Application for Beneficial Use Determination for Structures

Yankee Nuclear Power Station
Site Closure Project
Rowe, Massachusetts

22 September 2004

ERM
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TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 BACKGROUND

The Yankee Atomic Electric Company (YAEC) is in the process of decommissioning and closing the Yankee Nuclear Power Station (YNPS) located in Rowe, Massachusetts (see Figure 1). YNPS began operations in 1960 and operated safely and successfully for 31 years. In February 1992, the YAEC Board of Directors decided it was in the best economic interest of electric customers to cease operations permanently at YNPS and decommission the plant. YAEC intends to complete the majority of decommissioning and physical site closure activities at the site by mid-2005 and to restore the site to environmental quality standards that will enable future unrestricted use of the site, where feasible.

The site is located at 49 Yankee Road in the northwestern Massachusetts Town of Rowe, adjacent to the Vermont border (Figure 1). The site consists of an approximately 1,800-acre property owned by YAEC (see Figure 1) and portions of an adjacent property to the west owned by USGen New England, Inc. (USGen NE). The site abuts the eastern shore of the Deerfield River and Sherman Reservoir, adjacent to Sherman Dam, one of several dams along the Deerfield River used for hydroelectric power generation.

This application for a Beneficial Use Determination (BUD) – Major was developed by YAEC, with the assistance of Environmental Resources Management (ERM) and Gradient Corporation (Gradient), to support the site closure project. Copies of the transmittal and application forms (BWP SW 13) are provided in Appendix A.

1.2 PURPOSE AND SCOPE

The purpose of the BUD application is to provide the Massachusetts Department of Environmental Protection (DEP) Division of Solid Waste and other stakeholders with the BUD application and supporting information necessary to review and approve plans to use processed concrete and asphalt for site regrading and to leave building slabs and foundations and utility lines in-place. The grading plan for the site will provide at least 36 inches of soil over any non-native materials that are left on site under the BUD. This application includes a description of the solid

waste material to be beneficially used, its estimated quantity, physical and chemical properties, and proposed handling methods to ensure that there are no adverse effects to public health, safety, or the environment.

This BUD application does not address the management of soil in the Southeast Construction Fill Area (SCFA). A separate BUD, along with a Corrective Action Design, both dated 26 July 2004, have been submitted to address the removal of the SCFA and the reuse of soils from the SCFA for site regrading.

2.0 GENERAL INFORMATION

2.1 GENERAL DESCRIPTION

Structures to be Completely Removed

YAEC is in the process of demolishing the buildings at the site. As shown in Figure 2, YAEC intends to completely remove the following site structures and associated foundations:

- Ion Exchange Pit
- Spent Fuel Pool
- Fuel Transfer Enclosure
- Potentially Contaminated Area (PCA) #1
- Fuel Oil Transfer House
- East Storm Drain System
- Portion of West Storm Drain System east of proposed dam extension including drain system along access road to the Independent Spent Fuel Storage Installation (ISFSI)
- The portion of all existing utilities that pass through the alignment of the proposed dam extension including, stormwater, sewer, electrical conduit and duct banks, and the ground wire network

Subsurface Structures to Remain In-Place

The solid waste to be beneficially used includes subsurface concrete slabs and foundations, concrete and corrugated steel circulating water pipes, and subsurface utility lines. The subsurface structures that will remain at the site are summarized in Table 1 and are highlighted in Figure 2. YAEC proposes to leave portions of the following subsurface structures in-place:

- Vapor Container/Reactor Supports
- Screenwell House
- Turbine Building (partial removal of slab and foundations is planned to accommodate site grading plan)
- Safe Shutdown Building

- Primary Auxiliary Building
- Waste Tank Moats
- Miscellaneous Tanks and Equipment
- Waste Disposal Building
- Compactor Building
- PCA #2 (partial removal of slab and foundations is planned to accommodate site grading plan)
- PCA Warehouse
- Pipe tunnel
- Fuel Transfer Chute
- Safety Injection/Diesel Generator Building
- Service Building (partial removal of slab and foundations is planned to accommodate site grading plan)
- Stores Warehouse (partial removal of slab and foundations are planned to accommodate site grading plan)
- New Fuel Vault
- Discharge Structure

The building foundations that will remain on-site consist primarily of concrete reinforced with steel, and also include concrete masonry units (i.e., cinder blocks) and asphalt paving. Concrete slabs and sumps will be broken up as necessary to allow water infiltration through the foundations and to prevent ponding of stormwater within the structures.

Building surfaces were characterized for PCB-containing paint prior to demolition. On-going abatement of PCB-containing paint at concentrations of 50 mg/kg or greater of PCBs has been conducted under specific US EPA approved work plans developed in accordance with the Alternative Method of Disposal Authorization (AMDA), issued by the US EPA under Section 6(e)(1) under the Toxic Substance Control Act (TSCA) and the PCB regulations (40 CFR 761).

The concrete foundations remaining in the subsurface will be visually inspected, where accessible, to document if any coatings are present. Any paint that is to be left in-place (except spray paint incidental to demolition) will be tested to confirm that PCBs are not present in the paint. Any paint found to contain PCBs will be removed from the surface

of the concrete prior to reuse under the BUD. Any non-PCB paint to remain on concrete will also be tested for RCRA 8 metals.

Mastic coatings are present on some subsurface foundations that will remain in-place. The mastic coatings have been tested for asbestos. Non-friable asbestos has been detected in the following areas:

- Turbine Building – coating on top of slab along perimeter (approximately 300 square feet)
- Service Building – coating on top of slab along perimeter (approximately 300 square feet)
- PAB – coating on south wall (approximately 200 square feet)
- Waste Disposal Building – coating on top of slab along perimeter (approximately 200 square feet)

The volume estimates of materials to be reused on-site under the BUD are based on the current site closure plans and reasonable knowledge of the dimensions/construction of features to remain on-site. Some variability is expected in the actual volumes used and these final site conditions will be documented on as-built drawings showing fill areas and buried features. In the event that additional structures/foundations are deemed eligible for on-site use, YAEC will ensure that these items meet all of the criteria that have been specified in this submittal.

Utility Lines to Remain In-Place

YAEC intends to leave in-place certain inactive utility lines, such as water lines, wastewater lines, and electrical conduits, following the completion of the site decommissioning. Reasonable measures will be taken to remove the contents of the utility lines (i.e., water, wires, etc) as part of the decommissioning process, however, wires/cables may remain in-place in inaccessible locations (including some wires that could be coated with Rockbestos material). Utility lines that are greater than 8 inches in diameter, including the circulating water piping, will be left in-place and filled to eliminate voids in the subsurface and eliminate the abandoned portion of the pipe as a potential safety hazard. Utility lines that are 8 inches in diameter or less may be left in-place as-is. Utility lines that will remain in-place are shown in Figure 3 and are described below:

- Circulating Water System and Piping
    - One 100-foot long, 10-foot diameter buried corrugated steel intake pipe between Sherman Reservoir and Screenwell House

    - One 7-foot diameter concrete intake pipe between Screenwell House and Turbine Building
    - Two 1-foot diameter steel water service line between Screenwell House and Turbine Building
    - Two 5-foot diameter steel pipes below Turbine Building
    - One 3-foot diameter corrugated steel pipe between Screenwell House and Discharge Structure
    - One 7-foot diameter concrete discharge pipe between Turbine Building and Discharge Structure (a portion of the pipe is lined with steel and a portion of the pipe is all steel)
    - Three 4-foot diameter steel capped pipes near Discharge Structure branching off from the 7-foot diameter steel pipe
- Ground wire network
- Electrical conduit
- Duct banks
- Fire water header (8-inch diameter) and subsurface lines

Sanitary sewer lines are considered outside the scope of this BUD application since the closure of septic systems will be addressed under the requirements of the State Environmental Code Title 5 regulations (310 CMR 15.000).

Processed Concrete and Asphalt

The solid waste to be beneficially used also includes concrete block and reinforced concrete from the aboveground portion of the Primary Auxiliary Building, the reactor support structure, and the Ion Exchange Pit/Spent Fuel Pool; the portion of the slabs and foundations from the Turbine Building, Service Building, Stores Warehouse, and PCA #2 that will be removed to accommodate site grading; and asphalt from paved areas at the site. The locations where processed concrete and asphalt will be reused to grade the site are shown in Figure 4. All paint containing PCBs will be removed from the concrete prior to reuse. Non-PCB paints that remain on concrete will be evaluated to ensure the metals concentrations comply with BUD risk criteria. Processed concrete and asphalt used on site will be placed in horizontal lifts and compacted to reduce void space and create a stable fill material.

End-State

Following the completion of demolition activities aboveground structures that will remain at the site will include the facility for the long-term storage of spent fuel (i.e., the Independent Spent Fuel Storage Installation (ISFSI)), associated security structures, an office building, and a potable water well house. YAEC intends to extend the east embankment of the Sherman Dam to permanently replace the temporary flood control measures that had been part of YNPS. The site will be regraded and planted following the completion of demolition activities. The regrading plan will provide a minimum of 36 inches of soil cover above any foundations or utility lines that are left in-place.

2.2 SOURCE

The Yankee Nuclear Power Station in Rowe, Massachusetts is the source of the solid waste that will remain on-site. The name and address of the generator are:

Yankee Atomic Electric Company
49 Yankee Road
Rowe, MA 01367

2.3 INDUSTRIAL PROCESSES

The solid waste that will remain in-place is derived from the decommissioning of YNPS. The buildings were constructed using traditional construction methods.

2.4 QUANTITY

A summary of the volumes by structure is provided in Tables 1 and 2. The volume of subsurface foundations to remain in-place is approximately 7,300 cubic yards and the volume to of concrete and asphalt to be processed is approximately 11,100 cubic yards. Therefore, the total quantity of concrete and asphalt to be managed under the BUD is estimated to be 18,400 cubic yards. This corresponds to approximately 38,000 tons.

3.0 CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES

3.1 CHEMICAL PROPERTIES

Overview

The solid waste to be beneficially reused consists of concrete blocks, reinforced concrete and asphalt. Concrete is produced by mixing cement and water with inert materials such as sand and gravel. A chemical reaction known as hydration occurs between the cement and water that creates a hard, rock-like product. Steel reinforcing bar (rebar) is imbedded in poured concrete. Asphalt pavement typically contains approximately 95 percent aggregate, consisting of stone, sand, or gravel and five percent asphalt cement as a binder.

Due to the inert nature of the concrete and asphalt, reactivity, leachability, metals content and volatile organic compound concentrations are not a potential concern. The pH of groundwater at the site, which currently ranges from 5 to 8, is not expected to be impacted by leaving the reinforced concrete in-place.

Radiological Characterization

Characterization of radiological content of the concrete and asphalt to remain at the site will be performed by YAEC in accordance with Nuclear Regulatory Commission (NRC) requirements, including the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) Guidance, NUREG-1575. The method for testing the concrete and asphalt has been described and submitted to the NRC with Draft Revision 1 of the facility's License Termination Plan (LTP), dated September 2, 2004. The LTP submittal also includes the Derived Concentration Guideline Levels (DCGL) for concrete debris (see Table 3). The DCGLs are calculated using dose models to establish the levels of residual radioactivity that will allow compliance with 10 CFR 20 criteria for NRC license termination for unrestricted use.

Prior to decommissioning, structures to be demolished will be surveyed and the concrete debris data will be evaluated for compliance with the DCGL. Materials that are below the DCGL for concrete are acceptable for reuse under the BUD (see Section 4.2 for summary of BUD risk assessment issues). Materials that are above the DCGL will be segregated and

transported off-site for disposal at an NRC-approved disposal facility as radioactive waste.

Materials that are free-released (i.e., no detectable radiation) will be processed and used for site grading. Concrete and asphalt that have detectable radiation, but that are below the DCGL will be processed for reuse on-site and placed into 20 cubic yard containers for a second radiological test as part of the Final Status Survey (FSS). The materials will be placed into a truck-mounted testing unit to measure the radiological levels and confirm that they are below the DCGL. Processed materials found to be above the DCGL will be segregated and transported off-site for disposal at an NRC-approved disposal facility.

Non-Radiological Characterization

As described in Section 2.1, paint containing PCBs will be removed from concrete and asphalt to be used for site grading. YAEC has collected core samples of the concrete to verify that PCB concentrations are less than two (2) milligrams per kilogram (mg/Kg) following the removal of paint. In the event that non-PCB paint remains on concrete, core samples will be collected to verify that that metals concentrations do not pose a risk (see Section 4.2 for risk criteria).

A mastic coating will remain on some foundation walls at the site. The mastic coating is inert. As described in Section 2.1, some of the mastic contains non-friable asbestos.

3.2 PHYSICAL PROPERTIES

Size

The concrete foundations and walls are generally up to 1 foot thick, except where two walls abut. Concrete to be used for site grading and asphalt from paved areas will be processed as necessary to provide a suitable base for the three feet of soil that will be placed over the non-native materials.

Density

The concrete will contain rebar and typically has a density of 150 pounds per cubic foot. Certain structures, such as the Fuel Transfer Chute (most of which has been shipped off-site), were constructed with concrete that had a density of at least 225 pounds per cubic foot. The density of asphalt is estimated to be approximately 140 pounds per cubic foot.

Percent Solids

The solid waste to be beneficially used is reinforced concrete and asphalt that is 100 percent solid.

Liquid Content

The concrete is free of liquids. Water that may be present in some subsurface utility lines (e.g., water and sewer lines) will be removed prior to decommissioning the lines.

3.3 BIOLOGICAL PROPERTIES

Due to the nature of the concrete and asphalt, there is no biological activity or pathogens associated with the foundations or utility lines.

4.0 PROPOSED HANDLING METHODS AND UTILIZATION

4.1 Proposed Handling

The foundations, concrete and asphalt and utility lines remaining at the site will not be transported, stored, or processed. Voids within utility lines greater than 8 inches in diameter will be filled. Utility lines less than 8 inches in diameter will be abandoned in-place. Three feet of soil will cover any non-native materials left in-place.

The concrete structures (buildings, slabs and support columns) will be demolished using standard construction practices and heavy machinery. Large structures such as the Reactor Support Structure will be minimized by use of a wrecking ball and hydraulic shears. Smaller structures will be demolished with various hydraulic claws and shears, as appropriate. Once the buildings are brought to grade elevation, structural steel beams and metal will be segregated into piles for sorting, packaging and disposal. Rebar that is exposed will be cut off for disposal and rebar that is contained within concrete will remain on-site. Concrete will be crushed using heavy equipment to accommodate stockpiling, prior to being loaded into containers for release surveying on-site. Material surveyed for re-use on site will be either placed directly into building voids or stockpiled until used for site grading.

4.2 Proposed Utilization

General Description

The remaining foundations and buried utility lines will be incorporated in the final site regrading.

Locations Where Material is to be Used

Figure 2 shows the locations of foundations that will remain, Figure 3 shows the locations of utility lines that will remain, and Figure 4 shows where processed concrete and asphalt will be used.

Health and Environmental Impacts

The material to be reused under the BUD primarily consists of inert construction materials comprised of concrete and asphalt. Potential

residual impacts on the concrete include paint, as well as radiological constituents (below DCGLs).

The BUD guidance document states that the applicant must demonstrate that Critical Contaminants of Concern (CCCs), such as PCBs as defined in the guidance document, are consistent with background. Based on discussions with DEP at a pre-application meeting held on 1 July 2004, it is our understanding that this requirement of the BUD guidance may not be applicable for a Category 3 BUD and that this issue will undergo further review by DEP.

Confirmation sampling of the concrete is being performed to ensure that the maximum residual PCB concentration will be no more than 2 mg/kg in the concrete debris. This maximum threshold is essentially equivalent to the proposed default BUD S-2 and S-3 standard of 1.6 mg/kg for PCBs. The S-2 and S-3 BUD values represent an average concentration (this is inherent to the risk assessment process). Although all concrete will be confirmed to contain no more than 2 mg/kg, the actual average PCB concentration in concrete will be well below the S-2 and S-3 BUD standards for PCBs. Because PCBs in concrete will meet the BUD S-2 and S-3 standards, no further assessment for PCBs is required.

In the event that non-PCB paint is left on concrete surfaces, the coated concrete will be tested for RCRA 8 metals. The sampling results will be evaluated to ensure that the average concentrations are below the S-2 and S-3 BUD values. If the average concentrations are higher, then the paint will be abated or the concrete will be disposed off-site.

No standards exist in the draft BUD guidance for radionuclides. Due to the operation of the power plant, the concrete may contain radiological constituents at concentration less than or equal to the DCGL. The use of concrete meeting the DCGL is consistent with a Category 3 Beneficial Use of Secondary Materials in Restricted Applications because the management of the concrete beneath 3-foot of soil overburden meets the DEP BUD guidance risk management criteria (overall cancer risk less than or equal to 5 in 10,000; or 0.5×10^{-5}).

The DCGLs developed in the LTP ensure that the radiation dose from exposure to residual radionuclides is no more than 25 mrem/yr to meet NRC requirements. These DCGLs for the concrete debris were developed using the RESRAD multipathway risk assessment and radionuclide fate modeling system developed by the U.S. Department of Energy.

The risk assessment guidelines for the BUD, which adopt those defined under the MCP with a more conservative risk threshold, define health protection on the basis of cancer risk, rather than radiation dose. MADEP does not have guidelines for the evaluation of cancer risk for radionuclides. Consequently, the U.S. EPA guidelines, published in the *Soil Screening Guidance for Radionuclides* (USEPA, 2000a,b) were used for this assessment.

The final site grading and re-vegetation plan will ensure that the concrete will reside beneath 3-feet of soil. An Activity and Use Limitation (AUL) will require a Health & Safety Plan and Soil Management Plan for subsurface excavation activities. Thus, the AUL will prevent "direct contact" pathways such as incidental ingestion and dermal contact with subsurface materials. Thus, the primary pathway of possible concern for exposure to radionuclides in the subsurface concrete, is from external radiation (*e.g.*, ionizing radiation emitted as the result of radioactive decay).

Using the US EPA risk assessment guidelines for radionuclides combined with RESRAD to determine the degree of radiation reduction, cancer risks for external radiation were calculated assuming the concentration in concrete debris equaled the concrete DCGL (because all concrete will be at most equal to the DCGL, the true average concentration will be less than the DCGL). The risk results are presented in Table 4. A more detailed summary of the risk calculations is presented in Appendix B. The risk results summing overall radionuclides indicate a calculated risk of 1×10^{-8}, or well below the BUD risk guideline of 0.5×10^{-6} per chemical, and 0.5×10^{-5} for all chemicals (radionuclides) combined. As is evident from the risk analysis in Appendix B, the 3-foot soil overburden attenuates external radiation over what would be the case in the absence of the overburden.

The health assessment presented here indicates that soil grading plan and use of concrete debris as fill, satisfies the interim draft BUD guidance for Category 3 use of Secondary Materials in Restricted Applications.

REFERENCES

U.S. Environmental Protection Agency (USEPA). 2000a. Soil Screening Guidance for Radionuclides: Technical Background Document. EPA/540-R-00-006. Office of Radiation and Indoor Air; Office of Solid Waste and Emergency Response. Washington, DC.

U.S. Environmental Protection Agency (USEPA). 2000b. Soil Screening Guidance for Radionuclides: User's Guide. EPA/540-R-00-007. Office of Radiation and Indoor Air; Office of Solid Waste and Emergency Response. Washington, DC.

Massachusetts Department of Environmental Protection, Bureau of Waste Prevention, "Draft Interim Guidance Document for Beneficial Use Determination Regulations 310 CMR 19.060", March 18, 2004.

Table 1
Summary of Structures to Remain In-Place
Yankee Nuclear Power Station, Rowe, MA

Structure Name	Portion to Remain In-Place	Approximate Volume of Concrete to Remain In-Place (cubic yards)
Vapor Container/Reactor Supports/ Elevator	Foundations	1,712
Turbine Building	Portions of slabs and foundations	1,428
Service Building	Portions of slabs and foundations	351
Stores Warehouse	Portions of slabs and foundations	100
Primary Auxiliary Building	Slabs, walls, and foundations	702
Waste Tank Moat Area	Foundations	382
Waste Disposal Building	Slabs and foundations	133
Miscellaneous Tanks and Equipment	Foundations	320
Potentially Contaminated Area Storage Building #2 and Warehouse	Slabs and foundations greater than 18 inches below grade	10
Potentially Contaminated Area Warehouse	Slabs and foundations	164
Pipe Tunnel	Vertical column support foundations	42
Fuel Transfer Chute	Vertical column supports	45
Safety Injection/Diesel Generator Building	Slab, walls, and foundations	53
Compactor Building	Slab and foundations	81
New Fuel Vault	Slab and foundations	140
Screenwell House	Slabs, walls, and foundations greater than 36 inches below grade	1,348
Discharge Structure	Slabs, walls, and foundations greater than 36 inches below grade	284
Utility Lines ≤ 8 inches in diameter	Abandoned in-place	NA
Utility Lines > 8 inches in diameter	Filled with flowable fill and left in-place	NA
Total		**7,295**

Table 2
Summary of Materials to be Reused for Site Regrading
Yankee Nuclear Power Station, Rowe, MA

Structure Name	Approximate Volume of Concrete (cubic yards)
Vapor Container/Reactor Supports	7,250
Primary Auxiliary Building	1,150
Spent Fuel Pool/Ion Exchange Pit	850
Misc. Slabs/Foundations*	350
Asphalt	1,500
Total	**11,100**

* Slabs/foundations to be removed to accommodate site grading plan (see Figure 2).

Table 3
DCGLs for Concrete Debris
Yankee Nuclear Power Station, Rowe, MA

Radionuclide	DCGL† (pCi/g)
H-3	9.5E+01 (cellar holes) 2.8E+02 (grading)
C-14	7.20E+00
Fe-55	1.40E+02
Co-60	4.30E+00
Ni-63	1.00E+02
Sr-90	7.60E-01
Nb-94	7.00E+00
Tc-99	6.10E+01
Ag-108m	7.00E+00
Sb-125	3.10E+01
Cs-134	4.70E+00
Cs-137	6.70E+00
Eu-152	9.50E+00
Eu-154	9.10E+00
Eu-155	3.80E+02
Pu-238	9.50E+00
Pu-239	8.80E+00
Pu-241	1.40E+02
Am-241	4.10E+00
Cm-243	4.70E+00

† Represents a dose of 23.73 mrem/yr
Source: YNPS License Termination Plan, Draft Revision 1, Section 6.

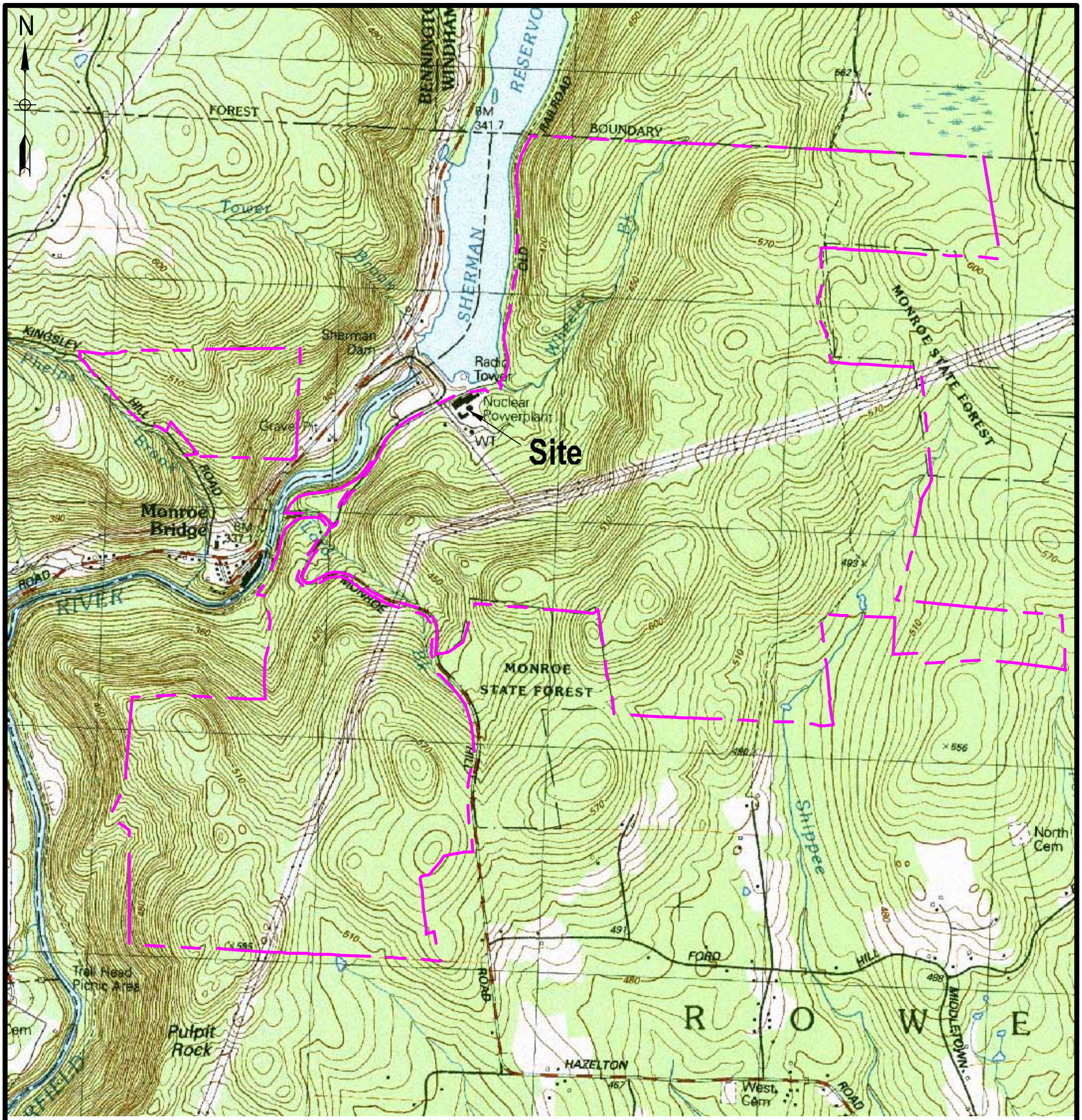
Table 4
Summary of Radionuclide Risk Calculations for BUD
Yankee Nuclear Power Station, Rowe, MA

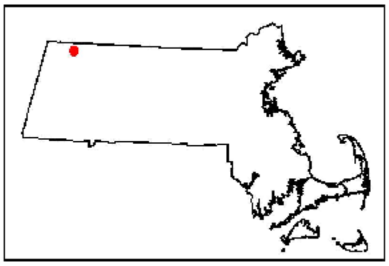
Radionuclide	Concrete Debris DCGL [1] (pCi/g)	External Radiation Risk Including 3-Foot Overburden
Co-60	4.3	2.6E-09
Cs-137 + D	6.7	2.5E-10
Silver - 108m + D	7.0	7.0E-10
Hydrogen-3	280.0	n/a
Carbon-14	7.2	8.6E-26
Iron-55	140.0	n/a
Nickel-63	100.0	n/a
Strotium-90+D	0.8	6.7E-15
Niobium-94	7.0	1.8E-09
Technetium-99m	61.0	1.0E-20
Antimony-125+D	31.0	7.0E-11
Cesium-134m	4.7	8.4E-11
Europium-152	9.5	2.2E-09
Europium-154	9.1	2.1E-09
Europium-155	380.0	3.9E-16
Plutonium-238	9.5	3.6E-21
Plutonium-239	8.8	1.2E-16
Plutoniumu-241	140.0	1.0E-18
Americium-241	4.1	2.1E-25
Curium-243	4.7	1.1E-13
	Sum All Radionuclides =	**1E-08**

Notes:
[1] Dose concentration guideline levels for concrete debris in LTP.
(Radionuclide concentration in concrete will be less than or equal to these values.)

n/a - radionuclide not a cancer risk for external radiation (EPA, 2000).

Source: Gradient Human Health Risk Assessment (Appendix B).





YAEC Property Boundary

Scale 1:25,000

0.5 km 0 500 m

0.5 mi 0 1,000 ft

Figure 1 - Locus Map
Yankee Nuclear Power Station - Rowe, MA

ERM

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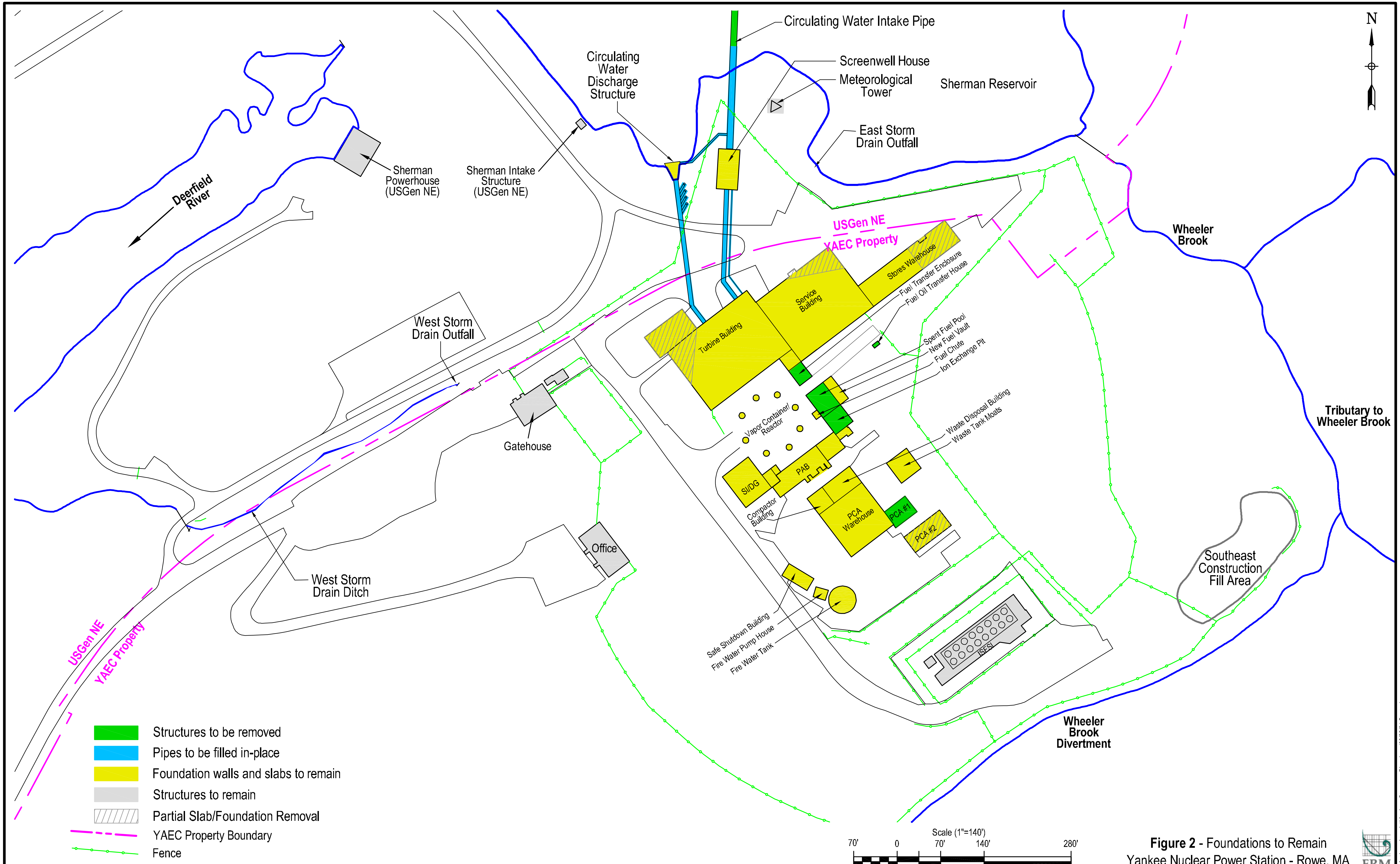
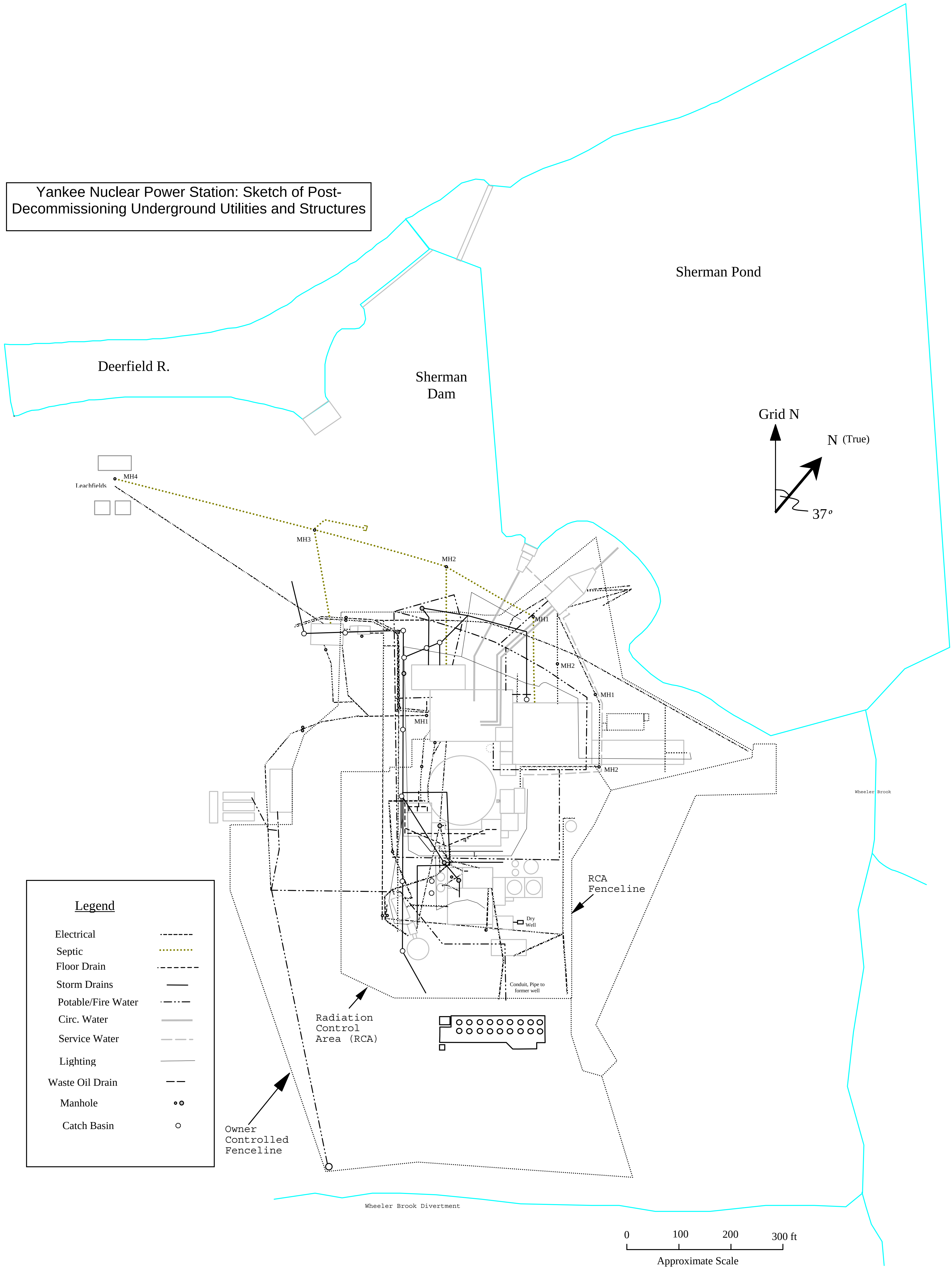


Figure 2 - Foundations to Remain
Yankee Nuclear Power Station - Rowe, MA



Yankee Nuclear Power Station: Sketch of Post-Decommissioning Underground Utilities and Structures
Sherman Pond
Deerfield R.
Sherman Dam
Grid N
N (True)
37°
Leachfields
MH4
MH3
MH2
MH1
MH2
MH1
MH1
MH2
Wheeler Brook
RCA Fenceline
Dry Well
Conduit, Pipe to former well
Radiation Control Area (RCA)
Owner Controlled Fenceline
Legend
Electrical
Septic
Floor Drain
Storm Drains
Potable/Fire Water
Circ. Water
Service Water
Lighting
Waste Oil Drain
Manhole
Catch Basin
Wheeler Brook Divertment
0
100
200
300 ft
Approximate Scale

Figure 3

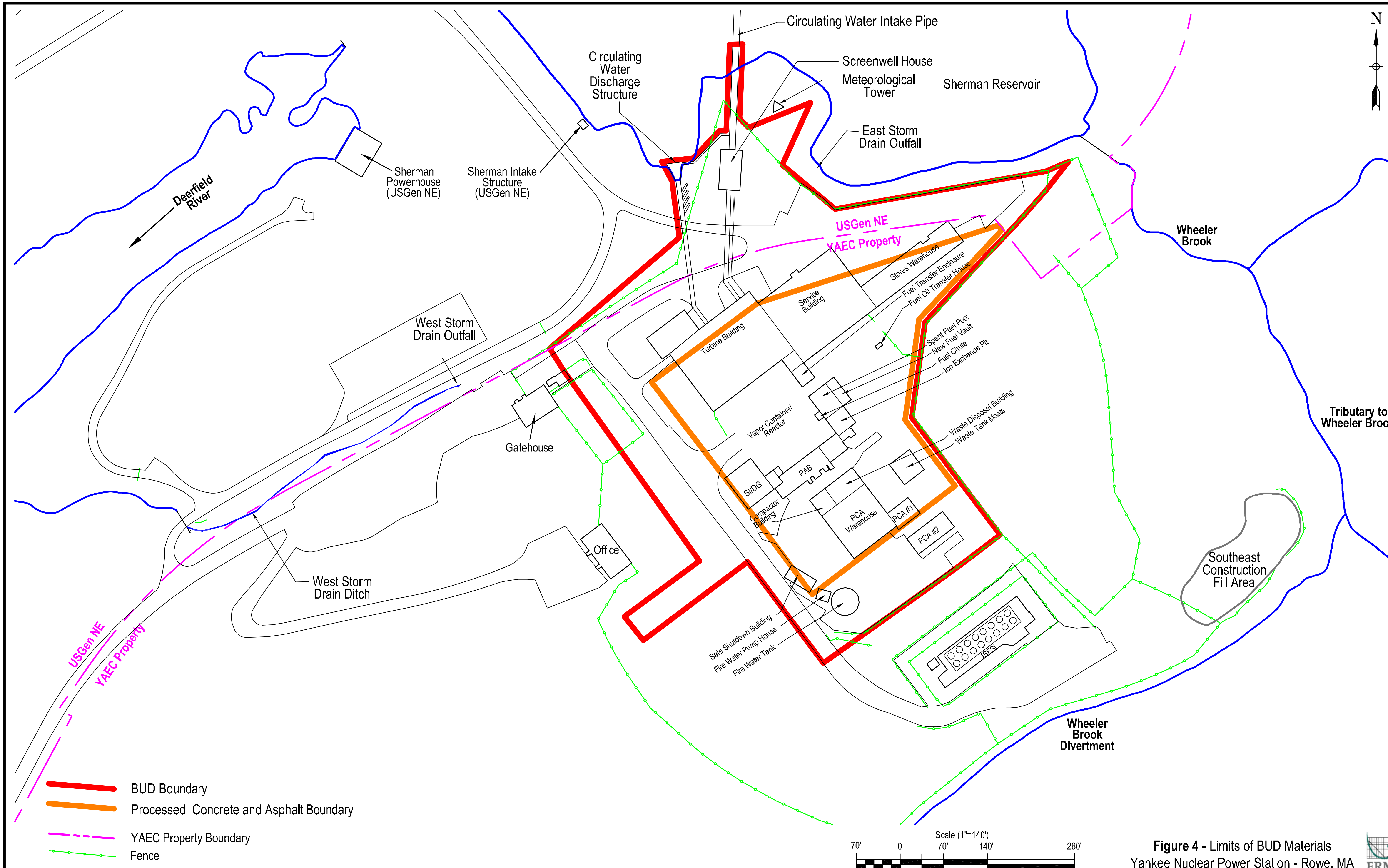


Figure 4 - Limits of BUD Materials
Yankee Nuclear Power Station - Rowe, MA

Appendix A
Transmittal and Application Forms

Enter your transmittal number →

W050861
Transmittal Number

Your unique Transmittal Number can be accessed online: http://www.state.ma.us/scripts/dep/trasmfrm.stm or call DEP's InfoLine at 617-338-2255 or 800-462-0444 (from 508, 781, and 978 area codes).

Massachusetts Department of Environmental Protection

Transmittal Form for Permit Application and Payment

1. Please type or print. A separate Transmittal Form must be completed for each permit application.

2. Make your check payable to the Commonwealth of Massachusetts and mail it with a copy of this form to: DEP, P.O. Box 4062, Boston, MA 02211.

3. Three copies of this form will be needed.

Copy 1 - the original must accompany your permit application. **Copy 2** must accompany your fee payment. **Copy 3** should be retained for your records

4. Both fee-paying and exempt applicants must mail a copy of this transmittal form to:

DEP
P.O. Box 4062
Boston, MA
02211

*** Note:** For BWSC Permits, enter the LSP.

A. Permit Information

BWPSW013
1. Permit Code: 7 or 8 character code from permit instructions

Beneficial Use Determination - Major
2. Name of Permit Category

Beneficial use of concrete foundations and utility lines
3. Type of Project or Activity

B. Applicant Information – Firm or Individual

Yankee Atomic Electric Company
1. Name of Firm - Or, if party needing this approval is an individual enter name below:

2. **Last Name** of Individual
3. **First Name** of Individual
4. MI

49 Yankee Road
5. Street Address

Rowe	MA	01367	413-424-5261	
6. City/Town	7. State	8. Zip Code	9. Telephone #	10. Ext. #

Kenneth Dow
11. Contact Person

dow@yankee.com
12. e-mail address (optional)

C. Facility, Site or Individual Requiring Approval

Yankee Atomic Electric Company
1. Name of Facility, Site Or Individual

49 Yankee Road
2. Street Address

Rowe	MA	01367	413-424-5261	
3. City/Town	4. State	5. Zip Code	6. Telephone #	7. Ext. #

8. DEP Facility Number (if Known)
9. Federal I.D. Number (if Known)
10. BWSC Tracking # (if Known)

D. Application Prepared by (if different from Section B)*

Environmental Resources Management
1. Name of Firm Or Individual

399 Boylston St. 6th Floor
2. Address

Boston	MA	02116	617-646-7842	
3. City/Town	4. State	5. Zip Code	6. Telephone #	7. Ext. #

John McTigue
8. Contact Person

9. LSP Number (BWSC Permits only)

E. Permit - Project Coordination

1. Is this project subject to MEPA review? ☒ yes ☐ no
If yes, enter the project's EOEA file number - assigned when an Environmental Notification Form is submitted to the MEPA unit:

13247
EOEA File Number

F. Amount Due

DEP Use Only

Permit No:

Rec'd Date:

Reviewer:

Special Provisions:

1. ☐ **Fee** Exempt (city, town or municipal housing authority)(state agency if fee is $100 or less).
There are no fee exemptions for BWSC permits, regardless of applicant status.
2. ☐ Hardship Request - payment extensions according to 310 CMR 4.04(3)(c).
3. ☐ Alternative Schedule Project (according to 310 CMR 4.05 and 4.10).
4. ☐ Homeowner (according to 310 CMR 4.02).

Fee addressed under MOU between Yankee and DEP

$1,580.00
Dollar Amount

Date

Massachusetts Department of Environmental Protection
Bureau of – Waste Prevention – Solid Waste Management
BWP SW 13 Beneficial Use Determination – Major
BWP SW 30 Beneficial Use Determination - Minor
Application for Beneficial Use Determination

W050861
Transmittal Number #

Facility ID (if known)

A. Project Information

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

DIRECTIONS:
1. Specify the page numbers in which the following information is located.

2. Enter NA if information requested is not applicable.

1. Which permit category are you applying for? ☒ BWP SW 13 ☐ BWP SW 30

	Page #	DEP USE ONLY
2. **General Information about the Solid Waste**		
a. General description of the waste	3	
b. Source of the waste		
(1) Name of the generator	7	
(2) Address of the generator	7	
c. Description of the industrial process which produces the waste	7	
d. Quantity (volume and/or tonnage)	7	
3. **Chemical, Physical and Biological Properties of the Waste**		
a. Chemical properties of the waste		
(1) pH	8	
(2) reactivity	8	
(3) leachabilty (TCLP test)	8	
(4) total metals	8	
(5) VOCs	8	
(6) other appropriate constituents	8	
b. Physical properties of the waste		
(1) size	9	
(2) density	9	
(3) percent solids	10	
(4) liquid content of the waste	10	
c. Biological properties of the waste, if applicable		

W050861
Transmittal Number #

Facility ID (if known)

A. Project Information (cont.)

	Page #	DEP USE ONLY
(1) pathogens	10	
4. **Proposed Handling Methods and Utilization**	11	
a. Proposed handling methods		
(1) transportation	11	
(2) storage	11	
(3) processing	11	
b. Proposed utilization		
(1) general description	11	
(2) location(s) where material is to be used	11	
(3) health and environmental impacts	11	

B. Certification: 310 CMR 19.011

Any person, required by these regulations or any order issued by the Department, to submit papers shall identify themselves by name, profession, and relationship to the applicant and legal interest in the facility, and make the following certification: "I certify under penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate and complete. I am aware that there are significant penalties both civil and criminal for submitting false information including possible fines and imprisonment.

Frank Helin
Print Name

[signature]
Authorized Signature

Decommissioning Director
Position/Title

9/22/2004
Date

Massachusetts Department of Environmental Protection
Bureau of – Waste Prevention – Solid Waste Management
BWP SW 13 Beneficial Use Determination – Major
BWP SW 30 Beneficial Use Determination - Minor
Application for Beneficial Use Determination

W050861
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W050861
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Michael G. Kline
Print Name

Michael G. Kline
Authorized Signature

General Manager
Position/Title

9/21/04
Date

Appendix B
Human Health Risk Assessment
BUD for Concrete

Human Health Risk Assessment
Beneficial Use Determination (BUD) for Concrete
Yankee Nuclear Power Station
Rowe, Massachusetts

Prepared for
Yankee Atomic Electric Company
49 Yankee Road
Rowe, Massachusetts 01367

Prepared by
Gradient Corporation
20 University Road
Cambridge, MA 02138

September 22, 2004

Table of Contents

List of Tables

1 Introduction and BUD Goals

This document presents a human health risk assessment to support the Category 3 Beneficial Use Determination (BUD) for Secondary Materials in Restricted Applications for concrete debris. This BUD is a component of the environmental site closure underway at the Yankee Nuclear Power Station (YNPS). Yankee Atomic Electric Company (YAEC) owns YNPS and surrounding lands, which comprise approximately 1,800 acres, of which approximately 12 acres is occupied by the nuclear plant itself.

Since 1992, the plant has been in the process of being dismantled and YAEC is terminating the YNPS federal license with the Nuclear Regulatory Commission (NRC). In order to terminate its nuclear operating license, YAEC must complete a process of radiological cleanup defined by the NRC and set forth in YAEC's License Termination Plan (LTP). In addition, YAEC will comply with the Massachusetts Department of Public Health (MADPH) requirements for meeting radiological dose guidelines. Both the NRC and MADPH require compliance with radiological "dose-based" requirements for the protection of human health.

In parallel with the license termination and cleanup to meet the NRC and MADPH radiological dose requirements, YAEC is conducting a comprehensive environmental closure that will ensure that the property poses no adverse human or environmental risks once YAEC transfers title of the property. The environmental site closure is being performed as a voluntary action that will adhere to guidelines established by the Massachusetts Department of Environmental Protection (MADEP) as well as guidelines established by the U.S. Environmental Protection Agency (USEPA) -- in addition to the requirements noted above established by NRC and MADPH.

This human health risk assessment was performed to support a Category 3 BUD as outlined in the March 18, 2004 Draft Interim Guidance Document for Beneficial Use Determination Regulations, 310CMR19.060 (MADEP, 2004). The risk management guidelines defined in the draft BUD guidance require demonstration of meeting 0.5×10^{-6} cancer risk for an individual constituent, and 0.5×10^{-5} overall cancer risk summed over all constituents. No cleanup standards for radionuclides are available in the Draft BUD Guidance. This risk assessment develops risk-based support for residual levels of radionuclides in concrete debris, and is consistent with an MCP Method 2 approach.

The BUD risk assessment methods follow those defined under the MCP (MADEP, 1995). However, MADEP does not have any published radiological risk assessment guidance. Thus, the

assessment of radiological risks to support the BUD relied upon the most recent guidance set forth in the USEPA (2000a) Soil Screening Guidance for Radionuclides: Technical Background Document.

2 Hazard Identification

Constituents of potential concern (COPCs) for the BUD include residual PCBs and radionuclides in concrete debris. Confirmation sampling of the concrete will ensure that the maximum residual PCB concentration will be no more than 2 mg/kg in the concrete debris. This maximum threshold is essentially equivalent to the default BUD S-2 and S-3 standard of 1.6 mg/kg for PCBs. The BUD S-2 and S-3 defaults represent a risk-based acceptable average concentration (this is inherent to the risk assessment process). Although all concrete will be confirmed to contain no more than 2 mg/kg, the actual average PCB concentration in concrete will be below the S-2 and S-3 BUD standards for PCBs. Thus, no further risk assessment is required for PCBs in concrete to meet the BUD Category 3 guidelines.

No standards exist in the draft BUD guidance for radionuclides. Thus, the COPCs for the BUD risk assessment are the radionuclides listed in the YNPS LTP. The radionuclide COPCs are listed in Table 1.

The Dose Concentration Guideline Levels (DCGLs) developed in the LTP ensure that the radiation dose from exposure to residual radionuclides is no more than 25 mrem/yr to meet NRC requirements. These DCGLs for the concrete debris were developed using the RESRAD multipathway risk assessment and radionuclide fate modeling system developed by the U.S. Department of Energy (ANL, 2001). The concrete debris that is proposed to be used as fill, covered by 3-feet of soil overburden, will have residual radionuclide concentrations that are less than or equal to the DCGL concentrations. Thus, for this risk evaluation, we conservatively assumed that the concrete debris had concentrations equal to the DCGLs, even though the actual average concentration will by definition be less than the DCGLs.

3 Dose-Response Assessment

USEPA classifies all radionuclides as carcinogens, based on their property of emitting ionizing radiation and on the extensive weight of evidence provided by epidemiological studies of radiologically induced cancers in humans. For radiological constituents, cancer slope factors have been published in the

USEPA (2000a) Soil Screening Guidance for Radionuclides: Technical Background Document. This document was used as the bases of the dose-response (toxicity) factors used for the BUD risk assessment.

4 Exposure Assessment

Although the ultimate use for the Site has not been determined, it will likely include open space for recreational activities. Furthermore, an Activity Use Limitation (AUL) will be enforced over that portion of the site that constituted the former industrial area, and this is the area applicable to the BUD for concrete. The AUL will ensure that the 3-foot overburden in the former industrial area is maintained.

The AUL will preclude excavation, without a DEP-approved soil management plan and would occur only under the oversight of a Licensed Site Professional (LSP). Thus, the AUL will prevent "direct contact" pathways such as incidental ingestion and dermal contact with subsurface materials. Furthermore, indirect pathways such as intake from vegetables that might conceivably be grown on the graded area, would not lead to the uptake of radionuclides as they would lie beneath the 3-foot of graded material. Thus, the remaining pathway of possible concern for exposure to radionuclides in the subsurface concrete, is from external radiation (*e.g.*, ionizing radiation emitted as the result of radioactive decay).

In order to evaluate the attenuation provided by the 3-feet of overburden, we used the U.S. Department of Energy RESRAD multipathway risk assessment model (ANL, 2001). We first calculated the external radiation dose assuming no overburden, then performed a parallel calculation for a scenario that included 3-foot of soil overburden. For both scenarios, a unit concentration (*e.g.*, 1 pCi/g) was used for each radionuclide (the dose and risks scale directly as a function of the source concentration).

As summarized in Table 1, the dose reduction provided by the 3-foot of overburden is quite large, ranging from over 10,000-fold at a minimum, and for some radionuclides diminishing the external radiation dose by well over a million-fold.

Although the AUL may not necessarily preclude installation of a well for drinking water from a regulatory perspective, as a practical matter installation of a drinking water well would be implausible with the AUL in place. Nevertheless, we examined the leaching to groundwater pathway for the radionuclides in concrete, as discussed in the next section.

5 Radiological Risk Characterization

Although the AUL will preclude direct contact with subsurface concrete debris, radionuclides can have a deleterious effect on humans without being taken into or brought in contact with the body. This is because high-energy beta particles and photons from radionuclides can exert their energy directly in human tissue. Such "external radiation" exposures can result from exposure to residual radionuclides at the site. Gamma and x-rays are the most penetrating of the emitted radiation and comprise the primary contribution to the radiation dose from external exposures. Radionuclide intake is expressed in units of radiation activity (*i.e.*, picocurie or pCi) rather than mass.

5.1 External Radiation

Cancer risk associated with external radiation exposures was calculated using the following equation, which accounts for external radiation exposure while indoors and outdoors (USEPA, 2000b):[1]

$$\mathrm{Risk} = \overline{\mathrm{C}} \times \left(\frac{\mathrm{EF}}{365\ \mathrm{days/yr}}\right) \times \mathrm{ED} \times \mathrm{ACF} \times [\mathrm{ET_o} + (\mathrm{ET_i} \times \mathrm{GSF})] \times \mathrm{CSF_{ext}} \quad (5\text{-}1)$$

where:

$\overline{C}$	=	Average exposure point concentration (pCi/g)
EF	=	Exposure frequency (days/yr)
ED	=	Exposure duration (*e.g.*, 30 years)
ACF	=	Area correction factor (default = 0.9; USEPA, 2000a)
ET_o	=	Exposure time fraction outdoors (default = 0.073; USEPA, 2000a)
ET_i	=	Exposure time fraction indoors (default = 0.683; USEPA, 2000a)
GSF	=	Gamma shielding factor (default = 0.4; USEPA, 2000a)
CSF_{ext}	=	Cancer slope factor for external radiation (risk/yr per pCi/g)

Values for the radionuclide cancer slope factors are given in USEPA's Soil Screening Guidance for Radionuclides (USEPA, 2000a) as well as the RESRAD User's Manual (ANL, 2001).

[1] Note that the equation in the USEPA Technical Background Document contains a typographical error, the correct equation is found in Equation 4, page 2-22, of the USEPA User's Guide. Note further that the USEPA SSLs are written in terms of a "risk based concentration" (*e.g.*, the SSL term is the radionuclide concentration (C) term); the risk equation here simply rearranges the USEPA equation to express it as a function of risk.

Adjustment of Concentration for Radioactive Decay

The concentration of radionuclides in the environment declines according to radionuclide-specific decay rates. Thus, the radionuclide concentration (C) is not a constant, but rather declines as a function of time according to the following exponential equation:

$$C(t) = C_o e^{-\lambda t} \qquad (5\text{-}2)$$

where

$C(t)$ = concentration at time "t" in years (pCi/g)

C_o = initial concentration at time t=0 (pCi/g)

λ = $\frac{\ln(2)}{t_{1/2}}$ is the decay constant (per year)

$t_{1/2}$ = half-life (years)

The average concentration ($\overline{C}$) over a particular time period (T) is given by integrating the declining concentration over the time period:

$$\overline{C} = \frac{1}{T}\int_0^T C_o e^{-\lambda t} dt = C_0 \frac{(1-e^{-\lambda T})}{T\lambda} \qquad (5\text{-}3)$$

where C_o is the exposure point concentration at the beginning (time t=0) of the exposure period. In this analysis, we adopted the standard "default" assumption of a 30-year exposure duration (*i.e.*, T = 30 years, where T and ED are synonymous).

For radionuclides with short half-lives (*e.g.*, shorter than the typical exposure duration of interest), the time-averaged concentration can be appreciably less than the initial concentration. Conversely, for long-lived radionuclides, the adjustment for radioactive decay is insignificant.

A summary of the external radiation cancer risks for the BUD is provided in Table 2. The risks calculated for the 3-foot overburden are given by calculating the risks using Equation 5-1 with the average concentration given by Equation 5-3 as though no overburden existed (see Table 3), and then

adjusting these risks by accounting for dose reduction provided by the 3-foot overburden. The risk assessment results meet the dual BUD risk-based criteria:

- All individual radionuclide risks fall below 0.5×10^{-6}
- The total risk of 1×10^{-8} (rounded from 9.8×10^{-9}) is well below the BUD risk guideline of 0.5×10^{-5}.

This evaluation demonstrates that the Category 3 BUD for concrete meets the risk management guidelines in the Draft BUD Guidance document (MADEP, 2004).

Relationship Between Radiation Dose (mrem/yr) and Cancer Risk

As noted in Section 2, the DCLGs in the LTP are established on the basis of limiting the possible radiation dose to 25 mrem/yr. Cancer risk can be related to radiation dose through the following equation:

$$Risk_{ext} = Dose_{ext} \times ED \times \frac{(1 - e^{-\lambda T})}{\lambda} \times \left(\frac{CSF_{ext}}{DCF_{ext}}\right) \qquad (5\text{-}4a)$$

For radionuclides with long half-lives, this reduces to:

$$Risk_{ext} = Dose_{ext} \times ED \times \left(\frac{CSF_{ext}}{DCF_{ext}}\right) \qquad (5\text{-}4b)$$

where

$Dose_{ext}$ = External radiation dose (mrem/yr)
CSF_{ext} = External radiation cancer slope factor (risk per pCi/g)
DCF_{ext} = External radiation dose conversion factor (mrem/yr per pCi/g)

The relationship between "risk" and "dose" is provided here for completeness. For the BUD, the dose calculations are not needed to ensure compliance with the BUD risk management guidelines. However, as shown in Table 2, the dose for due to subsurface concrete materials would be approximately 10,000-fold below the Massachusetts Department of Public Health dose guideline of 10 mrem/year.

5.2 Leaching to Groundwater

Using methods consistent with the MCP and MADEP Guidelines (MADEP 1994, 1995), and also defined in U.S. EPA's (2000a,b) Soil Screening Guide for Radionuclides, we examined possible leaching to groundwater for the radionuclides in concrete. For this evaluation we performed the following stepwise screening evaluation:

1. Calculate an equilibrium concentration of radionuclide in pore water using standard equilibrium partitioning equations:
2. Applied a "dilution attenuation factor" (DAF) to the pore water values as a screening estimate of the concentration at a hypothetical well.
3. Compared the resulting concentrations in "groundwater" to drinking water standards for radionuclides.

The equations used for step 1 and 2 are outlined below:

Step 1:

$$C_w = C_s \times \left(\frac{\rho_b}{\phi + \rho_b K_d} \right) \times 10^3 \ (g/kg) \qquad (5\text{-}5)$$

Step 2:

$$C_{gw} = \frac{C_w}{DAF} \qquad (5\text{-}6)$$

where

C_w	=	concentration in pore water (pCi/L)
C_s	=	concentration in soil (pCi/g)
C_{gw}	=	concentration in groundwater (pCi/L)
K_d	=	soil-water partition coefficient (L/kg)
ϕ	=	porosity or water content (cm^3/cm^3)
ρ_b	=	soil bulk density (g/cm^3)
DAF	=	dilution attenuation factor (unitless)

The radionuclide soil-water partition coefficients, which are based on values published in the RESRAD User's Manual, are also summarized in the LTP (Appendix 6N).

There are no DAF values for radionuclides in the MADEP (1994, 1995) guidance. However, the MADEP has derived DAF values for a range of organic compounds with varying soil-water K_d parameters, as summarized below:

Parameter	**K_{oc} (L/kg)**	**K_d (L/kg)**	**DAF**
benzene	83	0.083	56.5
ethylbenzene	575	0.575	121.1
toluene	270	0.27	80.6
o-xylene	302	0.302	83.3
TCE	124	0.124	76.3
PCE	468	0.468	86.2
1,1,1-TCA	157	0.157	169.2
naphthalene	1288	1.288	222.2

Notes:
$K_d = K_{oc} \times f_{oc}$ (foc = 0.001, *i.e.*, 0.1% organic carbon)

Source: MADEP (1994)

Based on these modeled DAF values, MADEP (1994) developed a regression equation for DAF values for non-modeled compounds as a function of chemical partition coefficient.

As summarized in Table 4, the soil-water partition coefficients for radionuclides are greater than (*e.g.*, less soluble in water) than all of the compounds modeled by MADEP. Rather than extrapolate beyond the range of the MADEP modeled results, we adopted a DAF value of 222 (*e.g.*, the value for naphthalene with a K_d value of 1.3), as this was the compound with the largest K_d value modeled. This DAF value is likely to underestimate the dilution for the radionuclides, with typical K_d values ranging from approximately 10 L/kg to over 1,000 L/kg (see Table 4).[2]

The calculated radionuclide concentrations in groundwater (C_{gw}) calculated in this manner, were compared to the drinking water standards, as summarized in Table 4. Note that for this calculation, the average concentration in concrete debris over a 30-year period, taking into account radioactive decay (Equation 5-3), was used for the value of C_s in Equation 5-5. As the results in Table 4 indicate, the placement of subsurface concrete debris under the BUD with radionuclide concentrations equal to the DCGLs would not lead to groundwater contamination above drinking water standards.

[2] Tritium (Hydrogen-3 in Table 4) is the notable exception, as it does not "partition" to soil.

References

Argonne National Laboratory (ANL). 2001. User's Manual for RESRAD Version 6. Environmental . Prepared for U.S. Department of Energy (USDOE). July 2001.

Massachusetts Department of Environmental Protection (MADEP). 2004. "Draft Interim Guidance Document for Beneficial Use Determination Regulations, 310CMR19.060." Bureau of Waste Prevention, March 18, 2004.

Massachusetts Department of Environmental Protection (MADEP). 1995. "Guidance for Disposal Site Risk Characterization - In Support of the Massachusetts Contingency Plan (Interim final policy)." Bureau of Waste Site Cleanup and Office of Research and Standards (Boston, MA). BWSC/ORS-95-141. July.

Massachusetts Department of Environmental Protection (MADEP). 1994. "Background documentation for the development of the MCP numerical standards." Bureau of Waste Site Cleanup and Office of Research and Standards (Boston, MA), April 1994.

U.S. Environmental Protection Agency (USEPA). 2000a. Soil Screening Guidance for Radionuclides: Technical Background Document. EPA/540-R-00-006. Office of Radiation and Indoor Air; Office of Solid Waste and Emergency Response. Washington, DC.

U.S. Environmental Protection Agency (USEPA). 2000b. Soil Screening Guidance for Radionuclides: User's Guide. EPA/540-R-00-007. Office of Radiation and Indoor Air; Office of Solid Waste and Emergency Response. Washington, DC.

Tables

Table 1
Radiation Dose Reduction Due to 3-Foot Soil Overburden

Radionuclide	Radiation Dose at Year 1		
	External Radiation Dose (mrem/yr)		Dose Reduction
	No Overburden	3-Foot of Soil	
Cobalt (Co-60)	7.5E+00	1.6E-04	4.6E+04
Cesium (Cs-137)	1.8E+00	4.1E-06	4.5E+05
Silver (Ag-108m)	1.7E+00	2.9E-06	5.9E+05
Tritium (H-3)	n/a	n/a	n/a
Carbon (C-14)	3.1E-08	5.4E-24	5.8E+15
Iron (Fe-55)	n/a	n/a	n/a
Nickel (Ni-63)	n/a	n/a	n/a
Strotium (Sr-90)	1.3E-02	9.4E-10	1.4E+07
Niobium (Nb-94)	1.7E+00	6.7E-06	2.6E+05
Technetium (Tc-99)	2.3E-05	5.4E-18	4.3E+12
Antimony (Sb-125)	3.1E-01	3.0E-07	1.0E+06
Cesium (Cs-134)	3.2E+00	9.4E-06	3.4E+05
Europium (Eu-152)	3.7E+00	3.6E-05	1.0E+05
Europium (Eu-154)	3.9E+00	4.9E-05	7.9E+04
Europium (Eu-155)	8.5E-02	3.3E-13	2.6E+11
Plutonium (Pu-238)	8.9E-05	5.9E-17	1.5E+12
Plutonium (Pu-239)	1.7E-04	1.3E-12	1.3E+08
Plutonium (Pu-241)	1.0E-05	3.9E-15	2.6E+09
Americium (Am-241)	2.5E-02	5.3E-21	4.8E+18
Curium (Cm-243)	3.2E-01	2.9E-09	1.1E+08

Notes:

All doses calculated using RESRAD 6.22 for a unit concentration (1 pCi/g) in soil and default parameters from RESRAD.
Doses and dose reduction are for external radiation pathways (all other pathways turned off).

gamma shielding factor = 0.7
fraction of time outdoors = 0.5
fraction of time indoors = 0.25

n/a = not applicable, not a cancer risk for external radiation (USEPA, 2000).

Table 2
Summary of External Radiation Risk Calculations for BUD

Radionuclide	Concrete Debris DCGL [1] (pCi/g)	External Radiation Cancer Risk Without 3-Foot Overburden [2] (pCi/g)	Dose/Risk Reduction 3-Foot Overburden [3] (at Year 1)	External Risk With 3-Foot Overburden [4]	External Dose With 3-Foot Overburden [5] (mrem/yr)
Co-60	4.3	1.2E-04	4.6E+04	2.6E-09	4.5E-04
Cs-137 + D	6.7	1.1E-04	4.5E+05	2.5E-10	1.5E-05
Silver - 108m + D	7.0	4.2E-04	5.9E+05	7.0E-10	3.4E-05
Hydrogen-3	280.0	n/a	n/a	n/a	n/a
Carbon-14	7.2	5.0E-10	5.8E+15	8.6E-26	4.9E-21
Iron-55	140.0	n/a	n/a	n/a	n/a
Nickel-63	100.0	n/a	n/a	n/a	n/a
Strotium-90+D	0.8	9.5E-08	1.4E+07	6.7E-15	3.9E-10
Niobium-94	7.0	4.6E-04	2.6E+05	1.8E-09	7.8E-05
Technetium-99m	61.0	4.5E-08	4.3E+12	1.0E-20	5.3E-16
Antimony-125+D	31.0	7.2E-05	1.0E+06	7.0E-11	2.2E-05
Cesium-134m	4.7	2.9E-05	3.4E+05	8.4E-11	3.9E-05
Europium-152	9.5	2.3E-04	1.0E+05	2.2E-09	1.9E-04
Europium-154	9.1	1.7E-04	7.9E+04	2.1E-09	2.6E-04
Europium-155	380.0	1.0E-04	2.6E+11	3.9E-16	8.0E-11
Plutonium-238	9.5	5.5E-09	1.5E+12	3.6E-21	2.8E-16
Plutonium-239	8.8	1.6E-08	1.3E+08	1.2E-16	6.1E-12
Plutoniumu-241	140.0	2.7E-09	2.6E+09	1.0E-18	3.0E-13
Americium-241	4.1	9.9E-07	4.8E+18	2.1E-25	1.1E-20
Curium-243	4.7	1.2E-05	1.1E+08	1.1E-13	7.4E-09
			Totals	**9.8E-09**	**1.1E-03**
			Regulatory Guideline	**5.0E-06**	**10**

Notes:

[1] Dose concentration guideline levels for concrete debris in LTP (radionuclide concentration in concrete will be less than or equal to these values).
[2] External radiation risk for no overburden calculated using EPA (2000) default parameters and cancer slope factors.
[3] Dose reduction for 3-foot soil cover calculated using RESRAD 6.22 for a unit concentration (1 pCi/g) in soil and default parameters from RESRAD.
[4] Cancer risk for BUD based on 3-foot overburden (Column [2] divided by column [3].)
[5] External radiation dose at year-1 Cancer risk for BUD based on 3-foot overburden (Dose with no cover from Table 3, divided by column [3])

n/a - radionuclide not a cancer risk for external radiation (EPA, 2000).

Table 3
External Radiation Risk and External Dose Calculations -- No Overburden Conditions

Radionuclides Evaluated	Concentration (C_o) (pCi/g)	Half-Life $t_{1/2}$ (yrs)	Ave. Conc. (C_{ave}) (pCi/g)	Slope Factor (CSF) (Risk/yr- pCi/g)	DCF (mrem/yr - pCi/g)	Cancer Risk (C_{ave} × IF × CSF)	Dose - 1 yr (C × IF × DCF) (mrem/yr)
Co-60	4.3	5.3	1.07	1.24E-05	1.62E+01	1.19E-04	2.1E+01
Cs-137 + D	6.7	30.0	4.83	2.55E-06	3.41E+00	1.10E-04	6.8E+00
Silver - 108m + D	7.0	127.0	6.46	7.19E-06	9.65E+00	4.2E-04	2.0E+01
Hydrogen-3	280.0	12.0	133.02				
Carbon-14	7.2	5730.0	7.19	7.83E-12	1.34E-05	5.0E-10	2.9E-05
Iron-55	140.0	3.0	20.18				
Nickel-63	100.0	100.0	90.29				
Strotium-90+D	0.8	29.0	0.54	1.96E-08	2.46E-02	9.5E-08	5.6E-03
Niobium-94	7.0	20000.0	7.00	7.29E-06	9.68E+00	4.6E-04	2.0E+01
Technetium-99m	61.0	210000.0	61.00	8.14E-11	1.26E-04	4.5E-08	2.3E-03
Antimony-125+D	31.0	3.0	4.47	1.81E-06	2.45E+00	7.2E-05	2.3E+01
Cesium-134m	4.7	2.0	0.45	7.10E-06	9.47E+00	2.9E-05	1.3E+01
Europium-152	9.5	13.0	4.74	5.30E-06	7.01E+00	2.3E-04	2.0E+01
Europium-154	9.1	8.0	3.24	5.83E-06	7.68E+00	1.7E-04	2.1E+01
Europium-155	380.0	5.0	89.94	1.24E-07	1.82E-01	1.0E-04	2.1E+01
Plutonium-238	9.5	88.0	8.46	7.22E-11	1.51E-04	5.5E-09	4.3E-04
Plutonium-239	8.8	24000.0	8.80	2.00E-10	2.95E-04	1.6E-08	7.8E-04
Plutoniumu-241	140.0	14.0	72.91	4.11E-12	1.89E-05	2.7E-09	7.9E-04
Americium-241	4.1	432.0	4.00	2.76E-08	4.37E-02	9.9E-07	5.4E-02
Curium-243	4.7	28.0	3.32	4.19E-07	5.83E-01	1.2E-05	8.2E-01
					Total:	**2.3E-04**	**2.8E+01**

IF_{risk}	(EF/365) x ED x ACF x (ET_{out} +(ET_{in} x GSF))	**8.96E+00**
IF_{dose}	(EF/365) x ACF x (ET_{out} +(ET_{in} x GSF))	**2.99E-01**

where:

EF	=	Exposure Frequency (d/yr)	350	(EPA, 2000)
ED	=	Adult + Child Exposure Duration(yr)	30	(EPA, 2000)
ACF	=	Area Correction Factor	0.9	0.5 acre (EPA, 2000)
Etout	=	Exposure time outside (fraction)	0.073	(EPA, 2000)
Etin	=	Exposure time inside (fraction)	0.683	(EPA, 2000)
GSF	=	gamma shielding factor	0.40	(EPA, 2000)
		ACF x (ETout +(ETin x GSF)) =	3.12E-01	
		Exposure time at site (hr/day)	18.1	
		Away from site (hr/day)	5.9	

Table 4

Screening Comparison of Radionuclide Leaching to Groundwater Compared to Drinking Water Guidelines

Radionuclide	**Half-life** (yr)	**Initial Conc. (DCGL)** [1] (pCi/g)	**Average Conc. 30-years** [2] (pCi/g)	**Partition Coeff. Kd** [3] (L/kg)	**Concentration in Pore Water** [4] (pCi/L)	**Concentration DAF = 100** [4] (pCi/L)	**Drinking Water Guidelines** [5] (pCi/L)
Co-60	5.27	4.3	1.1	282.0	3.8	0.02	100
Cs-137 + D	30	6.7	4.8	137.0	35.2	0.16	200
Silver - 108m + D	127	7.0	6.5	6500.0	1.0	0.00	5.8 (RBL)
Hydrogen-3	12	280	133.0	0.00	731,598.7	3,295	20,000
Carbon-14	5,730	7.2	7.2	70.70	101.4	0.46	2,000
Iron-55	3	140	20.2	12.5	1,591.1	7.17	2,000
Nickel-63	100	100	90.3	35.5	2,530.4	11.4	50
Strotium-90+D	29	0.76	0.5	10.50	50.8	0.23	8
Niobium-94	2.00E+04	7.0	7.0	316.0	22.1	0.10	6.1 (RBL)
Technetium-99m	2.10E+05	61	61.0	14	4,458.3	20.08	900
Antimony-125+D	3	31	4.5	1,550	2.9	0.01	300
Cesium-134m	2	4.7	0.5	137.0	3.3	0.01	80
Europium-152	13	9.5	4.7	1,000.0	4.7	0.02	200
Europium-154	8	9.1	3.2	1000.0	3.2	0.01	60
Europium-155	5	380	89.9	1,000	89.9	0.41	600
Plutonium-238	88	9.5	8.5	888.0 [a]	9.5	0.04	15
Plutonium-239	2.40E+04	8.8	8.8	888.0 [a]	9.9	0.04	15
Plutoniumu-241	14	140	72.9	888.0 [a]	82.1	0.37	27 (RBL)
Americium-241	432	4	4.0	447 [a]	9.0	0.04	15
Curium-243	28	4.7	3.3	400.0 [a]	8.3	0.04	15

Notes:

[1] Values reported in License Termination Plan.
[2] Calculated average concentration in subsurface concrete over 30 year time period based on radioactive decay (see text).
[3] Median Kd values reported in LTP (from RESRAD). Values noted [a] are 25th percentiles from LTP Appendix 6N.
[4] Equilibrium concentration between concrete/soil and groundwater assuming no dilution (see text).
[5] Drinking water guidelines are MCLs from USEPA (2000) Soil Screening Guidance for Radionuclides. RBL = Risk Based Limit (no MCL)

<u>Parameters for [2] , [3] and [4]:</u>

Averaging Period (yrs):	30
bulk density (g/cc):	1.54
porosity (cc/cc):	0.28
Dilution Attenuation Factor (DAF)	222