Environment, Safety, and Health Considerations for the Neutrino Source

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I. Introduction

The Neutrino Source presents a number of challenges in environment, safety, and health.

- Some are familiar ones, solved at Fermilab and other laboratories.
- Others are novel ones that need early attention to assure cost-effective solutions that meets the approval of the public and DOE.
- Here, the novel ones will be emphasized.

II. Procedural/Regulatory Matters

The Neutrino Source will have to meet a several important milestones.

Early attention to these issues is likely the best path to success.

Current requirements are in Fermilab's Work Smart Standards, part of the DOE-URA contract. It is reviewed annually.

- Includes Federal and State Regulations along with internal and national standards.
- Requirements could be different at a later time.

A. Environmental Protection Procedural/Regulatory Matters

The National Environmental Policy Act will require an Environmental Assessment (EA).

- Covers emissions of pollutants, impacts on floodplains/wetlands, exposures of people to chemicals, radiation, noise, dust, etc.
- Broad in scope, includes societal impacts.
- Analyzes alternatives for the project, including that of "no action".
- Result is either a Finding of No Significant Impact (FONSI) or the need to prepare an Environmental Impact Statement (EIS).
- Based on the scale of other projects an EIS may well result.
- A Record of Decision (ROD) completes the EIS process.
- NEPA must be satisfied prior to expenditures of project funds.

Environmental permits, from State and Federal agencies, will be needed during both construction and operational stages;

- Storm water and cooling water discharges,
- Wetlands/floodplain mitigation (if needed),
- Releases of air pollutants (both non-radioactive and radionuclides), &
- Identification and mitigation of affected archaeological sites.

B Safety and Health Procedural/Regulatory Matters

A Safety Assessment Document (SAD) will be needed.

- A Preliminary Safety Assessment Document (PSAD) should be prepared (includes environmental issues as well).
- DOE will probably review the PSAD, and certainly the SAD, by using an external review team.
- A readiness review will be similarly conducted using an external review team prior to operations. DOE concurrence is required.
- The current contract with DOE will specify the applicable requirements.
- PSAD/SAD activities generally begin <u>after</u> funds are issued.

The "self-regulating" status of DOE on occupational and radiation safety matters could change requirements at a future date.

III. Occupational Safety During Construction of the Facility

A. Proton Driver, Target Station, Cooling Region, and Muon Acceleration Linacs-The "cut and fill" zone

The Occupational Safety and Health Administration's (OSHA's) regulations apply. Particular issues are:

- Excavations,
- Personnel protective equipment,
- Emergency response measures, fire safety, chemical safety, and
- Electrical safety.

These should present no new problems.

If industrial radiography is used to inspect welds, etc, State of Illinois requirements will be followed.

B. Muon Storage Ring (MuSR)

The MuSR presents some novel issues related to underground operations (e.g., "mining" activities)-similar issues are being addressed for NuMI;

- Tunneling safety, material movement, and prevention of flooding,
- Provisions for emergency response and underground rescues (on a steep slope!), and
- The significant downward slope presents new "gravitational" hazards.

IV. Environmental Protection During the Construction of the Facility

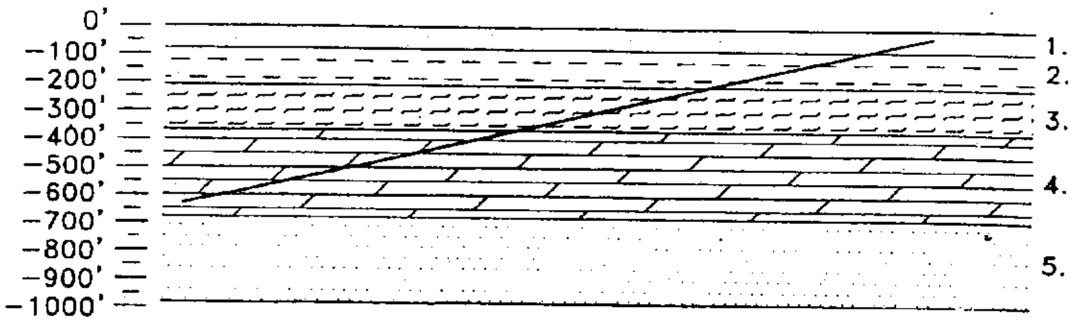
A. Proton Driver, Target Station, Cooling Region, and Muon Acceleration Linacs-The "Cut and Fill" Zone

- The issues are largely conventional and have been encountered before.
- Erosion control, must follow Federal and State regulations.
- Dust from must controlled.
- A stormwater management plan will need to be developed.
- A National Pollutant Discharge Elimination System (NPDES) Stormwater Permit for construction will be needed, if > 5 acres is impacted.
- If > 3 acres of wetlands are impacted, they will have to be replaced.
- Spills of chemicals from construction equipment must be prevented.

B. Muon Storage Ring (MuSR)

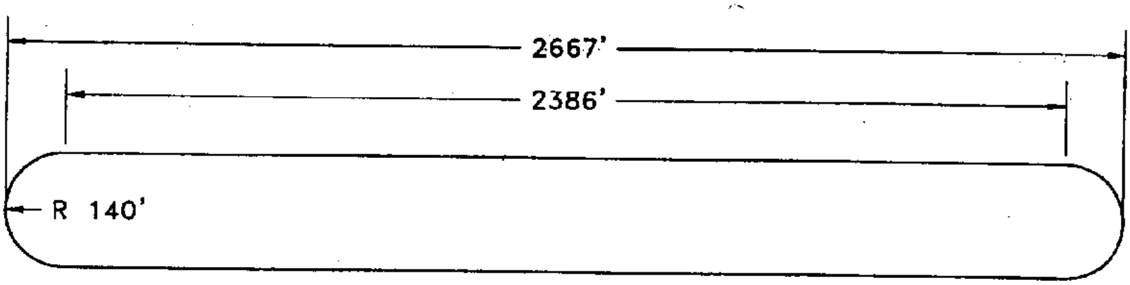
The NuMI project should provide valuable experience in dealing with the "tunneling" issues:

- The management of the spoil and its stockpiling,
- Control of rock dust, and
- Control of noise and vibration.



GEOLOGY DETAIL

1. GLACIAL TILL – NON-AQUIFER
2. SILURIAN GROUP – AQUIFER (PRIMARILY DOLOMITE)
3. MAQUOKETA GROUP – AQUIFER (PRIMARILY SHALE)
4. GALENA / PLATTEVILLE GROUP – AQUATARD (PRIMARILY DOLOMITE)
5. ANCEL GROUP – AQUIFER (PRIMARILY SANDSTONE)



CE 2.1 LATTICE PLAN

ORIENTATION:

NAME	AZIMUTH (DEG-MIN-SEC)	VERT. ANGLE (DEG-MIN-SEC)
PALO ALTO CA.	271-20'-42.27"	-13-09'-26.99"

MuSR
CTE 15-OCT-99

Conceptual layout of the Muon Storage Ring (MuSR) in the various geological units. The orientation is constrained to direct the neutrinos toward Palo Alto, CA.

The construction in aquifer layers merits special attention:

- The storm water management plan will need to cover the "dewatering" of the tunnel.
- Hydrogeologic studies need to be performed to understand the interplay of the construction of the project with the various aquifers, especially the top of the aquatard (Galena/Platteville) unit.
- Must provide assurance of no impact on individual or municipal water supplies.
- Must prevent the tunnel from connecting the upper aquifers, commonly used by individual wells and municipalities to lower ones commonly used by the local municipalities.
- Must prevent spills of chemicals in the tunnel from getting into the aquifers.

V. Occupational Safety During the Operation of the Facility

A. "Ordinary" Occupational Safety Hazards

Many hazards commonly encountered at Fermilab will be present:

- High current electrical circuits in the magnets on a large scale,
- Radiofrequency (RF) generation and distribution,
- Large amounts of cables in cable trays (fire protection),
- Life Safety Code/fire protection issues, and
- Mechanical handling of large, heavy components.

B. Novel Occupational Safety Hazards

Large scale use of cryogens both in magnets and RF systems (familiar to FNAL and TJNAF) and at large depths in the MuSR-new ODH issues?

Ionization cooling using liquid hydrogen (LH_2)

- Scale of LH_2 use is larger than for "targets", will require engineering controls and reviews on the scale of the 15 Ft Bubble Chamber.
- RF and magnets are interleaved with LH_2.

Muon Storage Ring Life Safety (egress) considerations-needs analysis by qualified engineer

Muon Storage Ring slope hazard-perhaps needs spiral gutters to both route water and to prevent unimpeded downhill rolls of equipment.

VI. Ionizing Radiation Safety During Operation of the Facility

A. Proton Driver

Prompt radiation shielding

- There are no new issues raised here. MARS calculations have already addressed the shielding needs for both hadrons and neutrons.

Residual radioactivity of components

- The present Fermilab Booster already presents problems w.r.t. residual activity.

- Mokhov has found that a loss of 1 watt meter^{-1} will result in a residual dose rate of 100 mrem hr^{-1} after 30 days irradiation and 4 days cool down. This level is **high**, makes maintenance difficult! Further work is needed.

Residual radioactivity of the Target Station;

- General residual dose rates will be large, of the order of a few krads hr^{-1}.

- Significant activation of cooling water will occur.

- Provisions for remote handling will be needed such as used at LAMPF and planned for SNS.

The target itself poses particular problems. If the target material is carbon, at 1.5 MW beam it produces (at saturation):

^{3}H (12.3 year half-life)-1540 Curies,

^{7}Be (53.6 day half-life)-1020 Curies, and

^{11}C (20.3 minute half-life)-2055 Curies.

- The residual dose rate due to the ^{7}Be from the target is about 21 rads hr^{-1} at one meter at "equilibrium".
- The total activity is less than 10% of that which would result in the target being classified by DOE as a "nonreactor nuclear facility".
- Nuclear facility designation would impose some stringent additional requirements in training, QA, etc. DOE developments on this topic continue to be monitored.

Airborne Radioactivity

- The targeted beam power is > 3 times that of NuMI.
- If the site boundary annual dose due to all of Fermilab is < 0.1 mrem. "EPA-approved" continuous monitoring is needed.
- The ventilation system should be carefully designed to maximize the travel times of air to promote decay and to minimize thermal neutron production.
- Management decisions will be needed as to how to manage this and other release points. The total site release is a "zero sum game".

Soil and Groundwater Activation

- Present Monte-Carlo techniques can adequately describe production of radionuclides in soil (MARS) and the resultant shielding requirements.
- Recent work indicates that water migration times in glacial till are quite long compared to our standard assumptions of a few years ago.
- Specific hydrogeological studies are needed to do design well.
- The glacial till is a much better host for the target station than bedrock.

B. Cooling and Muon Acceleration Stages

These stages need to assure adequate muon shielding, done easily if located underground.

Some attention needs to be paid to the electromagnetic showers resulting from the decay electrons in the higher energy stages.

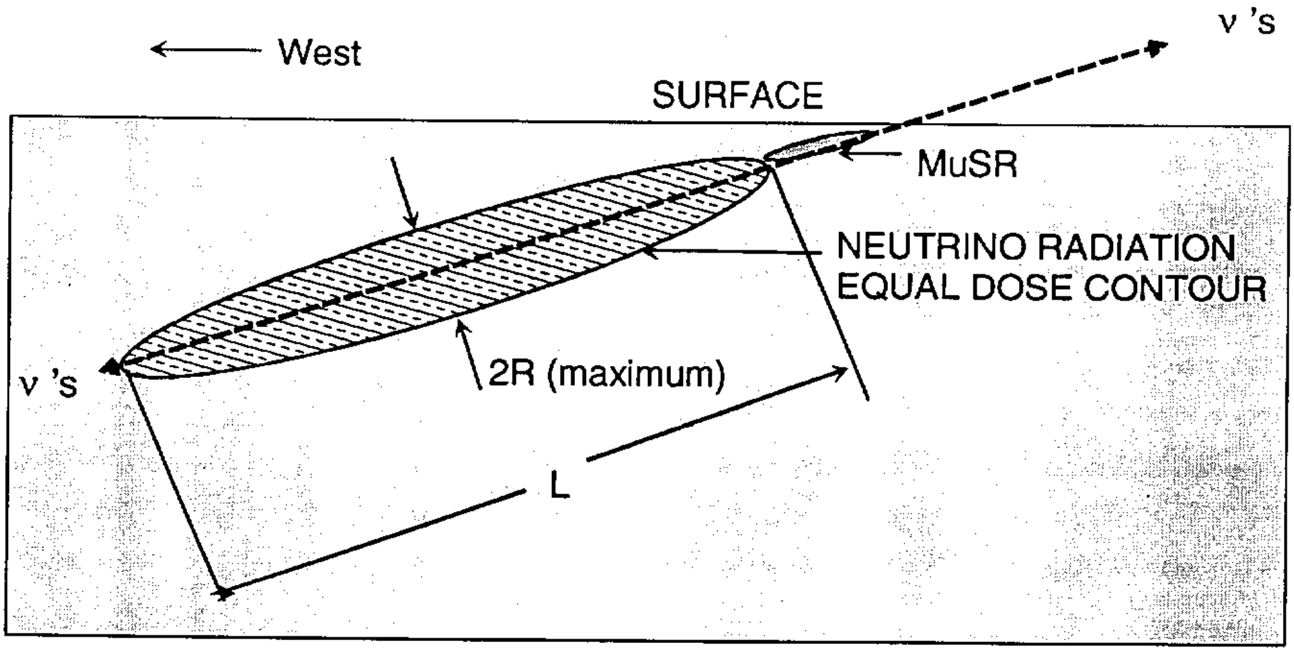
Residual activity is not all that important in these stages.

D. Muon Storage Ring

Control of radiation dose due to neutrinos

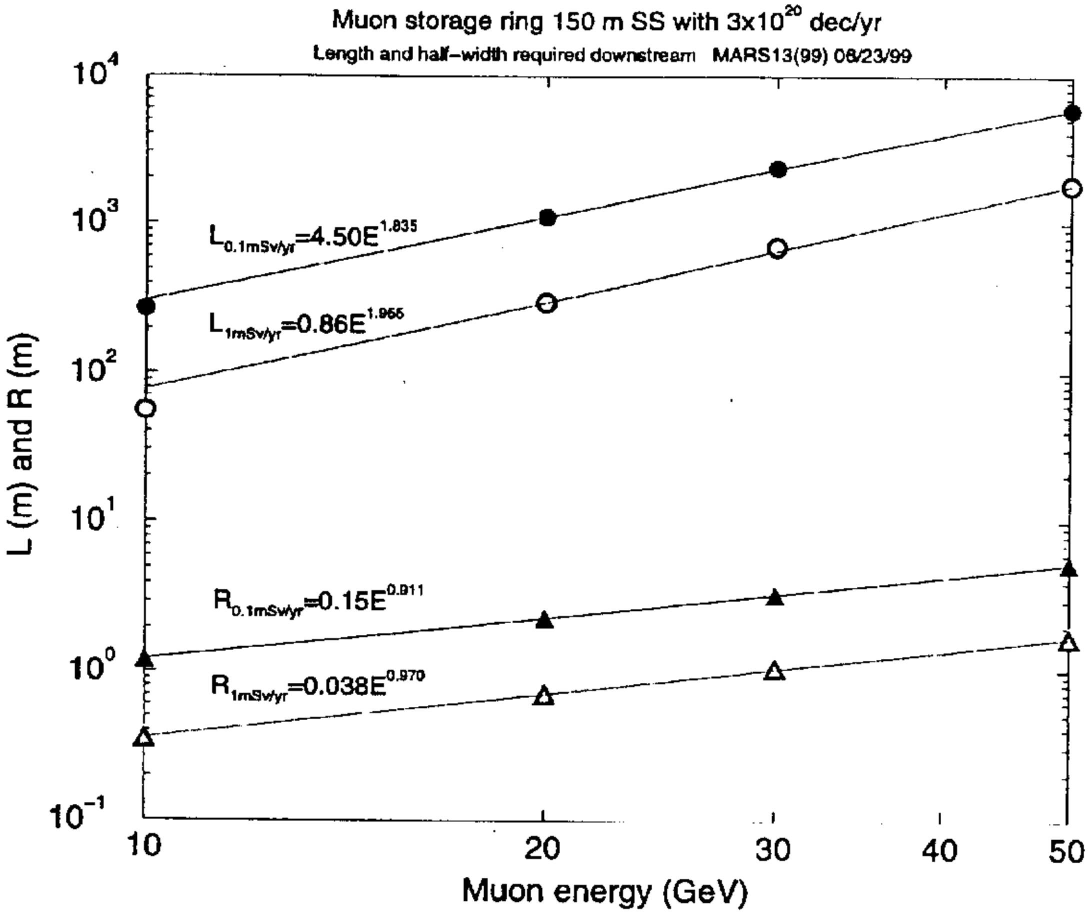
The DOE limits to members of the public (interpreted as applied to actual people that could be present):

- < 100 mrem in a year to an individual person,
- Special reporting if the dose in one year to a person is > 10 mrem, and
- DOE expects doses to "real persons" to be only a few mrem in a year.



Schematic representation of the neutrino radiation fields due to muon decays in the MuSR. The gray region is the earth while the cross-hatched region is a schematic representation of the region inside of a selected contour of equal dose equivalent due to the neutrinos resulting from downward muon decays. A similar neutrino radiation lobe is to be found in the upward direction due to muon decays in the other straight section of the ring. The parameter L describes the intersection of this isodose contour with the center line of the neutrino trajectory while R is its maximum radial extent. The actual contours are more forward-peaked, and narrower than is this symbolic ellipse. However, symmetry about the center line of the neutrino trajectories is expected.

Mokhov has calculated the maximum values of L and R:



Results of calculations of the values of L and R which describe the neutrino radiation field resulting from muon decays from one Muon Storage Ring straight section ("SS") as a function of muon energy energy. These are presented for two different annual dose equivalents, 1 mSv y^{-1} (100 mrem y^{-1}) and 0.1 mSv y^{-1} (10 mrem y^{-1}). The symbols denote the actual calculations of Mokhov. The results of power law fits are also shown.

First consider the neutrinos from the downward leg:

- The annual dose at Palo Alto, CA is about 4.8×10^{-5} mrem.

- One can determine how to place the facility so that the annual dose underneath locations beyond the Fermilab site is less than a given value.

Now consider the neutrinos from the upward leg:

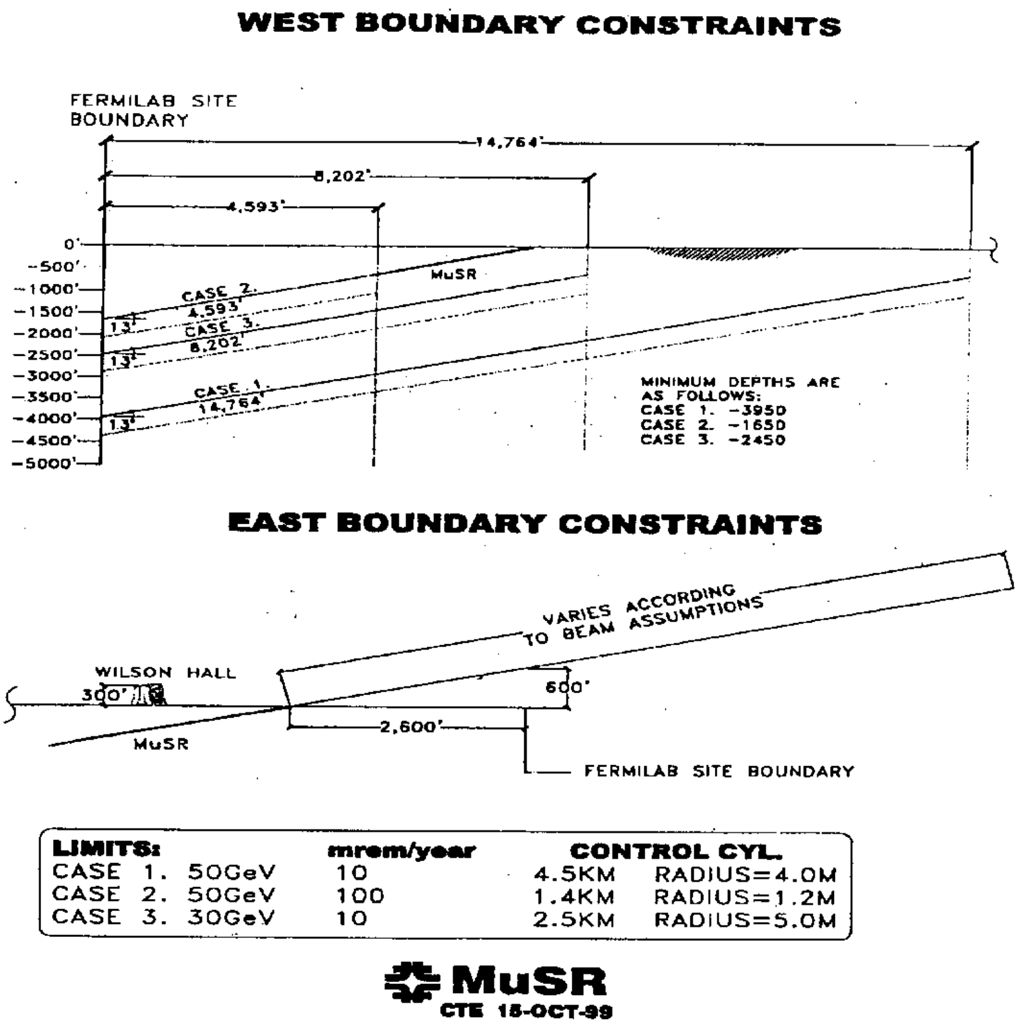
- Steady-state outdoor dose equivalent rates in fenced outdoor areas at Fermilab are limited to 100 mrem per hour.

- Thus, the annual dose in such an outdoor area is $< 5.7 \times 10^5$ mrem, based upon the specified "operating year".

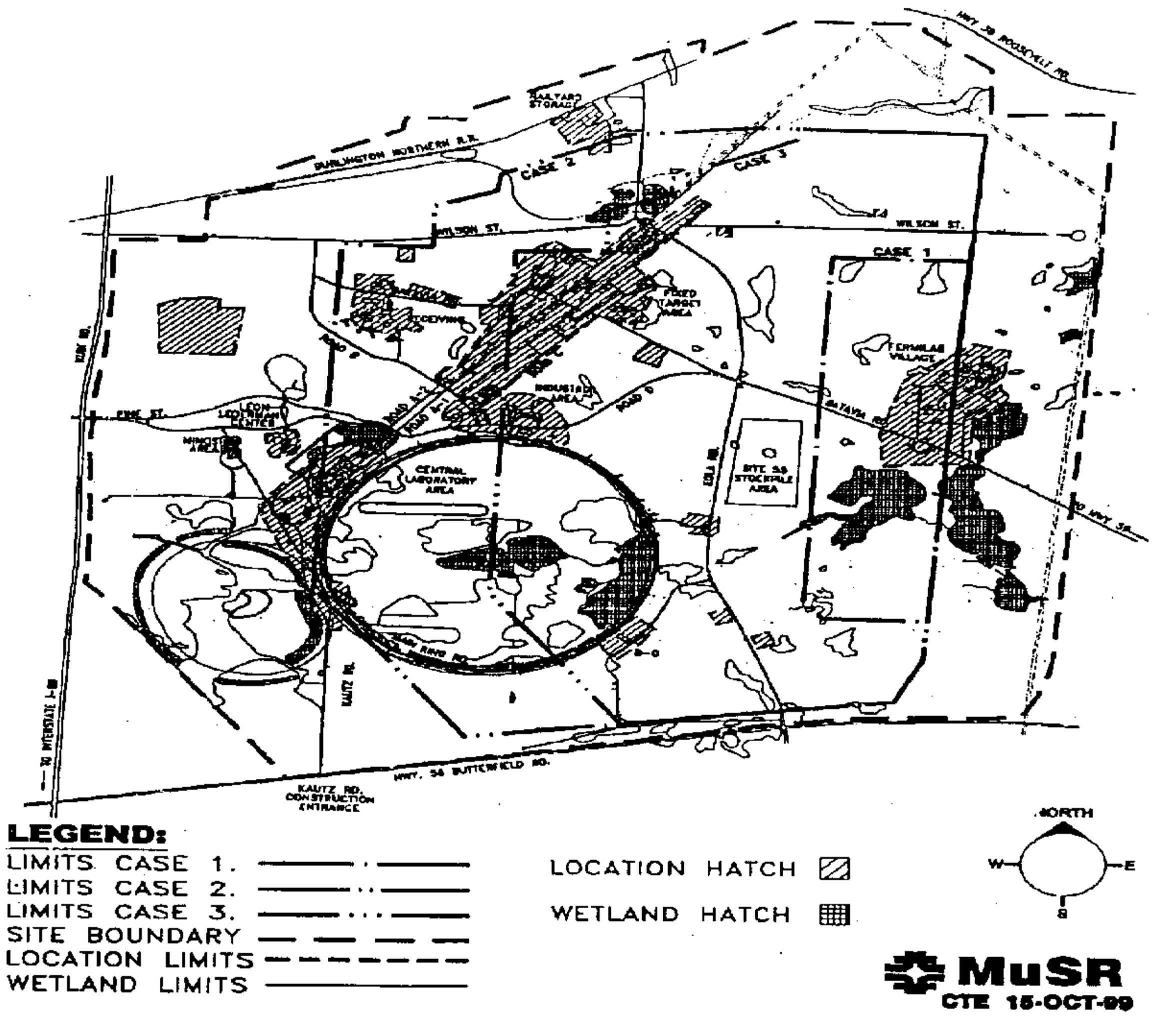
- By simple scaling of the L values, one finds this occurs at $z = 79.4$ feet, achieved if the high end of the enclosure is > 18.0 feet deep.

- Beyond the Fermilab site, one can site the facility so that a 600 ft. tall building at the site boundary just reaches the 10 mrem annual dose contour.

- Trigonometry, then, gives the east-west width of the fenced zone on the site east of the MuSR.



East-west vertical cross section through the Fermilab site showing the radiological constraints on siting. These are based on calculations, due to Mokhov, of the annual dose equivalent due to neutrinos originating from muon decays in the MuSR straight sections.



LIMITS:	mrem/year	CONTROL CYL.	
CASE 1. 50GeV	10	4.5KM	RADIUS=4.0M
CASE 2. 50GeV	100	1.4KM	RADIUS=1.2M
CASE 3. 30GeV	10	2.5KM	RADIUS=5.0M

Map of the Fermilab site that displays the siting constraints for locating the MuSR. These are based on calculations, due to Mokhov, of the annual dose equivalent due to neutrinos originating from muon decays in the MuSr straight sections.

Other radiation sources

- The radiological impact of the decay electrons has been calculated by Mokhov and appears to be significant, but manageable.
- The near detector halls will be exclusion areas during operations due to neutrinos and other particles.

VII. Non Radiological Environmental Protection Issues During Operation

A. Proton Driver, Target Station, Cooling Region, and Muon Acceleration Linacs

- Regulatory mixed wastes should be prevented.
- Spill control plans should be implemented.
- Surface water discharges should be properly managed.

These considerations are very conventional.

B. Muon Storage Ring

- Spill control must be provided
- Prevention of the production of "mixed wastes" must occur.
- Avoidance of contamination of the various aquifer layers must be done.
- Effects of pumping on individual and municipal water supplies must be prevented.

VIII. Major ES&H Issues

These are the major "novel" ones:

- The NEPA process will need to be completed successfully.
- During construction, mining operations must meet safety standards (use NuMI experience).
- Issues related to spoil piles, dust, erosion control, surface water discharges, and archaeological site mitigation must be carried out.
- Efforts should continue to minimize stray beam loss in the Proton Driver.
- Target activation questions need more detailed analysis (components, air, and groundwater).
- Target station remote handling capabilities must be pursued.
- Liquid hydrogen hazards will require careful engineering.
- Special cryogenic hazards deep underground must be assessed.
- The aquifer layers need protection from depletion, contamination, and cross-connection from chemicals and radionuclides.
- We may have to carefully educate our neighbors about the neutrino radiation issue.

In conclusion, The Neutrino Source provides a number of challenges in the area of environment, safety, and health. Many of these have been encountered, and effectively addressed, at other accelerator facilities. Some of the problems are common to other recent projects undertaken at Fermilab and elsewhere that have resulted in the need to develop new approaches.

Not surprisingly, this project raises a few new issues that must be addressed. It is concluded here that with adequate planning in the design stages, these problems can be adequately addressed in a manner that merits the support of the Laboratory, the Department of Energy, and the public.