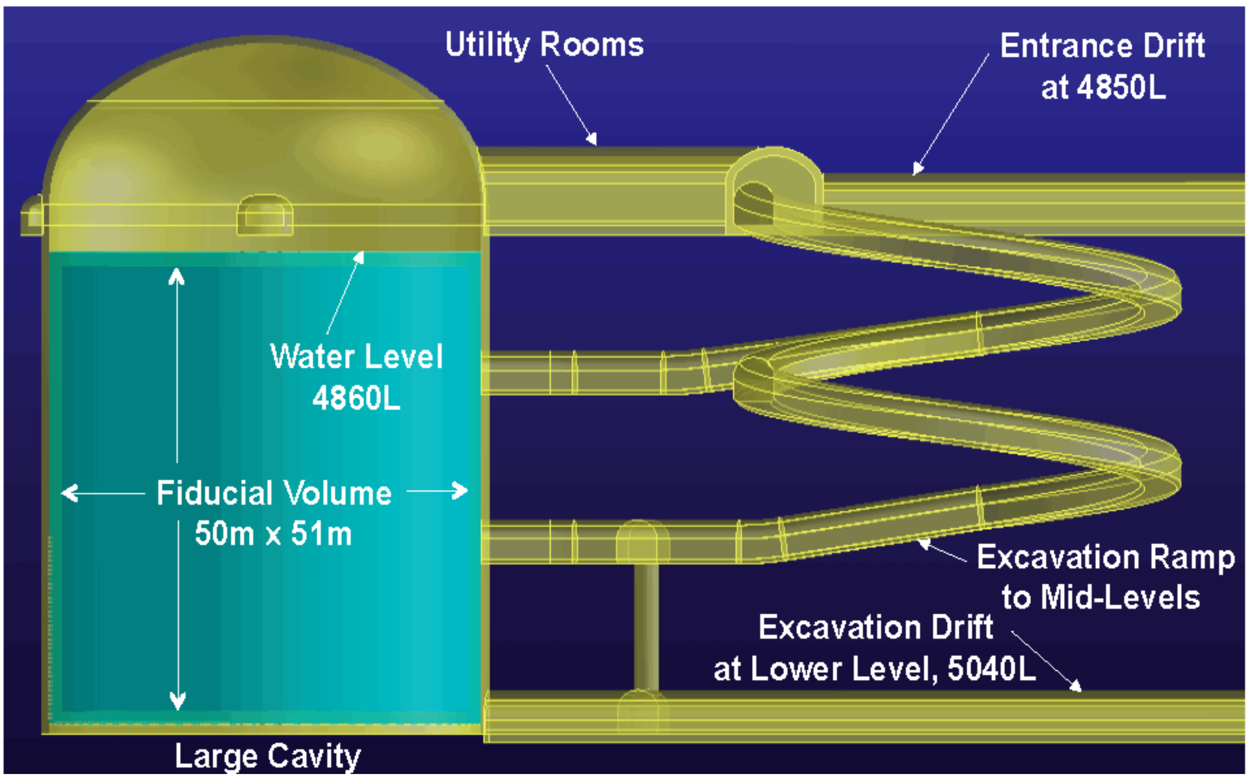
Long-Baseline Neutrino Experiment (LBNE) Project

Conceptual Design Report

Volume 4: The LBNE Water Cherenkov Detector

March 23, 2012



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12 Environment, Safety and Health (WBS 1.4.8.4)

WCD safety involves coordination with the LBNE safety committee and the Sanford Laboratory safety organization. Sanford Laboratory has responsibility for safety throughout the local site and establishes requirements and expectations that user facilities, such as WCD, must meet. The WCD safety organization implements those requirements and has direct responsibility for the day-to-day safety of the WCD experiment, and maintains compliance with the LBNE Integrated Environment, Safety, and Health Management Plan[**?**]. The WCD Safety Officer will serve as a member of the LBNE Safety Committee. The organization and primary responsibilities of the WCD, LBNE and Sanford safety organizations is shown in Figure 12–1.

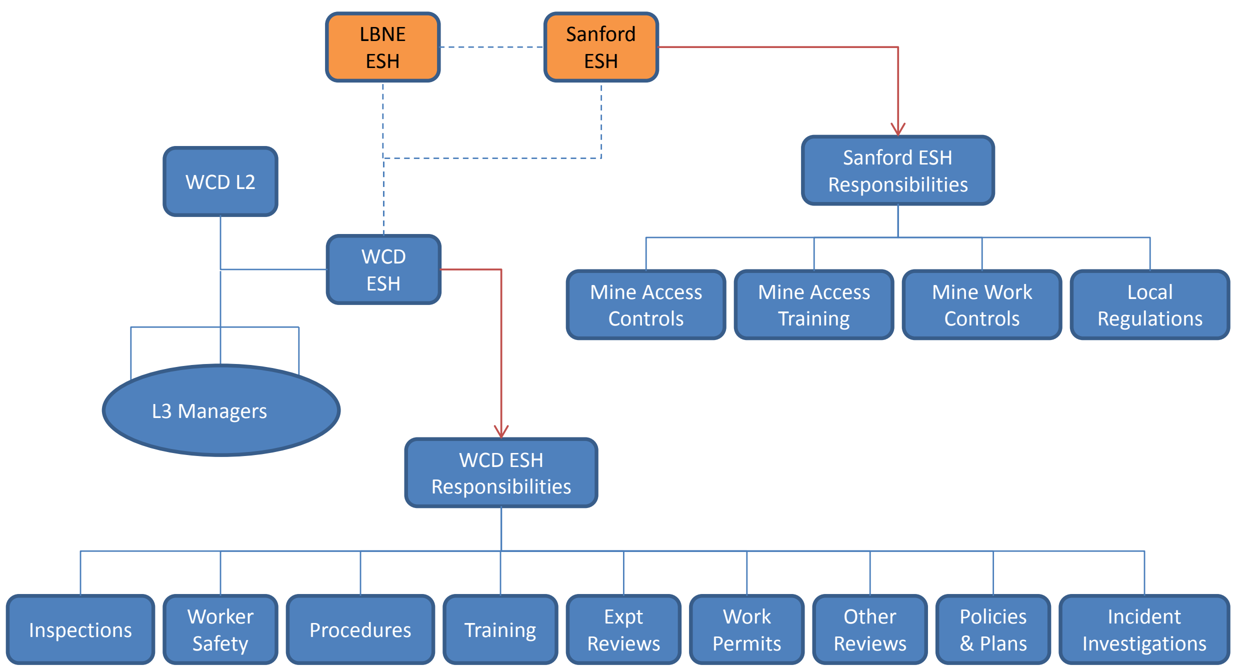

Figure 12–1: WCD safety organization chart

A WCD Safety Committee will be established that includes the WCD Safety Officer, a Local

Safety Officer (LSO), who will be stationed at the site, a WCD project engineer, a WCD project scientist, and a representative from the Sanford Laboratory safety organization. The proposed structure of the WCD ESH Committee is shown in Figure 12–2. Additional experts

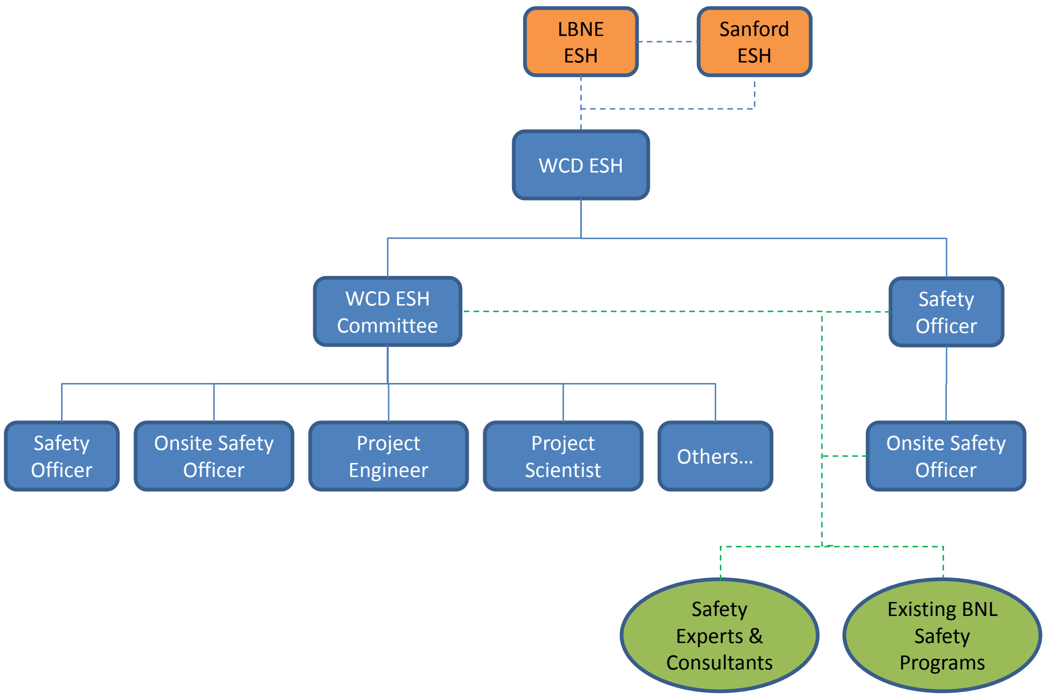

Figure 12–2: Proposed structure for the WCD safety committee.

may be added to the committee or consulted as needed.

The WCD Safety Committee responsibilities include:

- establishing safety procedures and rules
- establishing training requirements and courses that are needed to supplement Sanford training requirements
- to review and approve all planned work, installation and operational procedures, and other activities
- to represent safety concerns at all engineering and design reviews
- to conduct incident investigations and report findings to management
- and to report to Sanford Laboratory and LBNE safety organizations

The LSO will reside at the site and be charged with implementing safety requirements that are established by the WCD, LBNE, and Sanford safety committees. The LSO will oversee working conditions, perform safety inspections, assist in training and maintaining training records, report incidents and injuries to safety management and perform other activities necessary to ensure a safe working environment.

Training courses from Brookhaven National Laboratory (BNL) will be used as the basis for training that is required for WCD, but not available from Sanford. These courses may be modified to reflect local conditions or requirements, as needed.

The WCD must comply with all applicable federal, state and local regulations. To accomplish this, we will implement an Integrated Safety Management System (ISMS) to ensure that all stages of the project, planning, design and physical work are performed with attention to the potential hazards. This system will encourage supervisor and worker interaction, and a shared responsibility for safety among all parties.

Work can begin only after a successful safety review or hazard analysis and approval by the WCD safety committee. WCD will establish formal procedures where necessary to ensure that work is done safely and correctly. The reviews are part of a safety system that includes compliance with OSHA 29 CFR 1910 and 29 CFR 1926 standards. The WCD project is committed to meeting those requirements.

12.1 Hazard Analysis

All work will be reviewed for safety and environmental concerns. These reviews will:

- Define the scope of the work
- Identify and analyze the hazards associated with the work
- Develop and implement hazard controls and assess risks
- Provide a basis for working within the controls
- Provide a mechanism for feedback for continual improvement

In addition, engineering reviews and external reviews for tasks or procedures will be performed as warranted. Approval by appropriate supervisors and safety committees is required before work can begin. Workers on an approved project will be required to read and sign the approved safety review or work plan, indicating that they understand the hazards, risks and controls, before they begin work.

All workers and other participants are responsible for safety. They must individually ensure that they and their coworkers understand the tasks, hazards and risks involved, and how to implement controls or utilize existing controls to mitigate these hazards and risks. Controls are applied using the following hierarchy:

1. Elimination or substitution — change the process so that the hazard is removed
2. Engineering controls — use a physical system or barrier to avoid exposure to the hazard
3. Administrative controls — use procedures or rules that reduce the likelihood of the hazard leading to an event
4. Personal Protective Equipment (PPE) — use clothing or devices that reduce the impact of a hazard

Supervisors must seek feedback from workers to improve procedures, controls, and working conditions. All personnel will be given the authority to stop work if and when they perceive an unsafe working condition.

As required by ISMS, the ongoing design, assembly, installation and operation of the WCD will be reviewed on a regular basis to identify any necessary changes or additions to the identified job hazards and the associated mitigation procedures. The reviews will occur at least annually or more frequently if necessitated by changes to the system design and/or operation. Regular walk-throughs of the experimental areas will be included as part of the on-going hazard review.

12.1.1 Identification of Hazards

This section identifies potential hazards, the corresponding safety concerns and the apparatus and/or activities around which or in which these hazards are present. This hazard identification is part of the LBNE Project Preliminary Hazard Analysis Report[**?**]. Tables 12–1–12–3 list the general hazard categories for the WCD and specific examples. Hazard assessment for the WCD covers the entire experimental program, but is not intended to supersede safety programs at institutions or facilities where work is performed. At a minimum, those institutions are expected to work in compliance with federal, state and local regulations and agencies that apply, as well as any additional WCD-imposed procedures that apply.

The construction phases of the experiment will involve some contracted work. Environment, safety, health and quality requirements are specified in contracts from the issuing institution or organization. At a minimum, contractors will be expected to follow contractual obligations, to comply with applicable federal, state and local regulations and agencies, and to follow any WCD-imposed procedures or requirements.

Table 12–1: Experimental Systems Hazards.

Hazard Type	Hazard	Safety Concerns	Equipment or Activity
Electrical	Electrical shock Electrically induced fire Arc flashes	Electrocution or shock injuries Burns from electrically induced fire Arc flash injuries	Photomultipliers (PMTs) Low-voltage power supplies Energized electrical equipment Magnetic field compensation coils General electrical use
Material handling and rigging	Lifting objects Falling objects	Being struck by falling or dropped objects Muscle injuries from handling heavy objects	Storage of materials and equipment above ground Transfer of equipment from surface Transfer of equipment or personnel inside detector vessel Lifting in place at detectors Operation of small rail cars, forklifts
Working at heights	Falls Dropped objects	Injuries from falling Being struck by falling or dropped objects	Installing PMTs, electronics and cables Repairing and calibrating detectors
Oxygen deficiency	Low oxygen concentration	Asphyxiation Injury or death from low oxygen atmosphere	Gas blanket over pool Gases emitted from mine Air circulation
Pressurized systems	Low oxygen concentration Explosion due to overpressure Sudden release of energy	Asphyxiation Injury or death from low oxygen atmosphere Muscle and skeletal injuries	Gas blanket over water volume Transfer of gas cylinders Water circulation and purification
Cryogenic systems	Low temperature fluids Low oxygen concentration Explosion due to overpressure Sudden release of energy	Frostbite to skin Asphyxiation Injury or death from low oxygen atmosphere Muscle and skeletal injuries	Gas blanket over pool
Water pool	Falling into water	Drowning Hypothermia	Work in proximity of pool Inspection of tank interior

Table 12–2: Experimental Systems Hazards (continued).

Hazard Type	Hazard	Safety Concerns	Equipment or Activity
Chemical	Acute and chronic exposure Toxicity Corrosives Explosions	Skin and eye injuries Poisoning due to exposure Long and short term health effects Muscle and skeletal injuries Allergic reactions	Water-treatment chemicals Cleaning agents Adhesives Exposure during liner application or installation
Radiation	Radiation exposures Personnel contamination	Long term health effects	Calibration sources Radiation-generating devices Exposure to radioactive gases (Radon), dust, or minerals
Lasers	Intense laser light High energy laser beams	Eye injury Skin burns	Calibration and testing of PMTs Survey equipment
Non-ionizing radiation	Radiation with wavelength longer than 100 nm	Heating of body tissues	UV lamps in water system Accelerator power supplies
Environmental	Waste handling and disposal Spills and leakage	Personnel exposure to toxic wastes Environmental damage or contamination	Broken PMTs Water treatment chemicals Oil/fuel from vehicles, generators
Underground events	Rock fall or fracture or seismic events Ventilation failure Flooding	Muscle or skeletal injury or death from falling rocks Injury or death from low oxygen atmosphere Exposure to toxic or radioactive gases or minerals Drowning in flooded area Claustrophobia	Occupation of and work in underground spaces

Table 12–3: Experimental Systems Hazards (continued).

Hazard Type	Hazard	Safety Concerns	Equipment or Activity
Welding and cutting	Flammable welding gases Fires Explosion	Burns to personnel Eye injury Muscle and skeletal injuries	Assembly of detector Maintenance and repair
Fire and smoke	Entrapment by fire Asphyxiation	Smoke inhalation Skin burns Injury or death from low oxygen atmosphere	Liner storage, staging and installation PMT cable storage, staging and installation General conditions and concerns
Stored energy	Explosion Arc flash PMT implosion	Muscle and skeletal injuries Cuts and abrasions	Electrical service Compressed gases Hydraulic systems PMTs
Routine work	Slips, trips and falls Cuts, lacerations, and abrasions Low overhead clearance Ergonomic conditions Low light levels	Muscle and skeletal injuries	General working conditions DAQ and computer operation and use Office-type work
Confined spaces	Entrapment during emergency or injury Injury or death from low oxygen atmosphere Chemical exposure due to poor ventilation	Entrapment, asphyxiation, chemical exposure Claustrophobia	Entry into cavern or other excavations

12.1.2 Mitigation of Hazards

Many of the hazards we need to prepare for are those typically found in any scientific laboratory for which controls and mitigation techniques are addressed in their Environment Safety and Health manuals. Other hazards are associated with non-routine activities, such as underground work, that require additional consideration.

Training will be an important component of hazard mitigation. The WCD Safety Committee will be responsible for ensuring that training course are developed when necessary training is not provided by the Sanford facility. All workers will require underground access training, which is expected to be provided by the Sanford facility. Personnel will be assigned other training based on safety-review and work-permit requirements and supervisor input. Training records will be maintained in a project database, or by employing an existing database at one of the collaboration institutions. Each work plan will specify the training requirements, and require a pre-job briefing to confirm that the training is current.

The following section discusses mitigation strategies for the anticipated hazards associated with the WCD, both at the detector location and at collaborating institutions. This is not a complete list, but it serves to illustrate the processes employed to apply hazard identification, hazard mitigation through controls, and personnel protection. All hazards and controls are described and reviewed as part of the work-planning phase of ISMS.

12.2 Identified Hazards and Controls

This section lists the hazard types associated with the WCD and their mitigations.

12.2.1 Electrical Hazards

Electrical hazards exist in the installation, operation, and maintenance of a wide variety of equipment. Most of the work will involve low voltages (<50 VDC), where the primary concern is for arc-flash hazards associated with high-current devices. High-voltage, low-current power supplies are used for PMTs; low-voltage DC power supplies are used for preamplifiers and associated electronic modules; low-voltage, high-current power supplies are used for magnetic field compensation coils, DAQ electronics and interfaces such as VME; and typical "household" AC is used for general purposes, including supplying power to the mentioned power supplies, computers and associated equipment, and lighting. Electrical work will be performed in compliance with NFPA 70E.

Controls:

- All purchased electrical equipment will be rated by a nationally recognized testing laboratory (NRTL), or be verified as equivalent by an appropriate local authority.
- Lock out tag out (LOTO) will be used to reduce the risk of shock hazards whenever voltages could exceed 50 volts and the worker cannot disconnect or directly control the source of power.
- Other common low-hazard electrical work will involve high-voltage, low-current (<10 mA) devices, for example PMT power supplies. The current limit of these power supplies prevents harmful electrical shock.
- Work on electrical or electronic devices is done with power off whenever possible. Working "hot" is not allowed for voltages exceeding 120 VAC unless a working-hot permit is completed by the worker and approved by the supervisor. Working hot on line voltages above 208 VAC is allowed only for qualified linemen using Personal Protective Equipment (PPE) required for the work.
- Electrical terminals will have a physical cover over them wherever accidental contact is a concern.
- Damaged cords on electrical equipment will be replaced before use.
- Cables and connectors for high voltage, signals or power will be rated for the intended task.
- The working environment (e.g., contact with water) will be considered before choosing connectors, housings, and cables.
- AC power cables will kept separate from PMT cables, and from other utilities when placed in cable trays.
- All cabling must meet specifications for the environment, e.g., in or near ultra-pure water, in which it will be used or installed. Cabling and any associated fire suppression systems must be approved by project engineering and fire safety reviews.
- Electrical safety training will be required for any work with exposed electrical components.
- Final installation of electrical service will include testing and certification of the safety ground to prevent against shock hazards due to poor grounding. The grounding and power supply safety for the magnetic field compensation coils must also be tested and verified before installation.

12.2.2 Material Handling and Rigging Hazards

Lifting and material-handling equipment, which includes elevators, hoists, cranes, forklifts, and so on, are used to move or place items too large to be safely handled manually. This hazard is present when unloading large, purchased equipment, transporting it, and installing elements of the experiment. Operations both above-ground and underground are subject to this hazard. Material handling and rigging work will be in compliance with OSHA 29 CFR 1910 Subpart N.

Controls:

- Operators of hoisting or rigging equipment, including forklifts, must be trained and authorized to use this equipment.
- All material-handling equipment will be inspected annually, and lifting attachments, such as slings, will be inspected for any wear or damage before each use.
- All personnel in the area must wear hard hats and safety shoes when a lift is performed.
- Procedures for lifts of critical equipment will be reviewed and approved by project engineers prior to the work.

12.2.3 Working at Heights

Assembly of detector tanks and installation of detector components will require working at heights in excess of four feet, and possibly scaffolds exceeding six feet. This may include work on platforms and using a human-occupied gondola or mast climber. All work at heights will be in compliance with the OSHA fall protection standard, 29 CFR 1926.500.

Controls:

- As their jobs call for it, workers' training will include working at heights. They will also receive any medical evaluation to meet worker qualification requirements.
- OSHA-compliant railings and fall-suppression equipment will be used where required.
- We will inspect fall-protection equipment for wear and other maintenance issues before each use.
- All personnel in the vicinity will wear hard hats when performing work at heights above six feet.

12.2.4 Oxygen Deficiency Hazards

Ventilation failure or escape of nitrogen from the detector gas blanket into an occupied space could cause low-oxygen conditions. Once the overall parameters of the system are established, an analysis will be performed to determine the level of hazard, if any, that exists. An alternate system would use radon-free air in the gas blanket instead of an inert gas and would not present an Oxygen Deficiency Hazard (ODH) condition, but the presence of oxygen may negatively impact water quality. Hazards will be analyzed and work performed in compliance with OSHA 29 CFR 1910.134.

Controls:

- Oxygen-level sensors will be installed if the ODH calculations indicate they are warranted, and emergency plans will include response to ventilation failure and ODH alarms.
- Personnel will be trained to properly respond to ODH and other emergencies, and to follow established evacuation procedures. Personnel training requirements will include those for work in ODH areas.
- Oxygen sensors, if utilized, will be tested, calibrated and maintained on a regular schedule.
- The blanket volume is expected to be 2300–4800 m^3 and separated from the occupied deck by a gas barrier. The volume above the deck is expected to be more than 3000 m^3 larger than the gas blanket volume. Leaks from the gas blanket would not likely exceed the gas flow rate, which further reduces the potential asphyxiation hazard.

12.2.5 Pressurized Systems

Pressurized systems include compressed-gas cylinders, pressurized water, hydraulic systems, and reverse-osmosis purification systems. Compressed gases are used in the nitrogen gas blanket and for other activities such as soldering and welding. Other pressurized systems include water circulation and purification. Work with pressurized systems will be in compliance with 10 CFR 851.

Controls:

- Compressed-gas and hydraulic systems will use components rated for the intended application and operating range. Any custom components will be tested to 150% of the rated pressure.

- Cylinders will be fixed to stationary objects; regulators rated for the gases used and pressures required will be installed.
- Pressure relief devices will be installed in pressurized lines and chambers.
- Backflow prevention valves will be used if there are mixed gas systems in use.
- Personnel who use and transport gas cylinders will complete a safety training course for this task.
- Pressurized water systems, including reverse osmosis purification systems will be equipped with pressure relief and backflow prevention valves.
- Personnel who operate the water system will be trained and authorized.
- Pressurized systems will be inspected on a regular basis, at least annually.

12.2.6 Cryogenic Systems

Cryogenic systems may be used as a source of dry nitrogen for the gas blanket, and for other purposes, such as to cool detectors used for calibration or analysis. They will be located above or underground, as required for their application. Work with cryogenic systems will be in compliance with 10 CFR 851.

Controls:

- Cryogenic storage and piping systems will be constructed of materials rated for cryogenic use and equipped with proper pressure relief valves to prevent bursting and uncontrolled venting of cold gases.
- Cryogenic systems, whether located above or underground, require review and approval before installation and operation.
- Persons handling dewars will wear appropriate PPE and use approved carts to move dewars.
- Personnel will be trained in the proper handling of cryogenic liquids, dewars and material handling equipment.
- Analysis of the planned storage and use of cryogens may indicate a need for oxygen monitors, ODH training, or other mitigation strategies.

12.2.7 Water Pool

After the PMTs are installed and the tank filled with water, no nonessential entries into the water tank will be allowed. Any access will require an extensive safety review. However, it is possible that a worker may fall into the water during work on the deck structure. In this case, the worker could drown or suffer from hypothermia, since the water will be maintained at 13○C. Work requiring entry into, or possibly falling into the water vessel will follow the relevant OSHA 29 CFR 1918.105 requirements.

Controls:

- The deck structure will be designed to reduce the likelihood of falling into the tank during normal work. In the event that work requires spaces open to the water, the specific circumstances and work to be performed will be evaluated and, when necessary, fall prevention devices will be used, water rescue devices will be available, and a two-person rule will be imposed.
- A training course on techniques for water rescue will be developed.

12.2.8 Chemical Hazards

Most chemical use will involve cleaning and degreasing agents, such as alcohol, glues, epoxies and other bonding agents, and water treatment chemicals. If a spray-on liner material is used, that will also present a chemical exposure hazard to workers who are applying the liner material, and to other workers who may be exposed to vapors during the curing period. Potential hazards include eye injuries, skin injuries, skin sensitization, inhalation, and ingestion of toxic chemicals. Gadolinium sulfate may be added to the water to enable the detector to observe neutrons with high efficiency. For this purpose, a 0.1% gadolinium solution would be maintained, requiring about 200 tons of gadolinium sulfate per 100 kTon tank. Except for water treatment, which includes gadolinium sulfate, and chemicals for applying the vessel liner, chemicals will be used in bench-top quantities that are easily handled by a single person. Chemical work will comply with the relevant OSHA 29 CFR 1910 Subpart Z requirements.

Controls:

- The Material Safety Data Sheet (MSDS) for each chemical in use will be available to all workers, either in printed form or via an electronic database.
- A chemical inventory will be maintained; chemicals will be entered into the inventory when received, and removed when the container is emptied or discarded.

- All personnel using chemicals will be trained to understand the hazards of the chemicals they use. Personnel involved in water treatment will receive job-specific training that will include chemical hazard awareness.
- All personnel working with chemicals will use the proper PPE, including protective eyewear, clothing, and gloves appropriate to the chemical(s) in use.
- The gadolinium content of water will require monitoring at sumps for each tank location and the underground facility pump-out station to maintain effluent concentrations in compliance with environmental regulations.
- A monitoring plan will be developed to assess leak rates and, if possible and necessary, reclaim water loss.
- If the vessel liner is a spray-on application, those chemicals could represent an exposure hazard. Exposures will be controlled by supplying sufficient ventilation, limiting work time, use of filtering or air supplied respirators, or a combination of these mitigating controls.

12.2.9 Radiation Hazards

Personnel will be exposed to radiation from radioactive sources or radiation-generating devices during detector calibrations, and from exposure to radon from the rock in the detector excavation. Another risk from use of radioactive sources includes contamination to personnel and equipment due to failure of a source containment. The use of certain radiation-generating devices, for example a neutron generator, could cause activation of materials and exposure of personnel from the primary beam and/or activated materials. Work with radiological materials or radiation generating devices will be in compliance with 10 CFR 835. ALARA (As-Low-As Reasonably Achievable) principles will be followed in planning and reviewing radiological work. ALARA requires that workers and line management understand radiological hazards, are properly trained, incorporate steps in their work planning to minimize radiological risks, and are accountable for radiological performance and compliance.

Controls:

- An inventory of radioactive sources will be maintained and verified annually.
- Radioactive sources will be stored in a locked cabinet and away from public access.
- Personnel using radioactive sources will be trained to understand the hazards involved and proper handling techniques.
- Radiation monitoring devices will be used (e.g., TLDs) if required.

- If a source needs to be put into the detector water, it will be checked for leakage before and after use to check for possible contamination of the water.
- Operators of radiation generating devices will be trained on the proper operation of each device.
- Radiation-producing devices will be stored and operated in such a manner as to preclude measurable radiation exposure above background levels in public areas, e.g. neighboring access drifts to adjacent experiments.
- Operation, maintenance, and interlock testing logs will be maintained for radiation-generating devices, if the level of radiation warrants such controls.
- Exposure to radon will be controlled by the ventilation system.

12.2.10 Laser Hazards

Lasers may be used to test and calibrate PMTs, in survey instruments, and other applications. For calibration, the laser output will be connected to a fiber or diffuser ball that distributes the light to the PMTs being tested. Survey instruments use low-hazard lasers. Laser light may also be distributed over a large region inside the water vessel. The laser class and output power will be determined by the specific requirements of the PMTs and light-distribution system. Use of lasers will comply with ANSI Z 136.1 Safe Use of Lasers.

Controls:

- The lasers will be evaluated by a laser safety officer to determine if specific written operating procedures or interlocks are required (class 3B and 4), and what protective eyewear is required.
- Areas where lasers are in use will be posted with warning signs .
- Personnel operating lasers will have training in safe operation and use of the system, and use appropriate protective eyewear and other PPE.
- Personnel operating class 3B and 4 lasers will have laser medical eye examinations prior to use of such lasers.

12.2.11 Non-ionizing Radiation Hazards

Non-ionizing radiation includes exposures from ultraviolet light sources, intense magnetic fields, accelerator power supplies, and microwave sources. A primary concern in the WCD is the use of UV lamps for sterilization in the water purification process. All work involving non-ionizing radiation will be reviewed for acceptable exposures. The BNL non-ionizing radiation exposure limits, which summarize the ACGIH and OSHA 29 CFR 1910.97 limits, will be used to determine allowable exposures. Consumer microwave ovens for food preparation, video display terminals, consumer telecommunication equipment and heat lamps used in food service are exempt from these requirements.

Controls:

- Non-ionizing radiation devices will be identified and evaluated for their potential exposure.
- Devices capable of producing non-ionizing radiation in excess of limits will be labeled to warn of the potential exposure.
- Areas where non-ionizing radiation exposure potential exists will be posted with appropriate warnings, or interlocked.
- Procedures for routine maintenance or replacement of components (e.g., UV lamps) will be developed.
- Personnel who routinely work within areas where an exposure above the limits is possible will be trained in non-ionizing radiation safety.

12.2.12 Environmental Hazards

Environmental hazards include waste disposal and possible contamination of subsurface water at the detector site. Wastes may include broken PMTs, oils and fuels from vehicles in underground areas, cleaning solvents, adhesives, gadolinium sulfate, and water-treatment chemicals. Wastes will be handled and disposed of in compliance with federal and local regulations.

Controls:

- Hazardous waste will be stored in closed containers, clearly marked as hazardous waste, with the hazardous content listed, the name of the waste generator, and the date the waste was generated.
- Liquid wastes will be stored with secondary containment so that waste cannot enter the ground due to a leaking container.
- Wastes will be stored in containers suitable for the waste material and incompatible wastes will be stored separately.
- Wastes will be stored in designated locations.

12.2.13 Underground Events Hazards

Working underground presents hazards associated with geology, air circulation, exposure to gases, exposure to naturally occurring radioactivity, fires, operation of vehicles in confined areas, and flooding of work areas. Geological hazards such as underground collapse, earthquakes, and other seismic events will be evaluated by qualified engineers. Falling rock or rock fractures could result in debris that presents a hazard to both personnel and equipment. Human performance factors, such as fatigue, also play a role in underground work hazards.

Controls:

- Plans will be formulated for evacuation in case of emergency. The working areas will be evaluated for life safety and means of egress, in compliance with federal regulations.
- Access will only be permitted in compliance with established access rules, and a two-person rule will be enforced.
- First aid supplies will be located in proximity to work areas, and will be stored in water resistant containers.
- Monitors for oxygen levels, toxic gases, fire, smoke, and radiation will be installed if it is determined that these are needed to enhance safety for occupancy.
- Personnel will be trained on the proper response in case of an emergency and will participate in drills that are required.
- Vehicles operated underground will only be operated by trained personnel.
- Hard hats will be required in areas where exposed rock faces could result in falling rocks.
- To address radiation exposure and human performance factors, a time limit for continuous underground work or occupancy will be considered.

12.2.14 Welding and Cutting Hazards

Welding and cutting operations may be performed by contractor personnel or collaborators, depending on the extent and nature of the work. The work may be performed in machine shops, on or off the detector site, in surface assembly areas or underground. Welding or cutting will comply with OSHA 29 CFR 1910 Subpart Q. The hazards of these tasks include:

- Burns from contacting hot objects, from sparks or molten metals or from accidental contact with welding heat devices,

- Eye injury from high intensity welding light emissions,
- Impact of debris from shattered cutting wheels,
- The dropping or falling of heavy objects being welded,
- Fires started from high temperature operations.

Controls:

- Welding and cutting operations will be carried out by qualified workers.
- Workers will use the appropriate PPE, tinted goggles, welding helmets, heat resistant gloves, and proper clothing.
- Work areas will be kept free of flammable debris to reduce the risk of fire.
- Operations that must be done in the presence of flammable material will utilize an additional worker as a fire watch.
- Compressed welding gases will be used, stored and maintained in compliance with OSHA regulations and local requirements.
- Jigs and lifting devices will be used where needed to reduce the likelihood of heavy objects falling on personnel while welding or cutting.

12.2.15 Fire and Smoke Hazards

Hazards from smoke or fire are present in all phases of any project. Storage and installation of cables and liner materials represent perhaps the most significant fire hazard. Although when the vessel is filled with water the hazard is minimized, there will remain exposed liner material above the water line and substantial amounts of combustible cables will remain on the deck. During installation, all of the installed cable will be exposed as a potential fuel source. Hazards due to combustion in laboratories and work areas, above- or below-ground, include: asphyxiation; smoke inhalation; severe or minor burns; and entrapment due to fire. Fire protection will be in compliance with OSHA 29 CFR 1910 Subpart L.

Controls:

- Work areas will be kept in good order, minimizing the accumulation of flammable and combustible materials, maintaining good egress paths, and careful use of open flames and heat-producing equipment.
- Evacuation plans will be developed for the detector site.

- Personnel will participate in fire and evacuation drills.
- Fire suppression systems are being investigated to mitigate the underground cable-storage and vessel liner hazards during installation and operation. Cable storage above ground also represents a fire hazard and may require suppression systems to protect against material loss and personnel injury.

12.2.16 Stored-Energy Hazards

12.2.16.1 Conventional systems

Stored-energy hazards will be present in electrical service, compressed gases, hydraulic and other pressurized systems. The hazards include explosions, electrical-arc flashes and other rapid energy releases that can lead to burns, muscle and skeletal injuries. Work with stored energy systems will be performed in compliance with OSHA 29 CFR 1910.147.

Controls:

- Hydraulic and pressurized systems will be affixed with appropriate pressure-relief devices and will be rated and designed to comply with relevant standards and ASME codes.
- Electrical equipment will be installed and constructed to meet the appropriate electrical codes and the NFPA 70E codes.
- Workers involved with operation or maintenance of devices with stored energy will be trained on the potential for injury or system damage for each system.
- Procedures will be developed for safe operation and maintenance, where applicable.
- Lockout-Tagout (LOTO) procedures will be developed for stored energy systems.

12.2.16.2 Photomultiplier Tube Hazards

The number and size of PMTs in the experiment represents a special hazard with respect to stored energy. Due to the large evacuated volume and thin glass used, a PMT that breaks produces very sharp fragments that can easily cause cuts to personnel. Individuals must be protected from implosion of a PMT during installation, and the entire system of PMTs must be protected against a chain reaction of imploding PMTs caused by the failure of a single one. Studies are being performed to understand the magnitude and propagation of pressure waves from an imploding PMT.

Controls:

- The required PPE during handling PMTs will include appropriate eye protection, non-slip cut-resistant gloves, long-sleeved shirt, long pants and closed-toed shoes.
- In high bay or construction areas where there is a danger of falling objects from above, a hard hat is also required.

12.2.17 Routine Work Hazards

We must also address hazards that can be found in any machine shop, laboratory or office space. This includes slips, trips and falls on working and walking surfaces, repetitive stress injuries, fires, cuts and abrasions from using common tools, and so forth. During winter weather additional hazards of walking through snow and in icy conditions, driving on-site in inclement weather, tornados and severe thunderstorms for surface buildings. Some underground areas may have low overhead clearance, others may be noisy environments. Working with PMTs could result in lacerations from accidental breakage of the glass enclosures. Another working concern is the potential transfer of dust, which may contain naturally occurring radioactivity to the WCD, or from the WCD to other low background areas.

Controls:

- Working and walking areas must remain clear of debris, and be well lighted to reduce the likelihood of slips, trips and falls. Routine walk-throughs will be performed to check and correct these conditions.
- Areas requiring PPE such as hard hats and hearing protection will be be clearly marked.
- General worker training will include awareness of areas requiring PPE and the importance of following those requirements.
- Personnel will be trained on the proper response in case of an emergency and will participate in drills.
- Underground access will only be permitted in compliance with established access rules, and a two-person rule will be enforced.
- The collaboration will arrange for timely snow removal and keeping walkways clear of ice.
- Procedures for removal of dust before entering or leaving areas will be established if it is determined to be necessary.

12.2.18 Confined Space Hazards

Work within the excavated caverns may qualify as confined space work, depending on egress paths and the nature of hazards within those spaces. Entry into the excavations will be performed according to safety standards, which are developed from applicable OSHA and MSHA regulations. Personnel working will be trained to understand and recognize the hazards of such work. Prior to entry, routine services will be confirmed to be operating, such as ventilation and fire suppression systems. If there are times when additional hazards, such as welding or spraying chemical coatings, are introduced, an entry permit that identifies those hazards and their mitigation, and authorization by safety personnel will be required. Work in confined spaces will comply with OSHA 29 CFR 1910.146.

Controls:

- Work with safety personnel to establish proper cavern entry requirements.
- Evaluate and approve planned work for hazards prior to entry, and provide appropriate mitigation.
- Establish routine atmosphere testing of oxygen levels, carbon monoxide levels, and other noxious gases, as warranted.
- Review and approve entry permits when they are required for the planned work.