UNREVIEWED SAFETY ISSUE DETERMINATION (USID) FORM

Title of USID: MI/RR Berm Shielding Reconfiguration Due to LBNF Site Prep

Description of Proposed Activity: The MI berm shielding will be reconfigured due to LBNF site prep work. New steel shielding and a concrete culvert was added near cell 113, and an existing culvert and steel shielding near cell 110 was removed. Compacted soil was added to both locations to restore berm.

Does the proposed activity or discovered condition affect information in the Fermilab SAD regarding safety analyses, administrative controls, or credited controls? If so specify the relevant sections. n/a - shielding configuration specifics described in the Shielding Assessment, updated with Post-Assessment Document

Does the proposed activity or discovered condition affect any of the requirements in the Fermilab ASE? If so specify the relevant sections. no

USI Determination Criteria:

- ○ Yes ◉ No Could the change significantly increase the probability of occurrence of an accident previously evaluated in the SAD?
- ○ Yes ◉ No Could the change significantly increase the consequence of an accident previously evaluated in the SAD?
- ○ Yes ◉ No Could the change significantly increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the SAD?
- ○ Yes ◉ No Could the change significantly increase the consequence of a malfunction of equipment important to safety previously evaluated in the SAD?
- ○ Yes ◉ No Could the change create the possibility of a different type of accident than previously evaluated in the SAD that would have a potentially significant safety consequence?
- ○ Yes ◉ No Could the change increase the possibility of a different type of malfunction of equipment important to safety than any previously evaluated in the SAD?

Justification: (use attachment if necessary) see attached "Shielding Analysis of New MI-113 Culvert and Demolition of MI-110 Culvert" post-assessment document and SRSO approval.

USI Determination: A USI is determined to exist if the answer to any of the 6 questions above is "Yes". If the answer to all 6 questions id "No", then no USI exists.

- ■ No — Proposed activity may be implemented following the applicable FESHM or FRCM chapter requirements.
- ☐ Yes — Director's approval is required prior to implementation.

For a positive USI Determination, does the ASE require changes?

- ■ No — Proposed activity may be implemented following the applicable FESHM or FRCM chapter requirements. Attach a copy of this USI Determination after Director's approval to the applicable SAD Chapter.
- ☐ Yes — DOE-FSO Manager's approval is required prior to operation.

Check documents requiring creation or modification

- ☐ PHAR/PHAD
- ■ Shielding Assessment
- ☐ SAD
- ☐ ASE

Madelyn Schoell, UID:maddiew Digitally signed by Madelyn Schoell, UID:maddiew Date: 2020.11.16 12:35:59 -06'00' 11/16/20

Preparer Date

Matthew Quinn, UID:mquinn Digitally signed by Matthew Quinn, UID:mquinn Date: 2020.11.16 12:56:22 -06'00' 11/16/20

Senior Radiation Safety Officer Date

Approval:

Amber Kenney Digitally signed by Amber Kenney Date: 2020.11.16 16:21:27 -06'00' 11/16/20

Chief Safety Officer Date

Director (for positive USIDs) Date

Note: Contact your Division Safety Officer with any questions regarding this form.

William S. Higgins
Radiation Physics Science Department
Environment, Safety, and Health Section
630.840.4318
higgins@fnal.gov

Memorandum

12 November 2020

To: Post-Assessment Documents for Main Injector 1500 kW Shielding Assessment

From: Bill Higgins

Subject: Shielding Analysis of New MI-113 Culvert and Demolition of MI-110 Culvert

Introduction

In anticipation of the Long Baseline Neutrino Facility (LBNF), recent site preparation work has altered the configuration of culverts crossing the Main Injector berm. The effect of these changes upon Main Injector shielding must be assessed.

This memo will serve as a post-assessment document to the Main Injector 1500 kW Incremental Shielding Assessment [Reference 1].

In the spring and summer of 2020, soil was removed from above the Main Injector enclosure near cell 113, near station 650. Steel shielding was placed above the enclosure. A new concrete culvert was installed above the steel, then covered with compacted soil. This culvert conveys the water of Indian Creek across the Main Injector tunnel from north to south. It consists of two rectangular channels in cross-section; the leg passing through the Main Injector berm has a length of approximately 92 feet.

Following this installation, the existing culvert at cell 110 near station 500, incorporating seven 48-inch concrete pipes, was excavated and removed. Steel shielding underneath the culvert was also removed. Compacted soil was added to restore the Main Injector berm above the enclosure.

Shielding Considerations of New MI-113 Indian Creek Culvert

For the newly installed MI-113 culvert there are two radiological aspects to consider: First is the prompt dose through the overburden; second is prompt dose at the ends of the culverts.

Consider accidental loss of 120 GeV proton beam within the Main Injector tunnel at an intensity of 9.75E13 protons per pulse and a cycle time of 1.2 seconds, or 2.93E17 protons per hour.

The top of the culvert lies at an elevation of 738.07 feet above sea level. The berm contains compacted soil to at least 746.0 feet, and uncompacted topsoil was added to an elevation exceeding 747 feet. Therefore between the berm and the top of the culvert, there is, conservatively, an overburden exceeding 8 feet.

The bottom of the culvert lies at an elevation of 734.07 feet. The ceiling of the Main Injector lies at 721.5 feet. Between these are 9.37 feet of soil and 3.2 feet of steel, which, given a conversion factor of 3.07 equivalent feet of dirt (efd) per foot of steel [3], amounts to 9.81 efd. The total shielding between the ceiling and the bottom of the culvert is thus about 19.2 efd.

The total overburden above the Main Injector tunnel exceeds (19.2 + 8) = 27.2 equivalent feet of dirt. In this vicinity the enclosure is classified as Category 4A. This sets a limit, for the prompt dose rate for a loss on a magnet within the enclosure, of no more than 500 millirem per hour. This limit requires shielding of at least 20.7 equivalent feet of dirt. The overburden exceeds this requirement.

Next, consider the dose emerging from the ends of the MI-113 culvert due to an accidental loss in the Main Injector tunnel. Following the method of Reference 2, a labyrinth calculation (PWKS-AIP296A) finds the "Leg 2" attenuation due to the shortest side of the culvert, a leg 40 feet long running southward. Another calculation (PWKS-AIP296B) finds the attenuation due to the longer side, running north of the Main Injector berm across Indian Creek Road. To simplify this work, we consider only a single leg of length 52.2 feet from the Main Injector beam centerline; this will give a conservative result, because the subsequent legs we neglect will contribute further attenuation.

These labyrinth calculations give an attenuation of 1.14E-3 for the short side and 4.02E-4 for the long side. They are an input into the next step of the method of Reference 2.

"Complex" culvert is the term used in Reference 2 for culverts composed of multiple parallel channels, such as the two side-by-side rectangular channels of the new MI-113 culvert. In a revised Complex Culverts spreadsheet, PWKS-AIP295A, the short-side and long-side attenuations are used in applying a scaling formula to estimate accident doses at their exits. This Complex Culverts sheet supersedes the previous document, PWKS-AIP191A.

The spreadsheet results in an estimated dose of 3.40 millirem per hour or 1.13E-3 millirem per pulse at the south short-side culvert exit, and 1.19 millirem per hour or 3.89E-4 millirem per pulse at the end of the long-side leg (even less at the more distant north exit of the culvert). The culvert, like other culverts around the Main Injector, is classified as category 4, meaning an accident limit of 500 millirem per hour. The estimated dose rates of the MI-113 culvert exits do not exceed this limit.

Effect of MI-113 on Groundwater and Surface Water

Between the Main Injector tunnel and the bottom of new culvert lies the same amount of shielding as the previous culvert had, about 19.2 efd. Therefore any activation of culvert water due to losses in the tunnel is unchanged from the previous configuration.

Activation of surface water remains the same, with the new culvert, as that reported in Attachment G of Reference 1, and discussed further in Section 11 of [1]. For losses distributed around the Main Injector ring, combined tritium and sodium-22 concentrations in surface water are again estimated to be 1.3% of the annual limits [Attachment C of this document]. Groundwater calculations have been revised to incorporate an updated reduction factor for sodium-22 of 3.5E-62 as recommended by Kamran Vaziri [also Attachment C]. This does not significantly alter the groundwater estimate for combined concentrations of tritium and sodium-22, which remains a fraction 7.3E-5 of the annual limits.

Note Regarding the MI-110 Culvert As a Model

The Complex Culverts worksheet scales exit doses from a calculation that uses a particular culvert as an exemplar. This is a detailed MARS simulation, performed in 2009 by Igor Rakhno, of the seven-pipe MI-110 culvert. The Complex Culverts worksheet, in turn, calculates doses taking into account differences between each culvert and the MI-110 exemplar culvert.

Although the physical MI-110 culvert has now been demolished, we continue using the simulated MI-110 culvert as a baseline in the Complex Culverts worksheet.

Demolition of Existing MI-110 Culvert

The existing 7-pipe culvert and the steel beneath it have been removed. A layer of soil over the Main Injector tunnel has replaced the culvert. Compacted soil graded to an elevation at least 746 feet is covered with uncompacted topsoil to a level exceeding 747 feet. The Main Injector ceiling lies at 721.5 feet, so the overburden exceeds 24.5 efd. In this vicinity the enclosure is classified as Category 4A. This sets a limit, for the prompt dose rate for a loss on a magnet within the enclosure, of no more than 500 millirem per hour. This limit requires shielding of at least 20.7 equivalent feet of dirt. The new overburden of feet exceeds this requirement.

References

1. W. S. Higgins, M. Quinn, D. Reitzner, W. Schmitt, K. Vaziri, and M. Vincent, *Main Injector 1500 kW Incremental Shielding Assessment*, 23 May 2018.

2. R. Zimmermann, "Methodology Used to Determine Dose at Ends of Main Injector Culverts," 18 July 2011, attachment N in *Main Injector Incremental Shielding Assessment 700 kW*, W. Schmitt, *et al.*, August 16, 2012.

3. W. S. Higgins, "Revised Soil Equivalent for Selected Shielding Materials," 10 September 2018.

Attachments

A. Main Injector Complex Culverts 1500 kW, PWKS-AIP295, worksheet "Complex Results" within workbook file "MI Complex Culverts PWKS-AIP295.xlsx"

B. Workbook file "MI-113 Culvert PWKS-AIP 296.xlsx"

C. Workbook file “MI 1500 kW Groundwater and Surface Water 11-12-20.xlsx”

Memorandum

Matthew Quinn
Senior Radiation Safety Officer

ES&H Section
P.O. Box 500, MS 371
Kirk Road and Pine Street
Batavia, Illinois 60510-5011 USA
Office: 630.840.5175
mquinn@fnal.gov

Date: November 13, 2020
To: Michael Lindgren, Head – Accelerator Division
William Higgins, ES&H RPS Department
From: Matthew Quinn, Senior Radiation Safety Officer
Re: Approval of Main Injector Post Assessment Document

Message:

I have reviewed Bill Higgins' memo of November 12th, 2020: Shielding Analysis of New MI-113 Culvert and Demolition of MI-110 Culvert. This addendum details the shielding on and around the new culvert and in place of the old culvert. Because the shielding in those areas now equals or exceeds the amount previously in place, I concur that the addendum is satisfactory in terms of methodology, completeness, and compliance with the Fermilab Radiological Control Manual article 815(5), and thus approve of this assessment and planned operations within its scope.

A USI determination will be completed to indicate that the SAD and ASE are not impacted by these changes.

Cc:
D. Capista
M. Convery
A. Kenney
S. McGimpsey
E. McHugh
W. Schmitt
M. Schoell