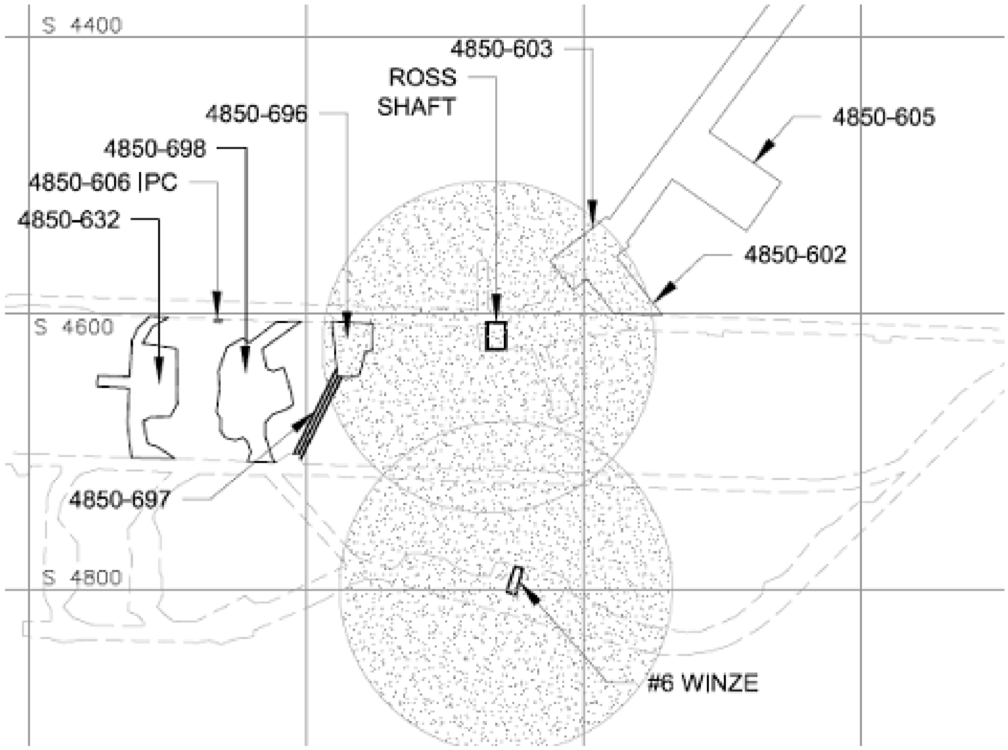

Figure A–27: Spaces required for WCD near the Ross Shaft. (Golder Associates)

A.5.1 WCD Cavity

The required experimental spaces were defined through interaction with the WCD design team[**?**]. The size and depth of the WCD cavity was prescribed to suit the scientific needs of the experiment. The nominal 200 kTon detector size is shown graphically in Figure **??**. The WCD will be housed in a large underground cavity at 4850L. Siting deep underground is required to shield the detector from cosmic rays[**?**]. The 4850L level is deeper than what is absolutely required, but is used because of existing access and related infrastructure at this level.

The limits on size for the detector are determined by rock strength, clarity of the water, and by maximum hydrostatic pressure that may be applied to submersed photomultiplier tubes. Spaces occupied by the vessel wall, liner, and photomultiplier tubes (PMTs) reduce the total volume to the fiducial volume needed to satisfy the physics requirement for the detector mass. Current assessment of rock quality indicates that an excavated cavity diameter of 65 m is achievable with sufficient rock support. LCAB concluded in its April 2011 meeting that, "A combination of favorable rock mass strength and structural conditions and an in situ stress field that is reasonably benign means that a stable 65 m diameter 97 m high vertical cylindrical cavity with a dome-shaped roof can be constructed at the selected location on 4850 level of the [former] Homestake mine"[**?**].

Preliminary modeling of the proposed excavations included 2D and 3D numerical modeling. The intact rock strength and joint strength had the greatest impact according to the 2D modeling, and 3D modeling confirmed that the domed right-cylinder cavity to be the most favorable geometry.

The WCD cavity will be excavated using modern drill and blast techniques, in phases from the top down. Excavation access to the crown of the cavity will be via an exploration drift ramp constructed as part of the geotechnical investigation. This drift will begin from the West Access Drift on 4850L through the planned utility drift and end in the crown of the WCD cavity. The mucking drift from 4850L at the Ross Shaft to the bottom of the WCD cavity at 5117L will be excavated to the center of the cavity. Then a raise bore will be pulled to the crown. The dome and can portions of the cavity will be excavated in lifts, with ground support installed as excavation progresses. Given the size of the WCD cavity excavation, the presence of structural features, potential for overstress zones and critical requirements for long-term stability, special attention will be paid to controlled drilling and precision blasting techniques. This will minimize overbreak and create smooth, stable walls as much as possible, which is also essential for the WCD liner to be installed as part of the experiment.

The WCD cavity and drifts will be supported using galvanized rock bolts/cables, wire mesh, and shotcrete for a life of 30 years. The floor of the cavity will also be supported to resist uplift and provide a stable surface for detector equipment. Figure A–28 illustrates the ground support conceptual design, as detailed in the Golder Associates design report and Golder drawing WCD-G3P-LC1-1.

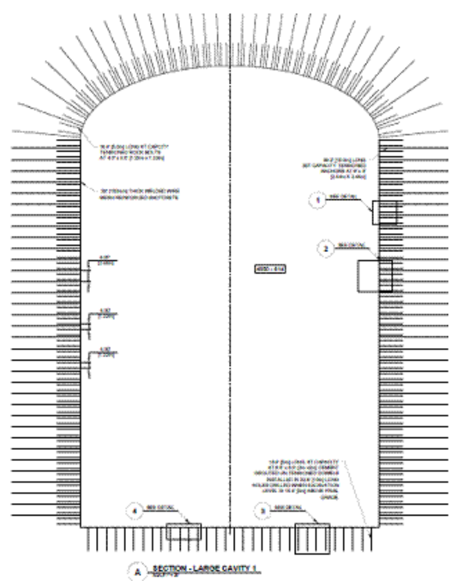

Figure A–28: WCD cavity ground support. (Golder)

A groundwater drainage system will be placed behind the shotcrete in the arch and walls of the WCD cavity rock excavation. This drain system is comprised of a membrane fabric will collect groundwater (native) seepage and eliminate the potential for hydrostatic pressure build-up behind the shotcrete. Channels will be placed in the concrete floor mud-mat to drain groundwater to the WCD sump system.

To seal the opening at the bottom of the WCD cavity, a conceptual design was done for a flat-wall bulkhead with a high pressure water-tight access hatch at the 5117L drift at the bottom of the cavity. The bulkhead will be installed at the end of the access drift 5117-601 providing a hydraulic barrier between the drift and the WCD, as depicted in Figure A–29. It

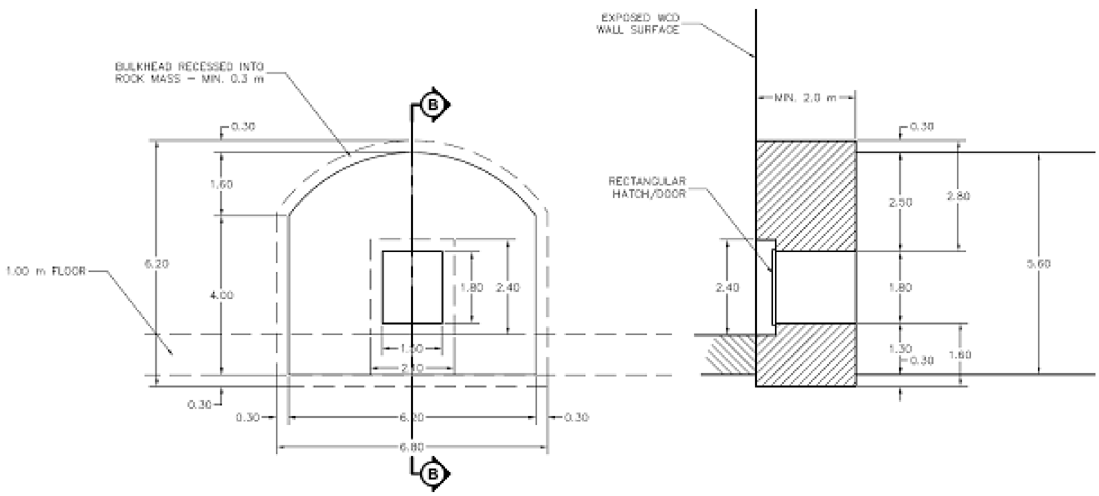

Figure A–29: 4850L bulkhead design option.

is designed[**?**] to withstand the hydraulic head of 85 mwe. The conceptual bulkhead design is an internal hatch with a rectangular opening, which utilizes water pressure to improve the seal between the door and the opening, i.e., reduces stresses on the latching mechanism which is likely to result in a simple, safe design. The access hatch allows for future access at this level for maintenance.

WCD Drifts

WCD experiment requires spaces for experimental equipment outside of the cavity. These requirements have been combined with that for the MEP utilities to create the utility drifts 4850-636 and 4850-625. These drifts will house the experiment's water recirculation system, electrical equipment to supply power for facility and experiment needs, sump pump access and controls, fire sprinkler room, and exhaust ducting from the cavity to the East Access Drift. Drift 4850-636 will have a steel mezzanine to increase the space available for equipment, which will be provided by the conventional facilities. The water system layout was coordinated with the underground infrastructure design team and is shown in Figure **??** in schematic format. This drift is sized to allow for additional equipment during experimental upgrades in the future. Specifically, this would allow for management of gadolinium in the water to enhance scientific capabilities.

The sump pump pit for WCD cavity will be outside the cavity at 5117L. The pit will be a repurposed excavation from the mucking operation, and fashioned to meet the long-term pumping needs. The pit is sized for containment of leak water from the WCD as well as native water leakage from behind the shotcrete. At the base of the Ross Shaft, an electrical switchgear room is necessary for power distribution at 4850L. More information on utility requirements and designs can be found in Section A.6 of this Appendix.

A.5.2 Access/Egress Drifts

The primary experimental access to and egress from the underground will be via the Yates Shaft, due to its proximity to the location of the WCD cavity at 4850L. The existing West Access Drift will be enlarged to accommodate installation of additional utilities, since this drift will become a main egress passageway for secondary exiting to the Ross Shaft. Secondary egress from the cavity to the West Access Drift will be via the WCD Egress Drift 4850-618.

Life safety requirements also dictate provision for areas of refuge at specific locations throughout the occupied areas. AoRs are provided at the base of the Yates and Ross shafts, the West Access Drift, and the WCD Egress Drift.

A.5.3 Excavations Necessary for Construction

Several spaces are shown on the excavation drawings that are not required by WCD experimental needs, but are believed to be necessary for the excavation activities. These may not be constructed exactly as shown, but represent one method of accomplishing the excavations, and thus provide a means to understand the scope and estimate and schedule the work properly. The spaces are the mucking drift 5117-601 from the bottom of the WCD cavity to the Ross Shaft, the powder and cap magazines (4850-691, 4850-692), and several spaces for waste rock handling and underground equipment near the Ross Shaft.

A.5.4 Interfaces between WCD and Excavation

There are several points at which the experiment and the facility interface closely. These are managed via discussions between WCD design team and the CF L3 managers and design contractors. The major programmatic elements of the WCD deck design are shown in Figure **??**.

- The WCD liner and magnetic compensation coils are applied directly over the shotcrete, so the smoothness of the shotcrete and stability of the excavation walls and floor are important to the experiment.

- The WCD deck is supported from the cavity roof via 50-ton cable bolts installed by the excavation contractor, as well as corbels along the side walls.
- The utility drifts to house the water system are directly influenced by the size of the water system equipment.

A.6 Underground Infrastructure

The requirements for underground infrastructure for the LBNE Project will be satisfied by a combination of existing infrastructure, improvements to those systems, and development of new infrastructure to suit specific needs. The Project assumes that the only other tenant underground at Sanford Laboratory for which infrastructure is required is the existing Davis Campus experiments.

The systems will support the WCD experiment installation and operations, the Conventional Facilities (CF) designed to support the experiment, and the CF construction activities. In general, excavation construction requirements exceed other infrastructure requirements and govern over experiment installation and other CF construction needs.

Some of the Sanford Laboratory infrastructure that requires upgrading for LBNE will be rehabilitated prior to the beginning of LBNE construction funding. This work is important for LBNE, but is considered not part of the LBNE Project scope. This includes Ross Shaft rehabilitation, Yates Shaft rope dog installation, Hoist Buildings' roof strengthening, and Headframe Buildings' structural upgrades. This work is expected to be performed using non-project funding, and is discussed below and elsewhere in this CDR as it is pertinent to the LBNE Project.

The conceptual underground infrastructure design for WCD were coordinated by Sanford Laboratory and performed by several entities. Arup's scope includes utility provisions and fire/life safety (FLS) strategy, covering infrastructure from the surface through the shafts and drifts, to the cavity excavations for the experiment. Utility infrastructure includes fire/life safety systems, permanent ventilation guidance, HVAC, power, plumbing systems, communications infrastructure, lighting and controls, per the experimental utility requirements provided by WCD and through coordination with LBNE, Sanford Laboratory and the excavation and surface design teams. The design is described in Arup's Conceptual Design Report for WCD at 4850L[**?**]. This chapter summarizes the work done by Arup and utilizes information from that report.

Shaft rehabilitation and waste rock handling design were previously provided by Arup for the DUSEL PDR. This chapter uses excerpts from the DUSEL *Preliminary Design Report,* Chapter 5.4. The research supporting this work took place in whole or in part at the Sanford Laboratory at Homestake in Lead, South Dakota. Funding for this work was pro-

vided by the National Science Foundation through Cooperative Agreements PHY-0717003 and PHY-0940801. The assistance of the Sanford Laboratory at Homestake and its personnel in providing physical access and general logistical and technical support is acknowledged.

A.6.1 Fire/Life Safety Systems

Life safety is a significant design criterion for underground facilities, focusing on events that could impact the ability to safely escape, or if escape is not immediately possible, isolate people from events underground. Design for fire events includes both preventing spread of fire and removing smoke through the ventilation system.

Life safety requirements were identified and the design developed by Arup, utilizing Sanford Laboratory 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 are defined in accordance with NFPA 101: Life Safety Code. The design was reviewed by Aon Risk Solutions[**?**].

Based on data provided by Sanford Laboratory the maximum occupant load of the WCD is 82 occupants which includes 42 underground operations staff and 40 science staff (during installation). In addition there will be 9 science staff associated with the Davis Cavity. The total operations occupant load at 4850L is 91 occupants which will be used to size the Yates and Ross Shaft AoRs at 4850L.

Compartmentation will be needed for egress routes to separate them from adjacent spaces to limit the horizontal and vertical spread of fire and smoke. Use of compartmentation will help to reduce the likelihood of fire spreading from the area of fire origin to other areas or compartments. Compartmentation will also help limit the spread of other materials such as cryogenic gases, leaks and spills. This results in design criteria of minimum 4-hour fire separation between the WCD cavity and adjacent drifts, while all rooms that connect directly to the egress drift at 4850L, as well as the shafts, will have 2-hour minimum fire separation.

In addition to the fire/life safety systems described above, LBNE in conjunction with Sanford Laboratory determined a requirement for a temporary fire suppression system during the time period from the start of detector liner installation through the start of filling the detector with water. This requirement is due to the lack of fire retardant chemical in the detector PMT cabling and the potential combustibility of the liner material. The conceptual design of this system includes a fire mist system for which there is a deployed piping network that protects all necessary large cavity surfaces.

A.6.1.1 Egress and Areas of Refuge

The evacuation strategy for occupants at 4850L is to egress directly to the Yates Hoist/Cage (or Ross Hoist/Cage if the Yates Shaft is not working or inaccessible) to evacuate to grade. If occupants are subjected to untenable conditions within the egress route, then they will need to evacuate to the alternate hoistway/cage or to their nearest AoR. There will be a minimum of two ways out of the WCD cavity and areas of high hazard. Once in a drift (exit route) there will be at least two directions to escape from any location leading to a choice of exit hoist/cage.

AoRs provide a protected environment for occupants during an emergency event, such as a fire or cryogen leak. AoRs are strategically located within 4850L such that the travel distance to an area of refuge is limited to within the NFPA 520 maximum travel distance of 2,000 ft. AoRs are to be located at each of the hoistways/cages (i.e. Yates Shaft and Ross Shaft), where people are working (i.e. WCD cavity), and intermittently throughout 4850L (i.e. within the drifts). AoR area calculations use a baseline area of 10 sf/person, derived from NFPA 520.

A.6.1.2 Emergency Systems

Systems will be installed to facilitate egress for life safety and protect personnel and equipment during emergencies. This includes fire suppressions systems, smoke control, alarm and detection systems, two-way voice communication, and emergency lighting. The details of these systems are described in the sections below.

A.6.2 Shafts and Hoists

The Ross and Yates Shafts provide the only access from the surface to the underground, and are therefore critical to the function of the Facility. Both shafts provide service from the surface to 4850L, though not every intermediate level is serviced from both shafts. The shafts also provide a path for all utilities from the surface to the underground.

The Ross and Yates Shafts were both installed in the 1930s and have operated since installation. These shafts, along with their furnishings, hoists, and cages, were well maintained during mining operations, but have experienced some deterioration as described in this section. A complete assessment of the Ross and Yates shafts was conducted for the DUSEL Project, and is documented in the Arup *Preliminary Infrastructure Assessment Report* (DUSEL PDR Appendix 5.M). The designs developed as part of the DUSEL PDR are applicable to the WCD experiment at 4850L, and are described below as excerpted from the DUSEL *Preliminary Design Report*, Chapter 5.4, *Underground Infrastructure Design*, and edited to include only information as it is relevant to the development of the LBNE Project.

A.6.2.1 Ross Shaft

The Ross Shaft will be used for facility construction, including waste rock removal, and routine facility maintenance, access to other levels and ramps (OLR), and secondary egress path for the finished underground campuses. It will not be used for WCD experiment primary access.

The Ross Shaft is rectangular in shape — 14 ft 0 in (4.27 m) by 19 ft 3 in (5.87 m), measured to the outside of the set steel. The shaft collar is at elevation 5,354.88 ft (1,632.17 m) and 5000L is the bottom at elevation 277.70 ft (84.64 m) above sea level. Service is provided to 28 levels and three skip loading pockets. The shaft is divided into seven compartments: cage, counterweight, north skip, south skip, pipe, utility, and ladder way. Figure A–30 shows the shaft layout.

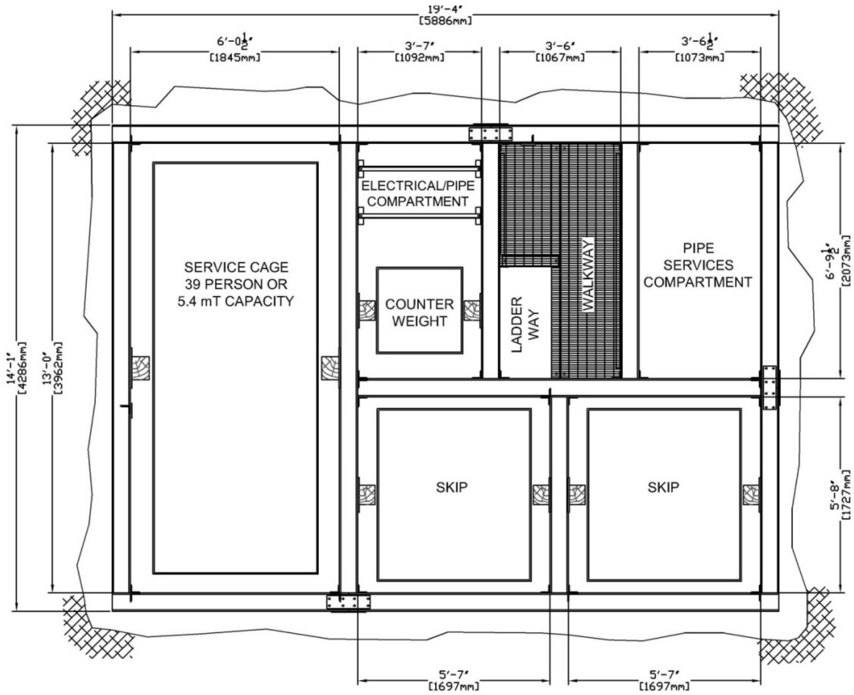

Figure A–30: Ross Shaft, typical shaft set. [SRK, Courtesy Sanford Laboratory]

The Ross Shaft was in operation until the Homestake Gold Mine closed in 2003. Deterioration through corrosion and wear on the shaft steel, including studdles (vertical steel members placed between steel sets), sets, and bearing beams, is evident today. Detailed site investigations were conducted by Arup for the DUSEL PDR through its subcontractor, Tiley. The results of their investigations are included in Section 3.4 of the Arup *Preliminary Infrastructure Assessment Report* (DUSEL PDR Appendix 5.M). Based on their visual assessment, the findings indicate that as much as 50% of the steel furnishings will need to be replaced to enable full operation of the shaft to be restored.

The production and service hoists at the Ross Shaft are located on the surface in a dedicated hoistroom west of the shaft. The service hoist operates the service cage and the production hoist operates the production skips. The DUSEL PDR describes the condition assessment of the electrical and mechanical hoisting systems which are described in detail in the Arup *Preliminary Infrastructure Assessment Report*. The Ross Headframe steel requires some strengthening and modifications to meet code requirements.

The Ross Shaft will not be significantly modified from the existing configuration. The requirements for this shaft are safety, performance, and code driven and defined by the existing configuration. This shaft will be used for construction, including waste rock removal, and routine facility maintenance, access to other levels and ramps (OLR), and secondary egress path for the finished underground campuses. It will not be used for WCD experiment primary access. The shaft rehabilitation and headframe work is planned to be executed by Sanford Laboratory with non-LBNE Project funds prior to the start of LBNE construction.

A.6.2.2 Yates Shaft

The Yates Shaft is rectangular in shape — 15 ft (4.572 m) by 27 ft 8 in (8.433 m) measured to the outside of the set timbers. There are two cage compartments and two skip compartments as shown in Figure A–31. In addition to the cage and skip compartments, there are two

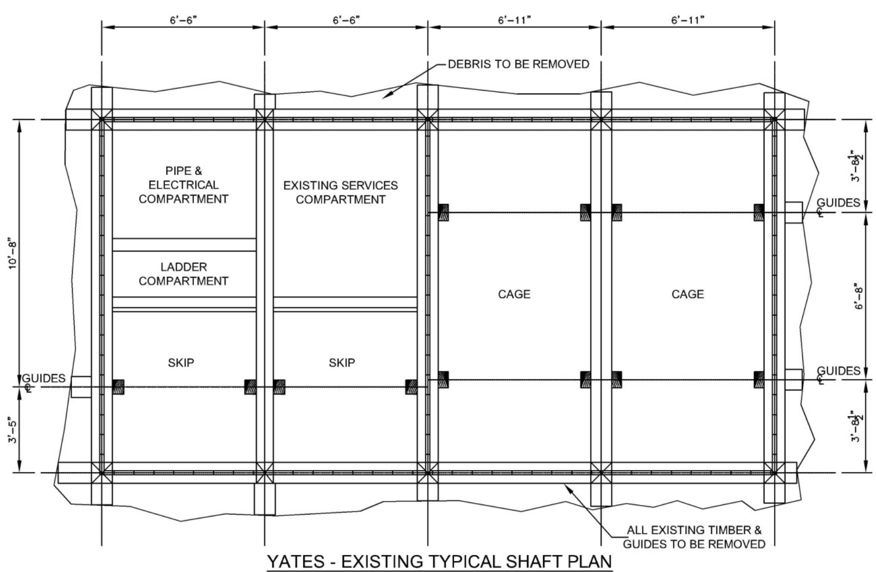

Figure A–31: Existing Yates Shaft layout. (Adapted from SRK, Courtesy Sanford Laboratory)

other compartments in which shaft services are located. The shaft collar is at 5,310.00 ft

(1,618.49 m) elevation and 4850L is the bottom level at elevation 376.46 ft (114.75 m) above sea level. Service is provided to 18 levels plus two skip-loading pockets. Sets are made up of various length and size timbers located to maintain compartment spaces. The Yates Shaft is timbered except for a fully concrete-lined portion from the collar to 300L. Recent repairs include full set replacement from the concrete portion to 800L and additional set repair below this level where deemed critical.

Finite Element Analysis (FEA) modeling by G.L. Tiley[**?**] showed that a dogging load produced by the cage would require vertical joint reinforcement, guide connection modifications, and additional new bearing beam installations. A dogging event occurs when emergency stop devices, called dogs, dig into the guides to stop the cage if the wire rope loses tension. The east and west wall plates are divided into two pieces, making the removal of a timber divider to make room for the Supercage structurally unsecure. Based on these factors, the support system in the Yates will only be used until it can be replaced.

The timber in the Yates Shaft, even if substantial repairs to the current conditions were made, presents a fire risk and has high maintenance requirements. The re-equip options studied during the DUSEL Project Preliminary Design included a completely concrete-lined shaft compared with installing new steel sets attached to concrete rings spaced on 20 ft (6.1 m) intervals vertically with shotcrete applied between rings. Although providing another degree of reduced maintenance, the fully concrete-lined shaft was not chosen due to cost. The concrete ring design was also not chosen following the DUSEL preliminary design due to the installation process required.

Similar to the Ross Shaft, there is both a production and service hoist at the Yates Shaft. The configuration of the hoists for the Yates Shaft is nearly identical to that of the Ross, with the only difference that the rope size for the production and service hoist are the same at the Yates. The Yates Shaft Hoists are located on the surface in a dedicated hoistroom east of the shaft.

The Yates Service Hoist and Production Hoist are planned to be used as existing, with maintenance performed to bring them into like new condition. The production hoist will no longer be used for material removal, but will be re-purposed to provide a secondary conveyance system to the underground. This enhances access, as well as providing secondary egress from the shaft if the primary conveyance is unavailable. Further details regarding the condition of the Yates Hoists' electrical and mechanical condition can be found in Section 2.2 of the Arup *Preliminary Site Assessment Report* (DUSEL PDR Appendix 5.M).

Figure A–31 shows the original Yates Shaft timbered layout. Figure A–32 shows the new arrangement with steel members.

The design shown in Figure A–32 is a modified version of a design prepared prior to mine closure and provides a basic concept for the design to be utilized. The design shown would replace the timber spaced at 6-foot centers with steel at 18-foot centers for the length of the

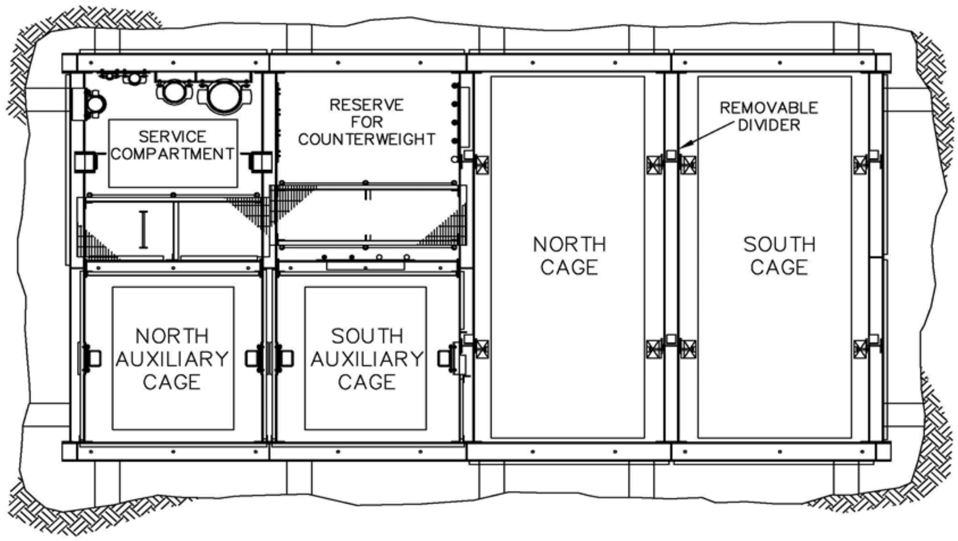

Figure A–32: Preliminary Yates Shaft design layout. (Sanford Laboratory)

shaft. It would allow for the divider between the North and South Cages to be removed at a future date to allow for a single cage to be installed with slightly over twice the width of the two existing cages. The replacement of timber with steel would be done by Sanford Laboratory personnel over a period of several years. During this time, secondary egress through this shaft requires maintaining the configuration as shown, with compartments and guides aligned with the existing timber. This secondary egress could be made available within hours of a need. Removing the divider during rehabilitation would not allow the work platforms to pass from the new guides to the old guides to provide this ease of secondary egress. Another incentive for not removing this divider initially is the requirements for modification to the headframe to relocate the sheave guiding the wire rope, and modification to the hoist to allow for a higher load capacity with the larger conveyance.

Ground support in the Yates Shaft currently consists of wood lacing around the perimeter of the shaft to prevent spalled rock from entering the occupied compartments. This ground support would be replaced with modern pattern bolting and screening to both control the ground and prevent material from entering the compartments.

A.6.3 Ventilation

The ventilation system will utilize the existing mine ventilation system as much as possible with minimal modifications. Fresh air for the WCD cavity and the utility drifts will be provided by pulling air directly from the adjacent West Access Drift, which is supplied from the Yates and Ross Shafts. Air will be exhausted from the WCD cavity and utility drifts to the East Access Drift, and then pulled out through the existing Oro Hondo exhaust vent. The 100,000 CFM design exhaust is sized for smoke extraction. The flow is shown in the Figure A–33.

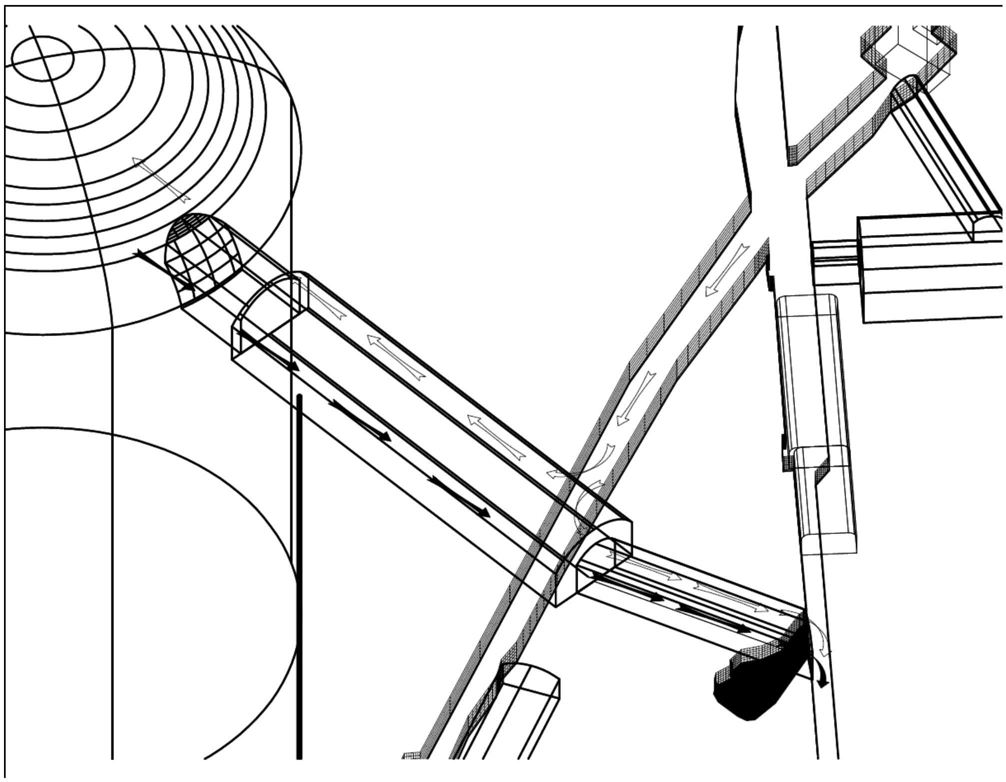

Figure A–33: Ventilation flow diagram. (Arup)

The environmental design criterion for WCD underground spaces is shown in Table A–4. A note on the large cavity entry: temperature, humidity and filtration requirements in localized areas of this space may differ, dependent on requirements. This will be provided by the experiment installation design team. The internal conditions stated above will be used to inform the design of plant and services for each space unless specific requirements that differ from this are provided by LBNE/Sanford Laboratory or the lab experiment design teams.

The WCD experimental spaces do not require air conditioning or humidification. The drift temperatures are low enough that adequate cooling can be attained by a once through air only system (untreated air). Much of the experimental equipment will be directly water cooled by experiment-provided systems, and the heat rejected by that cooling system which will be integrated into the overall mine ventilation air flow scheme.

Per historical data, outdoor temperatures can drop to $-20°$F, therefore the intake air will

Table A–4: Environmental design criteria. (Arup).

Room	Temp	Humidity	Air Changes	Occupancy (during assembly)
Large Cavity	40–82 °F (10–28 °C)	15–85%	1	20 (50)
Access Drifts	Min 50°F (10°C)	Uncontrolled		Transient space
Utility spaces Electrical rooms	50–95 °F (10–35 °C)	Uncontrolled	1	
Areas of Refuge	68–78 °F (20–25.6 °C)	Uncontrolled	Min 20 cfm/person	Room Dependent
Storage Rooms	59–104 °F (15–40 °C)	Uncontrolled	Min 15 cfm/person	Room Dependent

require heating to prevent ice will build up in the shafts which could potentially disrupt hoisting operations and damage shaft support members, cables and piping. Heating requirements will be calculated based on the induced airflow volumes at Ross and Yates obtained from the mine ventilation calculations. The heating systems are designed as part of the surface facilities and not underground infrastructure.

The HVAC systems will be controlled and monitored via Direct Digital Controls (DDC), through the Facility Management System.

A.6.4 Electrical

The underground facilities at 4850L will have electrical power for normal operations as well as standby power for emergency occupant evacuation. WCD experiment power does not require standby power.

A.6.4.1 Normal Power

The electrical systems both at the surface and underground are designed to meet International Building Code and applicable portions of the National Electric Code and National Electric Safety Code. Underground portions also comply with National Fire Protection Code (NFPA) 520, which is specifically intended for underground facilities.

The estimated electrical loads for both the WCD experiment and the underground infrastructure serving the experimental spaces are included in the facility load determination and design. These loads are shown in Tables A–5 and A–6.

Table A–5: WCD electrical load. (Arup)

Item	Electrical Load	Notes
LC Water (PMT-HV)	3 kW	August 12, 2011 Table 1-200
LC-Deck	138 kW	August 12, 2011 Table 1-200
LC-Balcony	88 kW	August 12, 2011 Table 1-200
Crane	6 kW	
Total Estimated Detector Power	235 kW	
With 20% Uncertainty factor	282 kW	20% based on LBNE requirements

Table A–6: WCD underground infrastructure electrical load. (Arup)

Item	Electrical Load	Notes
Detector Lighting — assuming 1w/sq.ft.	32 kW	
Drift Lighting — assuming .5w/sq.ft.	45 kW	
Exhaust Fans	63.4 kW	
Water System	351 kW	August 12, 2011 Table 1-200
Sump Pump @ 5117 Level for experiment	127 kW	August 12, 2011 Table 1-200
Sump Pumps for 4850 level drainage system	75 kW	
Utilities in Drift	694 kW	August 12, 2011 Table 1-200
AoRs — anticipate total load	76 kW	100% PDR typical AoR.
Fire alarm	2 kW	
Communication	12.5 kW	
Security (future place holder)	12.5 kW	
Total Infrastructure Power	1490.4 kW	
20% Spare factor	1788.5 kW	
Total Load — Detector + Infrastructure	2070.5 kW	Includes 20% spare factor
Total Load assuming .9 Power Factor	2300.5 kW	

Power to serve the WCD experiment will originate from the Ross substation and routed down the Ross shaft to 4850L. One 15-kV mining cable shall be installed down the Ross Shaft to 4850L and will be cable rated for mine use, highly flame retardant, low smoke toxicity with high tensile strength and self-supporting. At 4850L, the 15-kV mining cable will terminate in 15-kV switchgear located in the substations.

Varying voltages will be distributed at strategic locations at 4850L for use by WCD and the facilities. To conserve space within the drifts, armored cable with low smoke properties will be used to distribute normal power wiring throughout 4850L.

The WCD experiment equipment will have a dedicated shielded transformer to serve the detector electronics at 208V/120V. In addition, WCD mechanical equipment will be fed from a dedicated transformer. On the mezzanine platform structure installed in the WCD utility drift, electrical panels and small transformers will serve equipment operating in the WCD cavity.

In order to preserve the possibility of upgrading the WCD experiment in the future, provision has been made to provide power for future pumps at specific levels in the shafts with this initial installation, since work will already be going on in the shaft. Dedicated feeders originating from either the 1700 level or 4100 level substation will serve the POGO pumps, which would be installed in the future.

A.6.4.2 Standby Power

Surface level generator sets, provided under the surface facilities and located near the Ross shaft will be installed to provide standby power for life safety. The following 4850L electrical loads are anticipated to be connected to the standby power system: emergency lights, exit signs, 4850L AoRs, fire alarm, security, and IT System for communications.

There will be one multi conductor 15-kV mining armored cable, with low smoke properties, installed down the Ross Shaft from the surface level standby generation system to provide standby power at the 4850L. A redundant, 15-kV multiconductor armored mining cable will be installed down the Yates Shaft to 4850L to provide a redundant path for standby power. The two 15-kV standby feeders will be tied together at 4850L through sectionalizing switches.

A.6.4.3 Fire Alarm and Detection

The 4850L level will have notification devices installed to alarm the occupants of a fire. Notification devices will consist of speakers and strobe lights. Manual pull stations will be provided at each egress and within 200 ft of egress. Phones will be installed in the AoRs to communicate with the Command and Control Center. An air sampling and gas detection system will be installed in the drifts and WCD cavity as an early detection of a fire condition. The air sampling system will be connected into the fire alarm system.

A.6.4.4 Lighting

Suspended lights mounted at a height just below the lowest obstruction will be provided for all drifts and ramps. Mounting is to be coordinated with conduit and supports of other systems running overhead. Maintained average illumination of approximately 24 lux (2.4 foot-candles) at floor level will be provided throughout the drifts. Lighting control in drifts will be via low voltage occupancy sensors and power packs suitable for high humidity environments.

Lighting within equipment rooms will be UL Wet Location rated, watertight fluorescent fixtures. Exact layouts will be coordinated with final equipment at future design stages. Lighting control in equipment rooms will be via switch only, avoiding possibility of unexpected lights-off triggers.

All light fixtures within the WCD cavity will be UL Wet Location rated watertight industrial high-bay type LED fixtures. Low voltage wiring will be oversized according to distance to avoid voltage drop from remote drivers to the fixtures. Average illumination levels at 0.7 m above WCD work deck is assumed to be between 100 and 150 lux (10–15 foot candles). All light fixtures will be controlled through a networked lighting control system allowing switching of multiple zones or circuits from multiple locations, and time schedule or other automated functions. Emergency light fixtures will be provided with 90 minute battery backup from a centralized system.

A.6.4.5 Grounding

The grounding system will be designed for a resistance of 5 Ω, to provide effective grounding to enable protective devices to operate within a specified time during fault conditions, and to limit touch voltage under such conditions. A dedicated grounding cable will be distributed from the respective level substation ground bars to the water detector chamber and from there to individual items of equipment and distribution board.

A.6.5 Plumbing

Several water systems are required for the experiment and the facility operations underground. All have as their origin the Lead municipal water service to the Sanford Laboratory. The requirements, routing, and use are described below.

A.6.5.1 Domestic Water

An 8-inch potable water line will run down the Yates Shaft from the surface to 4850L. It is not feasible to run an uninterrupted main water supply line from grade level down to serve the lower levels due to the extremely high hydrostatic pressure that would occur in the system. A series of pressure reducing stations will be located at regular intervals in intermediate levels in order to maintain the pressure within the capability of readily available piping. Each pressure reducing station will have 2 pressure reducing valve assemblies (PRVs), 1 duty, and 1 standby. On either end of each PRV, there will be a pressure transmitter which controls a motorized valve. Both the pressure transmitter and motorized valve will be tied to the Facility Management System. Pressure reducing stations will be located adjacent to the Yates shaft at 800L, 1700L, 2600L, 3500L, 4100L and 4850L.

A domestic water double compartment storage tank will be located at 4100L in an existing drift. Water will be supplied to the tank from the potable water service downstream of the PRV at 4100L. Downstream of the PRV, the 8-inch potable water line will split to serve the domestic water tank and the fire water system for 4850L. The domestic water storage tank will be 3,000 gallons that will satisfy 91 occupants in either the Yates or Ross AoRs. Domestic water will be supplied to all AoRs, the WCD cavity and all ancillary spaces requiring domestic water.

A.6.5.2 Drainage

Drainage from the drifts, mechanical electrical rooms, and any areas where spillage is likely to occur will be collected locally in open sumps. Sumps will be located every 500 ft. throughout the West drift, and in any areas where drainage to the drifts is not practical. Sumps will be equipped with sump pumps. This will be a staged system, with each pump discharging to the adjacent sump until water is discharged to the de-watering station near the Ross Shaft at 5000L.

Leaks from the WCD vessel, as well as native water inflow around the WCD, will be collected in a sump located at the base of the WCD at 5117L. A well pump will be located in this sump and will pump water to the drift drainage system at 4850L.

A.6.5.3 Sanitary Drainage

Plumbing fixtures in the AoRs at Ross and Yates Shafts (4850L) will be drained by gravity pipes embedded in the floor slab piped to a vented sewage pit. This pit will be equipped with a manually operated sewage ejector. The sewage ejector will be emptied by the facility maintenance staff into a portable container after a signal from the ejector control panel to the Facility Management System indicates that the sump is full. The sump will be sized to hold all fixture discharges for 96 hours in addition to the normal fixture usage in the facility (i.e. beyond the point where a signal is sent to empty the sump).

An atmospheric vent to the surface is impractical. A 4-inch vent from the sewage ejector will terminate in the nearest appropriate drift. Plumbing fixtures in each AoR will be vented using air admittance valves.

All small AoRs (10–20 occupants) will be equipped with chemical toilets and vented to the nearest drift.

A.6.6 Cyber Infrastructure

A fiber optic backbone provides communications for voice, data, and control of all systems on the surface and underground. Redundancy is built into the fiber-optic backbone by providing multiple cables to communication rooms at strategic locations throughout the site. Two separate backbone cables are routed between communication rooms (CR) along separate, diverse pathways to create a ring topology. Damage to the backbone at any point along the ring will not disrupt connectivity to the communication rooms. This design drastically improves the reliability and fault tolerance of the network systems.

Voice communications are provided via two-way radios and phones distributed throughout the underground spaces (in every room as well as every 500 ft. in the drifts). Two-way radios utilize a leaky feeder system to ensure communications over long distance without line of site. These leaky feeders are cables that act as antennas installed the length of all drifts and shafts. Phones utilize Voice over Internet Protocol to provide communication though the fiber optic data backbone.

The data system is designed to provide 10-Gigabit Ethernet in the backbone and 1-Gigabit Ethernet to connected systems (computers). This system is intentionally left at a lesser level of design due to the continuous progression and advancement of technology that will almost certainly result in more advanced technologies than are currently available being utilized at the time of construction.

A Command and Control Center at the surface will be the primary location for Human Machine Interface with the control system for both the underground mechanical and electrical systems and the experiment. This room will also provide a central location for the asset and personnel tracking system (APTS) included in the design to provide personnel tracking for safety and asset tracking for security using Radio Frequency Identification (RFID) technology to sense when people or assets pass specified areas.

Along with the APTS system, an Asset Control and Alarm Monitoring System provides security through programmable access control points and cameras to remotely control and monitor access to specified areas. This system could use key card technology similar to what is currently in use for security at the site or utilize similar RFID technology to that used for APTS.

The fire alarm and control system will be an isolated system from the remainder of the cyber infrastructure to ensure reliability of this system independent of the control system.

A.6.7 Structural/Architectural

The underground structural work mainly includes a structural steel deck in the WCD Utility Drift 4850-636 to support electrical equipment, experimental operations and make more efficient use of this high space. This deck will be designed as the equipment layout is finalized.

The underground architectural items are limited to cross drift fire separations, including minimum 2-hour fire separation walls and doors. These separations will also assist with directing mine ventilation. These items are shown on the Arup drawings.

A.6.8 Waste Rock Handling

Prior to the commencement of any excavation activities, it will be necessary to complete the rehabilitation of the facility waste rock handling system. The capacity of this system will be equivalent to what was in place during mining. There are a number of components to the Facility waste rock handling system, including refurbishing the Ross Shaft hoisting system, the Ross Shaft crushers, and the tramway; procuring track haulage equipment; and installing a surface conveyor to the Open Cut from the tramway dump.

The design presented here was developed for the DUSEL Project PDR by Arup/Tilley, is described in great detail in the DUSEL Preliminary Design Report, Section 5.4.3.9 and is excerpted here. The systems utilize experience and equipment from the former Homestake Mining Company legacy, where rock was removed to the surface using skips in both the Yates and Ross Shafts. At the headframe of each shaft, the material was crushed to a nominal 3/4 in., passed through ore bins, and was transported via underground rail to the mill system. The underground rail passed through a level called the tramway at approximately 125 ft (38 m) below the collar of the Yates Shaft. The third supply of ore was the Open Cut, where material was transported with haul trucks to a surface crushing system. A pipe conveyor (the longest in the world when it was constructed in 1987) delivered the material overland to the mill system.

During LBNE construction, the excavated waste rock material from the underground will be removed for disposal, with no intention of further processing. The Yates Shaft will primarily provide science access and will be rehabilitated during a significant portion of construction. The Ross Shaft will be the means of removing of material from the underground during construction.

The Ross skipping system allows material to be transported at a rate of 3,300 tons per 18-hour day, allowing six hours of downtime for maintenance, breaks, shift changes, etc. The loading pocket at 5000L for 4850L will be cleaned of any accumulated sand during the skip pocket rehabilitation prior to excavation starting. Several components of the rock removal system require rehabilitation, including the loading system, the skips, the scroll and the bin at the top of the headframe, the crushers, the electrical service equipment, the belt conveyors, and the dust collector. The gates at the base of the fine-ore bin at the tramway level ($\sim$125 ft [38 m]) below the Ross Shaft collar will be replaced. The existing rail cars are not large enough to meet the cycle times required for construction, but the axles and wheels can be reused with new bodies. New locomotives will be purchased. At the point where the tramway exits the underground, the existing steel-sided building is in disrepair and will be replaced. All other equipment associated with this material handling system, including the original pipe conveyor, has been removed from the site.

The waste rock from the excavation will be relocated to the Open Cut via an overland conveyor, similar to one used during Homestake Mining Company operations, and the design team has been mindful of the impact this activity may have on the local community. The design will accommodate more stringent noise and dust requirements than other portions of the Project may require. In an effort to limit public exposure to this process, all material will be transported through residential areas only during a 10-hour daytime period, which requires a higher design capacity than a 24-hour operation would allow. A limit of 45 dBA at the property boundary has been established to further minimize the public impact. Extreme weather conditions experienced in Lead, South Dakota, must also be considered in the development of design requirements. The route of the waste rock handling system is shown in Figure A–34.

The design excavation volume with allowances for rock support and shotcrete will be approximately 484,000 cubic yards (yd^3; 371,000 cubic meters [m^3]). Assuming an average of 10.5 in (0.27 m) of combined overbreak and lookout, with a 50% swell factor, the total volume of waste rock is expected to be approximately 749,000 yd^3 (573,000 m^3). A detailed summary of each excavation volume is provided by Golder Associates[**?**].

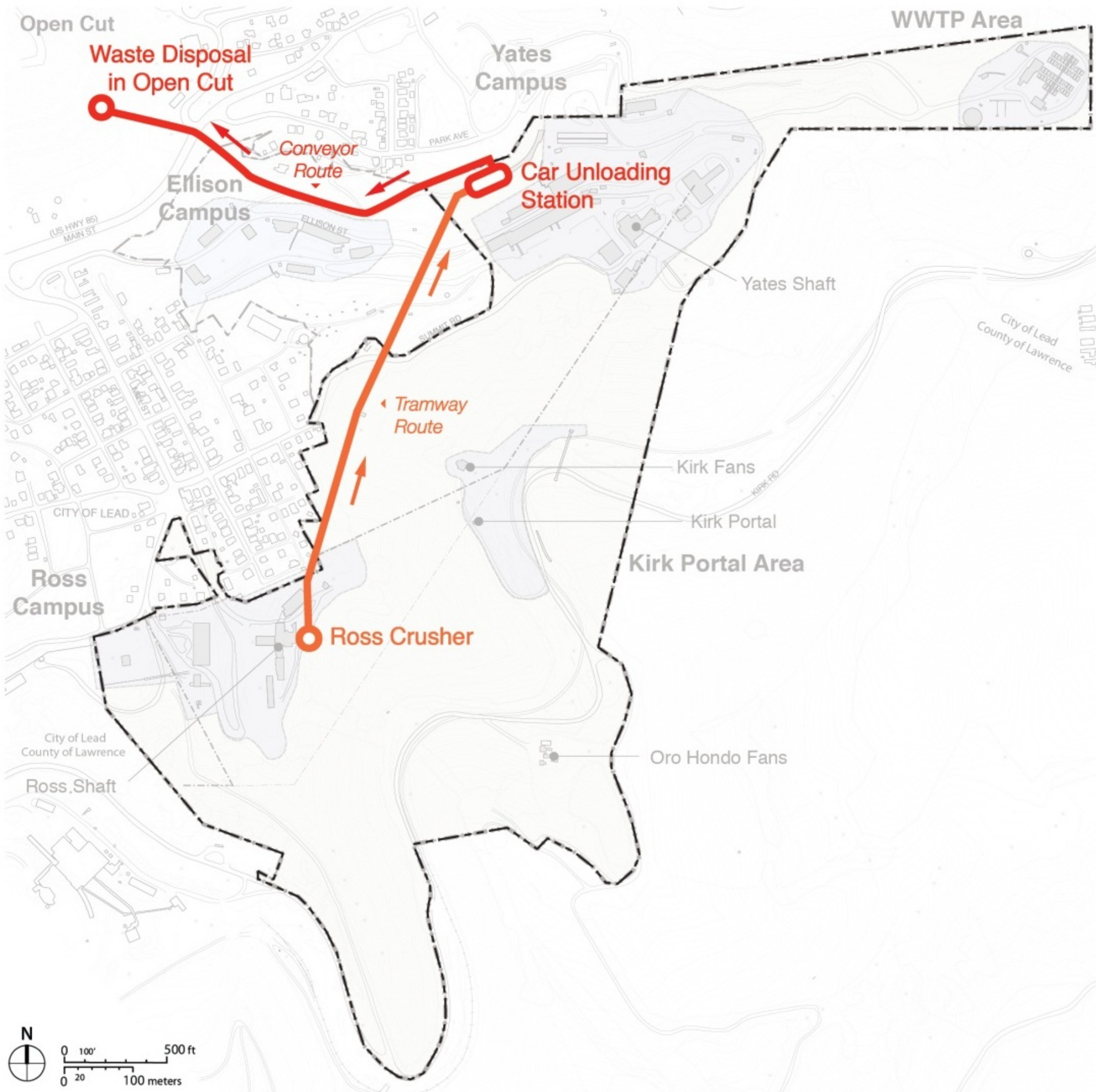

Figure A–34: Waste Rock Handling System route. (Dangermond Keane Architecture, Courtsey Sanford Laboratory)