DECOMMISSIONING PLAN

TOBICO MARSH SGA SITE
Kawkawlin, Michigan

PREPARED FOR:

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

MERA NO. 090015
MACTEC ENGINEERING & CONSULTING OF MICHIGAN, INC.
PROJECT NO. 50055

FEBRUARY 2003

DECOMMISSIONING PLAN

TOBICO MARSH SGA SITE
Kawkawlin Township, Michigan

US NRC License Number SUC-1581

Docket Number 40-9015

Prepared for:

Michigan Department of Natural Resources
Design and Construction Section
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Contract No. ERD-2004
Project No. 50055

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Signature Page

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ACRONYMS

Ac..............................Actinium

AEC............................Atomic Energy Commission

ALARA......................As Low As Reasonable Achievable

ASTM ....American Standards for Technology Manual

bgs..............................Below Ground Surface

Bi................................Bismuth

BOC ....Bureau of Census

CFR............................Code of Federal Regulations

CoC ....Chain of Custody

CPM...........................Counts Per Minute

Cs ....Cesium

DCGL.........................Derived Concentration Guideline Level

DQO...........................Data Quality Objectives

GPS ....Global Positioning System

HAZWOPER ....Hazardous Waste Operations and Emergency Response

HLA ....Harding Lawson Associates

ICR.............................Ignitability, Corrosivity, and Reactivity

ID ....Inner Diameter

K.................................Potassium

LCTS..........................Leachate Collection and Treatment System

MARSSIM ....Multi Agency Radiation Survey and Site Investigation Manual

MBS …………………...Midland/Bay City/Saginaw

MCL...........................Maximum Concentration Levels

MDC ....Minimum Detectable Concentration

MDEQ........................Michigan Department of Environmental Quality

MDNR........................Michigan Department of Natural Resources

MDPH ....Michigan Department of Public Health

msl..............................Mean Sea Level

MTC...........................Materials Testing Consultants, Inc.

NAD...........................North American Datum

NaI............................Sodium Iodide
NIST..........................National Institute for Standards and Technology
NORM........................Naturally Occurring Radioactive Material
NRC ....Nuclear Regulatory Commission
OD.............................Outer Diameter
OMB ....Office of Management and Budget
ORAU ....Oak Ridge Associated Universities
OSHA.........................Occupational Safety and Health Administration
Pa...............................Protactinium
Pb ....Lead
pCi/g..........................Pico Curies per Gram
PID ....Photo Ionization Detector
PPE............................Personal Protective Equipment
QAE ....Quality Assurance Engineer
QAPP ....Quality Assurance Project Plan
QC ....Quality Control
Ra ....Radium
RCOPC ....Radiological Constituents of Potential Concern
ROC ....Radioisotope of Concern
SDMP.........................Site Decommissioning Management Plan
SGA...........................State Game Area
SVOC.........................Semi-Volatile Organic Compound
TCLP..........................Toxicity Characteristic Leaching Procedure
TDS ....Total Dissolved Solids
Th ....Thorium
Tl ....Thallium
U................................Uranium
USEPA.......................United States Environmental Protection Agency
VOC ....Volatile Organic Compound
WMI ....Waste Management, Inc.

1.0 EXECUTIVE SUMMARY

The Michigan Department of Natural Resources (MDNR) has contracted MACTEC Engineering & Consulting of Michigan, Inc.[1] (MACTEC) to perform radiological characterization, and to develop the radiological decontamination and decommissioning (D&D) plan leading to license termination at their Tobico Marsh State Game Area (SGA) Site located in Kawkawlin Township, Michigan. MACTEC has developed this Decommissioning Plan (DP) to be implemented during D&D activities of the Tobico Marsh SGA Site (Site), such that radiologically impacted areas will meet the criteria for unrestricted use as specified by 10 CFR 20.1402 (NRC 1997a).

1.1 SITE AND LICENSEE INFORMATION

The Site is located in Bay County, Michigan, eight miles north of Bay City, Michigan. The entire property consists of approximately 6 acres; however, this DP applies only to the 3-acre portion of the property that is potentially impacted by radiological materials. The name and address of the licensee are:

Michigan Department of Natural Resources
c/o Denise Gruben
Design and Construction Section
Office of Land and Facilities
P.O. Box 30033
Lansing, MI 48909-7948

Street Address for UPS etc.:
Stevens T. Mason Building, 8th Floor
530 West Allegan
Lansing, MI 48933

The address where licensed material is possessed is:

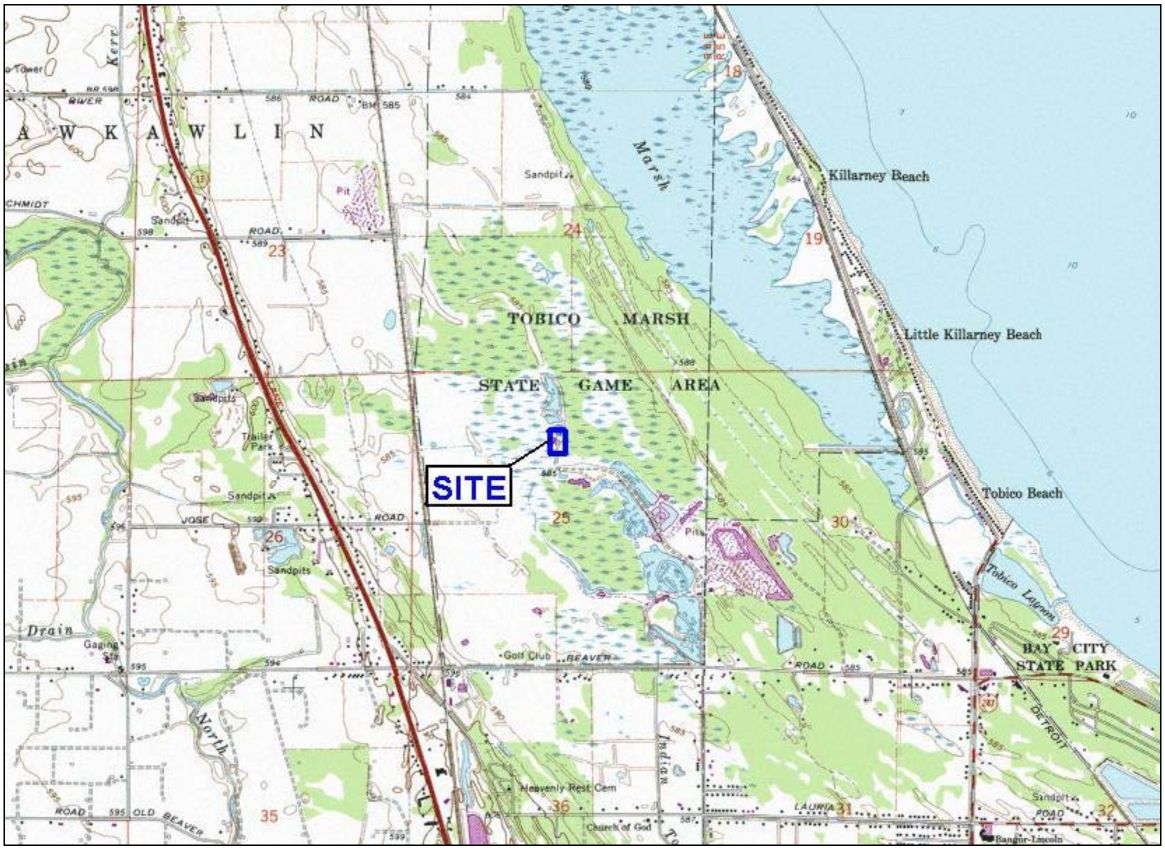
2301 Two Mile Road (north of Beaver Road)
Bay County, MI 48631

1.2 SITE DESCRIPTION

The Tobico Marsh SGA Site is a small part of a former (now closed) industrial waste disposal area locally known as the Hartley and Hartley Landfill. The SGA Site covers approximately 3 acres of land within the State of Michigan's Tobico Marsh State Game Area and is located within Kawkawlin Township, Bay County, Michigan (Figure 1-1 and

1 Formerly Harding ESE of Michigan, Inc. (Harding ESE).

Figure 1-2). The Site is located in a vast land preserve on the edge of Lake Huron's Saginaw Bay where swampy wetland conditions and ponded water prevail.



(Source: USGS Topographic Map, Bay City, Michigan)

Figure 1-1 Area of Site and Surrounding Area

The industrial disposal facility, which opened in the mid-1950s, was originally operated by the Hartley family and is estimated to have received some 18,000 barrels of spent solvents, oils, and other liquid and solid wastes for disposal during the 1960's and early 1970's. Foundry waste containing low levels of naturally occurring radioactivity in the form of magnesium-thorium slag was also disposed at the site beginning late in 1970.

Today, the industrial disposal site is treated as two separate sites after having been subdivided by ownership. In a formal land exchange concluded in 1973, the Hartleys conveyed land to the State of Michigan (including approximately 3 acres where land disposal had previously occurred) in return for lands bordering their industrial waste disposal site[2]. It was unknown to the State of Michigan at that time that a portion of the land they had received in the exchange with the Hartleys had been used to dispose of

2 Ownership of the industrial waste disposal site has changed hands a number of times since 1998 and is now owned by Waste Management, Inc.

thorium-bearing slag wastes. The approximately 3-acre portion where industrial waste disposal had occurred on what is now State of Michigan property is known as the Tobico Marsh SGA Site and is the subject of this DP.

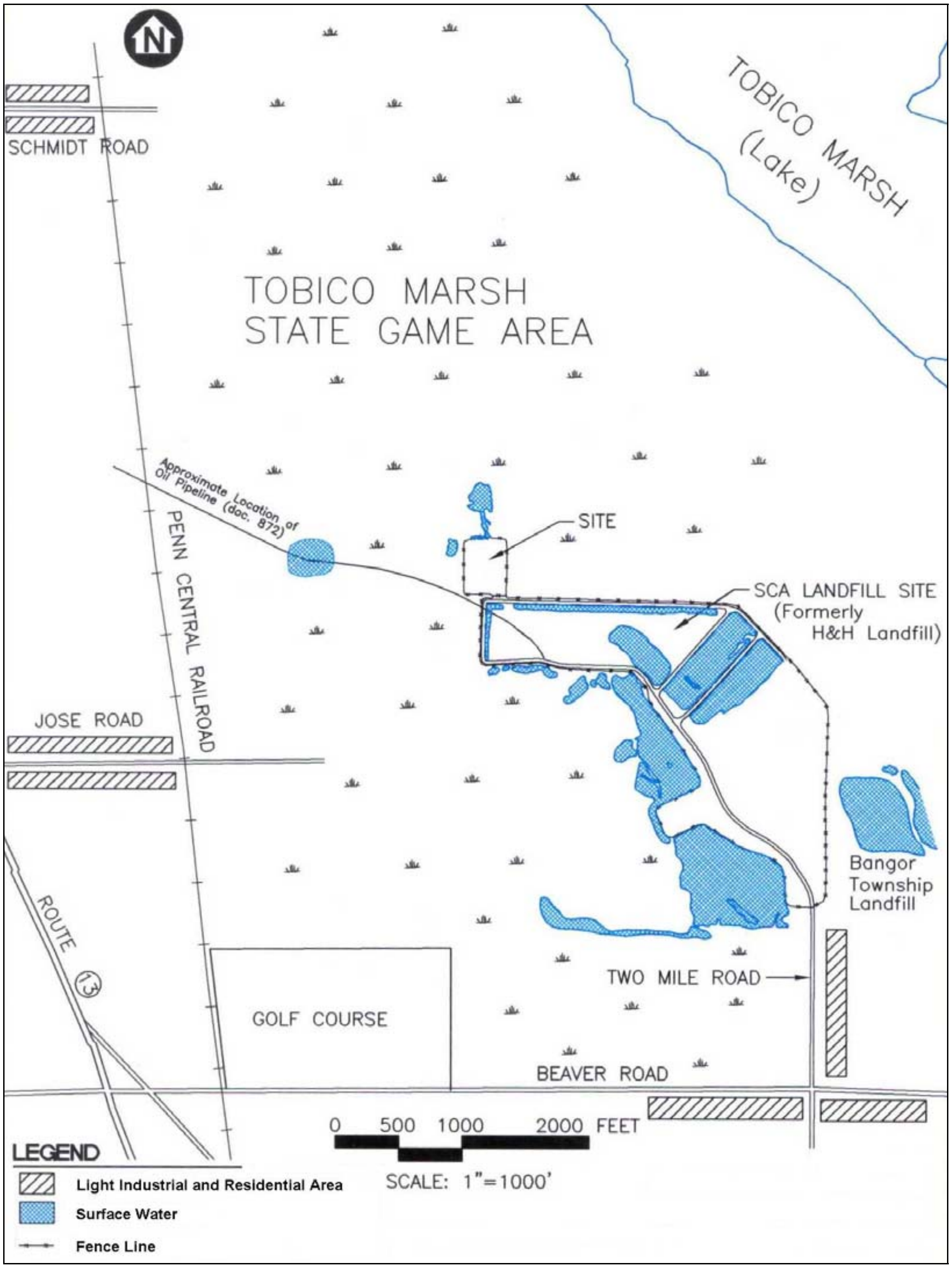


Figure 1-2 Location and Area Features Map

Residual radioactivity at the site is the result of the deposition of slag wastes bearing naturally occurring thorium (Th). The vitreous slag, generated by Dow Chemical and subsequently Wellman Dynamics at a site in Bay City, Michigan, is derived from casting and foundry operations involving magnesium-thorium alloys.

To preclude the potential migration of chemical contaminants (contaminants other than radioactivity) beyond those lands already impacted by the disposal, a bentonite slurry wall was placed around the disposal area and the disposal area was covered with a clay cap.

One building, constructed after the slurry walls and clay cover were installed, is present at the site. The building was designed to house equipment and controls associated with a leachate collection and treatment system (LCTS) that was installed within the slurry walls. The LCTS, designed by the Michigan Department of Environmental Quality (MDEQ) to address non-radiological contaminants, has never been completed or operated. The building has been used to stage characterization survey equipment and to temporarily store containerized, and potentially contaminated, personal protective equipment (PPE) and sampling-derived waste.

1.3 DECOMMISSIONING OBJECTIVE

The objective of MDNR is to decommission the Tobico Marsh SGA site, such that the site will meet the criteria for unrestricted use as specified by 10 CFR 20.1402 (NRC 1997a), thus permitting the termination of its radioactive materials license.

1.4 NATURE AND EXTENT OF RESIDUAL RADIOACTIVITY AT THE SITE

The radionuclides of concern in the slag are the isotopes of Th-230 and Th-232 and their progeny. The physical form of the slag material is vitreous (glass-like) material in irregularly shaped pieces ranging in size from approximately 1 to 50 mm in diameter. Most pieces are in the 5 to 15 mm diameter size range. Both thorium-bearing and non-thorium-bearing slags are known to have been disposed by the Hartleys over the years that the facility was in operation, but there is no known record indicating which slag forms were deposited where. They are comparable in physical appearance differing only in the occurrence of thorium in slags derived from magnesium-thorium alloys.

Radiological characterization surveys conducted at the site confirm that the thorium-bearing slag waste is confined to the area circumscribed by the slurry walls and vertically confined by an underlying, undisturbed, native clay-till layer and an overlying clay cover. Radioactivity associated with contributions from thoriated slag has not been identified in water samples collected at the site (ABB 1997, MACTEC 2002). Characterization survey results also showed that elevated radioactivity associated with thoriated slag disposal is generally confined to thin deposits (approximately 1.2 meters thick) along a track running near the center of the area confined by the slurry walls corresponding to the former access road into the site.

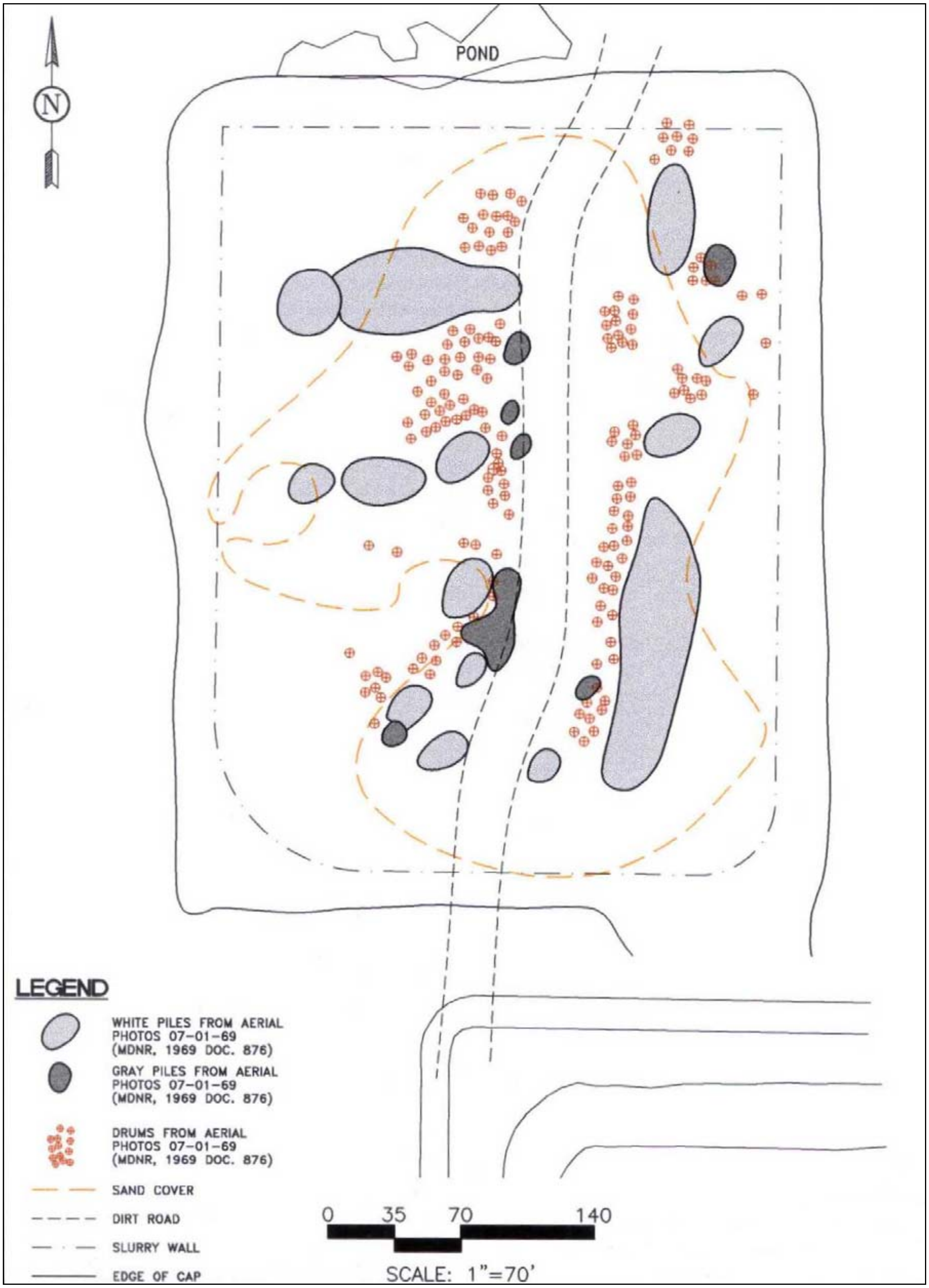


Figure 1-3 Historic Site Map with Former Access Road

1.5 SITE-SPECIFIC DCGLS

The objective of the MDNR is to decommission any soil that has been impacted with residual radioactivity associated with thoriated slag disposal in accordance with applicable Federal and State requirements and regulations such that the radioactive materials license held by MDNR can be terminated.

The evaluation of potential risks posed by hazardous or potentially hazardous substances present at the Site are being addressed by the MDEQ and is being carried out on a separate but parallel track to that for residual radioactivity. Residual radioactivity at the Site is being addressed by the licensee, the MDNR, following the U.S. Nuclear Regulatory Commission's guidance in the *NMSS Decommissioning Standard Review Plan,* NUREG-1727 (NRC 2000a). In keeping with this guidance, MDNR previously completed and documented the following tasks:

- Historical Site Assessment (HLA 1998a),
- Assessment of Local Background Radioactivity (ABB 1998, MDPH 1983),
- Radiological Scoping Survey (HLA 1998b),
- Radiological Characterization Survey (Cabrera 2001)

Based upon information gained through the completion of these former tasks, a conceptual model of the site was developed and site-specific permissible concentrations of residual radioactive material in soil–derived concentration guideline levels (DCGLs)– were calculated. The DCGLs were derived to be protective of human health and the environment and such that potential future exposures at the site are unlikely to result in an annual radiation dose exceeding 25 mrem total effective dose equivalent (TEDE) following release of the site for unrestricted use.

The RESRAD computer modeling code (Version 6.21) was used to derive the site-specific soil DCGL (Yu 2002). The proposed DCGL for soils containing thoriated slag is 1.09×10^{-1} μCi/g Th-232.

The proposed building surfaces DCGLs are:

- 200 dpm/100 cm^2 (removable, alpha or beta)
- 1000 dpm/100 cm^2 (total, alpha or beta, averaged over 1 m^2)
- 3000 dpm/100 cm^2 (maximum, alpha or beta)

1.6 ALARA ANALYSIS

A pre-remediation As Low As Reasonably Achievable (ALARA) analysis has been completed to evaluate whether it is reasonable to further reduce the allowable levels of residual radioactivity to levels below those necessary to meet the dose criteria (i.e., to levels that are ALARA below the DCGL).

Based on the MDNR's decision to implement the NRC's unilaterally approved annual dose limit under the unrestricted use criteria of 10 CFR §20.1402 (NRC 1997a), and given that potential exposure at the site is associated with bulk quantities of subsurface soils containing residual radioactivity (as opposed to discrete sources of radioactivity associated with systems, materials, or building structures), it is accepted on an *a priori* basis that compliance with the unrestricted use release criteria is ALARA. Decommissioning guidance published by the NRC (NRC 2000a) supports the rationale that concentrations of residual radioactivity in bulk soils at a DCGL corresponding to 25 mrem/y cannot reasonably be further reduced within the context of the ALARA principle. NUREG-1727, Appendix D, Section 1.5 states: "In certain circumstances, the results of an ALARA analysis are known on a generic basis and an analysis is not necessary. For residual radioactivity in soil at sites that will have unrestricted release, generic analysis show that shipping soil to a low-level waste disposal facility is unlikely to be cost effective for unrestricted release, largely because of the high cost of waste disposal. Therefore shipping soil to a low level waste disposal facility generally does not have to be evaluated [to determine whether it is ALARA] for unrestricted release."

Based on these factors, it was determined that the proposed remedial action DCGLs are ALARA, and no remedial action that is intended to reduce concentrations of residual radioactivity in soil below the proposed remedial action DCGLs is warranted.

1.7 START AND END DATES

Project schedules are discussed in Section 8.5.

1.8 POST-REMEDIATION ACTIVITIES

No post-remediation activities have been identified and none are anticipated.

1.9 AMENDMENT TO LICENSE TO INCORPORATE DP

This Decommissioning Plan submittal includes a request to amend NRC License No. SUC-1581 to incorporate the DP.

2.0 FACILITY OPERATING HISTORY

2.1 LICENSE NUMBER, STATUS, AND AUTHORIZED ACTIVITIES

The current radioactive materials license for the MDNR Tobico Marsh site is Source Materials license No. SUC-1581 (NRC 1999). The license was issued to the MDNR on August 26, 1999. Expiration of the license is dated August 31, 2009. The license authorizes possession and use for those activities leading to the decommissioning of the MDNR Tobico Marsh site. There have been no substantive amendments to license No. SUC-1581 since initial issuance dated August 26, 1999.

The radionuclides, maximum activities, quantities, and chemical/physical form of radionuclides authorized under the license are included in Table 2–1.

Table 2-1 Licensed Radionuclides and Maximum Activities

SOURCE MATERIAL	CHEMICAL/PHYSICAL FORM	MAXIMUM ACTIVITY
Thorium	Contaminated soil, sludge, sediment, trash, building rubble, structures, and any other material contaminated in excess of background levels.	2.6 Ci
Uranium	Contaminated soil, sludge, sediment, trash, building rubble, structures, and any other material contaminated in excess of background levels.	0.26 Ci
Thorium-230	Sealed sources	10 microCi
Americium-241	Sealed sources	0.5 microCi

There are no other radioactive materials at the site that require monitoring or control.

2.2 LICENSE HISTORY

Source Materials License No. SUC-1581, issued to MDNR to possess contaminated material at the MDNR Tobico Marsh site, is the initial source material license for the site. The site was never previously licensed and no revisions or modifications to the existing license have been issued.

2.3 PREVIOUS DECOMMISSIONING ACTIVITIES

Preliminary work in support of the development of this decommissioning plan has been completed, including a historical site assessment (HLA 1998a), an assessment of local background radioactivity (ABB 1998, MDPH 1983), a radiological scoping survey (HLA 1998b), and a radiological characterization survey (Cabrera 2001).

No remedial decommissioning activities have ever been performed at the MDNR Tobico Marsh site.

2.4 SPILLS

There is no record of radiological spills occurring at the MDNR Tobico Marsh site.

2.5 PRIOR ONSITE BURIALS

The MDNR's Tobico Marsh SGA Site was opened in the 1950's and was a small portion of an industrial disposal facility opened and originally operated by the Hartley family. The portion now owned by the MDNR apparently originated as the area where the Hartley's mined (excavation) a former beach ridge sand deposit. The excavation resulted in surface depressions flooded with surface water and near-surface groundwater. Industrial wastes including drums, spent solvents, oils, and other liquid and solid wastes were disposed in the excavations.

In addition to these materials, foundry waste containing low levels of naturally occurring radioactivity in the form of magnesium-thorium slag was also disposed at the site beginning late in 1970. The vitreous slag, generated by Dow Chemical and subsequently Wellman Dynamics at a site in Bay City, Michigan, is derived from casting and foundry operations involving magnesium-thorium alloys. Both thorium-bearing and non-thorium-bearing slags are known to have been disposed over the years that the Tobico facility was in operation, but there is no known record indicating which slag forms were deposited where. They are comparable in physical appearance, differing only in the occurrence of thorium in slags derived from magnesium-thorium alloys.

Interim corrective measures were undertaken with the installation of a clay slurry wall and clay cover (1984), intended to restrict or retard the migration of non-radiological, hazardous, or potentially hazardous substances to the surrounding environment. It is important to note that the decision to impound the area was based solely on the information known at the time about chemical constituents deposited in the disposal site. It is coincidental that the disposal of slag containing naturally occurring thorium residues was co-deposited with chemical constituents and that the installation of the clay slurry wall and cap system circumscribes the thorium-bearing slag deposits.

Radiological characterization surveys conducted at the site confirm that the thorium bearing slag waste is vertically confined by an underlying, undisturbed, native clay till layer. Characterization survey results also showed that elevated radioactivity associated thoriated slag disposal is generally confined to relatively thin deposits (approximately 1.2 meters thick) and along a track running near the center of the area confined by the slurry walls corresponding to the former access road into the site (Figure 2-1).

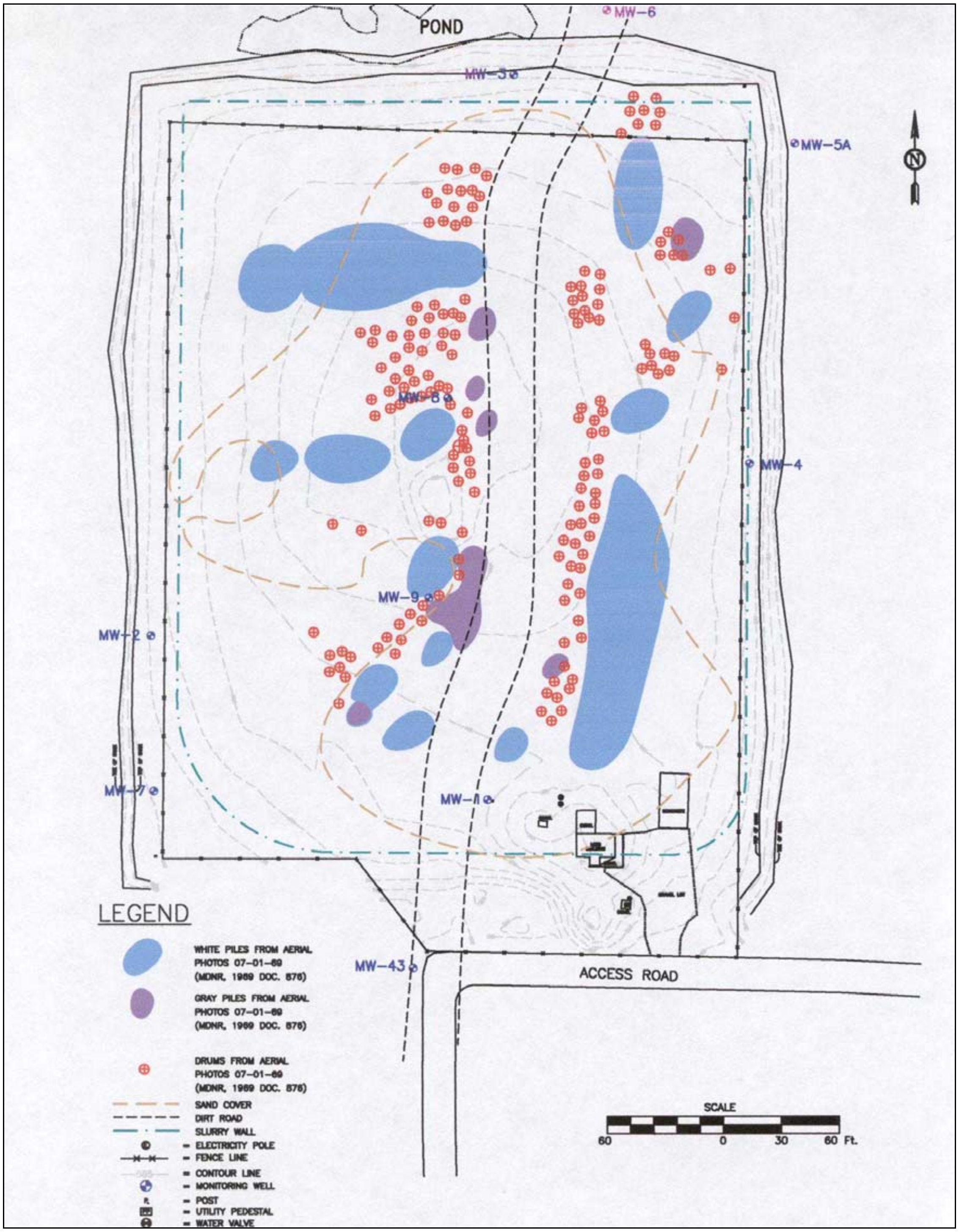


Figure 2-1 Site Map Showing Disposal Activity and Location

3.0 FACILITY DESCRIPTION

3.1 SITE LOCATION AND DESCRIPTION

The Tobico SGA Site covers approximately 3 acres of land within the State of Michigan's Tobico Marsh State Game Area and is located in the SE quarter of the NE quarter of Section 25, T15N, R4E in Bay County, Kawkawlin Township, Michigan (Figure 3-1). The site is located approximately 1.5 miles west of Saginaw Bay, which is part of Lake Huron, and approximately 1.75 miles north of the Kawkawlin River. The area surrounding the site is relatively flat with an average elevation of 585 feet above mean sea level (msl). The site itself (top of the cap) is elevated in relation to the surrounding area by approximately 5 feet with an approximate average elevation of 590 feet above msl. The highest point at the site is approximately 595 feet above msl.

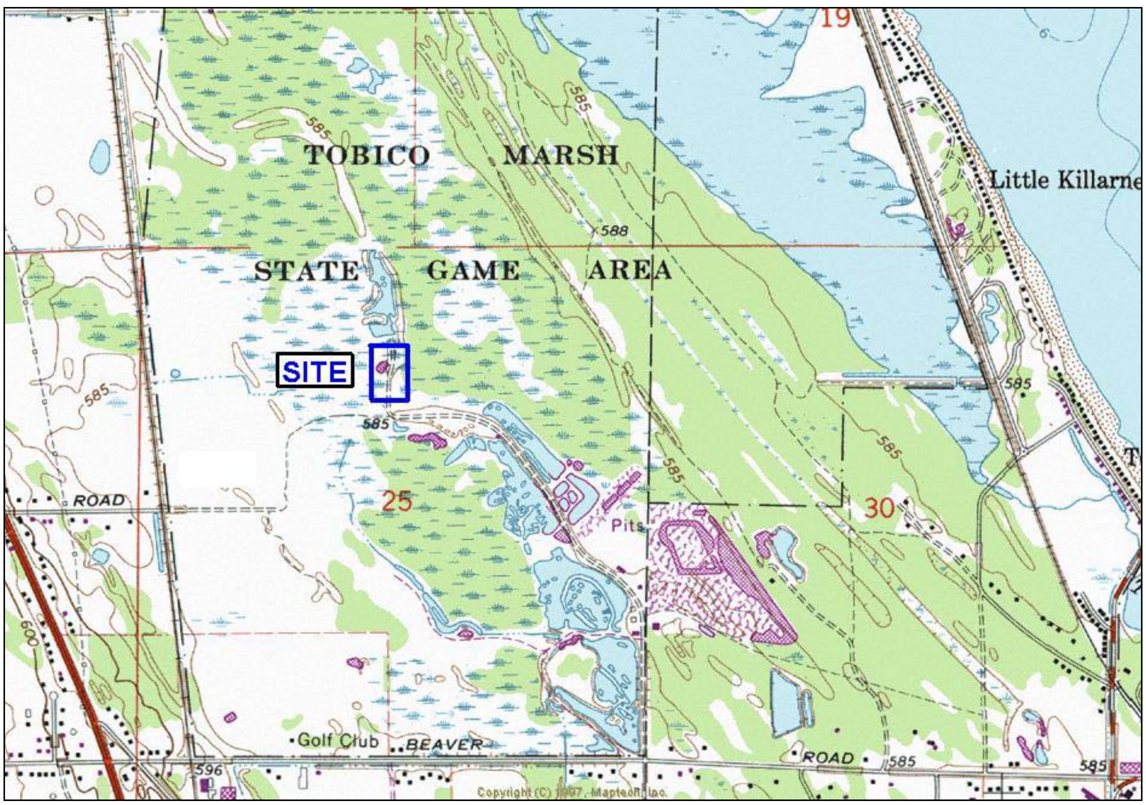


Figure 3-1 Topographic Map of the Site and Immediate Vicinity

Onsite facilities include one building, which was constructed to house a leachate collection and treatment system (LCTS) originally designed to collect and treat leachate from within the constructed cell. The LCTS system was never made operational and has been partially dismantled. The building remains on the property. The crock wells and piping from the leachate recovery system are still in-place. The site is surrounded by a chain-link and barb-wired fence, and has four gates with padlocks installed.

Properties immediately surrounding the site include:

- Tobico Marsh State Game Area

  The site is located within Michigan's Tobico Marsh State Game Area. The Tobico Marsh State Game Area land abuts the site property boundaries to the north, east, and west.

- Waste Management Landfill

  The parcel of land to the immediate south of the SGA Site is also part of the former Hartley and Hartley landfill operation and is currently owned by Waste Management, Inc.

Nearby (but not abutting) properties in the immediate vicinity of the site include:

- Residential

  The nearest residential properties to the site are located along Schmidt and Jose Roads approximately 0.5 miles (or more) to the west of the site.

  A few residential properties are situated along Beaver Road to the south of the site. These properties, however, are approximately 1 mile (or more) away from the site.

- Recreational Land

  Land to the north and east of the site within a radius larger than 1 mile lies within the Tobico Marsh SGA and is set aside for recreational land uses. A State park is located over 1 mile to the east of the site along the shore of Saginaw Bay.

  The Spring Valley golf course and clubhouse is located approximately 0.7 miles south-southwest of the site along Beaver Road.

- Commercial

  The nearest road to the site is Two Mile Road, which dead ends at the Waste Management property. This road provides access to the site. In addition to the Waste Management property, there are two small commercial properties located on Two Mile Road to the southeast of the site.

  Along Highway 13, nearly 1 mile to the west, there are a number of various commercial businesses and restaurants.

The nearest population centers/areas to the site include Kawkawlin Township, approximately 1.8 miles south of the site, and Bay City, approximately 5.5 miles south of the site.

A detailed list of the nearest residences, recreational lands, and commercial properties and facilities, along with their location relative to the site, are presented in Table 3-1.

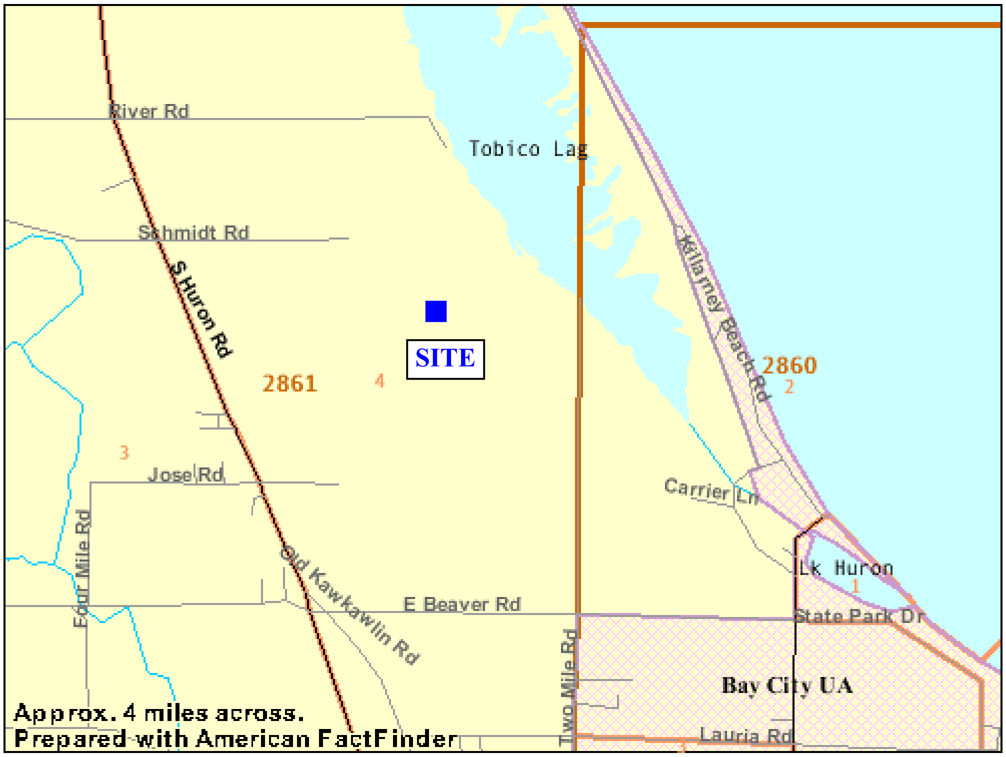


Figure 3-2 Immediate Vicinity of the Site

3.2 POPULATION DISTRIBUTION

The 2000 population of Bay County was estimated at 111,500 individuals. The population within a 1-mile radius of the site is estimated at 750 individuals[3]. No residential properties exist within a 0.5-mile radius of the site. The population data for Bay County, Michigan over the past five decades is presented in Table 3-2 (Bay County 2000).

The population of Bay County is projected to continue to decline over the next 20 years based on U.S. Census Bureau data. Table 3-3 presents Bay County projected future population trend (MI 2000).

3 This estimation was conservatively derived by multiplying the number of livable structures by 5 people for each livable structure. The 2000 U.S. Census data for Bay County, Michigan indicates that the average household size is 2.47 people.

Table 3-1 Location of the Nearby Residences and Properties

POPULATION AREA/LOCATION	APPROXIMATE DISTANCE (miles)	APPROXIMATE BEARING FROM SITE (degrees)
2430 Schmidt (Schmidt Road near RR tracks)	0.50	241
2446 Schmidt (Schmidt Road)	0.60	238
Spring Valley Golf Course	0.70	196
Beaver Road	0.75	180
Spring Valley Golf Course Clubhouse	0.75	193
Highway 13	0.80	244
Industrial Complex (Highway 13)	0.80	221
Little Killarney Beach	1.25	72
Killarney Beach	1.30	45
Tobico Beach	1.50	84
Kawkawlin Township	1.80	185
Bay City State Park	1.90	113
Lagoon Beach	2.80	116
Donahue Beach	3.90	116
Bay City	5.50	158

Table 3-2 Bay County Past and Current Population

YEAR	1960	1970	1980	1990	2000
POPULATION	107,042	117,339	119,881	111,723	111,500

Table 3-3 Bay County Future Population Projections

YEAR	2000	2005	2010	2015	2020
PROJECTED POPULATION	111,500	110,700	109,400	107,700	105,800

The overall trend in population (past and that projected for the near future) in Bay County is graphically portrayed in Figure 3-3.

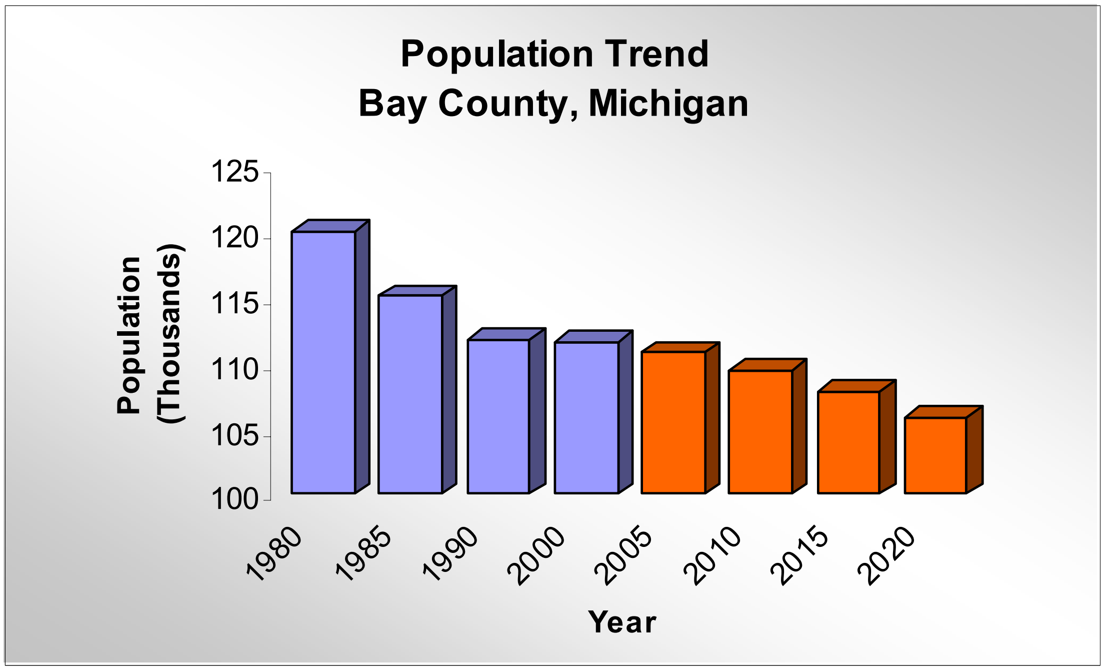


Figure 3-3 Population Trend—Bay County, Michigan

3.2.1 Minority Population Demographics

Localized demographic data tabulated by census tract and block group are useful in assessing the presence of minority or low-income populations in the immediate vicinity of the site that are significantly larger than those present in a larger regional area.

According to the U.S. Office of Management and Budget's (OMB) Directive No. 15 (OMB 1997), individuals who are Black or African American, Hispanic, Asian or Pacific Islander, American Indian, Eskimo, Aleut, or other non-white persons are identified as minorities. A geographic area is determined to have a "minority population" if either: (1) the minority population in the area is larger than 50 percent of the total population, or (2) the minority population percentage in the area under consideration is "meaningfully greater" than the minority population percentage in the general population or other appropriate larger unit of geographic analysis.

The site itself is located within (and near the eastern edge of) census tract #2861, block group #4. Blocks 2 through 5 in census tract #2861 describe the population to the west of the site. Blocks 2, 4, and 5 in tract #2862 describe the population to the immediate north of the site. Census tract #2860, with block groups 1, 2, and 3 lies to the east of the site. The southern side of the site is bounded by block groups 1, 3, and 4 of census tract #2857. The 2000 Census block groups immediately surrounding the site are mapped in Figure 3-4.

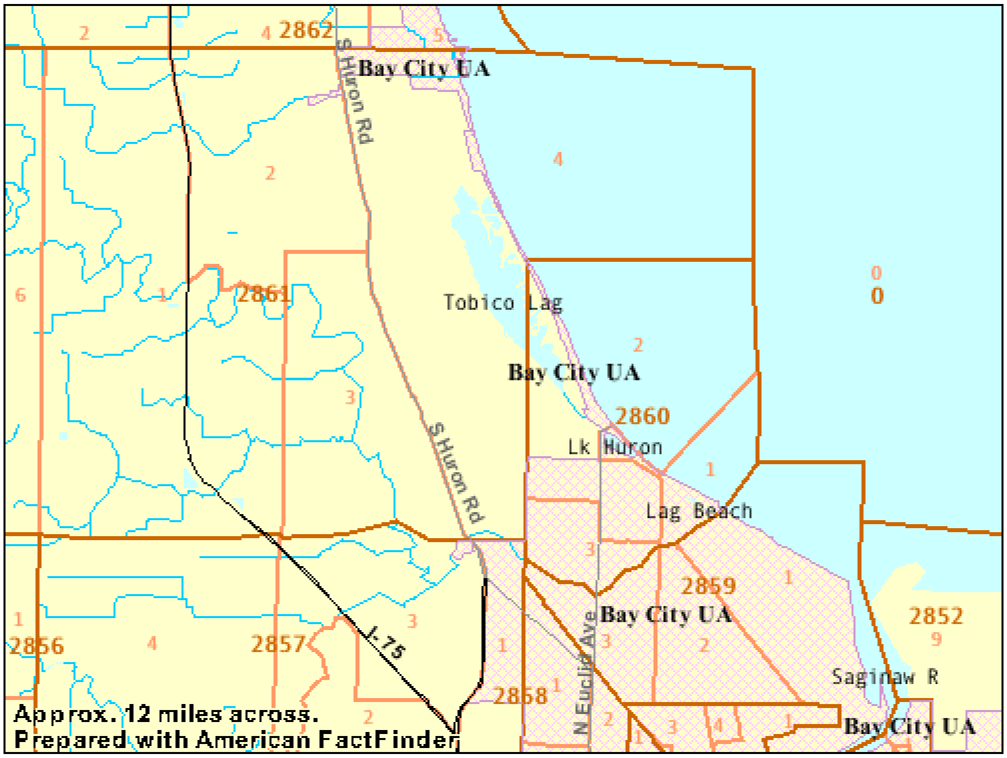


Figure 3-4   2000 U.S. Census Block Group Map for the Area in the Immediate Vicinity of the Site

According to the 2000 U.S. Census, the regional (Bay County) population is comprised of approximately 93 percent white, single race persons, while the greater Saginaw-Bay City-Midland region is comprised of approximately 85 percent white, single race persons. Table 3-4 presents the population demography for Bay County, Michigan based upon ethnicity as reported in the 2000 U.S. Census data. Inspection of Table 3-4 reveals that percentages of minority populations in both the census tract and block group geographic divisions are substantially less than the 50 percent benchmark criterion for identifying local minority populations. It is also evident from the percentage figures reported in Table 3-4, that the minority population percentages in the geographic units in the immediately vicinity of the site are not "meaningfully greater" than the minority population percentage in the two larger geographic units considered (Bay County and the greater Saginaw-Bay City-Midland area). In fact, the minority population percentage generally decreases as the geographic units consider smaller land areas near the site. From this analysis, it does not appear that a considerable minority population exists in the area potentially impacted by the site.

Table 3-4 Population Ethnicity Demographics by Region, Census Tract, and Block Group

Location	Total Population	Ethnicity by Percentage of Total Population							
		White	Hispanic or Latino	African American	American Indian	Asian	Hawaiian, Pacific Islander	Some Other Race	Mixed Ethnicity
Greater Saginaw-Bay City-Midland Area	403,070	84.8	4.9	10.3	0.4	0.9	0.0	1.9	1.7
Bay County, Michigan	110,157	92.7	3.9	1.2	0.5	0.5	0.0	0.0	1.2
BG 1, CT 2861	1603	96.2	1.4	0.2	0.3	0.1	0.0	0.0	1.7
BG 2, CT 2861	861	94.5	4.2	0.5	0.3	0.0	0.0	0.0	0.5
BG 3, CT 2861	913	94.9	2.5	0.0	0.5	0.4	0.0	0.1	1.5
BG 4, CT 2861	1727	94.6	2.0	0.9	0.6	0.2	0.0	0.0	1.6
BG 5, CT 2861	1257	97.5	2.1	0.0	0.2	0.2	0.0	0.0	0.1
BG 6, CT 2861	1549	98.1	1.0	0.0	0.1	0.2	0.0	0.0	0.6
BG 1, CT 2860	1077	96.3	1.8	0.0	0.3	0.1	0.0	0.0	1.6
BG 2, CT 2860	1185	98.1	1.3	0.0	0.0	0.4	0.0	0.0	0.2
BG 3, CT 2860	1557	96.6	2.1	0.3	0.3	0.5	0.0	0.0	0.3
BG 1, CT 2857	1724	95.8	2.6	0.2	0.3	0.2	0.0	0.0	0.9
BG 2, CT 2857	705	96.5	1.6	0.0	0.4	0.7	0.0	0.0	0.9
BG 3, CT 2857	534	96.4	0.9	0.6	0.6	0.2	0.0	0.0	1.3
BG 4, CT 2857	914	96.3	2.0	0.0	0.1	0.5	0.0	0.0	1.1
BG 2, CT 2862	546	96.0	0.2	2.7	0.2	0.0	0.0	0.0	0.9
BG 4, CT 2862	1008	94.9	1.5	0.7	0.5	0.8	0.0	0.0	1.6
BG 5, CT 2862	959	97.2	1.6	0.0	0.4	0.3	0.0	0.0	0.5
Source: U.S. Census Bureau, 2000 Census Data, http://factfinder.census.gov									

3.2.2 Low-Income Population Demographics

Low-income populations are identified as those communities within the region for which the percent of the population living in poverty exceeds 25 percent (Michigan State University Extension – Bay County). According to the 2000 Census Block Group estimates (which measures economic parameters based upon income for the calendar year 1999), about 9.7 percent of the regional population (Bay County, MI) is at or below the poverty level. A broader regional survey (2000 U.S. Census Supplementary Survey) covering the greater Saginaw–Bay City–Midland area estimates that approximately 12 percent of the population lives at or below the poverty level. U.S. Census Bureau calculations estimate the upper and lower bounds of this estimate to be between 8.9 and 15.1 percent respectively. Comparisons of the regional poverty statistics with those from the 2000 census block groups in the immediate vicinity of the Tobico Marsh SGA Site are presented in Table 3-5. No localized population (as demarcated by census block group) in the immediate vicinity of the site exceeds the low-income population threshold (more than 25 percent earning at or below the poverty level).

Table 3-5 Comparison of Poverty Level Statistics by Region and Block Group

Location	Population	Population Below Poverty Level	Percentage Below Poverty Level
Greater Midland, Bay City, Saginaw Region	~390,000	46,751	12.0%
Bay County, Michigan	108,881	10,605	9.7%
Block Group 1, Census Tract 2861	1764	62	3.5%
Block Group 2, Census Tract 2861	930	26	2.8%
Block Group 3, Census Tract 2861	747	72	9.6%
Block Group 4, Census Tract 2861	1591	89	5.6%
Block Group 5, Census Tract 2861	1250	46	3.7%
Block Group 6, Census Tract 2861	1550	105	6.8%
Block Group 1, Census Tract 2860	1085	77	7.1%
Block Group 2, Census Tract 2860	1160	49	4.2%
Block Group 3, Census Tract 2860	1525	43	2.8%
Block Group 1, Census Tract 2857	1727	130	7.5%
Block Group 2, Census Tract 2857	735	52	7.1%
Block Group 3, Census Tract 2857	524	32	6.1%
Block Group 4, Census Tract 2857	891	70	7.9%
Block Group 2, Census Tract 2862	524	25	4.8%
Block Group 4, Census Tract 2862	1026	107	10.4%
Block Group 5, Census Tract 2862	977	86	8.8%
Source: U.S. Census Bureau, 2000 Census Data, http://factfinder.census.gov			

All but one block census group population in the immediate vicinity of the site has a poverty rate lower than the county poverty rate and none exceed the rate for the broader region described[4]. A graphic portrayal of the geographic trend in low-income demographics is presented in Figure 3-5.

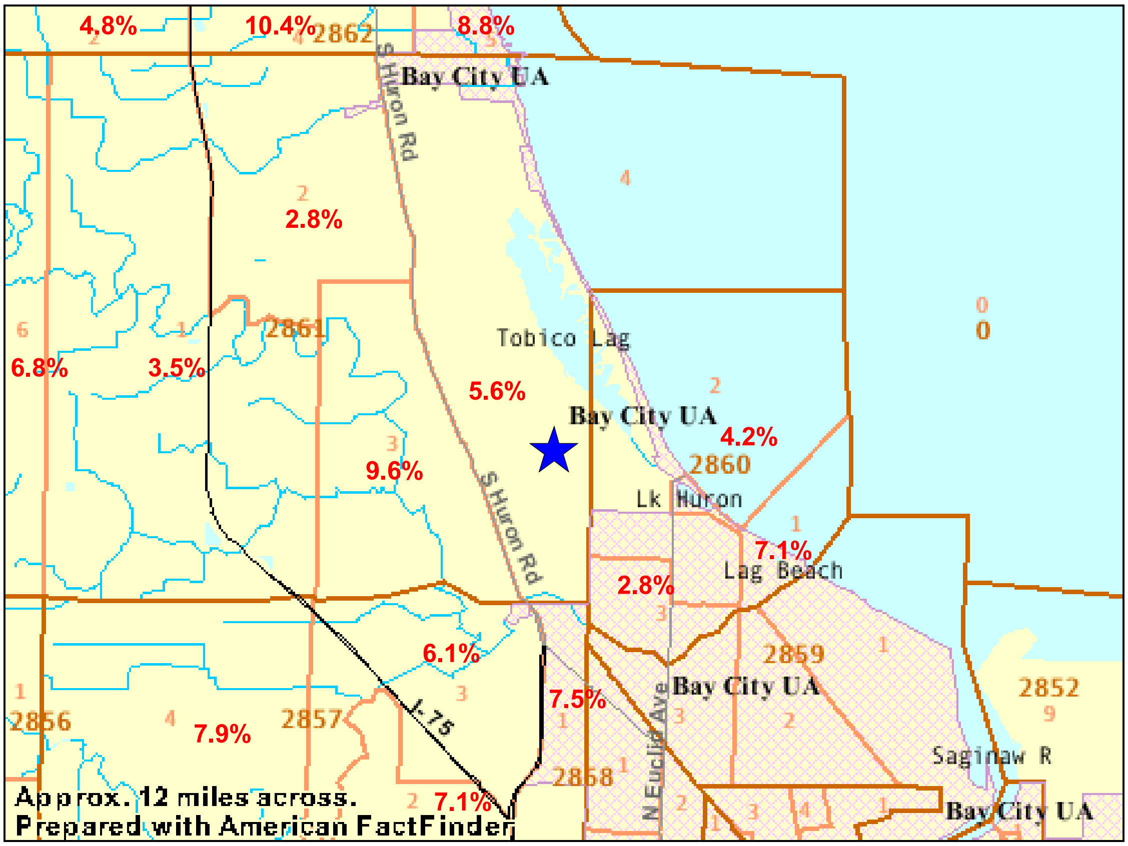


Figure 3-5 Households with Median Income Below the Poverty Level By Block Group

3.3 CURRENT/FUTURE LAND USE

Bay County is predominately rural but has an urban center (Bay City) near its southern end. Nearly half of the land use is agricultural, principally producing potatoes, sugar beets, beans, corn, and wheat. Pinconning, to the north of the site, is known for cheese, while Bay City is home to manufacturers of automotive parts, petroleum, cement, chemicals, beet sugar, and heavy machinery. While a significant portion of the land area of the county is agricultural land, the economy relies most heavily on the manufacturing,

4 Caution should be exercised in making direct comparisons of poverty rates computed for a block group because the sample size for a block group is relatively small resulting in larger margins of error.

services, retail, and government sectors (See Figure 3-6). Less than 1 percent of workers are employed in agricultural occupations (BOC 2000). There are several tracts of public land along Saginaw Bay including: Pinconning and Bay City State Parks, Quanicassee and Nayanquing Point Wildlife Areas, and Tobico Marsh State Game Area. The MDNR Site lies completely within the Tobico Marsh State Game Area.

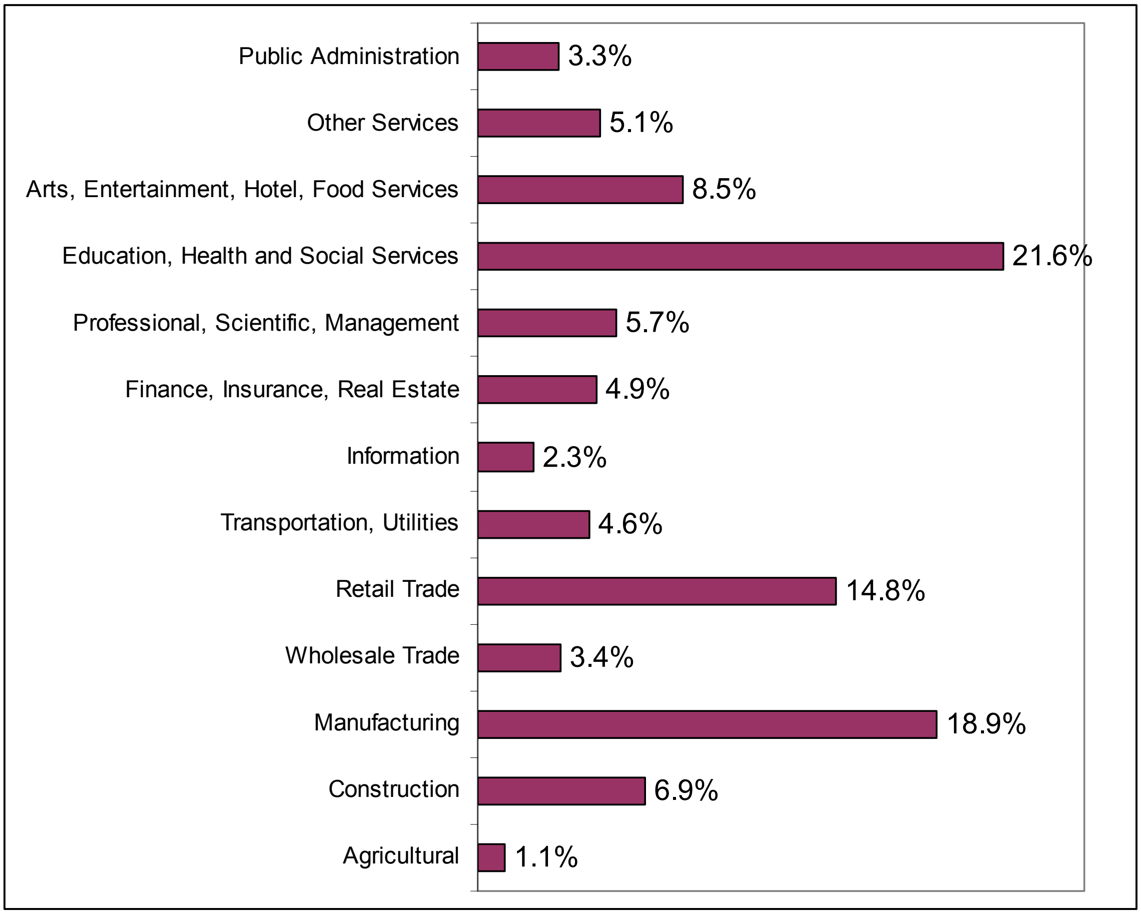


Figure 3-6 Employment by Industry in Bay County, Michigan in 2000

The MDNR site is currently fenced and posted to preclude unauthorized access. The land use in the surrounding Tobico Marsh SGA land is best described as seasonal/recreational. Activities commonly engaged in by land users include hunting, fishing, and naturalist activities.

Population growth is a key element in assessing the potential for changes in land use patterns and increasing development. The population in Bay County has been steadily decreasing over the past 20 years with a corresponding increase in the amount of farmland lying fallow. Economic and agricultural statistics for the region show a decreasing trend in the importance of agricultural land uses. The U.S. Census Bureau and State statistical resources project that the population of Bay County as well as that of the greater Saginaw–Bay City–Midland metropolitan area will continue to decrease over the next 20 years (BOC 2000, MI 1996). In spite of these trends, it cannot be ruled out that some development in the vicinity of the site might occur, but there is little reason to believe that an increased demand for agricultural land will result in further agricultural land development in the vicinity of the site and certainly not within the land area where the site is located. There may be some commercial and residential development along the major highway corridors, but there is no realistic expectation that development might occur along the stretch of Beaver Road to the south and east of the site. This is due to a variety of factors, such as wetlands in the area and public land (established State game and recreation areas). Many of the commercial properties in the immediate area cater to and depend upon tourism.

The site itself is anticipated to retain its current land use as a closed, MDNR-owned, industrial waste-disposal site. In the absence of fencing and posting, the land use at the site is anticipated to be consistent with the current designated recreational land uses in the publicly accessible portions of the Tobico Marsh State Game Area. It is further anticipated that the public recreational land designation for the Tobico Marsh SGA will remain in place indefinitely into the future. In fact, the State of Michigan has recently consolidated a number of designated public lands in the vicinity of the site (including the Tobico Marsh SGA) into an expanded Bay City Recreation Area (www.michigandnr.com/parksandtrails) further solidifying the publicly owned, recreational land-use future for the Site.

3.4 METEOROLOGY AND CLIMATOLOGY

The Site is located in southeastern Bay County near the southwestern edge of Saginaw Bay and north of Bay City, Michigan. The Saginaw River flows along the west side of downtown Bay City, the northwest side of Essexville and then empties into Saginaw Bay. Saginaw Bay is part of Lake Huron. Meteorological and climatic information presented in this section has been compiled from Federal and State historical weather data bases covering approximately 30-year periods (extending from 1951 to 1980 or 1961 to 1990, depending upon the data source) (http://climate.geo.msu.edu).

The effect of Lake Huron on the Bay City area's climate is most influential during periods of northeasterly winds. Under these conditions, the Bay City area receives cooler summer temperatures, while increased snow activity may accompany milder fall and early winter temperatures. Westerly winds blowing over Lake Michigan (to the west) often produces cloudiness and precipitation events (termed "Lake effect"), modifying fall and early winter temperatures.

3.4.1 General Meteorology and Climatology

Summers are generally considered moderately warm with the warmest period usually occurring in July with the mean daily temperature averaging 71.5 °F. Winters are generally considered moderately cold with the coldest period usually occurring in January when average daily temperatures is 21.6 °F. Precipitation amounts (Figure 3-8) and the daily chance of precipitation are usually well distributed throughout the year

(Figure 3-7). The "crop season", April through September, receives an average of 16.4 inches, or 59 percent of the average annual rainfall. The wettest month, on average, is August (2.93 inches), while the driest month, on average, is February (1.18 inches). Summer precipitation comes mainly in the form of afternoon showers and thundershowers. Local site conditions are similar to overall regional conditions. Since the site is situated in an open area with no trees or buildings to act as windbreaks, it is prone to being slightly colder in the winter months. In addition, the site is slightly warmer in the summer months from lack of shade.

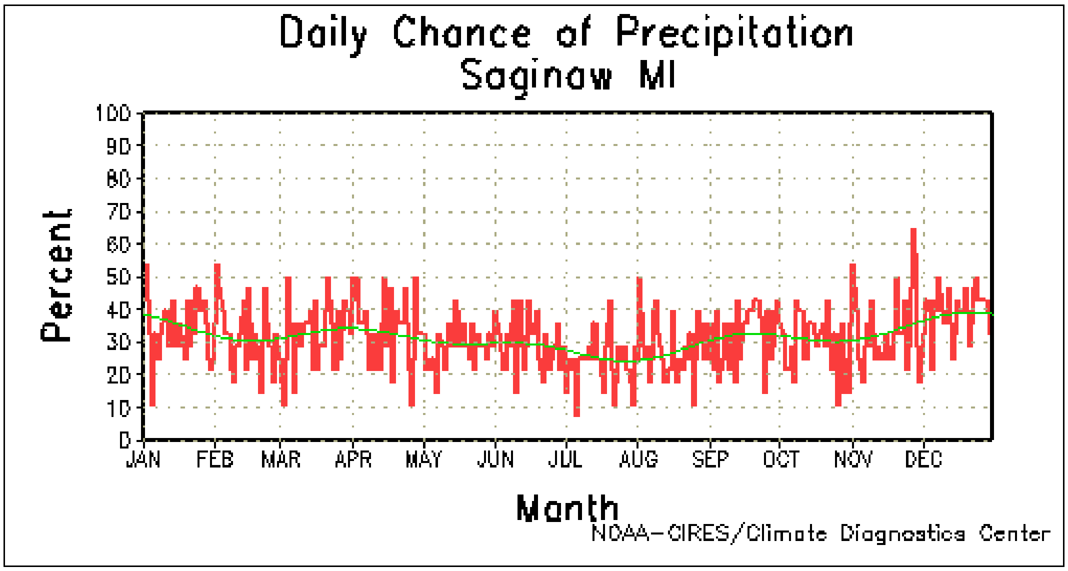


Figure 3-7 Mean Chance for Precipitation–Time Series

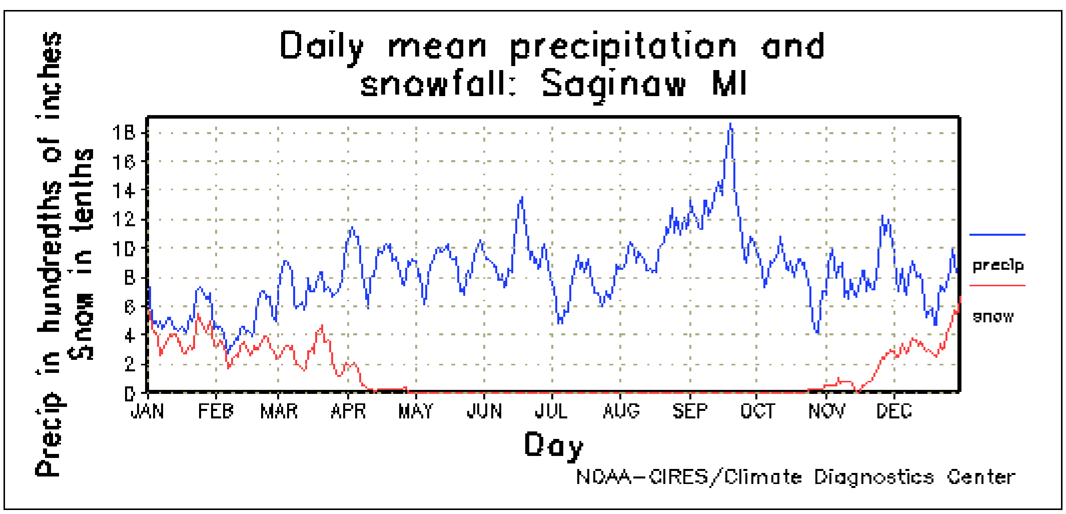


Figure 3-8 Mean Precipitation Amounts–Time Series

Annual snowfall (occurring in November through April) for the 30-year period averages 38.8 inches. January typically has the greatest monthly snowfall, averaging 11.3 inches. The average date for the last freezing temperature is May 1, while the average date of the first freezing is October 17. The freeze-free period, or growing season, averages 167.9 days annually. Table 3-6 presents the 30-year monthly average temperature ranges and precipitation levels.

Table 3-6 30-Year Monthly Average Temperature and Precipitation for Bay County

MONTH	HIGH TEMP (°F)	LOW TEMP (°F)	MEAN TEMP (°F)	PRECIPITATION (Inches)	SNOWFALL (Inches)
January	28.6	14.6	21.6	1.51	11.3
February	31.1	15.6	23.4	1.18	7.9
March	40.4	24.6	32.5	2.15	6.0
April	55.5	36.2	45.9	2.62	1.3
May	67.9	46.4	57.2	2.62	0.0
June	78.0	56.5	67.3	2.87	0.0
July	82.0	60.9	71.5	2.58	0.0
August	79.9	59.2	69.6	2.93	0.0
September	72.1	52.0	62.1	2.78	0.0
October	60.5	41.8	51.2	2.57	0.2
November	46.2	31.8	39.0	2.28	3.1
December	33.6	20.7	27.2	1.83	9.0

Wind conditions at the site are typically mild with winds trending from the south and west and blowing to the north and east. A cumulative average wind rose plot using data from the Saginaw MBS Airport meteorological station (Station #72639) collected over a 5-year the period, from 1987 to 1991, is presented in

Figure 3-9 (Lakes 1998). The average wind speed is calculated to be approximately 4.2 meters per second (9.35 mph) with calm winds reported approximately 7 percent of the time.

3.4.2 Extreme Meteorology and Climatology

This area seldom experiences prolonged periods of hot, humid weather in the summer or extreme cold during the winter. The highest average monthly maximum temperature in the 30-year period between 1951 and 1980 was 89.1°F in July 1955, and the lowest average monthly minimum temperature was 4.6°F in January 1977. On average, temperatures in excess of 90ºF occur only 10 days annually, and only 1 day in the 30-year period exceeded 100ºF. For the 30-year period, the high and low temperatures are listed in Table 3-7.

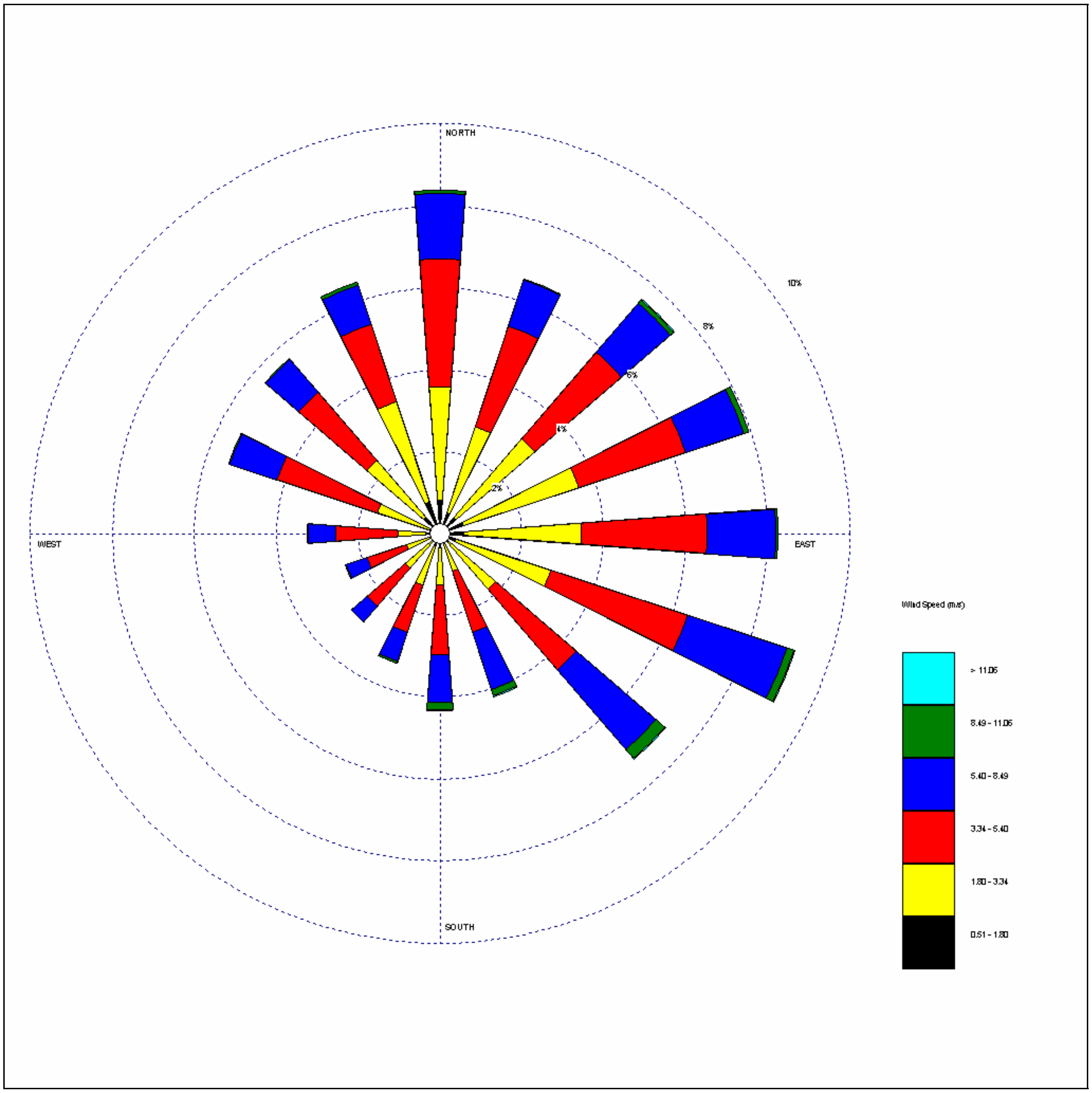


Figure 3-9 Wind Rose Diagram, Five Year Average (1987-1991)

Annually, thunderstorms occur on an average of 33 days. While drought occurs periodically, the Palmer Drought Index indicates drought conditions rarely reach extreme severity, historically occurring only 3% of the time. The largest single snowfall total, 24.0 inches, was recorded in January 1914. The greatest total monthly snowfall on record, 42.5 inches, occurred in December 1929. The greatest seasonal snowfall was

85.8 inches, recorded during the winter of 1911-1912. The smallest seasonal snowfall total was 7.3 inches, recorded during the winter of 1931-1932. The greatest snow depth was recorded in January 1979 at 25 inches. For the 30-year period, the severe weather maximum precipitation (by month) is presented in Table 3-8.

Table 3-7 Severe Weather Phenomena 30-Year High and Low Temperatures

MONTH	HIGH (°F)	YEAR	LOW (°F)	YEAR
January	62	1966	-14	1977+
February	58	1976	-15	1979
March	78	1963	-9	1962
April	85	1980+	12	1954
May	93	1977+	22	1966
June	99	1971+	36	1971
July	98	1977+	41	1965
August	100	1955	37	1971
September	98	1953	28	1976
October	87	1951	17	1976
November	76	1978	-6	1977
December	68	1971	-9	1951
+ indicates the last (of more than one) occurrence of the minimum or maximum temperature within the 30-year evaluation period.				

Monthly mean weather-related extremes are plotted in time series in Figure 3-10 for the 30-year period beginning in 1961. The same time-series data are normalized to the corresponding mean extreme value over the 30-year period and presented in high/low bar graphs in Figure 3-11 to portray the relative variability in the extreme weather data and to identify anomalies.

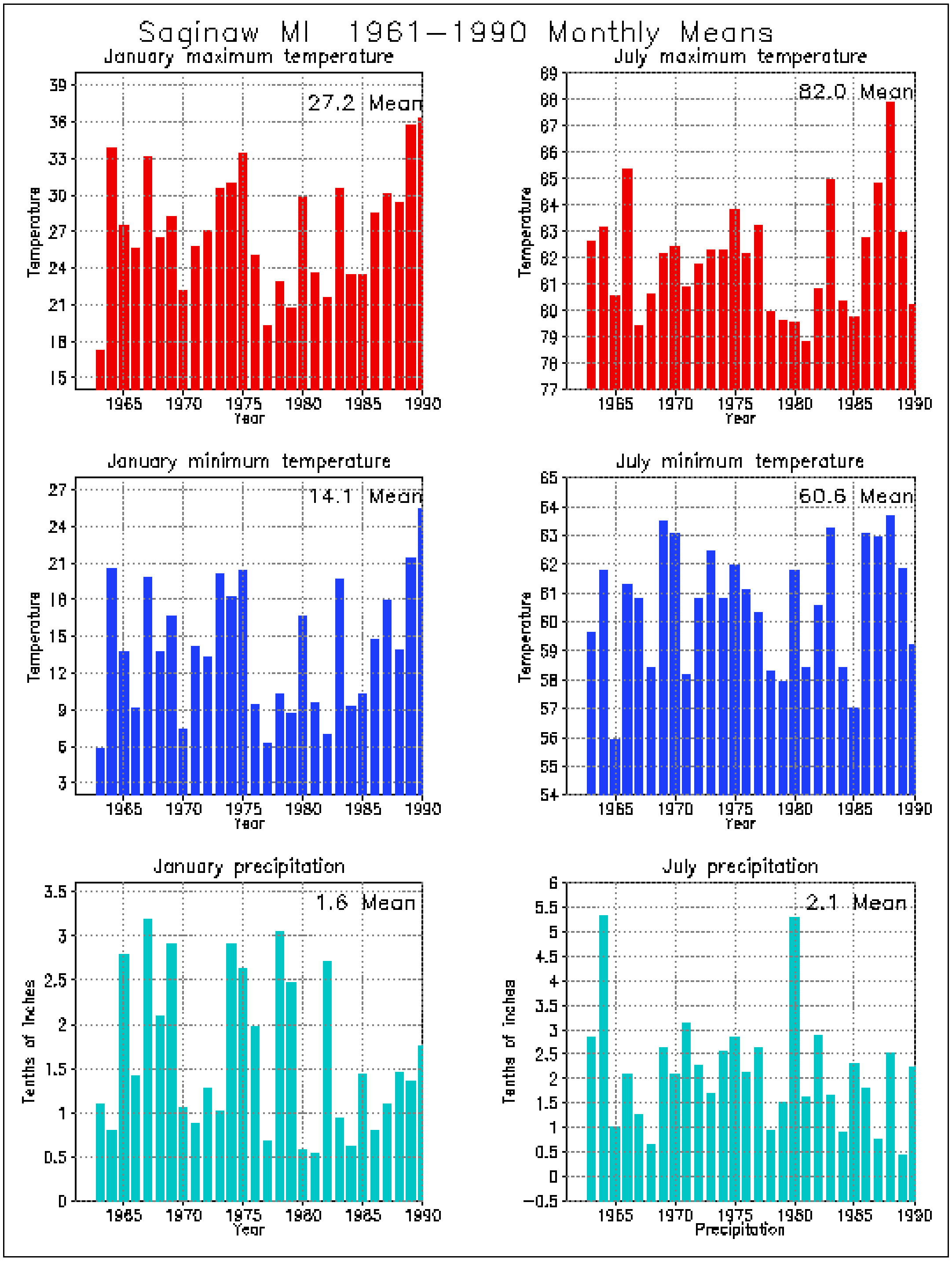


Figure 3-10 30 Year Time Series Plots of Weather Extremes

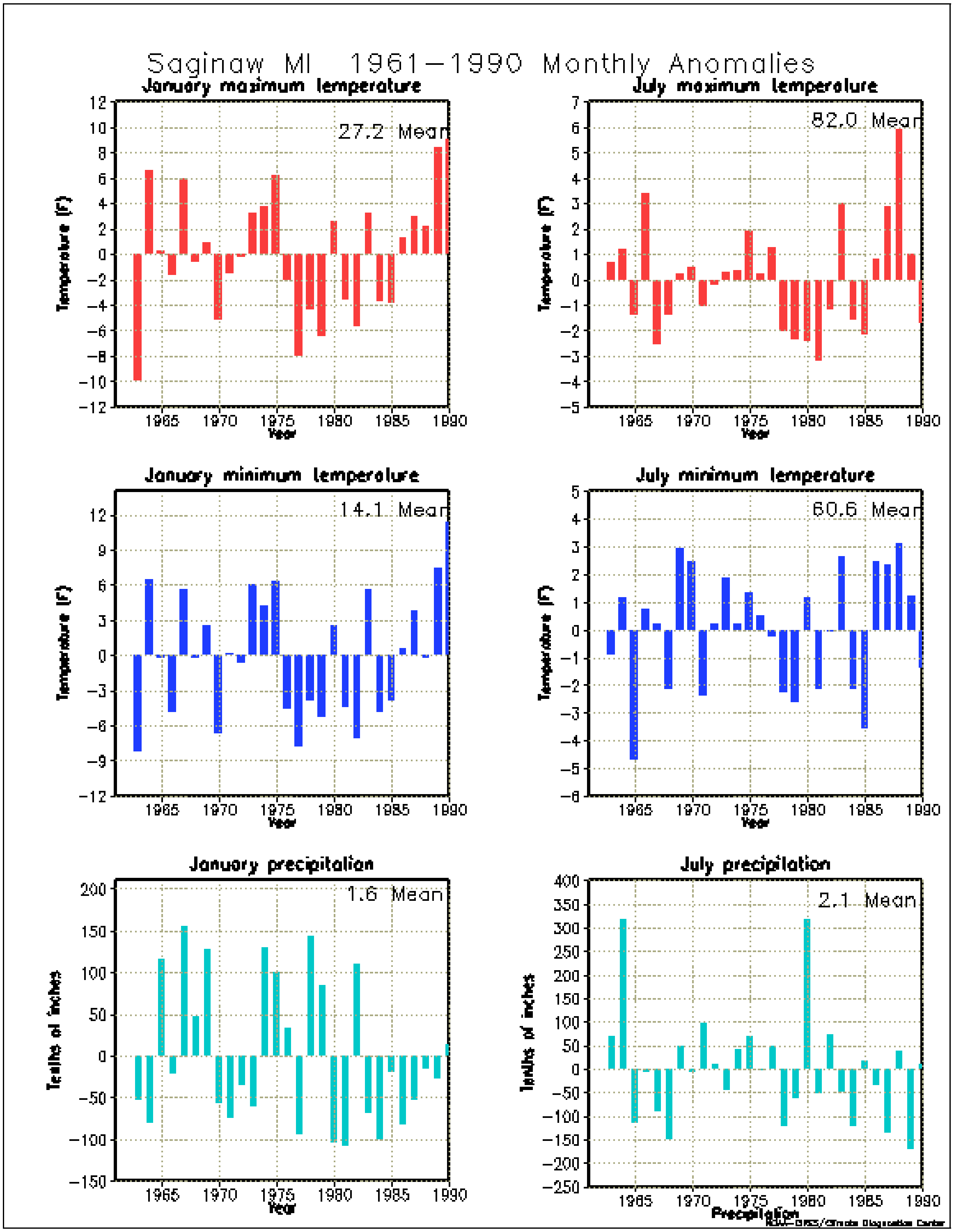


Figure 3-11 30 Year Time Series Plots —Monthly Anomolies

Table 3-8 Severe Weather Phenomena, 30-Year Maximum Precipitations

MONTH	MAX RAINFALL (inches, year)	MAX. SNOWFALL (inches, year)	MAX. DAILY SNOW AMOUNT (inches, year)	MAX. TOTAL SNOW DEPTH (inches, year)
JANUARY	2.02, 1974	29.0, 1979	12.0, 1967	25, 1979
FEBRUARY	1.28, 1974	19.5, 1956	6.7, 1962	21, 1959
MARCH	4.35, 1973	14.7, 1965	11.0, 1968	13, 1978
APRIL	2.31, 1967	13.0, 1975	9.0, 1970	12, 1975
MAY	2.17, 1978	Trace, 1961+	Trace, 1961+	Trace, 1957
JUNE	2.95, 1973	0.0	0.0	0
JULY	2.81, 1980	0.0	0.0	0
AUGUST	2.50, 1951	0.0	0.0	0
SEPTEMBER	2.20, 1957	0.0	0.0	0
OCTOBER	2.90, 1954	3.5, 1967	3.5, 1967	3, 1967
NOVEMBER	1.62, 1965	17.9, 1951	8.0, 1951	4, 1977+
DECEMBER	1.69, 1979	21.0, 1951	8.0, 1957+	12, 1962
+ indicates the last (of more than one) occurrence of the minimum or maximum temperature within the 30-year evaluation period.				

Michigan is located on the northeastern fringe of the Midwest "tornado belt". This results in a low frequency of occurrence for tornadoes in Michigan. When tornadoes or funnel clouds are reported, they are typically category F0 or F1, with little or no property damage reported.

3.4.3 Ambient Air Quality

The ambient air quality of the entire State of Michigan is in attainment for each of the five "criteria" pollutants as described by the National Ambient Air Quality Standards (NAAQS) (MDEQ 2000). In addition to the ambient air quality standards for so called criteria pollutants, the federal government has categorically designated 156 national parks and wilderness areas as Class 1 areas (Figure 3-12) subject to enhanced air quality protection guidelines. Some American Indian tribal governments have also designated lands under their jurisdiction as Class 1 areas (Figure 3-13). The MDNR Site is not located in a Class 1 Area as designated by Federal or tribal governments. The closest Class 1 Area to the site is the Seney Wilderness Area, located 200 miles to the north in the Upper Peninsula of Michigan. The first downwind Class 1 Area is the Lye Brook Wilderness Area, located approximately 550 miles to the east in the State of Vermont.

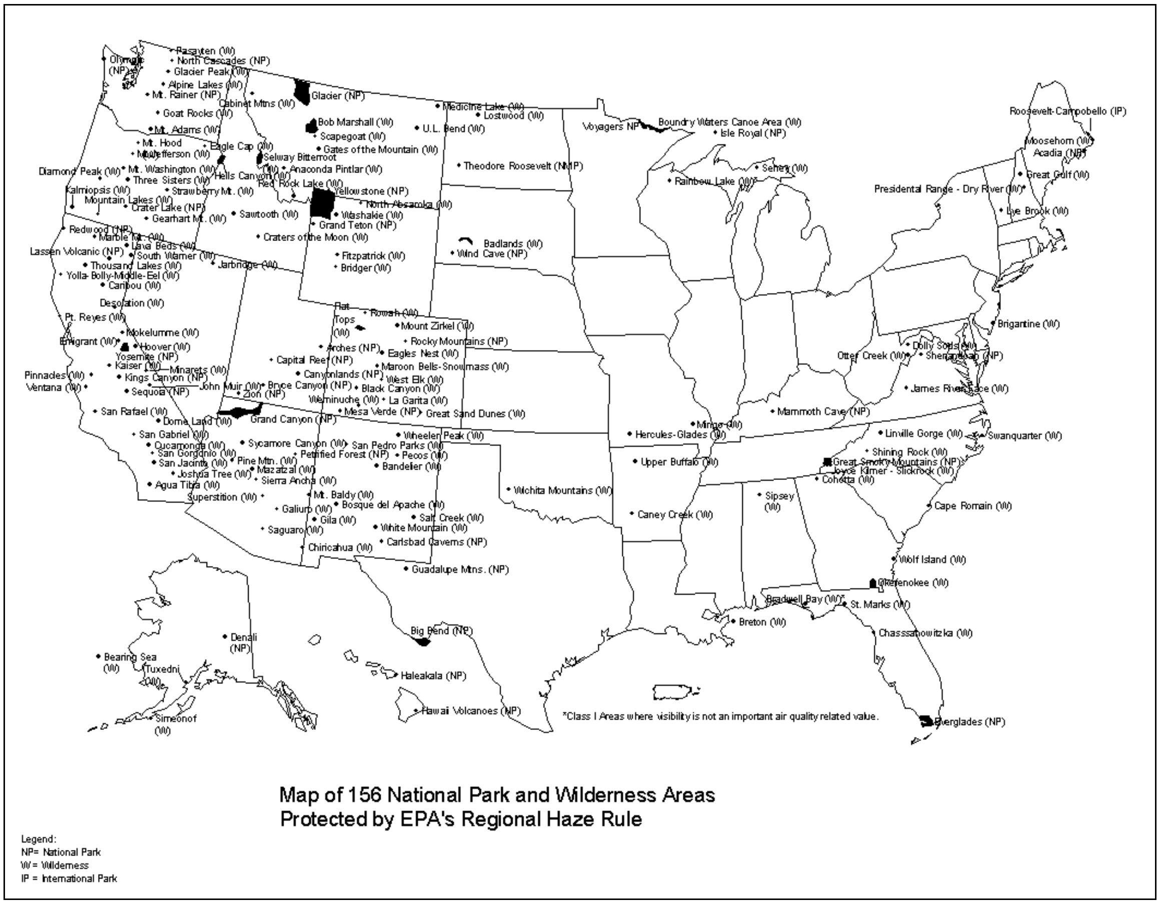


Figure 3-12 Federally Designated Class 1 Areas

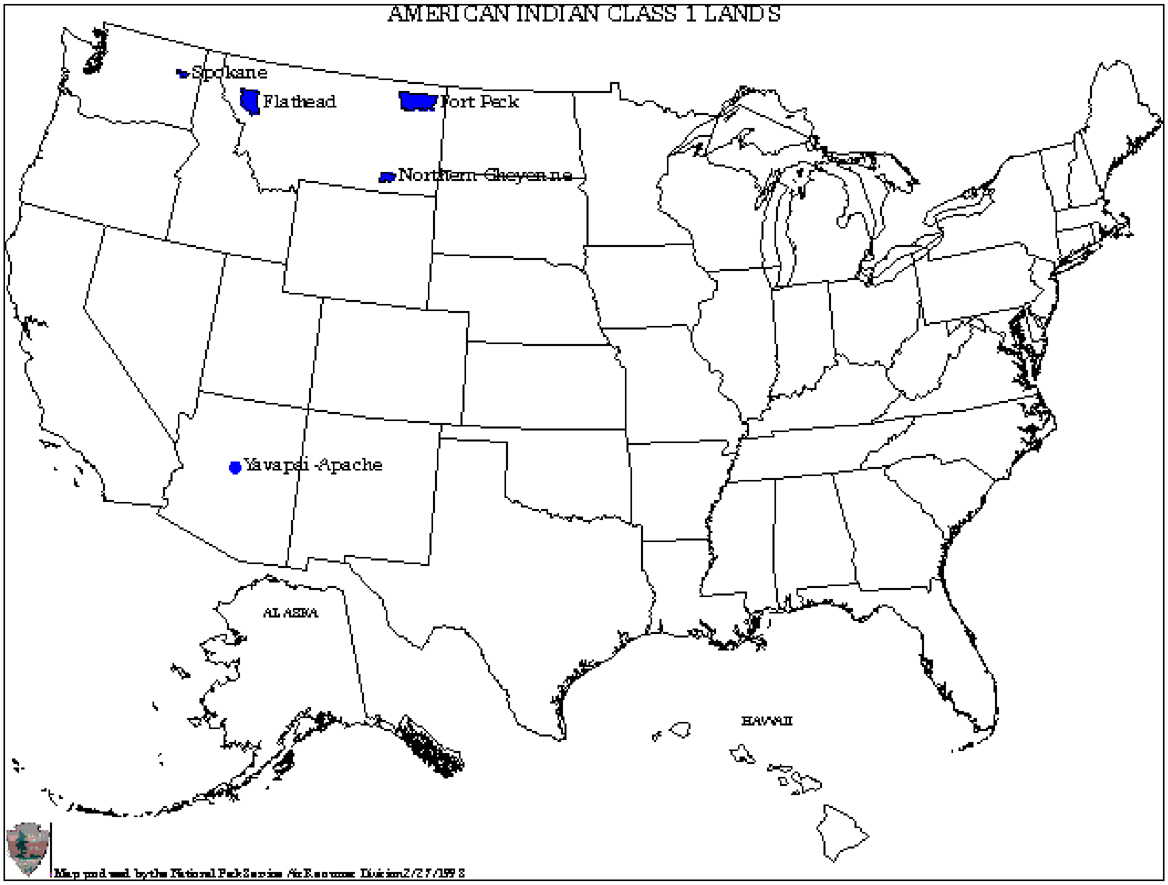


Figure 3-13 Lands Designated Class 1 Areas by American Indian Tribal Governments

3.5 GEOLOGY AND SEISMOLOGY

Glacial till underlies the entire site, and is composed of clay with silt, medium- to fine-grained sands, and trace amounts of gravel. The till was encountered at depths ranging from 3 to 9 feet beneath the surface of the landfill cap. The lacustrine (fresh water) deposits consist of silts and clays, little coarse- to fine-grained sands, and trace amounts of gravel. There is also some organic material (plant roots, wood chips) in the deposits.

The surface and near-surface soil in the area immediately surrounding the site, as defined by the United States Department of Agriculture – Soil Conservation Service and Michigan Agricultural Experiment Station Soil Survey of Bay County, Michigan, is Belleville loamy sand, ponded (#67 on Figure 3-14). Belleville loamy sand is described as nearly level poorly drained soil. It is covered with 6 to 36-plus inches of water throughout most of the year. Typically, the surface layer is very dark gray, loamy sand about 11 inches thick. The subsoil is grayish-brown, loose sand about 25 inches thick. The substratum is multi-colored clay loam and other loams about 60 inches thick (Soil Survey of Bay County). Permeability is rapid in the sandy upper part of the soil and moderately slow in the loamy lower part. In most areas, the soil is submerged underwater and covered in marsh vegetation.

Former beach sand deposits overlie the till and consist of fine- to medium-grained quartz sand, approximately 5 to 8 feet thick in the footprint of the cell. Thin peat laminations are encountered sporadically in the sand deposits. Highly organic, soft topsoil, approximately 2 inches thick, has formed on the surface of the site. The thickness of the clay cap ranges from 3 to 7 feet.

Geology of the Reference Area is generally the same as that found at the Site. The glacial till is encountered approximately 7 to 8 feet bgs. The overlying former beach sand deposits are approximately 4 to 6 feet thick. A thin gravel layer was encountered approximately 4.5 feet bgs. Highly organic, soft topsoil is found on the surface of the site.

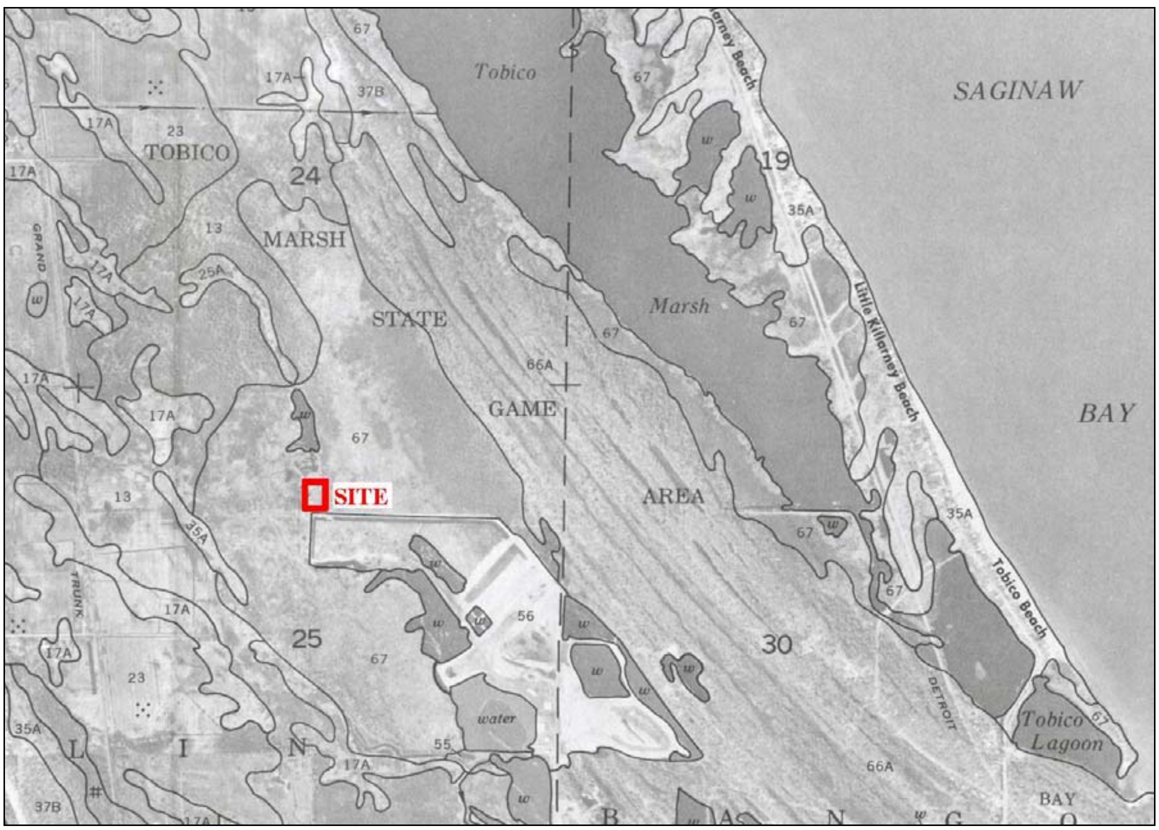


Figure 3-14 Soil Survey Map

3.5.1 Geotechnical Parameters

Soil samples, collected south of the pond (north of the site) and near the southeastern gate, were submitted to Materials Testing Consultants, Inc. (MTC) in Grand Rapids, Michigan. Soil samples consisted of one clay sample and one sand sample. The clay sample was analyzed using ASTM Standard Method D5084 (ASTM 1997), which measures the hydraulic conductivity of saturated porous materials. The sand sample was analyzed using ASTM Standard Method D2434 (ASTM 2000), which measures the hydraulic conductivity on granular soils. Hydraulic conductivity results for soils are presented in Table 3-9 (Cabrera 2001).

Table 3-9 Hydraulic Conductivity Results

Type of Sample	Dry Unit Weight	Water Content	Coefficient of Permeability
Clay	123.2 PCF	13.5 %	5.4×10^{-8} cm/s
Sand	102.9 PCF	14.7 %	6.4×10^{-3} cm/s
PCF = pounds per cubic foot			

3.5.2 Seismology Parameters

Michigan is defined by a "bowl-shape" geologic structure known as the Michigan Basin. This basin contains inward-dipping lithified strata. Michigan is located in the tectonically less active interior of the United States continent, between the Appalachian Mountains and the Rocky Mountains. The site is classified as a seismic Zone 0 in the unified building code, indicating the lowest design criteria necessary for new construction.

The seismicity of the site and region should be considered very low. Seismic activity is very infrequent due to the stability of the regional geology. The site is in a geological region called the Central Stable Region.

Seismic activity is uncommon in the Michigan Basin. Earthquakes within 200 miles of the site of a Magnitude (Richter scale) of 3 or greater, within the last 100 years, are listed in Table 3–10.

The Michigan Basin is an example of an intracratonic basin. The main deformational events in this central stable region took place during the Precambrian eras, and basins were formed in some areas in the stable interior. These basins accumulated cratonic sediments and are relatively stable geologic environments. There are no known or inferred faults in the site or vicinity (Dorr and Eschman, 1996, Geology of Michigan). The crust underlying the Great Lakes Basin continues to uplift through a process known as isostatic rebound resulting from post-glacial retreat.

Karst terrain is not a common feature associated with the geomorphology and structural geology of Michigan. The Alpena area of Michigan, located approximately 100 miles to the north of the site, is the only prominent Karst topography in the lower peninsula of Michigan. Karst features in the Alpena area are sinkholes.

Table 3-10 Seismic Activity Greater Than Magnitude 3

Location	Month Day, Year	Latitude & Longitude of Epicenter	Time of Event (Hr Min Sec)	Class	Magnitude (Richter Scale)
Gibralter, MI	Mar 13, 1938	42.08, 83.17	16 09	V	3.8
Gibralter, MI	Mar 14, 1938	42.08, 83.17	16 40	III	--
Lake Erie, OH	Mar 09, 1943	41.628, 81.309	03 25 24.9	V	4.5
Coldwater, MI	Aug 10, 1947	41.928, 85.004	02 46 41.3	VI	4.7
Gibralter, MI	Mar 13, 1938	42.08, 83.17	16 09	V	3.8
Gibralter, MI	Mar 14, 1938	42.08, 83.17	16 40	III	--
Lake Erie, OH	Mar 09, 1943	41.628, 81.309	03 25 24.9	V	4.5
Coldwater, MI	Aug 10, 1947	41.928, 85.004	02 46 41.3	VI	4.7
Pt. Pelee, ON	Feb 02, 1976	41.96, 82.67	21 14 02.0	IV	3.4
Harrow, ON	Aug 20, 1980	41.87, 82.99	09 34 53.4	IV	3.2
Central Michigan	Sep 02, 1994	42.57, 84.64	21 23 10	V	3.4

Figure 3-15 shows the Site location and its proximity to tectonic structures.

Landslides are an uncommon phenomenon in Michigan because the lack of topographic relief is generally not conducive to their occurrence. Infrequent landslides do occur along the eastern shoreline of Lake Michigan approximately 150 miles west of the site. These landslides are the results of shoreline erosion. There are no known or inferred faults in the immediate vicinity of the site. Man-made features at the site, or in the vicinity of the site, are sand pits located approximately 0.5 miles to the southeast of the site.

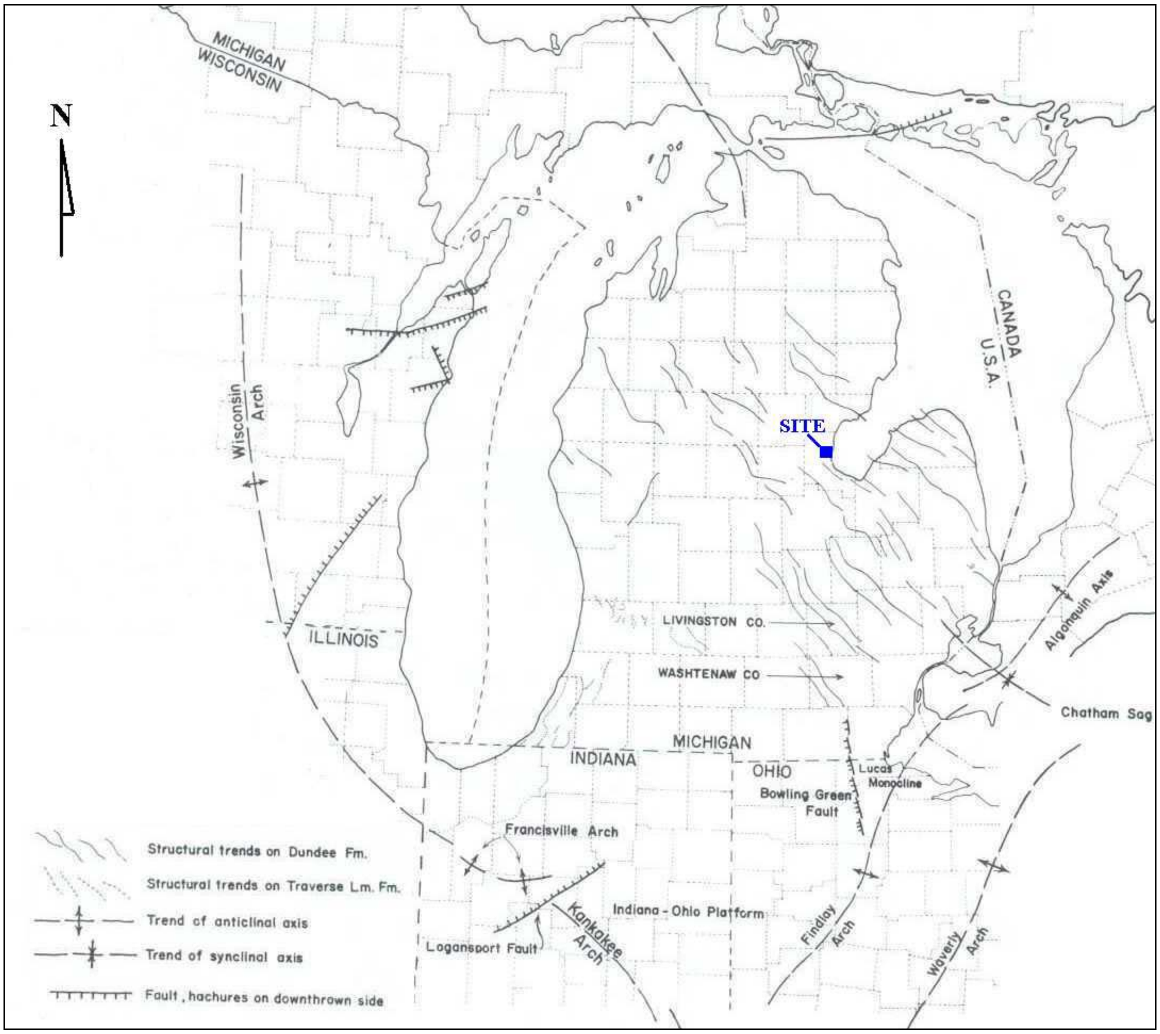


Figure 3-15 Michigan Basin and Surrounding Structural Elements (MBGS, 1969)

3.6 SURFACE WATER HYDROLOGY

The site is situated in the Tobico Marsh State Game Area. The area is a Federally and State regulated wetland and is adjacent to the Saginaw Bay, which is part of Lake Huron. Saginaw Bay is approximately 1.5 miles east of the site. The Kawkawlin River is approximately 1.75 miles south of the site with its North Branch tributary approximately 3 miles west of the site. Surface water bodies in the surrounding area near the site include Saginaw Bay and Lake Huron. Water bodies adjacent to the site include ponded waters to the north and southeast. Wetlands surround the site to the north, east and west.

3.6.1 Lake Huron Water Resource Data

Water level measurements from the Great Lakes Region have been recorded since at least the beginning of the 1900s. Lake Michigan-Lake Huron water level data recorded from 1918 to 2000 has been collected into a hydrograph (Figure 3-16). Water levels have ranged between a high 177.4 meters (1986) and low 175.6 meters (1964) above mean sea level (msl).

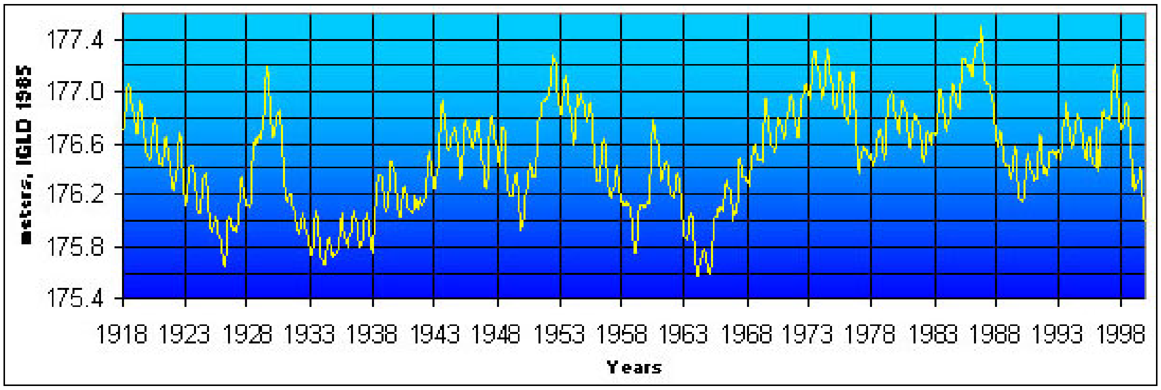


Figure 3-16 Lake Huron Hydrograph (USACE – Detroit District)

Lake Huron Physical Characteristics:

Low Water Datum (LWD):	175.81 m
Length:	331.52 km
Breadth:	294.51 km
Shoreline Length:	5,117.70 km
Total Surface Area:	59,569.43 km^3
Surface Area in U.S.:	23,568.77 km^3
Volume at LWD:	3,538.76 km^3
Average Depth Below LWD:	59.44 m
Maximum Depth Below LWD:	228.60 m
Average Surface Elevation (IGLD):	176.38 m
Maximum Surface Elevation (IGLD):	177.38 m
Minimum Surface Elevation (IGLD):	175.37 m

Natural drainage patterns, for the site, are directed eastward towards Saginaw Bay, which is part of Lake Huron. The topographic relief of the area (Figure 3-17) shows this drainage pattern.

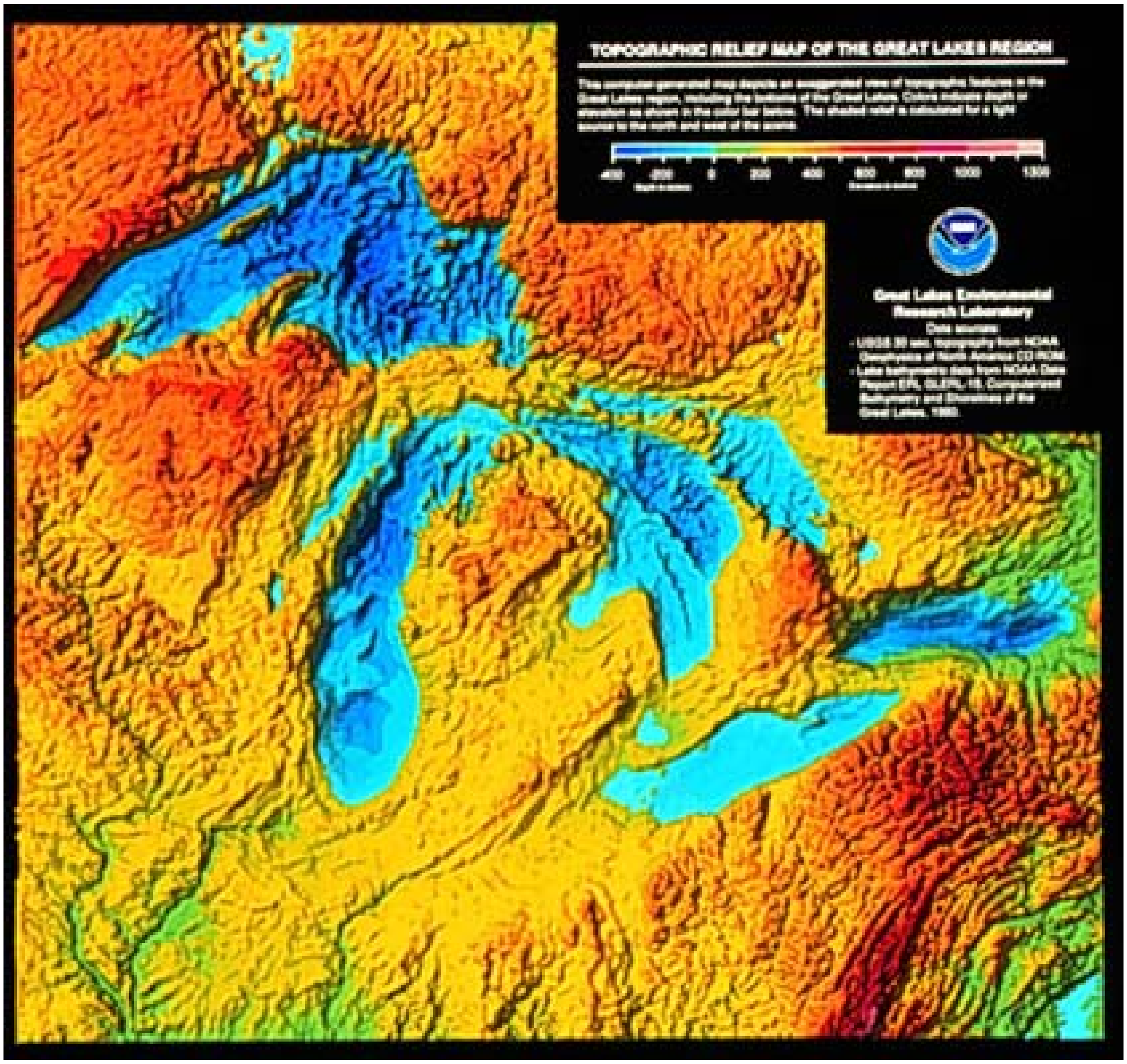


Figure 3-17   Great Lakes Region Topographic Map (NOAA-GLERL)

The Great Lakes Drainage Basin Area consists of Michigan, northern Ohio, northern Indiana, the northeast corner of Illinois, eastern Wisconsin, northeastern Minnesota, portions of southern Ontario (Canada), northwestern New York, and the northwestern tip of Pennsylvania (Figure 3-18).

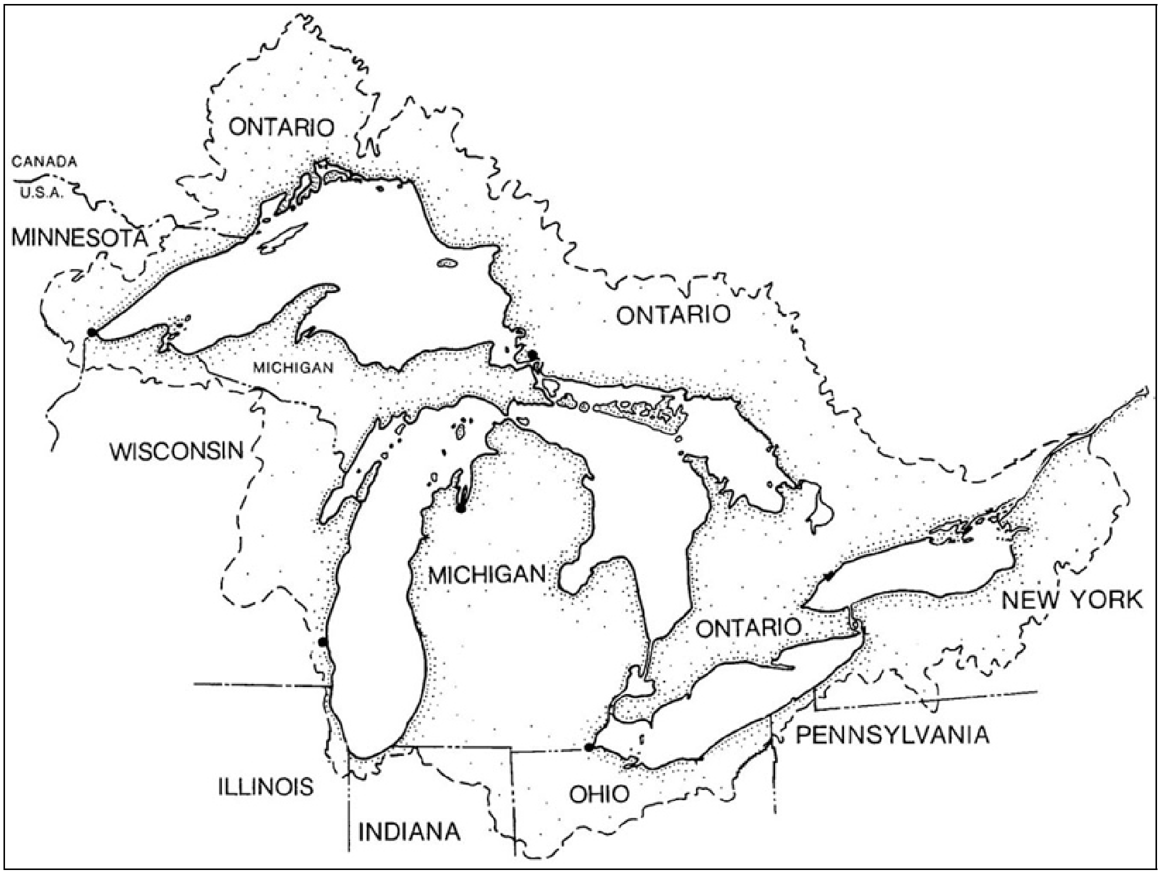


Figure 3-18 Great Lakes Region Drainage Basin Map (NOAA-GLERL)

3.6.2 Existing and Proposed Water Control Structures and Diversions

There are no known existing water control structures, upstream or downstream, that would influence the site. The U.S. Fish and Wildlife Service has proposed associated water-control structures for possible restoration actions for the marsh. Some proposed water-control measures taken into account include a water control weir, a flap gate, county drains, beaver activity, and irrigation practices in the watershed. The goal of the restoration effort being planned is "to facilitate to the extent practicable, natural fluctuations of water levels within Tobico Marsh, while providing adequate flood protection to residences riparian to Tobico Marsh." Other ecological restoration projects and projects that will enhance public use of Tobico Marsh may also be considered (U.S. Fish & Wildlife Service website).

3.6.3 Kawkawlin River Historical Stream Flow-Duration Data

The north branch of the Kawkawlin River is the nearest stream (river, tributary) to the Site and largest within several miles. Stream flow data is recorded in the north branch of the Kawkawlin River at:

USGS 04143500, North Branch Kawkawlin River, Bay County, Michigan
Hydrologic Unit Code 04080102
Latitude 43°40'05", Longitude 83°85'13" NAD27
Drainage area 101.00 square miles
Gage datum 584.00 feet above sea level NGVD29

Historical stream flow data for the north branch of the Kawkawlin River from 1951 through 1982 is presented in Table 3-11 below.

Table 3-11 Kawkawlin River Stream Flow Data Table

YEAR	Gage Height (feet)	Peak Stream flow Date	Peak Stream flow (cfs)	Annual Mean Stream flow (cfs)
1951	--	Apr 27	520	--
1952	--	Apr 15	990	84.3
1953	--	May 4	506	37.4
1954	--	Jun 22	1090	76.3
1955	--	Mar 13	1100	51.3
1956	--	May 8	855	52.5
1957	--	Apr 8	415	56.5
1958	--	May 6	714	34.9
1959	--	Apr 3	1220	78.2
1960	--	Apr 1	1540	64.1
1961	7.05	Mar 27	390	37.7
1962	9.97	May 4	1120	58.1
1963	7.28	Mar 29	396	33.2
1964	5.60	May 4	128	9.50
1965	10.33	Apr 13	1540	63.7
1966	7.45	Mar 25	472	51.8
1967	9.09	Mar 28	1020	75.7
1968	9.38	May 30	906	48.2
1969	8.44	May 11	719	70.4
1970	7.81	Apr 9	518	64.0
1971	8.76	Apr 4	846	41.1
1972	--	Apr 14	542	47.1
1973	8.98	Jan 22	840	94.0
1974	10.92	May 18	1610	96.2
1975	8.42	Sep 3	516	80.4
1976	10.44	Mar 22	1420	116
1977	4.58	Mar 13	87.0	19.1
1978	8.75	Mar 31	805	44.5
1979	8.19	Apr 2	548	49.1
1980	6.54	Apr 12	306	43.9
1981	9.44	Feb 25	1010	91.9
1982	9.27	Mar 26	957	--

3.6.4 Site and Adjacent Drainage Areas and Surface Gradients

The area surrounding the site is approximately 585 feet above mean sea level, is relatively flat, and usually contains standing or ponded surface water throughout the year.

Aerial photography (Figure 3-19) showing current site conditions (i.e., post disposal activity) provides a good picture of the surface water features in the near vicinity of the Site (surface water bodies are nearly black) and also shows where the natural tree line exists indicating marshy soils (marshy soils are dark gray in the photo, trees appear variegated). Ponded water to the north of the site is the result of former beach ridge sands being removed by a previous owner.

The majority of the surrounding area is located in marsh vegetation (Figure 3-20). Overall drainage is towards Saginaw Bay in the east/northeast.

Figure 3-19 Aerial Photography of Tobico Marsh SGA Site

The Site is situated in a fresh water marsh basin and is located within the 100 year flood plain. This is not due to the Kawkawlin River, but rather by high water levels that might occur within the Tobico Marsh system (Figure 3-21).

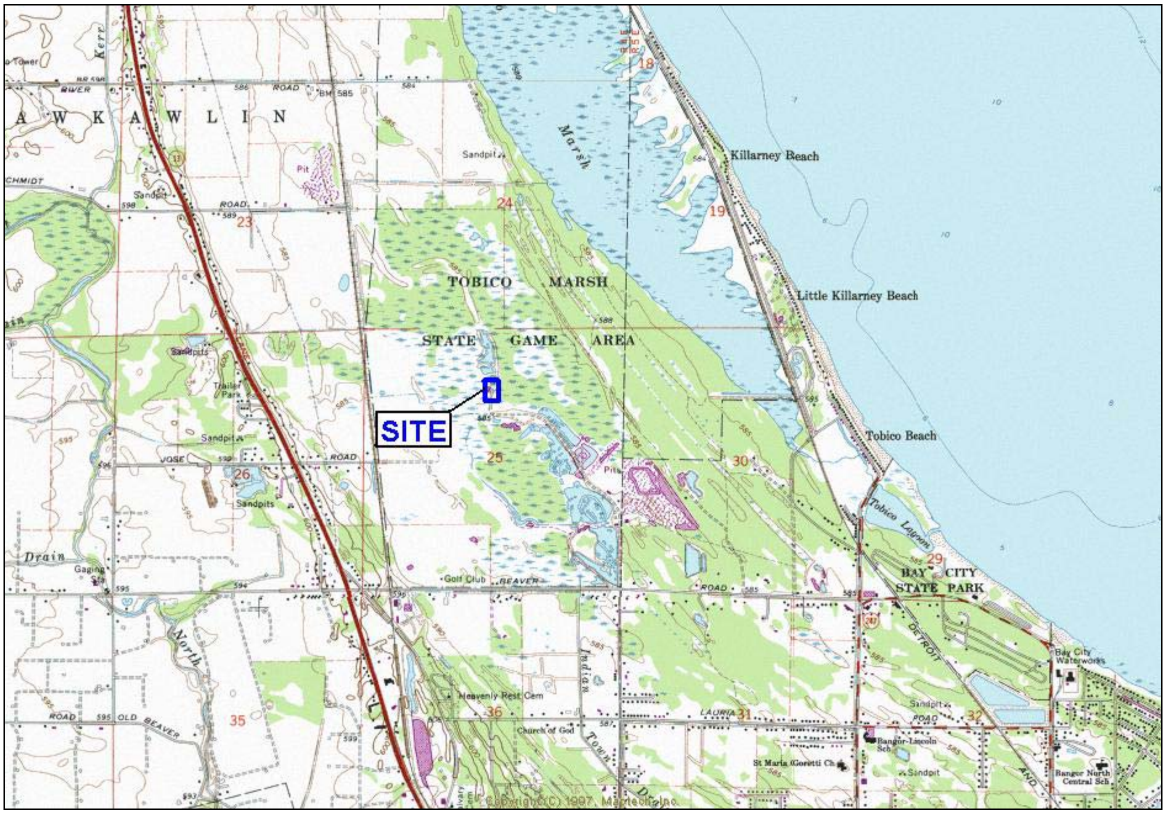


Figure 3-20 Topographic Map of Site and Surrounding Area

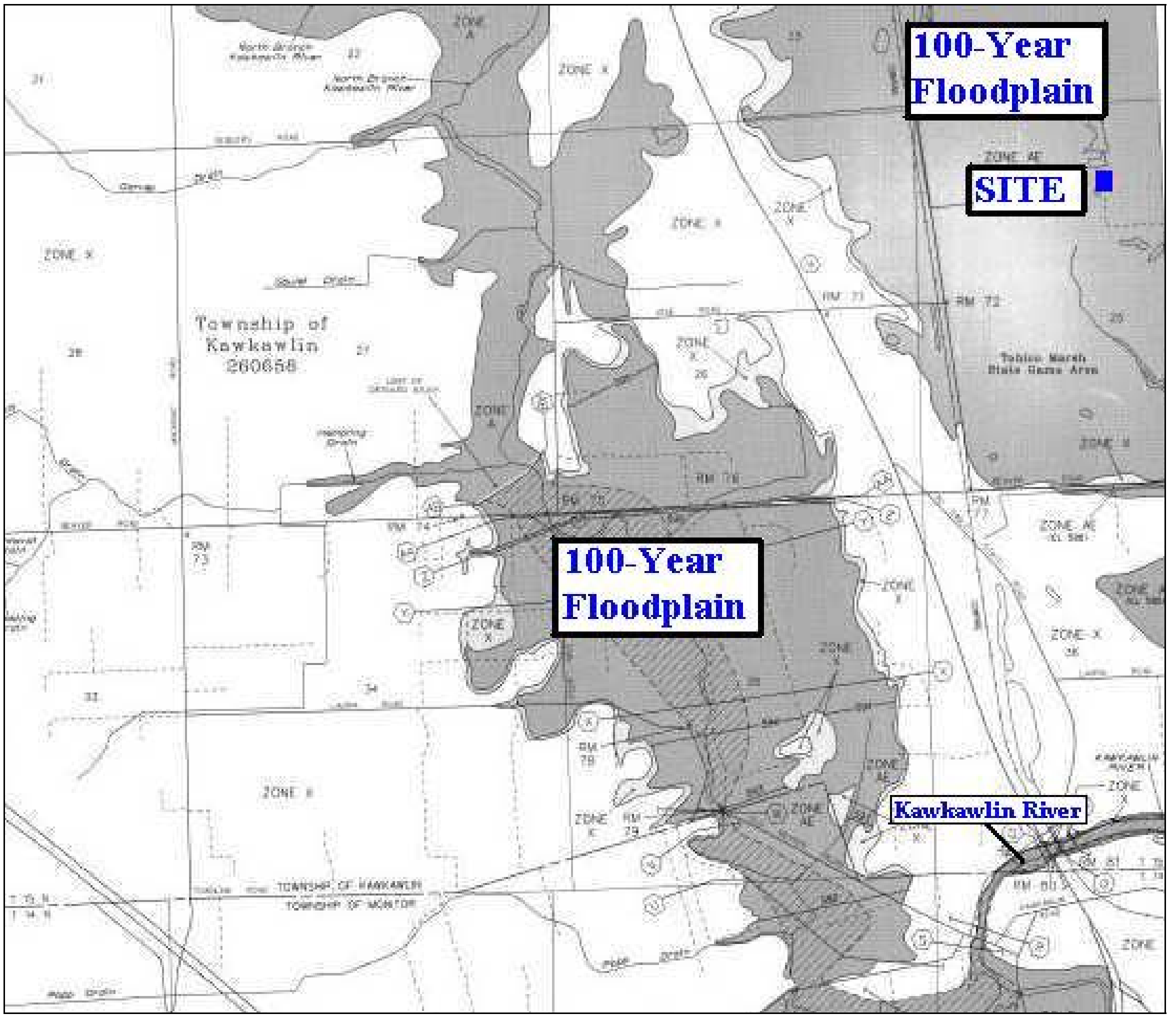


Figure 3-21 100-Year Floodplain Map

3.7 GROUNDWATER HYDROLOGY

Saturated Zone

Much of the land area surrounding the site (excluding the engineered clay cover) is covered with ponds and wetlands. As such, the saturated zone is either near or at the ground surface across these areas. The saturated zone is limited to the shallow sandy loam and is perched on the basal clay till unit. The thickness of the saturated zone varies seasonally but is generally one to three feet thick.

This groundwater has been designated by the State of Michigan (MDEQ) to be "groundwater, not in an aquifer". As such, it is not considered a viable nor adequate source for residential use and irrigation purposes. Refer to section 4.3 for additional information on groundwater.

Groundwater flow direction is difficult to trend due to the low hydraulic gradient, variability within the wetland habitat, and interaction with the landfill containment structures. Regionally, groundwater flow direction is to the east-northeast, towards Saginaw Bay.

Unsaturated Zone

Approximately 50 to 100 feet of glacial deposits underlie the site, which consist of glacial till with occasional interbedded layers of glaciolacustrine sediments. Former beach sands and peat deposits overlie this till. The glacial till is composed primarily of clay with some silt and medium- to fine-grained sand and a trace of gravel. The till is very dense, unstratified, and heterogeneous. The glaciolacustrine deposits consist of silts and clays with little, coarse- to fine-grained sand, and a trace of gravel. The silts and clays are high in organic material. The post-glacial former beach sand deposits overlie the till and consist of fine- to medium-grained quartz sand. The thickness of the sand is 5 to 8 feet. With the exception of the overlying sands, the geologic conditions are not conducive to lateral or vertical mobility of groundwater, which is therefore considered discontinuous. The glacial till underlying the sands is also an impediment to vertical migration of groundwater and its contents.

There are three monitoring wells (MW-1, MW-8, and MW-9) inside the site and seven monitoring wells (MW-3, MW-4, MW-5a, MW-6, MW-7, and MW-43) along the perimeter of the site.

Monitoring wells on site are constructed with a 2-inch I.D. stainless-steel well screen and a 2-inch I.D. galvanized riser. Screens were installed in two lengths: 2-foot or 8-foot sections (Table 3-12). Groundwater was sampled for the following parameters: volatile organic compounds, semi-volatile organic compounds, pesticides, polychlorinated biphenyls (PCBs), and inorganics (arsenic, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, mercury, potassium, selenium, silver, sodium, and zinc).

3.7.1 Distribution Coefficients for the Radionuclides of Interest at the Site

The distribution coefficient, K_d, is the ratio of the mass of solute species adsorbed or precipitated on the solids per unit of dry mass of the soil to the solute concentration in liquids within the pore spaces in the soil. The key component of this definition as it relates to the site-specific conditions and the RESRAD groundwater transport model is that it assumes that the radionuclide is introduced to the soil column as a *solute*. While this classical approach may be appropriate to describe the retardation of soluble contaminant migration in the soil column beneath the contaminated soil layer, it fails to address the situation encountered for the so-called "contaminated zone." The site-specific condition encountered at the Tobico Site is that the physical composition of the contaminant is a vitreous slag that is essentially insoluble even under the most extreme in-situ conditions that might reasonably be encountered.

Table 3-12 Monitoring Well Depths Table

MONITORING WELL	BOTTOM OF SCREEN DEPTH (Feet above mean sea level)
MW-01	579.10
MW-02	573.68
MW-03	576.33
MW-04	576.20
MW-05a	576.17
MW-06	578.37
MW-07	576.75
MW-08	583.23
MW-09	579.61
MW-43	Unknown

Leachability studies performed on comparable thorium-bearing slag found at a site in Washington, Pennsylvania affirm that very little thorium is expected to be leached out of the slag in the environment (Molycorp 1995). Radiological analysis of leachate samples collected from within the engineered cell support the conclusion that thorium is not readily leached from the slag found at the MDNR's site (ABB 1997, MACTEC 2002).

Within the contaminated zone, two key physio-chemical processes are potentially at work: (1) leaching of soluble contaminants from the slag, and (2) subsequent adsorption/desorption and precipitation/dissolution of contaminants that were introduced to the soil column as solutes. Both of these processes have an influence on the soil/water distribution coefficient. Two fundamental analytical approaches are employed to measure the K_d value of a specific soil column. The most common approach assumes that the contaminant is introduced to a soil column in a completely soluble form. Any retardation of the contaminant as it interacts with the soil can be attributed to the soil's ability to adsorb or precipitate the contaminant, thus removing it from solution. This is the classic approach used to assess the distribution coefficient of a particular soil, but it falls short in its ability to assess the combined effect of contaminant leaching when the contaminant is not introduced as a solute. An alternate approach to assessing what might be termed an "effective K_d", takes into account both of the key physio-chemical processes at work in the contaminated zone, and measures the "desorption distribution coefficient," a treatment that is comparable to a leachability test procedure.

Physical samples of the slag/soil composition within the contaminated zone are not available for measurement. Nonetheless, it is known with a high degree of certainty that the slag form present at the site does not readily leach thorium contaminants. Site-specific desorption distribution coefficient studies performed at other sites where contaminants are present in soil in physical and chemical forms that are highly insoluble and resistant to leaching under in-situ conditions, have shown that the effective, or desorption, K_d is many orders of magnitude higher than the "adsorption K_d" measured for the same soil (Wang 1996, ENSR 2001). Given that radio-analytical measurements of the leachate in the cell indicate that radiological contaminants are not present in concentrations greater than that found naturally occurring in unaffected groundwater, the effective K_d value of the contaminated zone is judged to be substantially greater than the RESRAD default value, which is derived from data based upon adsorption measurements.

The K_d value for thorium in the contaminated layer is described in the conceptual site model using the typical, and RESRAD default, lognormal-N distribution function, except that bounds have been established on the range of values sampled during probabilistic analysis (a bounded lognormal-N distribution). The central tendency value for the distribution has been set to match the default, single-point estimate used in the RESRAD deterministic module, 60,000 cm^3/g (Yu 1993, NRC 1980, Yu 2002). Probabilistic sampling is bounded between 3,200 and 89,000 cm^3/g, the lowest and highest geometric mean values for various soils as reported in literature and summarized in the *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil* (Yu 1993). Treatment of the contaminated zone K_d value for thorium in this manner is only slightly less conservative than the default treatment of this parameter in RESRAD's probabilistic module and is at least as conservative as the default treatment in RESRAD's deterministic module. For all other soil "layers," the RESRAD probabilistic module default values were used to describe K_d values as adsorption onto host soil particles, and not leaching from the slag matrix, which more appropriately describes the retardation of contaminant migration through the soil column. A graphic representation of the probability density function describing the thorium K_d parameter for the contaminated zone in the RESRAD probabilistic module is offered in Figure 3-22. The vertical green lines represent the bounding conditions at 3,200 and 89,000 cm^3/g as described above.

3.7.2 Typical Geologic Cross-Sections Showing Groundwater Elevations and Flow Direction(s)

A geologic cross-section (A-A') was developed by E.C. Jordan Company, for the MDNR, in the Hartley and Hartley Landfill Site Remedial Investigation Final Report (ECJC 1986) (See Figures 3-23 and 3-24).

The cross-section was profiled west to east and included monitoring wells MW-7, MW-2, the west slurry wall, monitoring well MW-1, the east slurry wall, and monitoring wells MW-4 and MW-5.

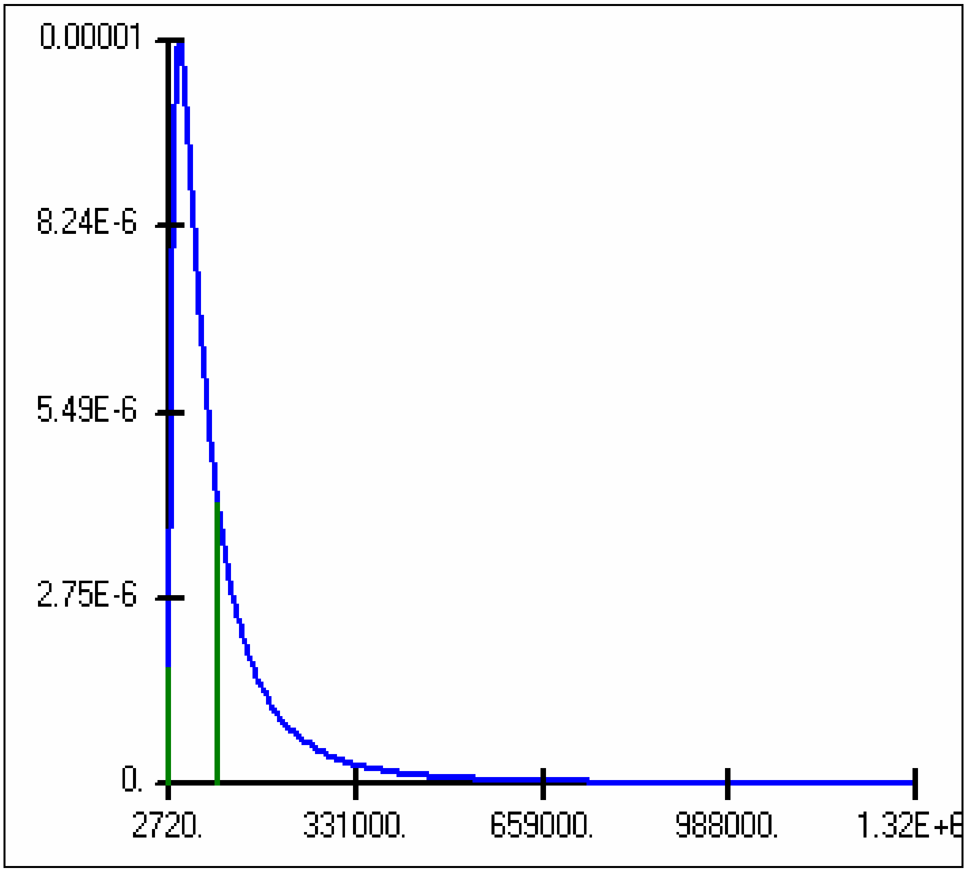


Figure 3-22 Probabilistic Thorium K_d—Contaminated Zone

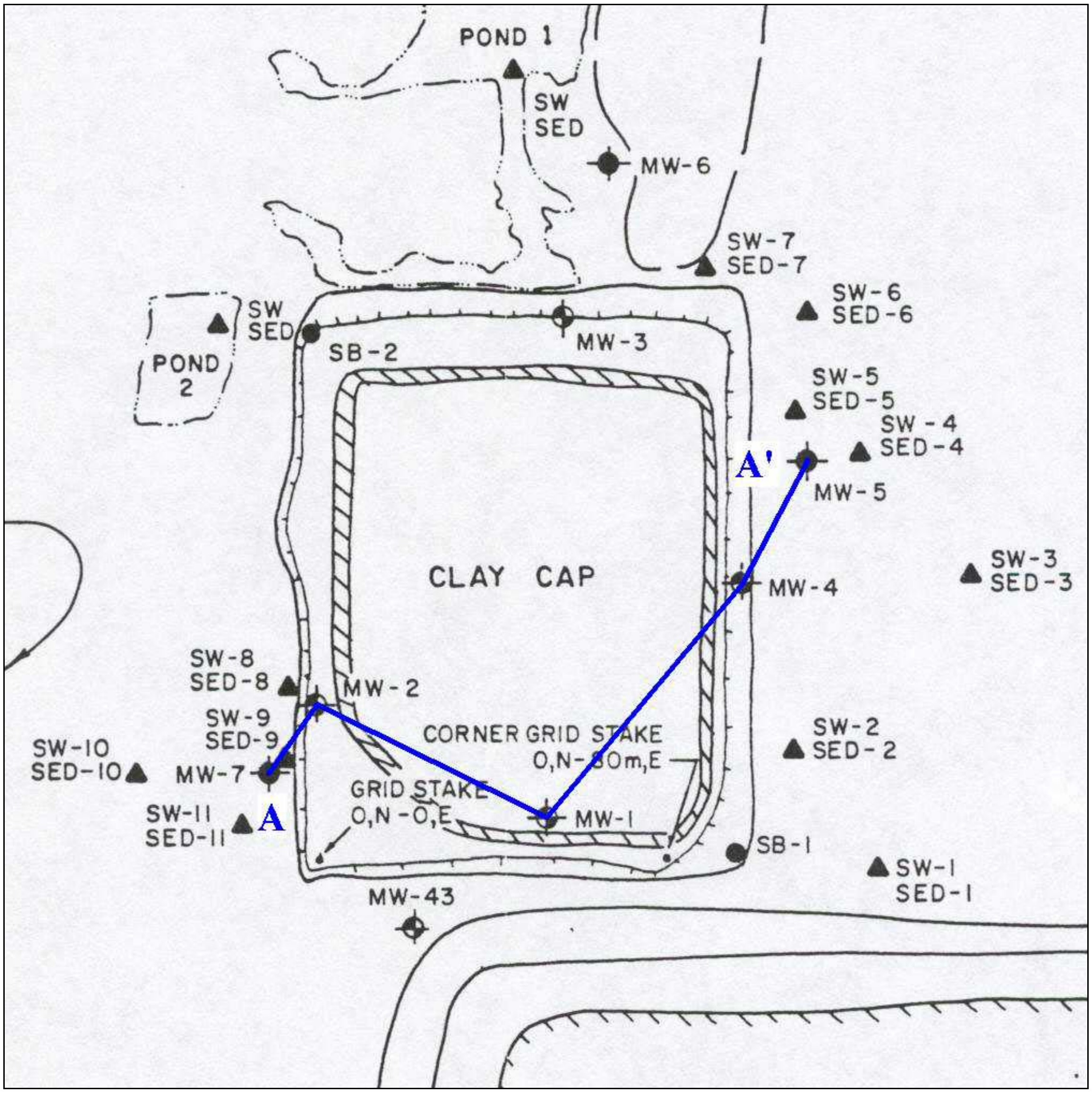


Figure 3-23 Cross-section Location Map

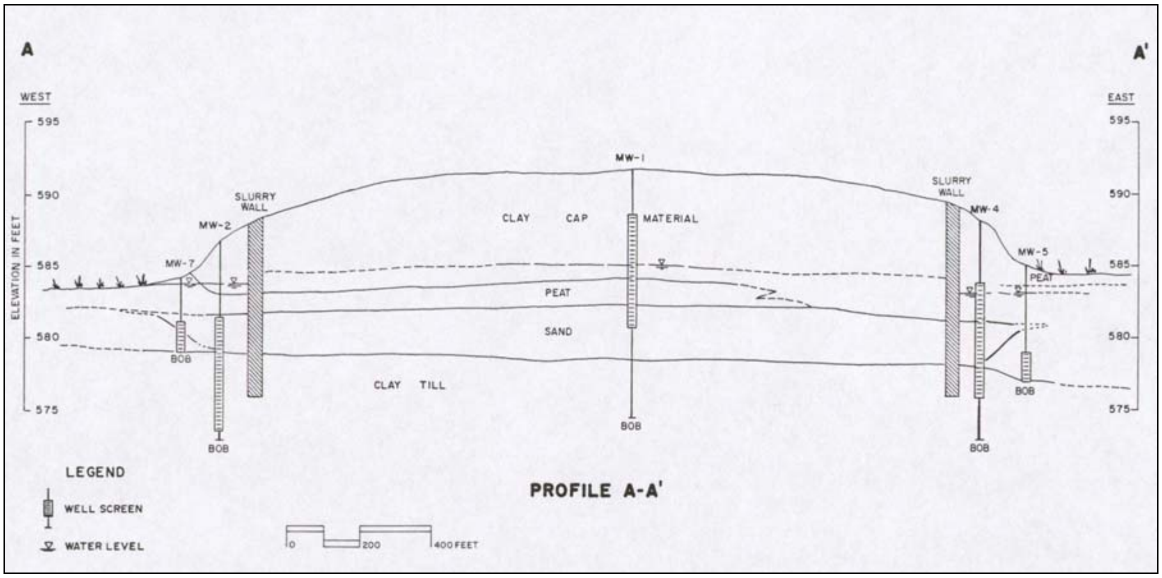


Figure 3-24 Cross-section Profile A-A'

3.8 NATURAL RESOURCES

Much of the site and surrounding lands are covered with ponds and wetlands. As such, the saturated zone is either at or near the ground surface. The saturated zone is not connected to a viable aquifer for potable, agricultural or industrial use. The MDEQ has determined that groundwater is not in an aquifer (MDEQ Hartley and Hartley, Bay County – Aquifer Determination, 2002). However, the Tobico Marsh State Game Area and surrounding area is home to many freshwater fish species.

The following fish species are found in the Tobico Marsh State Game Area and/or surrounding waters: Brown Trout, Burbot, Carp, Catfish, Chinook Salmon, Coho Salmon, Lake Trout, Northern Pike, Rainbow Trout, Walleye, White Bass, White Perch, White Sucker, Whitefish, and Yellow Perch (www.saginawbay.com and www.michigan.gov/dnr).

In addition to the presence of fish in the area's waters, agricultural lands in the region are used for both field crops and livestock. Field crops include beans, cantaloupes, cauliflower, corn, hay, oats, onions, peppers, potatoes, pumpkins, soybeans, sugar beets, and wheat. Livestock species include beef cows, milk cows, hogs, pigs, sows, and sheep.[5]

5 Based on 1995 land use data from the Michigan Agricultural Statistics Service.

Based upon information from the MDEQ and the USGS, there are no oil or gas resources in or adjacent to the site. Regionally, some oil wells are located to the southwest of the site (Figure 3-25) (MDEQ and GSD, Oil and Gas in Michigan, 2001).

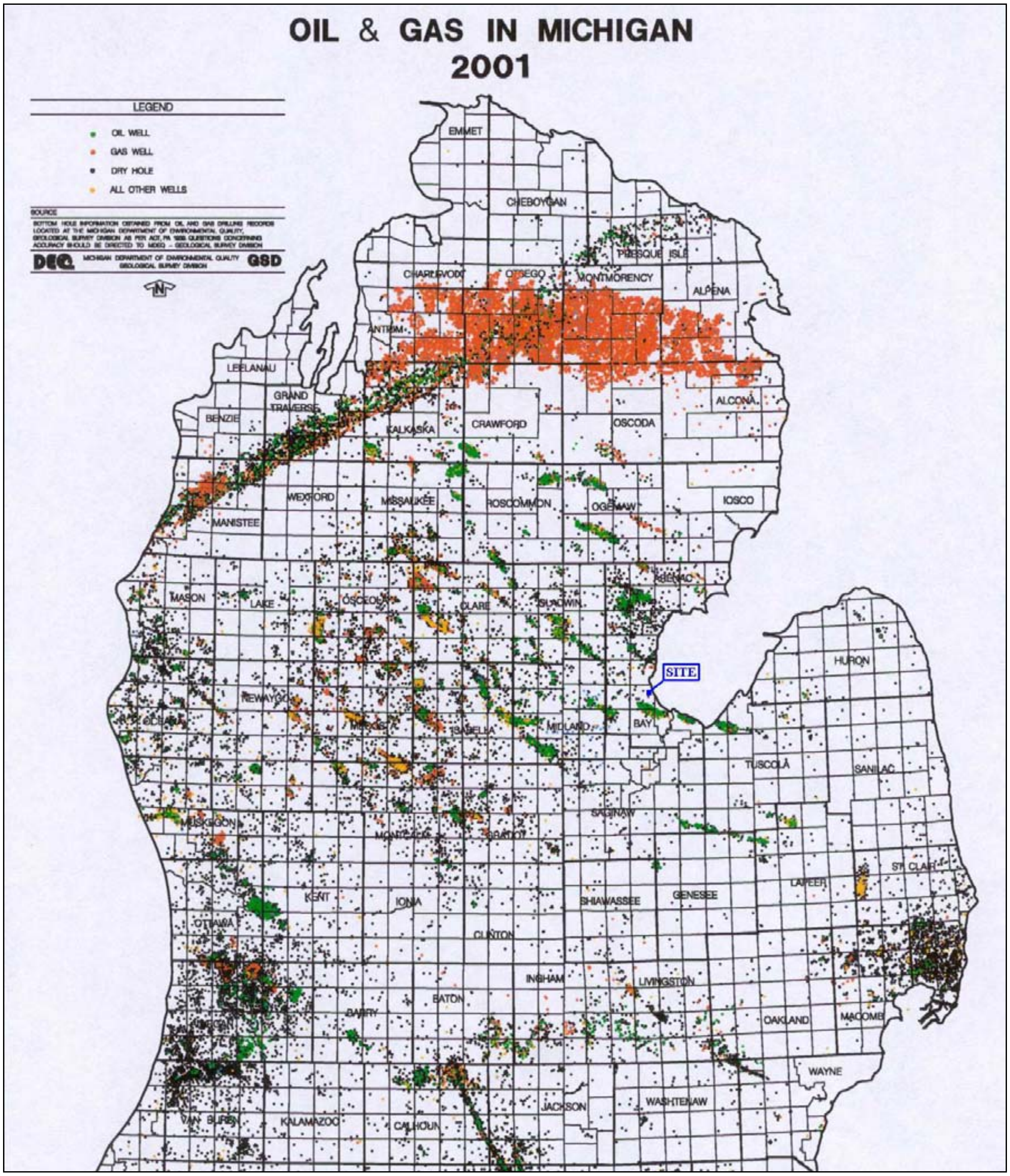


Figure 3-25 Oil & Gas Map of Michigan

3.9 ECOLOGY/ENDANGERED SPECIES

3.9.1 Commercially or Recreationally Important Invertebrate Species

Commercially or recreationally important vertebrate animals known to occur with 5 km of the site are listed below (MDNR – Bay City, and Bay City State Recreation Area):

Mammal Species

- White-tail Deer;
- Coyote;
- Gray, and Red Fox;
- Skunk;
- Raccoon;
- Possum;
- Gray, and Fox Squirrel;
- Chipmunk;
- Gopher;
- Woodchuck;
- Bobcat;
- Cottontail Rabbit;
- Muskrat;
- Mink;
- Badger;
- Beaver; and
- Otter.

Fish Species

- Brown, Lake, and Rainbow Trout;
- Burbot;
- Carp;
- Catfish;

Fish Species (continued)

- Chinook, and Coho Salmon;
- Northern Pike;
- Walleye;
- White Bass;
- White, and Yellow Perch;
- White Sucker; and
- Whitefish.

Bird Species

Various species can be found either year-round or seasonally. A partial list includes:

- Common Loon;
- Pied-billed and Horned Grebes;
- Great Blue, Green, and Black-crowned Night-Herons;
- Great Egret;
- Hooded, Common, and Red-breasted Mergansers;
- Turkey Vulture;
- Osprey;
- Bald Eagle;
- Northern Harrier;
- Sharp-shinned, Cooper's, Red-shouldered, Marsh, Broad-winged, Red-tailed, and Rough-legged Hawks;
- American Kestrel;
- Merlin;
- Peregrine Falcon;
- Black-bellied, and Semipalmated Plovers;
- Killdeer;
- Solitary, Spotted, Semipalmated, Least, White-rumped, Baird's, Pectoral, and Stilt Sandpipers;
- Eastern Screech, Great Horned, and Snowy Owls;

Bird Species (continued)

- Red-headed, Red-bellied, Downy, Hairy, and Pileated Woodpeckers;
- Alder, Willow, Least, and Great Crested Flycatchers;
- House, Winter, [Sedge], and Marsh Wrens;
- Swainson's, Hermit, Wood, and Brown Thrashers;
- Solitary, Yellow-throated, Warbling, Philadelphia, and Red-eyed Vireos;
- Blue-winged, Golden-winged, Tennessee, Orange-crested, Nashville, Yellow, Chestnut-sided, Magnolia, Cape Amy, Black-throated Blue, Yellow-rumped, Black-throated Green, Blackburnian, Pine, Palm, Bay-breasted, Blackpoll, Black-and-white, Mourning, Wilson's, and Canada Warblers;
- American Redstart;
- Northern Waterthrush; and
- Scarlet Tanager.

3.9.2 List of all Commercially Important Floral Species Known to Occur Within 5 km of the Site

There are no known *commercially important* (i.e. important to business) floral species known to occur within 5 kilometers of the site. There are, however, recreationally important floral species within 5 kilometers of the site.

3.9.3 Threatened and Endangered Species

Michigan's threatened and endangered species are:

- Animals

  King Rail, Caspian Tern, Common Tern, Indiana Bat, Gray Wolf, Bald Eagle, American Peregrine Falcon, Piping Plover, Kirtland's Warbler, Common Moorhen, Clubshell, Northern Riffleshell, Hungerford's Crawling Water Beetle, Karner Blue Butterfly, and Mitchell's Satyr Butterfly.

- Plants

  Pitcher's Thistle, Dwarf Lake Iris, Small Whorled Pogonia, Michigan Monkey-Flower, Eastern Prairie Fringed Orchid, Houghton's Goldenrod, and American Hart's-tongue Fern.

Of these, the American Peregrine Falcon and the Bald Eagle are the only species thought or known to be present within a 5 km radius of the site. The preferred decommissioning option selected by the MDNR is to leave the residual radioactivity in-place in the engineered cell. With no further remedial action, there is no evidence or expectation that residual radioactivity from the site will become available in the environment such that an ecological impact might result. It is estimated that a course of no further intrusive remedial action is likely to have the least impact on the local environment and its ecology.

4.0 RADIOLOGICAL STATUS OF FACILITY

A substantial amount of radiological data, in addition to the historical information (HLA 1998a) and other technical data, is available for the Site. From these data, it is evident that there are no radiologically contaminated structures, no contaminated systems or equipment, and no residual radioactivity in excess of background concentrations in surface soil on the site. There are, however, known deposits of foundry slags containing naturally occurring, but elevated concentrations, of thorium in subsurface soils.

The source of residual radioactivity at the site is known to be associated with the disposition of foundry slag generated at a site in nearby Bay City, Michigan. The foundry-generated slag came from operations involving magnesium alloys. Some, but not all, of these slag materials contained thorium as a natural composition of the ores from which the metals were derived. A review of historical documents indicates that the disposition of thorium-bearing slag materials at the site likely began sometime after a decision was made by Dow Chemical to discontinue the practice of stockpiling thoriated slag on its property, forcing then operator of the foundry, Wellman Dynamics, to look for alternative disposal options.

Prior to any known disposal of slag materials at the MDNR site, other industrial wastes were being disposed of on the ground surface and in surface depressions believed to have been created by the excavation of sand deposits. In response to regulatory pressure from the State of Michigan, the former landfill owner, Hartley & Hartley, installed a sand cover over a significant portion of the site. Some limited disposal is known to have occurred following the placement of the sand cover.

Initial placement of radioactive magnesium-thorium slag on top of the sand cover is believed to have occurred beginning in September of 1970.

4.1 SUBSURFACE SOIL CONTAMINATION

4.1.1 Location of Residual Radioactivity in Subsurface Soils

Radiological surveys performed subsequent to MDNR's acquisition of the property in 1974, along with both aerial and ground level photographs of the site taken in 1983 prior to installation of the engineered cell, indicate that slag was evidently placed in piles on top of the previously placed sand layer and along the trace of the former road through the center of the site. It is logical that the slag is deposited near and along the trace of the former road, since vehicles venturing very far to the east or west of the road would have readily sunk into the swampy native soils. A series of radiological surveys have been performed at the site over the years yielding valuable data that provide both qualitative and quantitative verification of the location of elevated concentrations of subsurface residual radioactivity.

These radiological surveys corroborate the historical, photographic, and physical evidence that the slag deposits are located along the trace of the former access road through the site. The Radiological Scoping Survey (HLA 1998b) and the subsurface soil Characterization Survey (Cabrera 2001) were both performed after placement of the clay cover and slurry walls. Both of these surveys confirmed that surface and near surface soils at the site were not contaminated with residual radioactivity. They further confirmed that concentrations of radioactivity in soil (both surface and subsurface) outside the footprint of the slurry walls are consistent with concentrations expected for naturally occurring background in native soils.

4.1.1.1 MDNR Survey Report

In April 1983, after placement of the sand cover but prior to construction of the clay cap and slurry walls, the MDNR performed a survey of a portion of the Site (MDPH 1983). Representatives of the USEPA and the State of Michigan Department of Public Health were present for the survey.

A survey line, down the center of the visible road trace (former access road), was established as a reference point. Exposure rates were measured at waist level (approximately 1 meter) using a micro-R meter along the length of this survey line. The survey was repeated moving incrementally to the east and west of the centerline until background radiation levels were consistently encountered. The areal extent of deposited radioactivity. An area approximately 450 feet long and 200 feet wide appears to have been surveyed. The survey area extended beyond (in most cases well beyond) the edges of the areas of elevated radiation levels. The survey also recorded 20 μR per hour exposure rate contours indicating the areal extent of residual radioactivity as measured by gamma radiation emission.

All elevated readings were found on or approximately within 50 feet from the road trace in areas where the ground had been disturbed or exposed. Elevated readings were not found in areas where there was no evidence of disturbance. The areal location of elevated measurements from the MDNR survey in 1983 is presented in Figure 4-1.

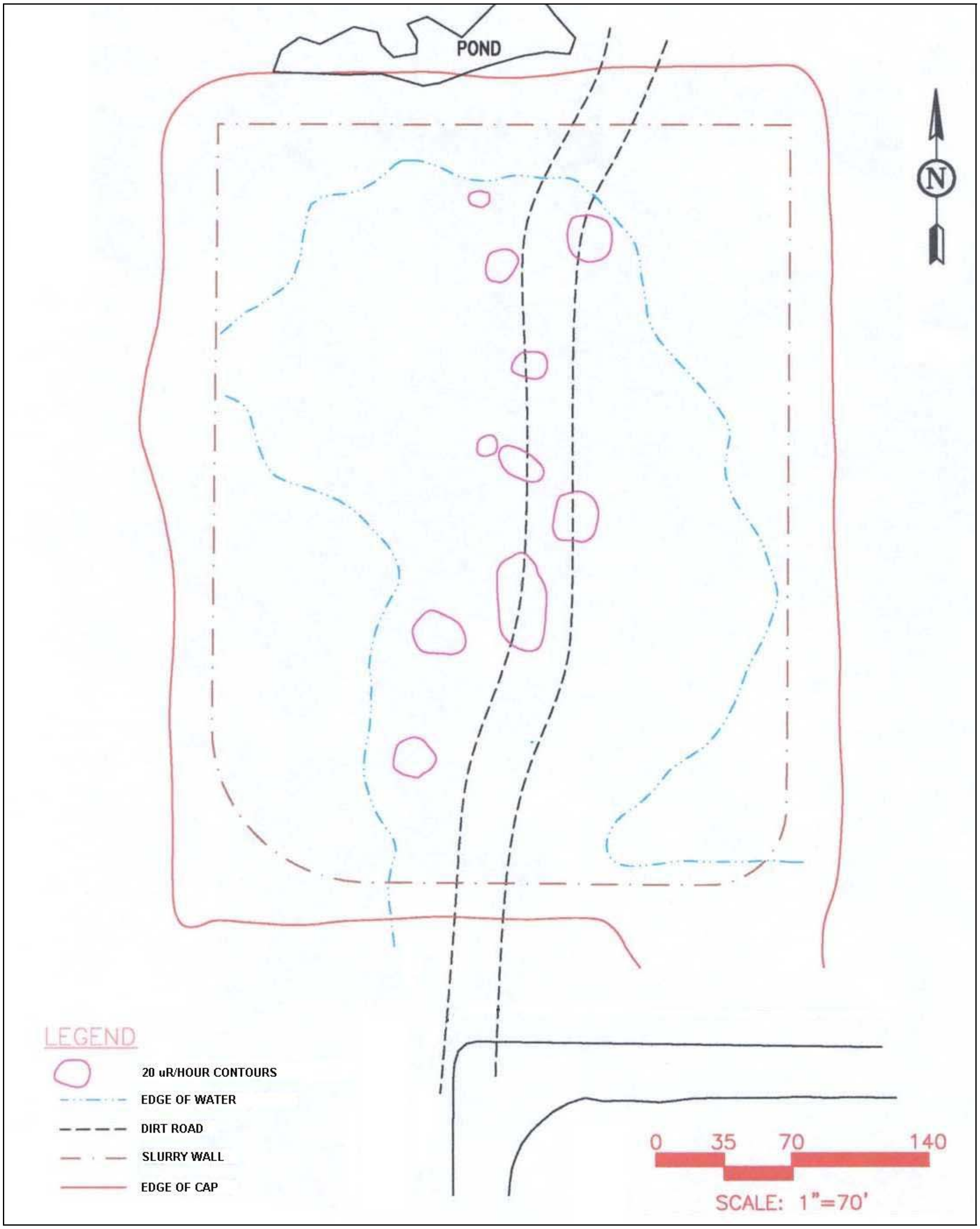


Figure 4-1 Extent of Elevated Radiation—1983 MDNR Radiological Survey

4.1.1.2 ORAU Radiological Assessment Survey

Under contract to NRC Region III, Oak Ridge Associated Universities (ORAU), conducted a survey to assess the radiological conditions of the MDNR's portion of the former Hartley & Hartley landfill (Tobico Marsh Site). ORAU actually conducted two surveys; one in July 1984 just prior to installation of the clay cap and slurry walls and another in June 1985 after their installation (ORAU 1985). The first of the two surveys is of interest in determining the location of subsurface radioactive materials.

The first survey was designed to systematically identify the areal extent of elevated concentrations of residual radioactivity. A 20-meter grid system was established over the sand cover area and approximately 20 meters into the marsh on either side of this area. The area was subdivided into 10-meter grids within the sand cover area. A walkover scan was conducted using NaI(Tl) gamma scintillation detectors at 1 to 2 meter intervals over accessible portions of the property and at 5 to 10 meter intervals in the swamp areas. Locations where elevated radiation levels were measured on contact with the ground surface were noted. Gamma exposure rate measurements were then made both at the ground surface and at 1 meter above the surface at each grid line intersection, and at locations identified as having elevated radiation levels during the walkover surface scan. All locations of elevated radiation levels identified by either the walkover scan or the grid node gamma exposure rate measurements were along or approximately within a 10 to 15-meter wide path corresponding to the road trace.

In addition to direct gamma radiation level measurements, ORAU collected surface soil samples (0 to 15 cm depth increment) at the grid nodes across the entire site, and at various depths from selected locations where elevated gamma radiation levels were measured on contact with the ground surface. Soil and sediment samples were analyzed by gamma spectrometry. Radionuclides of primary concern (given the analytical method and known source of the radioactivity) included Th-228 and -232, U-238, and Ra-226. Soil samples confirmed that elevated concentrations of residual radioactivity are approximately confined within this 10- to 15-meter-wide path corresponding to the road trace. The areal location of elevated measurements from the ORAU survey in 1984 (ORAU 1985) are presented in Figure 4-2.

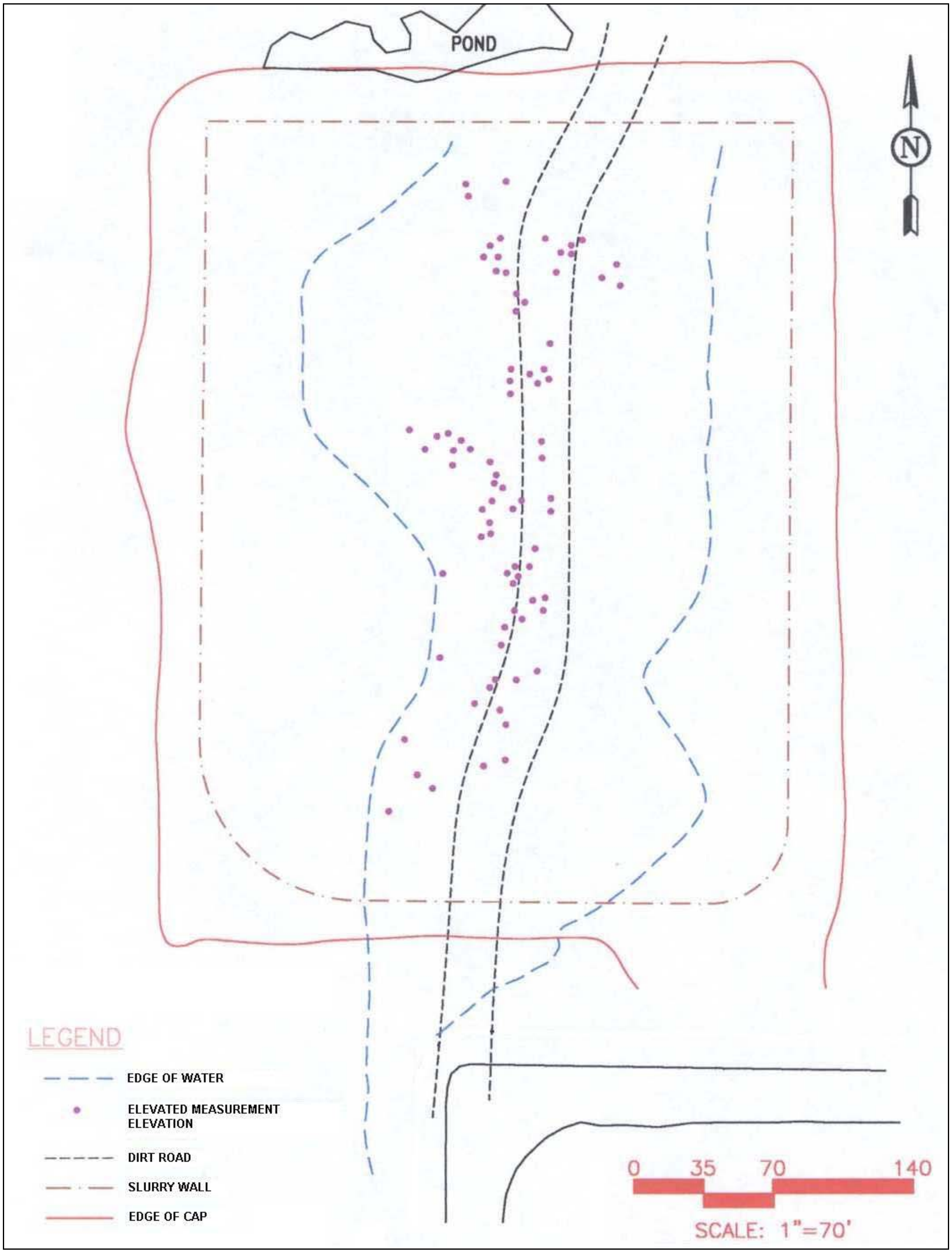


Figure 4-2 Extent of Elevated Radiation—1984 ORAU Radiological Survey

4.1.1.3 Radiological Scoping Survey

A radiological scoping survey was conducted by Harding Lawson Associates (HLA) in 1998 under contract to the MDNR (HLA 1998b). The primary objectives of the scoping survey were to determine the presence of radionuclides identified in the HSA as potential constituents of concern; evaluate the relative ratios of identified radionuclides in the affected areas of the site; and determine the general levels and extent of radionuclide contamination.

The survey area consisted of the area within the slurry wall and a 20-meter wide strip around the outside of the slurry wall[6]. A 10-meter grid system was established and mapped using a global positioning system. A walkover scan of the ground surface was again conducted using NaI(Tl) gamma scintillation detectors and covering the entire grid system (essentially 100% scan coverage except for grids covered by water). Sodium Iodide walkover surveys did not identify any areas with elevated gamma radiation levels.

Surface soil sampling to a depth of 1 foot was performed in the outermost grids beyond the edge of the clay cap to detect if residual radioactivity is present in soils beyond the footprint of the slurry wall and clay cover. Sediment sampling was conducted in the ponded water area located to the north of the Site. GeoProbe® soil cores were obtained from 36 grids within the slurry walls and in each of the 10-meter grids surrounding the outside of the slurry walls where the installed clay cover prevented conventional surface soil sampling techniques. The core samples were screened with a gamma survey instrument to identify the segment of the core having the highest gamma radiation signal. Samples were obtained from 18 of the 36 cores collected from within the slurry walls and from 18 of the 40 cores collected from grids surrounding the slurry walls. These soil samples were analyzed in the laboratory using alpha spectroscopy, gamma spectroscopy, and gross alpha/beta analyses. Sample results confirmed that elevated Th-232 concentrations were confined to the area circumscribed by the slurry walls and that elevated radioactivity, when detected, was consistently located in the near vicinity of the former access road through the site. Measured Th-232 activity outside the slurry wall compares well with background concentrations (measurements ranged from 0.01 to 0.68 pCi/g).

In situ gamma spectroscopy measurements were made at the ground surface in the grids surrounding the outside of the slurry walls that were not covered by the clay cap or surface water. Down-hole *in situ* gamma spectroscopy measurements were made at various depths in the cased GeoProbe® holes both inside and outside of the slurry walls where the clay cover impeded a surface measurement. A total of 84 measurements were made within the 36 core holes inside the slurry wall. A total of 49 measurements were made within 25 cased core holes outside of the slurry wall. The casings were logged over their entire length using a NaI detector to identify depths with elevated radiation levels.

6 The clay cap over the cell generally extends 5 to 10 meters beyond the slurry wall itself.

In situ gamma spectroscopy measurements made outside of the footprint of the slurry walls again indicated that Th-232 concentrations are comparable to those in non-impacted background soils with concentrations ranging from 0.01 to 0.49 pCi/g.

The location of elevated Th-232 concentrations measured during the scoping survey was consistent with those identified in the MDNR and ORAU surveys. No sample or survey measurements identified the presence of residual radioactivity in excess of background in the area outside of the slurry walls.

4.1.1.4 Characterization Survey

An extensive characterization survey of the Tobico Marsh SGA Site was performed by Cabrera Services in 2000 under contract to HLA and the MDNR (Cabrera 2001). The objectives of the characterization survey were to document the three dimensional location and concentration of residual radioactivity at the site and with sufficient detail to support site-specific dose assessment, development of this decommissioning plan, and an ALARA evaluation. The survey was also aimed at generating a sufficient quantity of quality data that might serve to support a final status decision and to focus any future sampling and analysis that might be warranted in the process of terminating the MDNR's radioactive material license (NRC 1999).

The radiological characterization survey employed a number of radio-analytical techniques including: 1) down-hole gross gamma logging, 2) down-hole gamma spectrometry, 3) gamma spectrometry of discrete soil samples, and 4) alpha spectrometry of discrete soil samples. Subsurface soils at the site were accessed by inserting GeoProbe® casings and core sampling tools. Watertight casings used to make *in situ* measurements were advanced to a depth equal to or greater than the upper boundary of the native clay-bearing till layer underlying the site. Sample cores (physical samples) were obtained at discrete depths immediately adjacent to the GeoProbe® casing.

The extremely dense configuration of the gross gamma logging measurements made across the site (both laterally and vertically) provides a well-defined representation of the location of buried slag bearing thorium radioactivity[7]. As previous radiological surveys concluded, residual radioactivity in soils was shown to be confined within the slurry walls and distributed principally along the path defined by the former access road through the site. The areal extent of elevated concentrations of residual radioactivity as identified by gross gamma logging is presented in Figure 4-3.

7 A total of 5926 gamma logging measurements were made in 397 casing locations distributed across the site. A series of measurements were made in 1-foot increments down to or slightly into the underlying clay bearing till interface.

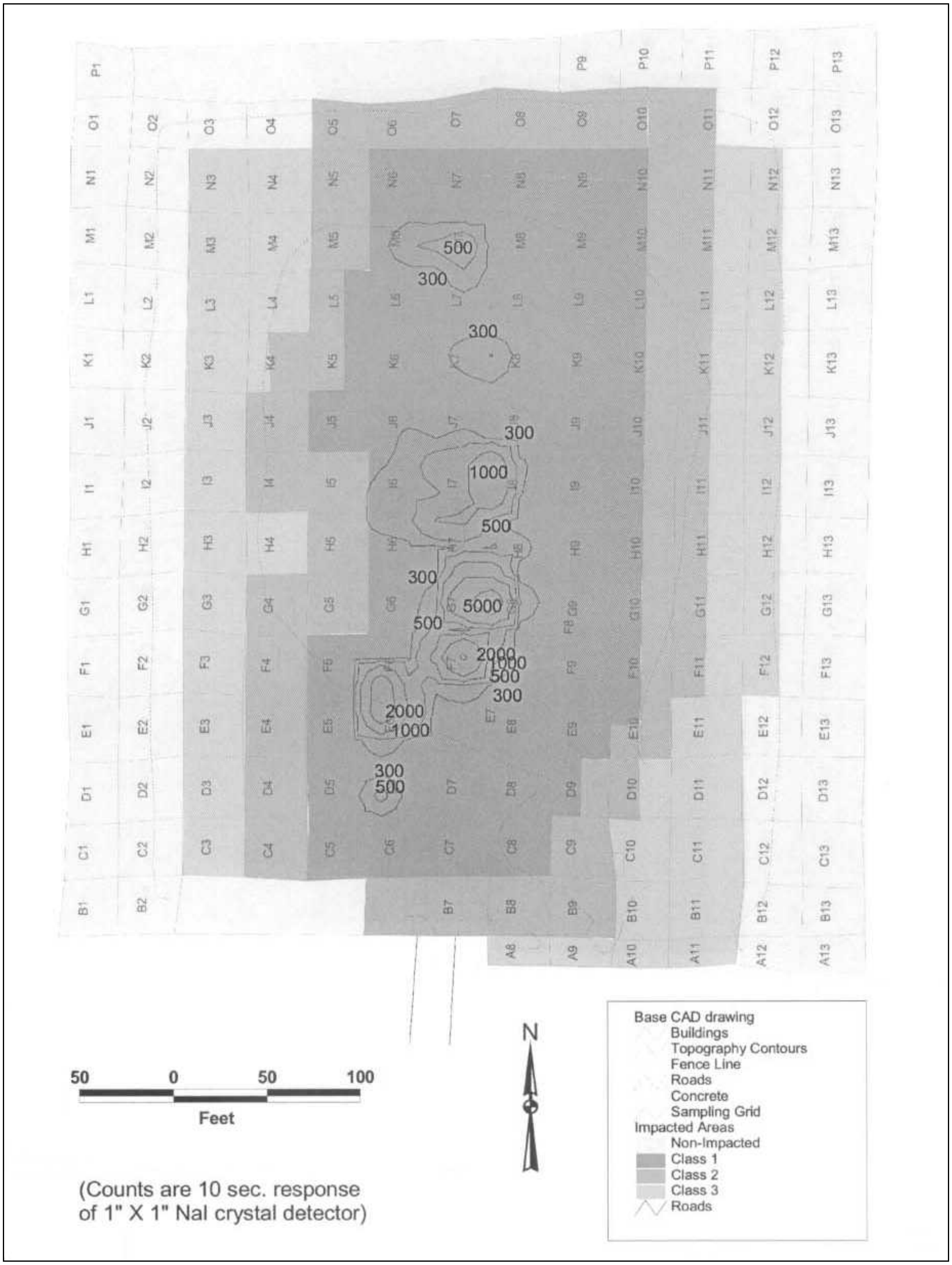


Figure 4-3 Extent of Elevated Radiation—Gamma Logging Survey

In addition to the gross gamma logging measurements, down-hole gamma spectrometry was utilized to quantify the activity of Th-232. Again, a very dense measurement configuration was achieved.[8] Of the 2,518 gamma spectroscopy measurements performed, only 131 identified Th-232 concentrations distinguishable from background. These positive detections averaged 33 ± 106 (2σ) pCi/g of Th-232 and ranged from near background to approximately 800 pCi/g. The locations at which these positive detections occurred correlates well with the elevated measurement locations as measured by the gamma logging technique. The areal extent of elevated concentrations of residual radioactivity as identified by down-hole *in-situ* gamma spectroscopy measurements superimposed over the gross gamma logging extent of elevated radiation contour lines is presented in Figure 4-4.

4.1.2 Summary of the Background Radioactivity

Three different surveys have been undertaken to assess and quantify the presence of naturally occurring background radioactivity in surrounding environs of the MDNR site. The first quantitative assessment of background radioactivity at the site was conducted by ORAU in conjunction with their radiological survey of the site in 1984/1985 (ORAU 1985). ORAU reported that direct gamma radiation background levels were 7 to 9 μR/h and background concentrations in soils and sediments ranged from 0.28 to 0.96 pCi/g for Th-232 and from 0.10 to 0.89 pCi/g from Th-228. Gross alpha background concentrations in water samples ranged from 0.21 to 8.02 pCi/L.

A second survey, focused expressly upon the detection and quantification of background concentrations of contaminants of potential concern (COPC), was completed in 1988 by ABB Environmental Services (ABB-ES) under contract to the MDNR (ABB 1998). Radiological data collected during the background study included direct gamma radiation levels, and the identification and quantification of radionuclide specific concentrations in surface soil, subsurface soil, sediment, surface water, and groundwater. All samples were analyzed for thorium and uranium isotopes by alpha spectroscopy, for natural uranium and thorium decay series nuclides by gamma spectroscopy (with daughter ingrowth for radium), and by gross alpha and beta counting. A summary of the results of the background assessment follows:

- 19 surface soil samples were taken. The range of Th-232 concentration was 0.099 to 0.680 with an average of 0.252 pCi/g. The range of Th-230 concentration was 0.094 to 0.830 with an average of 0.331 pCi/g.

- 5 sub-surface soil samples were taken. The range of Th-232 concentration was 0.151 to 0.369 with an average of 0.246 pCi/g. The range of Th-230 concentration was 0.128 to 0.383 with an average of 0.240 pCi/g.

8 A total of 2518 in situ gamma spectrometry measurements were made in 397 casing locations distributed across the site. Spectral measurements were typically obtained at six locations (depths) within the casing. Depth selection was often biased to coincide with the depth at which the highest gross gamma logging measurements were observed.

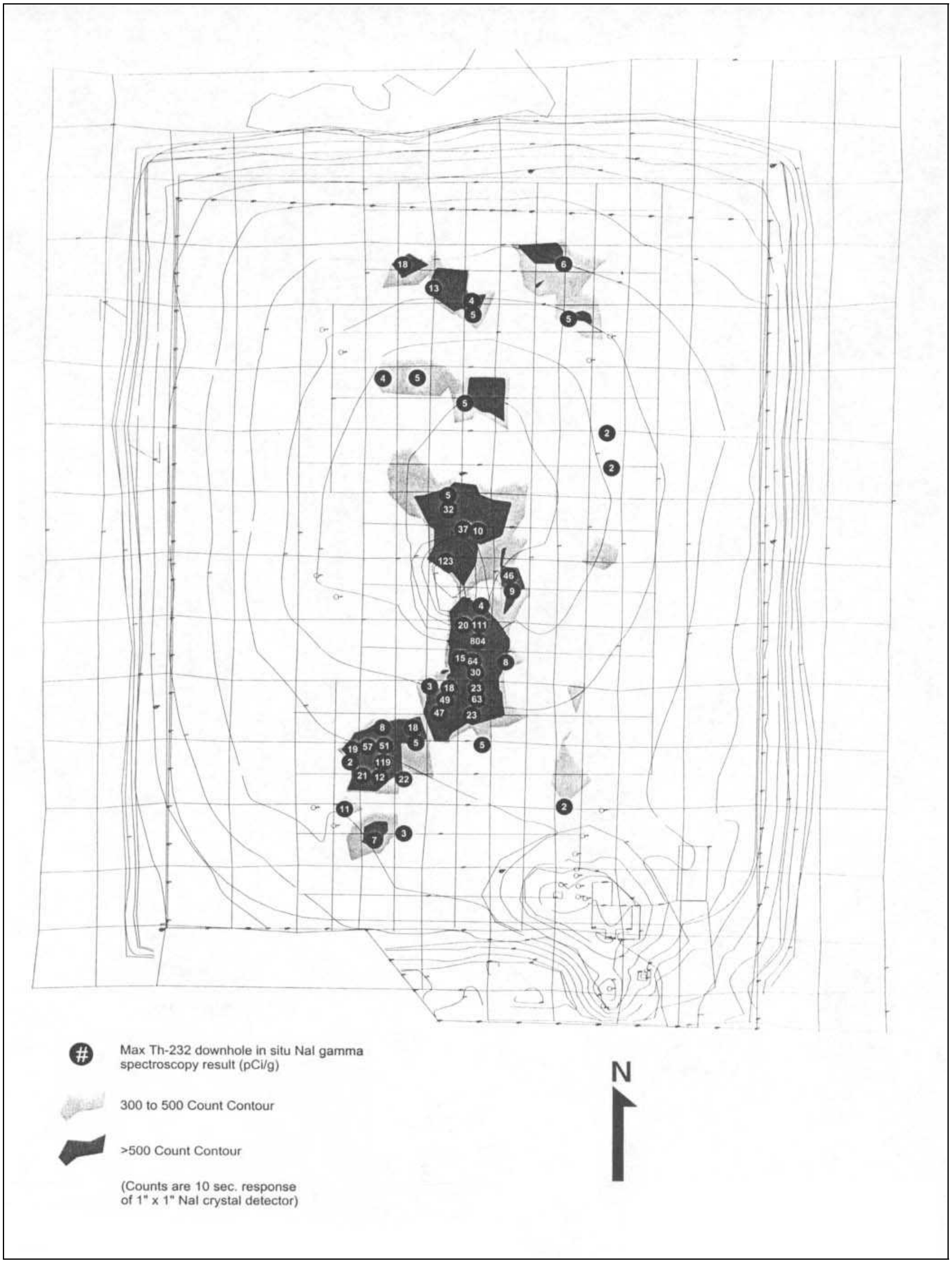


Figure 4-4 Extent of Elevated Radioactivity—In Situ Gamma Spectroscopy Survey

- 15 sediment samples were taken. The range of Th-232 concentration was 0.072 to 1.19 with an average of 0.346 pCi/g. The range of Th-230 concentration was 0.108 to 0.590 with an average of 0.368 pCi/g.

- 9 surface water samples were taken. The range of Th-232 concentration was 0.012 to 0.065 with an average of 0.032 pCi/L. The range of Th-230 concentration was 0.021 to 0.129 with an average of 0.054 pCi/L.

- 5 groundwater samples were taken. The range of Th-232 concentration was 0.025 to 0.100 with an average of 0.053 pCi/L. The range of Th-230 concentration was 0.084 to 0.190 with an average of 0.131 pCi/L.

These results are consistent with the background measurements reported in the ORAU survey (ORAU 1985) and compare well with values from the literature (ORNL 1980), which indicate a Th-232 concentration range for soils in the State of Michigan between 0.24 and 0.82 pCi/g with an average of 0.56.

4.1.3 Summary of the Radionuclide Composition of Residual Radioactivity at the Site

All of the isotope-specific radiological surveys performed at the site have identified the presence of Th-232 and its radioactive progeny (Figure 4-5). In addition, Th-230 in transient equilibrium with its radioactive progeny has been measured in concentrations well above what might be expected as naturally occurring in typical soils at the site (Figure 4-6).

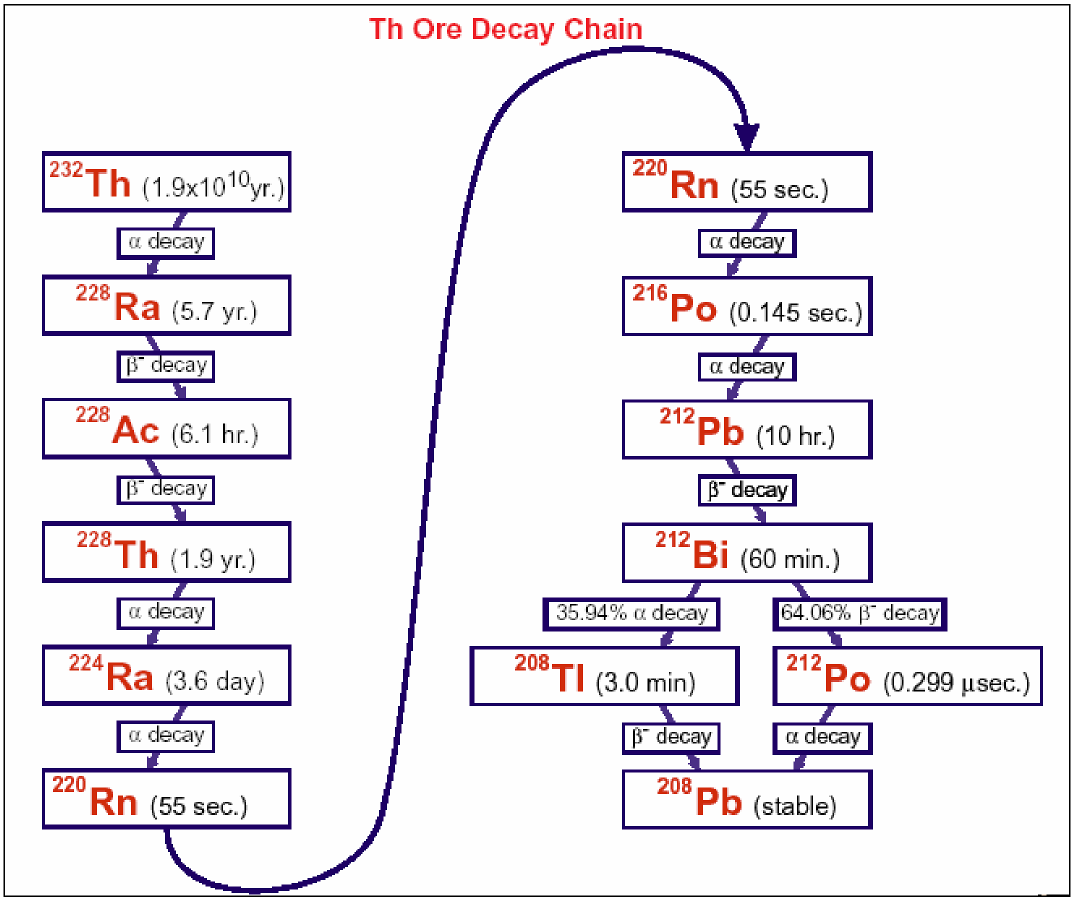


Figure 4-5 Th-232 Decay Series

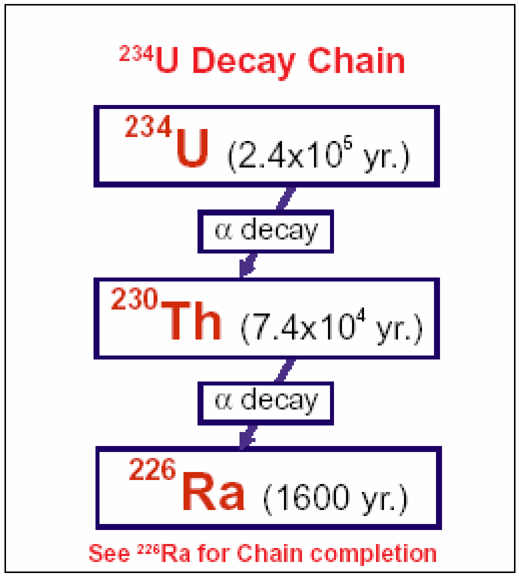


Figure 4-6 U-234 (Th-230) Decay Series

That Th-230 is elevated along with Th-232 in the slag is predictable considering the physio-chemical processes associated with the foundry operations that concentrated thorium and generated the slag.

The radiological characterization survey had as one of its objectives the identification of the radionuclide composition of the residual radioactivity at the site. From the ORAU survey (ORAU 1985), the scoping survey (HLA 1998b), and the characterization survey (Cabrera 2001), it is clearly and consistently reported that Th-232 is present in concentrations above background and in secular equilibrium with its radioactive progeny. However, the concentration relationship between Th-230 and Th-232, and the potential presence of elevated concentrations of Ra-226 and isotopes of uranium are also important to understanding the radionuclide composition of the source term.

A series of 52 subsurface soil samples were collected from across the site and analyzed by an independent off-site laboratory. Selection of the sample locations were guided by the knowledge gained through performance of both of the *in-situ* surveys described above and biased so as to collect soil samples from locations where the residual radioactivity concentration in soil was likely to be elevated. Each of these 52 samples was analyzed via gamma spectroscopy and 34 samples were analyzed by alpha spectroscopy for both uranium and thorium series radionuclides.

Soil sampling confirmed the presence of both Th-230 and Ra-226 in excess of background concentrations. Concentrations of Ra-226 ranged from background to a high of approximately 11 pCi/g, were co-located with elevated Th-230 concentrations, but were only approximately 3% of the corresponding Th-230 activity. Given the time elapsed since the slag might have been produced, it is reasonable to conclude that the slightly elevated Ra-226 concentrations present in the slag are the product of the radioactive decay of Th-230 and the resultant ingrowth of Ra-226.

The relationship between Th-230 and Th-232 concentrations in the slag is likely derived from their relative concentrations in the ores from which they were derived. Isotopic thorium analyses indicate that the Th-230 to Th-232 activity ratios are located in clusters, associated with what appears to be two different waste streams. Activity ratios were consistently measured at approximately 1:1 over the majority of the site. However, in two small clusters (one at the north end of the site, the other on the south end) the ratio is approximately 10:1 (See Figure 4-7). The estimated volume of radioactively contaminated material in these two small clusters is diminutive relative to the total volume of material with concentrations in excess of background. The volume-weighted Th-230:Th-232 ratio is calculated to be approximately 3.1:1.

It had been suggested earlier that concentrations of uranium isotopes might also be considered as a component of the elevated radioactivity in slag materials buried on the site. To assess this possibility, alpha spectroscopy for uranium isotopes was performed on 34 samples collected from among locations where the highest *in-situ* gamma measurements were recorded. The laboratory analytical analyses indicated the presence of U-234, U-235, and U-238 in concentrations comparable to those found in background soils in the vicinity of the site and in U.S. soils in general (Cabrera 2001). Correlation between uranium isotopes and elevated concentrations of thorium isotopes was not observed.

Having considered the analytical evidence for establishing the radionuclide composition of residual radioactivity at the site, the following source term isotopic composition is defined:

- Pb-210 0.5%
- Ra-226 1.1%
- Ra-228 16.1%
- Th-228 16.1%
- Th-230 50.0%
- Th-232 16.1%

The isotopic composition proposed is based upon the volume-weighted isotopic ratio between Th-230 and Th-232 as measured on the site (Cabrera 2001). It is assumed that the Th-232 series radionuclides are present in secular equilibrium. The Th-230 was decayed for a period of 50 years to calculate the amount of Ra-226 and Pb-210 progeny ingrowth. The Ra-226 ingrowth activity calculated by decaying Th-230 for 50 years results in a Ra-226:Th-230 ratio that agrees well with that measured (2–3%). The isotopic ratios used in calculating the projected annual dose to potentially exposed persons is presented in Figure 4-8. The short-lived progeny (those with half-lives less than 180 days) are assumed to be in equilibrium with the parent nuclide and are accounted for in the dose modeling through the RESRAD code's use of "parent +D" dose conversion factors.

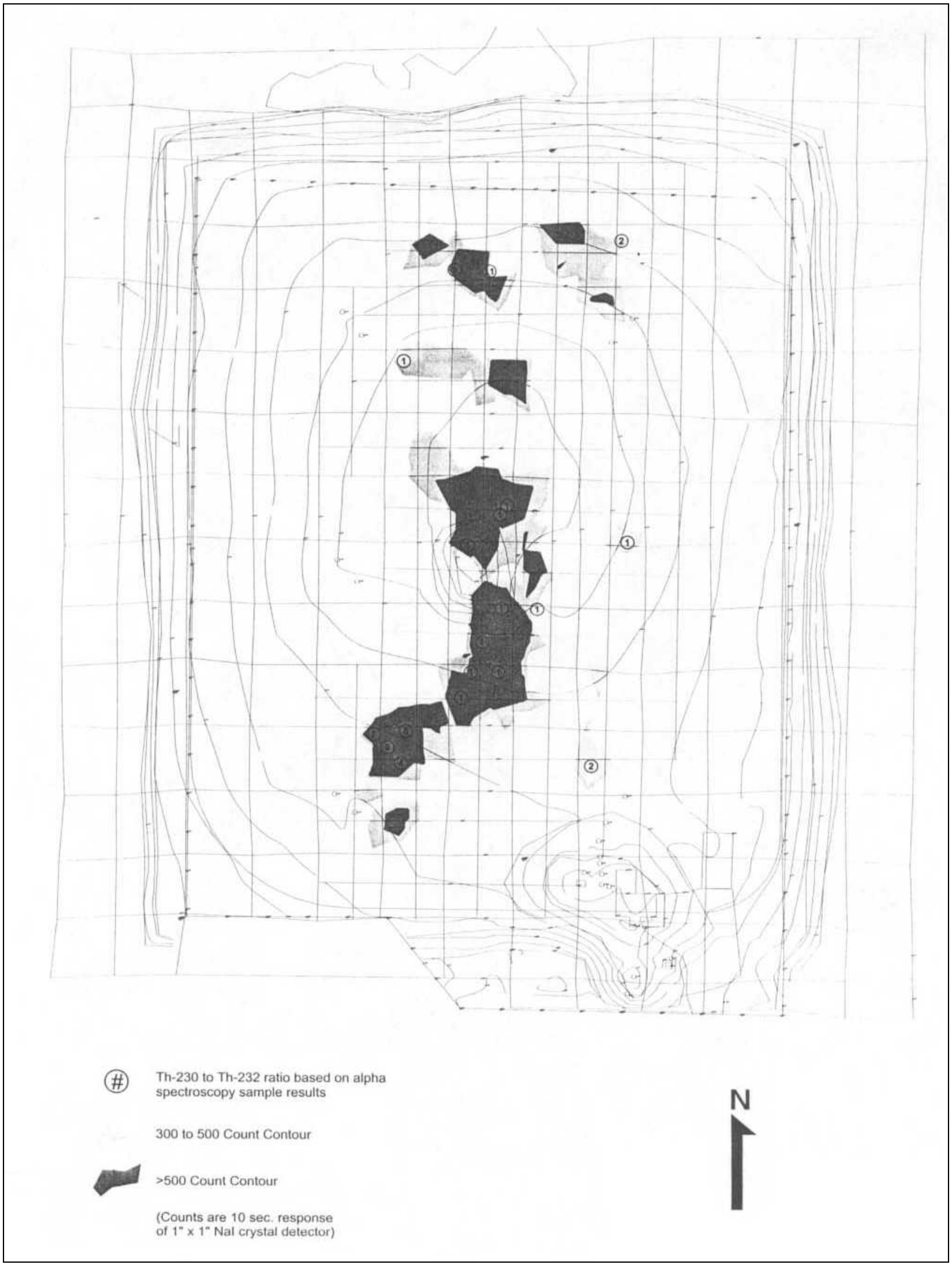


Figure 4-7 Lateral Distribution of Thorium 230:232 Activity Ratios

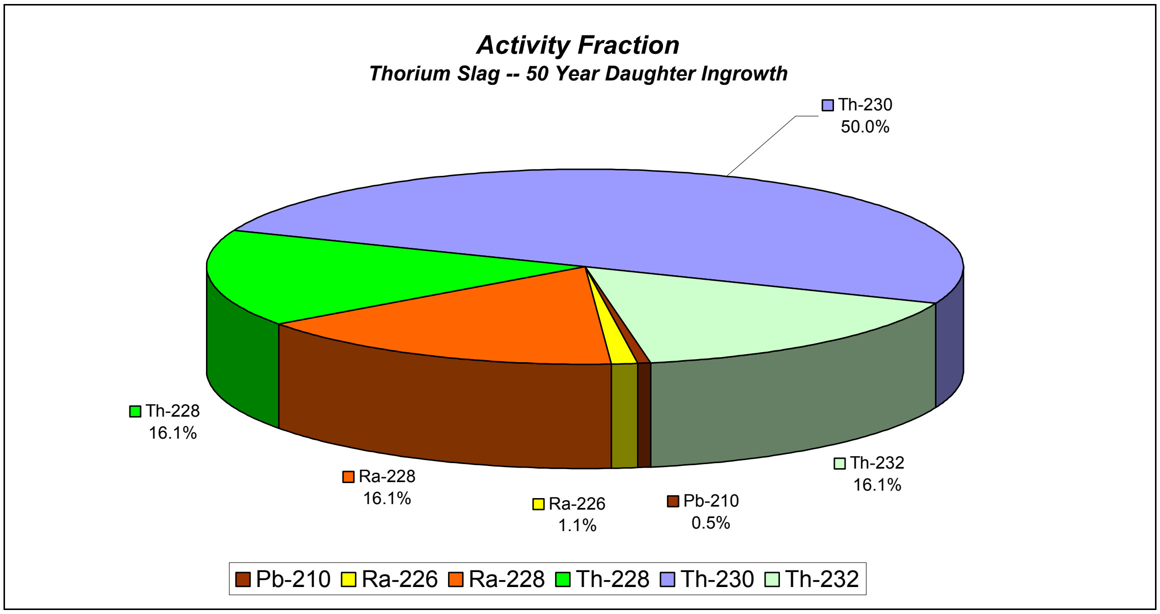


Figure 4-8 Radionuclide Composition of Residual Radioactivity

4.1.4 Depth of Residual Radioactivity in Subsurface Soils

A principle design objective for the radiological characterization survey was to develop a three-dimensional view of the site's residual radioactivity deposition. This was accomplished through the collection of almost 6,000 gross gamma radiation measurements within the GeoProbe® casings emplaced across the site. The lateral placement locations were determined by a systematic grid established with a global positioning satellite (GPS) system. Additional locations were placed in areas where elevated radiation levels were encountered to further resolve the three-dimensional profile. Vertically, measurements were made at 1-foot intervals beginning from a depth of 1 foot bgs and proceeding down until the casing terminated at the bottom of the sample core. Figures 4-9 through -12 present plots of gross gamma logging data displayed in vertical cross section. For reference, the ground surface (the top of the clay cover) is approximately 592 feet above mean sea level. Cross section "C–C" is drawn approximately down the path of the former access road through the site, along which radiological surveys have consistently located the elevated radioactivity deposits. This cross section provides the best overall (most representative) two-dimensional view of depth profile.

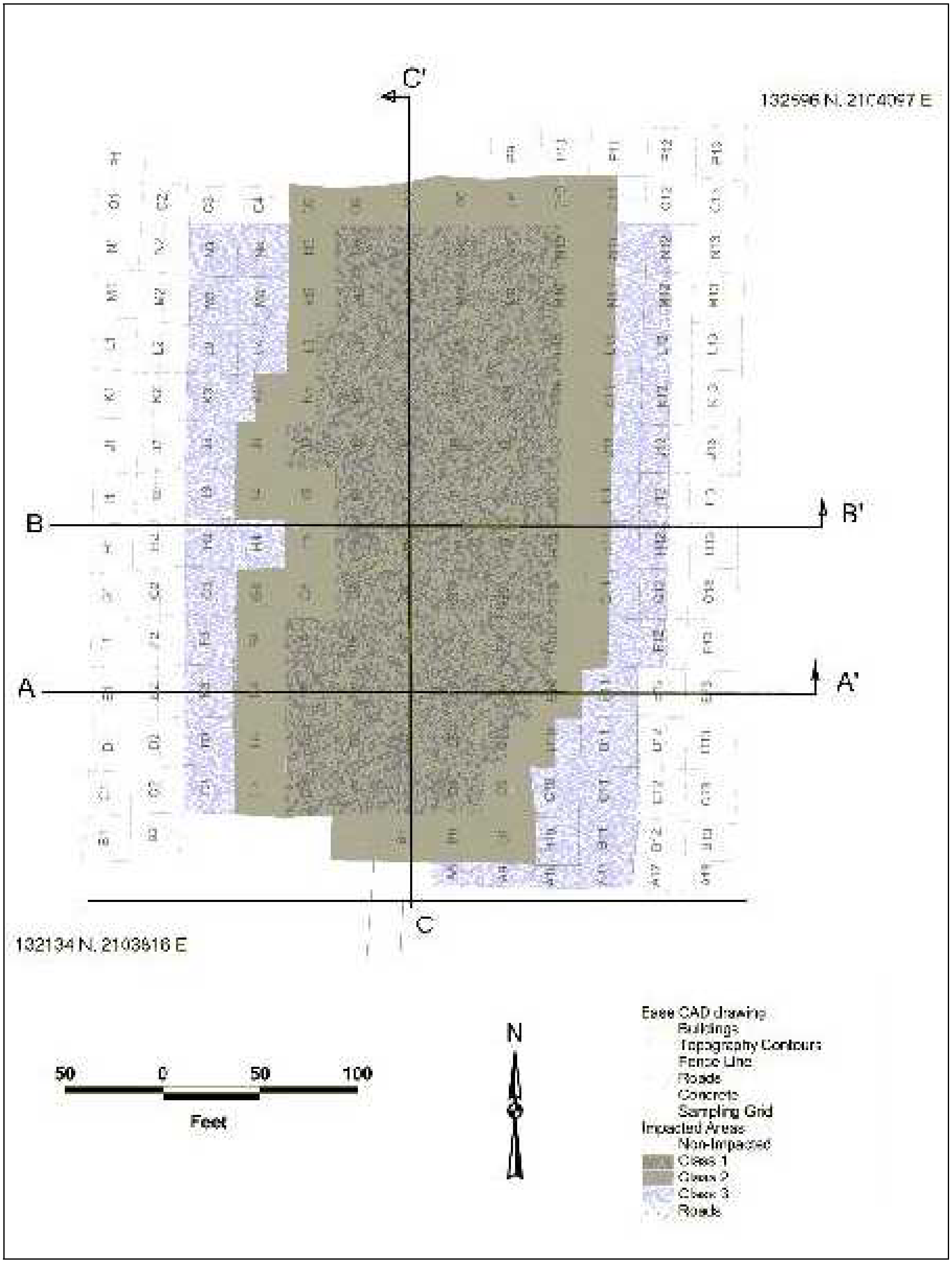


Figure 4-9 Cross Section Locations

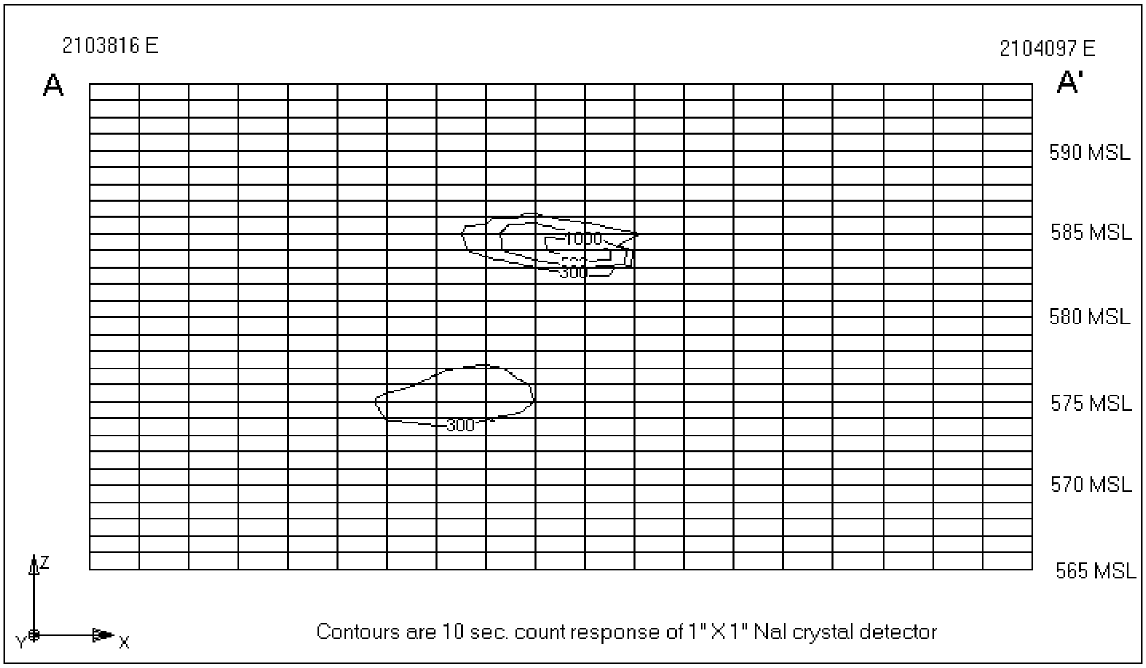


Figure 4-10 Cross Section A-A'

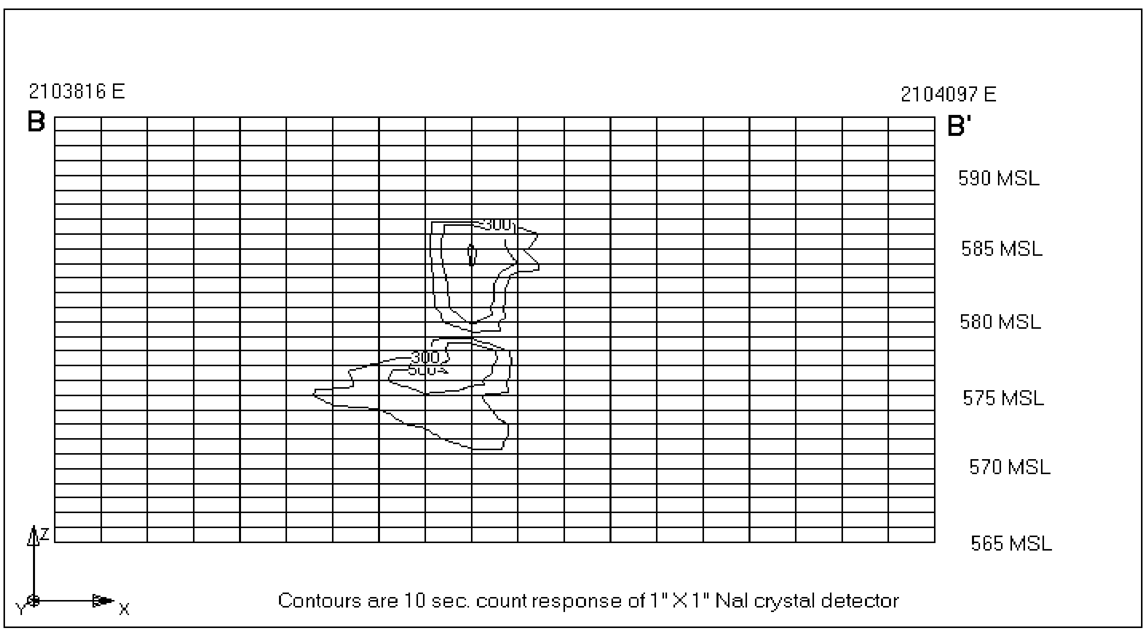


Figure 4-11 Cross Section B-B'

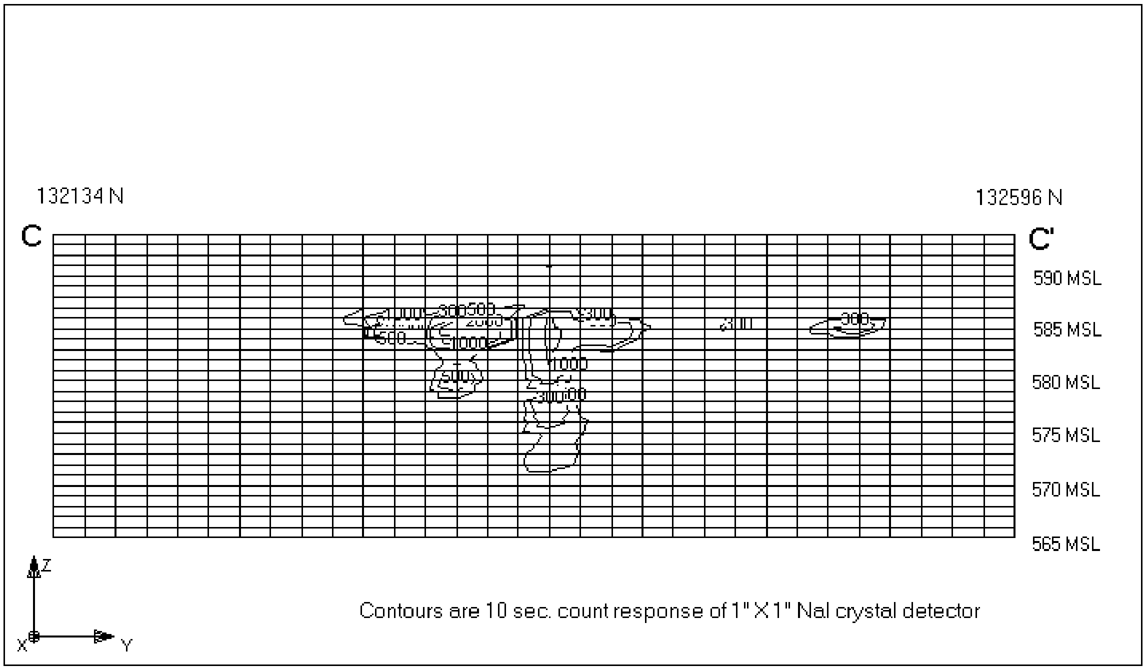


Figure 4-12 Cross Section C-C'

From these figures, it is evident that there are two discrete locations where radioactive slag has been deposited in pockets deeper than a few feet, but elevated radioactivity was confined to depths well above the interface of the clay-bearing till layer underlying the site. It is also evident that the majority of radioactivity is located just slightly beneath the clay cover and within a thickness of approximately 4 feet (1.22 meters).

4.2 SURFACE WATER

Surface water samples collected over the years have been analyzed for radioactivity by gross alpha and beta counting. There is no indication that surface water contains residual radioactive material in excess of site background levels on site (HLA, Historical Site Assessment, 1998 and MDNR, Gamma Analysis Results of MDNR Wells Plus Surface Water Results, 1991).

4.3 GROUNDWATER

Near-surface groundwater at the site exists in the region above and vertically confined by the native clay-bearing till layer that underlies the site. This groundwater has been designated by the State of Michigan (MDEQ) to be “groundwater, not in an aquifer”. Much of the site and surrounding land is covered with ponds and wetlands. The saturated zone is limited to the shallow sandy loam and is perched on the basal clay unit. The thickness of the saturated zone varies seasonally, but is generally one to a few feet thick. Several investigations into the clay unit (60 feet bgs.) indicated that saturated units were not present below the surficial loam water-bearing zone. Based on the above data and using reasonable and relevant assumptions, the saturated zone at the site is not in, nor connected to an aquifer pursuant to the general provisions provided in Rule 299.5101. (MDEQ letter, 2002). As such, it is not considered a viable or adequate drinking water source for residential use and irrigation purposes. Sampling of the groundwater at the site has shown that residual radioactivity from the slag deposits (contaminants of concern for the site) are not present in concentrations in excess of site background levels.

4.3.1 Leachate Sampling

In addition to groundwater sampling (outside of the slurry walls), a sampling program was undertaken to assess the radioactivity of leachate water that is confined within the bounds of the slurry walls. There are six dewatering wells and three monitoring wells within the site's slurry walls. In 1996 and 1997, ABB Environmental Services performed three rounds of leachate sampling to determine its radiological composition in comparison to background (ABB 1997). All nine wells were sampled during Round I and Round II using the low-flow technique. High turbidity samples were obtained from three of the nine wells. A well located approximately thirty yards north of the Site (MW-6) was sampled to provide an estimate of natural background radionuclide concentrations. Round III was a repeat of the Round II sampling and added a high turbidity sample from the background well.

Round I, II, and III samples were analyzed for thorium and uranium by alpha spectroscopy, total-uranium by fluoroscopy, Ra-226 by Rn-222 emanation, Ra-228 by β/γ coincidence counting, gamma spectroscopy, gross alpha counting, and gross beta counting. All sample analyses in Rounds II and III were performed on both the soluble and insoluble fractions of the samples.

This leachate sampling program identified elevated levels of Potassium-40 (K-40), a constituent not found to be in elevated concentrations within the slag. It is possible that some other non-licensed constituent within the disposal area (e.g., potassium-based pesticides) is contributing to the detection of K-40. It is noted that in each instance where gross beta activity was measured in concentrations higher than those expected in background, the K-40 concentration was correspondingly elevated as well. K-40 is not associated with the known and well-defined source term (thoriated slag), is naturally occurring, and not specifically licensable as a radioactive material; therefore, it is not considered further in this DP.

Analytical results for both soluble and insoluble radioactive alpha emitters indicated that some of the samples had detectable concentrations of alpha emitters consistent with background concentrations in groundwater and well below the surface water discharge limits specified by the NRC in 10 CFR 20 (NRC 1997a).

An additional leachate sampling program was undertaken in the summer of 2002. Two rounds of sampling were completed and submitted for analysis by alpha spectroscopy (for uranium and thorium) and gamma spectroscopy. Sample results confirm that concentrations of uranium, thorium, and radium in leachate within the slurry walls are very low and within the range encountered in background (MACTEC 2002). These results affirm that the radiological contaminants in the slag are highly insoluble and thus highly immobile. They are unlikely to impact the environment or the surrounding ecosystems provided the slag physically remains in-place within the confines of the cell.

5.0 DOSE MODELING

The NRC's post-decommissioning dose limit is constrained by the maximum allowable annual dose from all sources (in excess of background radiation contributions) of 100 mrem/y. A number of federal agencies, including the NRC (in regulation), as well as nationally and internationally recognized bodies recommending safe levels for public exposure (ICRP 1990, NCRP 1993), specify a limit on annual public radiation dose contribution of 100 mrem/y. Since it is possible that public exposure will occur from more than one site (such as the Tobico Marsh SGA Site), only a fraction of the maximum allowable dose is typically allotted to any single site. Within the jurisdiction of the NRC, the fraction allotted to a single site is specified in regulation. The compliance limit for unrestricted release and reuse[9] of the site is 25 mrem/y (NRC 1997a).

Computer modeling codes are used to ***derive*** a concentration-based ***site-specific guideline*** that is protective of the 25 mrem/yr established dose limit. A concentration-based guideline is critical to the license termination process since potential future dose (the performance criterion for obtaining release of the site) is a projection of future exposures, which cannot be physically measured. On the other hand, a media-specific concentration derived from the expected future human exposure scenarios can be physically measured. That derived concentration is then submitted for regulator approval. The derived concentration guideline level (average concentration) is identified as the $DCGL_W$.

5.1 UNRESTRICTED RELEASE USING SITE-SPECIFIC INFORMATION

As in any health risk assessment, the process involves defining the source(s), the Site conceptual model, the pathways for potential human exposure, and the availability of a receptor to receive a dose (see Figure 5-1).

The relationships between factors involved in defining the mechanisms for human exposure are complex and often interdependent. A computer program to model the plausible human exposure scenarios and to perform complex sets of computations is employed. The model portrayed in the computer code must sufficiently represent the actual Site-specific case, in order to achieve realistic correlation between dose and concentration. As source concentrations and pathway factors affecting concentrations to receptors vary, the potential for dose also varies. Factors affecting the mechanisms for, and intensity of, human exposure must be identified, and appropriate values must be defined. Many of these factors are highly dependent upon Site-specific conditions (e.g., wind velocity), while others are more related to fundamental physical properties

9 "Release for unrestricted use" is the term used by the NRC to indicate that there are no conditions or restrictions (e.g., institutional controls prohibiting residential uses of the property in the future) that must be emplaced by the licensee to ensure that the future uses of the site are consistent with the uses that are determined to be safe for public exposure to residual radioactivity originating from the site.

independent of the specific Site location (e.g., mass loading for inhalation). Many others are dependent upon the availability and projected activities of receptors (e.g., hours per day at the Site). To accurately determine the values to be used for many of these factors that become input parameters to the computer modeling codes, the risk assessor must first envision and characterize the plausible future exposure scenarios that a potential receptor may encounter. Clearly defining the expected future human exposure scenarios is key to obtaining a realistic correlation between projected future dose and existing source concentrations.

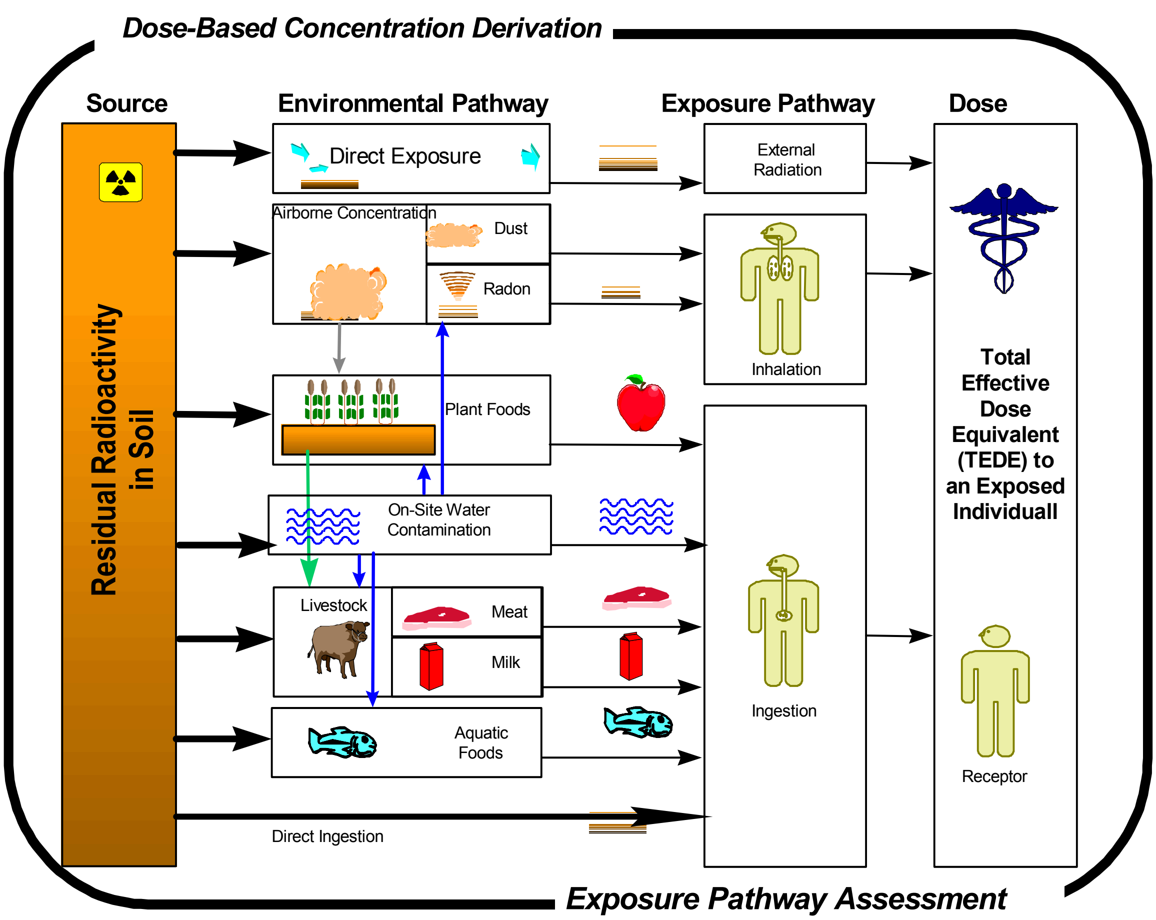


Figure 5-1 Conceptual Human Exposure Assessment Model

After human exposure scenarios are conceived, the second key element to be considered in constructing representative exposure models is determining which pathways are potentially complete from source to receptor. The conceptual pathway model shown in Figure 5-1 includes all conceivable pathways for human exposure to residual radioactivity associated with the Site. Not all of those pathways are potentially complete for a variety of reasons. Tables explaining which of the specific pathways are complete for each scenario evaluated are contained in the subsequent sections detailing each scenario.

Fundamentally, there are two types of risk assessment methods: deterministic and probabilistic. Most professionals are familiar with the deterministic approach because it has been, until recently, the most widely used of the two. The deterministic health risk assessment method is designed to capture the reasonable maximum exposure (RME) condition for a receptor using single point estimates of parameter values used to calculate dose. Such a calculation provides the risk manager with a single point estimate of dose that could result from a given concentration of radioactivity. Few parameters used to calculate future dose potential are so well known that they can be described by a single value. In recognition of this limitation, deterministic risk assessments typically use overly conservative values for parameters in an attempt to bound the inherent uncertainty.

By contrast, the probabilistic methodology specified by the NUREG-1727 (NRC 2000) addresses extreme case exposure potential through what is essentially an uncertainty analysis, taking the range and distribution of individual parameters into consideration. The probabilistic method provides a substantially clearer picture of the potential future dose corresponding to a residual radioactivity concentration for the risk manager to evaluate.

Rather than using the RME for the entire population (as is the case in the typical deterministic method risk decisions) the probabilistic method allows the risk manager to focus on what is termed the "critical exposure group." The critical exposure group is the sub-population expected to be the most exposed among those who may receive exposures at the site. The NRC establishes the decision criterion based upon the use of a probabilistic assessment method and the resulting mean or "most likely" exposure to an exposed member of the critical exposure group (NRC 1997a, NRC 2000). Table 5-1 summarizes the principal differences that exist between the deterministic and probabilistic methods.

Table 5-1 Comparison of Methodologies

	Probabilistic	***Deterministic***
Measure of Human Health Detriment	Annual Radiation Dose measured in millirems per year	Annual Radiation Dose measured in millirems per year
Parameter Value Basis	Mean value for average member of a defined critical exposure group in a specific exposure scenario	Reasonable Maximum Value picked from accepted default values
Calculation Method	Computer Modeling Code	Algebraic summation using Spreadsheet (or older computer codes without Monte Carlo sampling algorithms).
Time Integration	Yes. Integration intervals vary to allow for radioactivity in growth, decay and transport.	No. Point estimate, considering discrete point in time and Site conditions

MDNR has selected the computer-based, dose-modeling code RESRAD Version 6.21 (the latest non-beta version as of the writing of this decommissioning plan) to perform the site-specific dose modeling in support of the decommissioning of the Tobico Marsh SGA site (Yu 2002). RESRAD is chosen primarily because it adequately depicts the key site-specific features of the MDNR site that impact the potential future dose to a receptor exposed at the site. Among the other advantages that RESRAD brings to a radiological dose or risk assessment is its ability to derive values for exposure parameters based on built-in fate and transport computations using well-defined site-specific data. It is also able to integrate dose and risk projections over time taking into account transient conditions over that period. It is widely accepted as an industry standard tool for performing radiological dose assessments and specifically for deriving concentration guideline values. For the derivation of the Site-specific DCGL, a probabilistic analysis will be presented using the range and distribution of values for parameters expected for the site-specific exposure scenarios and conditions considered.

A few of the key points that should be recognized about the RESRAD modeling code and the algorithms it uses are:

- Default Dose Conversion Factors (DCFs) used in RESRAD 6.21 are taken from FGR #11 (EPA 1988a), FGR #12 (EPA 1993), and are derived using the ICRP 30 dosimetry model. The bio-kinetic dosimetry model accounts for particle fractioning that might occur following exposure. For example, the DCFs for particle inhalation account for the dose to the GI tract from the fraction of respired particles that are ingested. As a result, there is no need to independently account for biological fractioning in the dose calculations.
- Short-lived (<180 days) radioactive progeny isotopes are accounted for using the "parent+D" DCFs.
- RESRAD integrates and normalizes exposure factors based on the fraction of time a receptor is exposed over the exposure period. For example, a soil ingestion rate of 100 mg/d for a receptor who is exposed on Site for only 50% of one day would result in an ingestion intake of 50 mg.
- RESRAD requires that the risk assessor input single point estimates for values of every parameter required to evaluate complete pathways in the deterministic module of the code. RESRAD uses the single point deterministic value for a specific parameter to calculate dose or risk, unless the risk assessor specifies that the value be evaluated with a range of possible values selected from a specified distribution. It is not necessary to evaluate the uncertainty in every parameter, because variability (perhaps stemming from uncertainty) in many parameters does not contribute significantly to variability or uncertainty in the resulting dose.

5.2 SITE CONCEPTUAL MODEL

The site conceptual model has three fundamental components that must be conceptualized and described in terms that can be used to calculate or model the potential future dose to a receptor that might be exposed at the site. The first component is the source term itself. The size, thickness, and radiological composition of the source are conceptualized in the source term abstraction. The second component of the site conceptual model is the physical characteristics of the site itself. The site is described in the physical abstraction that includes physical and hydraulic characteristics of the site and its potentially impacted environs. The third component that must be conceptualized is the range of plausible human exposure scenarios, which are described primarily by factors that are associated with human behavior and metabolic physics. Each of these three fundamental components is discussed in the sections that follow.

5.2.1 Source Term Abstraction

The source term abstraction used by the computer modeling code to project potential future dose is derived from knowledge about the source material itself, and previously completed radiological assessments of the residual radioactivity at the site. The source term is defined by its radionuclide composition, as well as its lateral and vertical deposition (spatial configuration).

The source term for the Tobico Marsh SGA site is comprised of pockets of vitreous, thorium-bearing slag deposited primarily along a track approximately 50 feet wide (15 meters) corresponding to the former access road that transected the site (approximately north to south). There is some areal variability in the measured deposition, likely owing to the haul and dump deposition mechanism that is thought to have been used to place the slag at the site.[10] Still there is an obvious correlation between the trace line describing the position of the former access road and the lateral positioning of subsurface soils with elevated radioactivity.

Based upon characterization survey results, the areal extent of elevated radioactivity within the slurry walls is approximately 800 m^2. In describing the source term for input to RESRAD, the area (size) of the contaminated zone parameter (AREA) is represented by a loguniform distribution with a minimum value of 791 m^2 and a maximum value of 5,725 m^2 corresponding to the entire area within the slurry walls of the cell. The use of the loguniform distribution provides a realistic, yet conservative, description of the lateral variability in the size of the source term in that it assigns the most likely size (791 m^2) as the minimum size and allows for the possibility (albeit with lower probability of occurrence) of larger sizes up to the entire area covered by the cell.

Vertically, the radiologically significant material is located just beneath the cover (approximately 5 feet bgs) and lies in a lens that is nominally about 4 feet (1.2 meters) thick. There is, of course, some variability in the depth profile of the deposited radioactive slag material. The variability is likely the result of placing loads (piles) of slag materials in depressions along the roadside. Whatever the explanation for the variability, the radiological characterization survey suitably mapped the vertical (depth)

10 Aerial photographic evidence also suggests that slag was dumped in piles along the side of the former haul road that trended north and south through the site.

profile and its variability. The two-dimensional depth profile is mapped for three transects within the cell where the radioactivity was most concentrated and presented in Figures 4–9 through 4–12. The north-south transect (cross section C–C', repeated in Figure 5-2 for convenience) provides the best indication of depth profile and variability as it cross sections the site along the trace of the former access road and through the most concentrated deposits of elevated radioactivity measurements on the entire site.

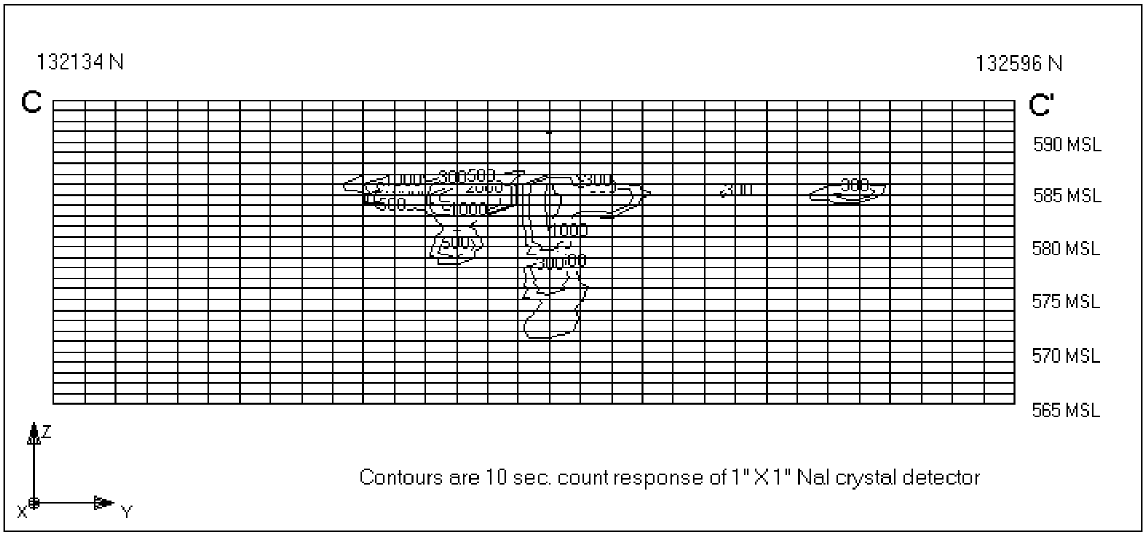


Figure 5-2 Cross Section C-C'

From Figure 5-2, it can be seen that the majority of the radioactivity lies in a lens that is approximately 5 to 6 feet below the ground surface (the thickness of the clay cover near the center of the cell) and approximately 4 feet thick. The amount of source material deposited rapidly depletes as the depth increases and terminates at a maximum thickness of approximately 15 feet in one location.

A lognormal-N distribution describes well the observed variability in the depth profile and thus the thickness of the contaminated zone or source term. In describing the source term for input to RESRAD, the thickness of the contaminated zone parameter (THICK0) is represented by a bounded lognormal-N distribution, with the central tendency (CT) value conservatively set to a thickness of 4 feet (1.22 meters). This thickness is conservative in that the mean source thickness over the entire footprint of the cell, the impacted area, is considerably less than 4 feet. It is only within the region along the former access road (the most heavily contaminated area) that the thickness averages approximately 4 feet. The distribution is bounded at a minimum value of 0 feet (0 meters), and a maximum value of 15 feet (4.5 meters).

As described in Section 4.1.3, radionuclide composition of the source term is defined by both measured isotopic ratios in soils samples collected from within the contaminated volume of the cell and by historical knowledge of the origin of the radioactivity found within the slag. The volume-weighted activity ratio between the isotopes of Th-230 and Th-232 is calculated to be 3.1:1. Measured activity ratios in individual samples ranged from 0.5:1 to as high as 11:1 (Cabrera 2001). In describing the source term for input to RESRAD, it is logical that the volume-weighted ratio would be used as ratios greater than 1:1 (the most common and prevalent relationship between the two isotopes) were found in only two discrete locations within the cell.

The relatively longer-lived progeny of Th-232 are assumed to be in secular equilibrium with Th-232. This assumption is conservative but frequently supported by analytical measurements. The relationship between Th-230 and its longer-lived progeny was calculated by decaying Th-230 for 50 years (the estimate of time elapsed since the thoriated slag was potentially produced) and determining the ingrowth of Ra-226 and its progeny, Pb-210. The calculated ratios between Th-230 and Ra-226 agree with the ratios typically measured in samples collected from within the contaminated soil volume. The source term input to RESRAD includes all of the isotopes in the Th-230 and Th-232 decay series with half-lives longer than 180 days and in the following ratios[11].

- Pb-210 0.5%
- Ra-226 1.1%
- Ra-228 16.1%
- Th-228 16.1%
- Th-230 50.0%
- Th-232 16.1%

5.2.2 Site Physical Abstraction

The second major conceptual component of the dose assessment is the physical abstraction of the site. The physical abstraction defines the physical, hydraulic, and geological conditions at the site[12] and places the source term in the context of the environment and systems which surround it. Figure 5-3 illustrates the site physical abstraction, conceptually describing the physical conditions found at the site in terms that can be used to calculate or model potential future dose to an exposed individual engaged in non-intrusive activities at the site.

Conceptually, the site is composed of 5 “layers” important to the dose modeling objective. Figure 5-3 is a highly stylized and simplified depiction of the site in cross section which is designed to communicate the basic composition of the site. The various parameters describing the composition in each “layer” are defined with probabilistic

11 Isotopes with half-lives shorter than 180 days are assumed to be in equilibrium with their first parent with a half-life greater than 180 days and are accounted for in dose calculations through the use of “parent+D” dose conversion factors (DCF).

12 RESRAD is not a comprehensive groundwater and surface water fate and transport code. It does, however, model the vertical migration of radiological contaminants from surface or near surface soils to groundwater sources of drinking water and surface water bodies for the purpose of calculating the dose potential to human receptors who might use such water. As such, detailed hydrogeologic depictions of the Site are not necessary for RESRAD to model the pertinent radiological parameters.

variables to account for the variability and uncertainty inherent in hydro/geological features.

The lower-most (deepest) layer is described as the deep aquifer layer. It is not important from a dose modeling perspective when groundwater at the site is not used for drinking water. Still, the RESRAD model will calculate the potential for radioactive material "breakthrough" allowing the decision makers and risk managers to evaluate the potential impacts on groundwater even if the drinking water pathway is not used in a given scenario. The lower-most layer thickness is not utilized in any calculations.

The next layer above is the clay-bearing native glacial till layer that underlies the site and surrounding area. The till is very dense, and is estimated to range in thickness between 50 and 100 ft. (15 to 30 meters) with a nominal or typical thickness of approximately 60 ft. (18.3 meters). RESRAD identifies this layer as *"unsaturated zone 2."* The thickness of this zone (H(2)) is described by the RESRAD default distribution, bounded lognormal-N, with a central tendency value of 18.3 meters bounded at a minimum of 15.25 meters and a maximum of 30.5 meters. The tightly packed clay soil composition makes the soil density parameter relatively high and the hydraulic conductivity parameter low. Measured soil density is 1.97 g/cm^3 and measured hydraulic conductivity is 0.017 meters/y. RESRAD default radionuclide distribution coefficients were used for all isotopes.

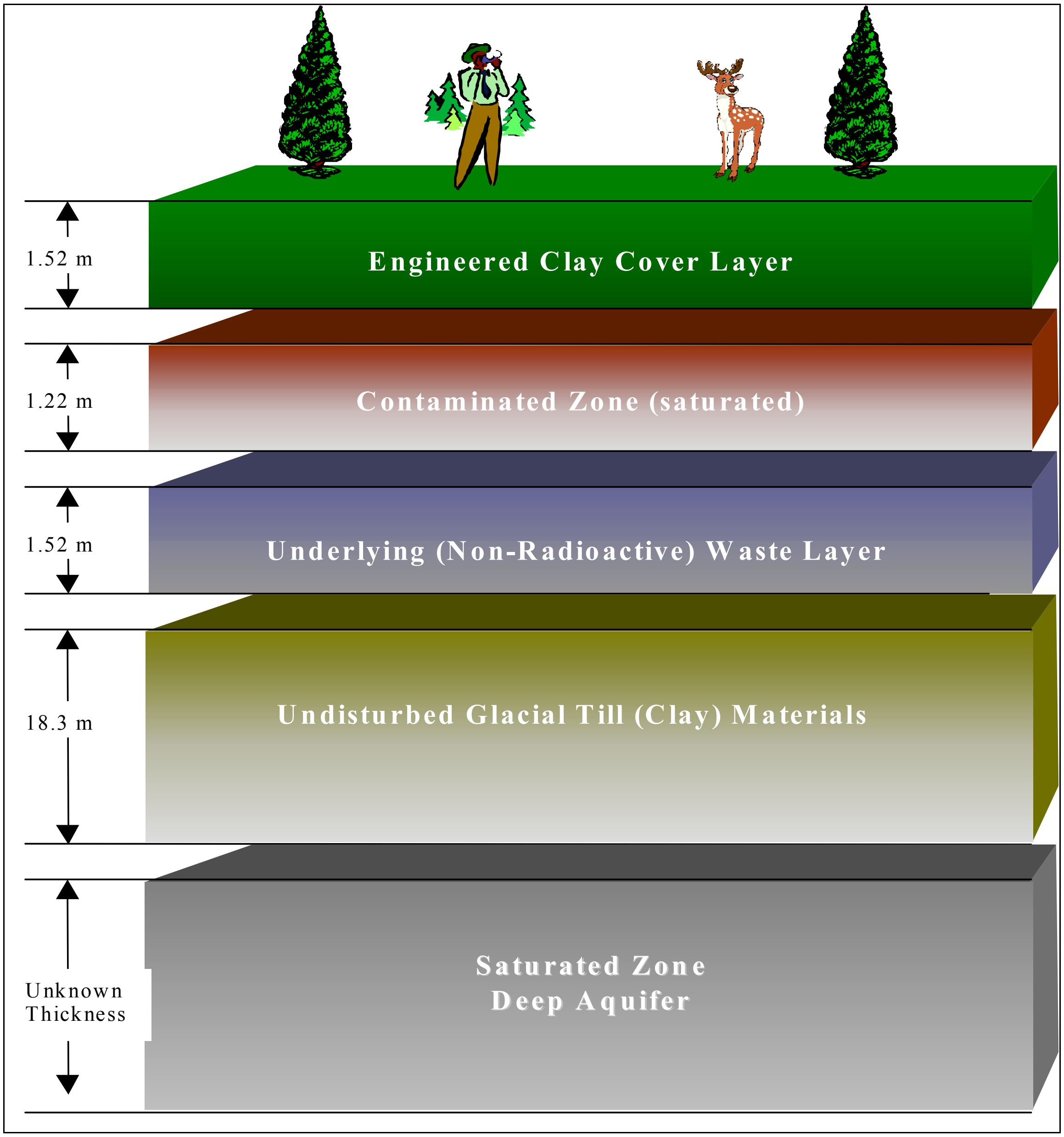


Figure 5-3 Tobico Marsh SGA Site Physical Abstraction

The third layer or zone is identified as the underlying (non-radioactive) waste layer. This layer is actually composed of as many as three different materials (depending upon the location) consisting of: 1) native soils cataloged as Belleville series soils, 2) industrial waste disposed on the site prior to placement of radioactive slag, and 3) the sand cover layer placed over the industrial wastes prior to deposition of slag on top of the sand cover. There is no credible and feasible way to adequately measure the presence or absence of these three subcomponents so that they might be described as separate layers with their own physical and hydrogeologic properties. Accordingly, MDNR has elected to conservatively describe the entire zone in terms of the physical and hydrogeologic properties that will result in the greatest potential for radioactive transport. RESRAD identifies this layer as *"unsaturated zone 1."* The thickness of the unsaturated zone 1 (H(1)) is described by the RESRAD default distribution, bounded lognormal-N, with a central tendency value of 1.52 meters bounded at a minimum of 0.5 meters and a maximum of 4 meters. The sand cover is the material with the lowest density and the highest hydraulic conductivity. Samples of native sand from the site were tested and found to have a soil density of 1.65 g/cm^3 and a hydraulic conductivity equivalent to 2,018 meters/y. RESRAD default radionuclide distribution coefficients were used for all isotopes.

The contaminated zone has previously been described in the source term abstraction. However, some additional features of the contaminated zone (those unrelated to it radiological composition) are described here. The thorium-bearing slag material is assumed to be comparable to the sand cover material in terms of its density and hydraulic properties. Thus it is described in RESRAD with a density of 1.65 g/cm^3 and a hydraulic conductivity of 2,018 meters/y. It is a vitreous-like material that is, by its very nature, very insoluble. As described previously (Section 3.7.1), the effective K_d for thorium in the contaminated zone is described using the RESRAD default, lognormal-N distribution function, except that bounds have been established on the range of values sampled during probabilistic analysis (a bounded lognormal-N distribution). The central tendency value for the distribution has been set to match the default, single-point estimate used in the RESRAD deterministic module, 60,000 cm^3/g (ANL 1993, USNRC 1980). Probabilistic sampling is bounded between 3,200 and 89,000 cm^3/g, the lowest and highest geometric mean values for various soils as reported in literature and summarized in the *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil* (Yu 1993). Treatment of the contaminated zone K_d value for thorium in this manner is only slightly less conservative than the default treatment of this parameter in RESRAD's probabilistic module and is at least a conservative as the default treatment in RESRAD's deterministic module. RESRAD default distribution coefficients were used for all other radionuclides in the source term.

The cover layer is an engineered clay cap installed in 1984 and designed to encapsulate the industrial wastes disposed at the site. The cover thickness (COVER0) is reported to be 1 to 2 meters thick (~4 to 7 feet). Radiological characterization surveys confirm the clay cover thickness to be in the range of 4 to 6 feet with the cover being thicker over the central portion of the cell where the deposits having elevated concentrations of residual radioactivity are concentrated. A triangular distribution is used to represent the cover thickness in the RESRAD model with a central tendency value of 1.52 meters and a minimum and maximum of 1 and 2 meters respectively. The engineered clay soil cover is designed to have a high soil density and a low hydraulic conductivity. Soil density is assumed to be equivalent to the native clays in the region (1.97 g/cm^3) and hydraulic conductivity is assumed to be comparable to that measured in native clays (0.017 meters/y). Cover erosion is defined in RESRAD by a fixed surface soil erosion rate parameter (VCV). The RESRAD default distribution, continuous logarithmic, is used with the cumulative distribution function spanning nearly two decades of erosion rate values and centered on the most probable erosion rate of 3.0 x 10^{-6} m/y[13]. The probability density function for the cover erosion rate parameter used in RESRAD dose modeling is presented in Figure 5-4.

Soil samples of the cover material were analyzed to determine its potential to support gardening or crop production. Analysis of the soil samples identified high (8.4) pH levels and low potash, phosphate, and organic matter levels compared with baseline averages for Bay County. Nitrogen levels were also identified in the low to average range. Soil composition is composed of 32.8 to 34.4 percent sand, 29.8 to 30.2 percent silt, and 35.4 to 37.4 percent clay. This composition is classified as a clay loam soil type.

Based on the soil sample results (Appendix F) and discussions with the Michigan State University Extension Center – Bay City, the cost and effort for crop production would be cost prohibitive in comparison with other available land/soil conditions.

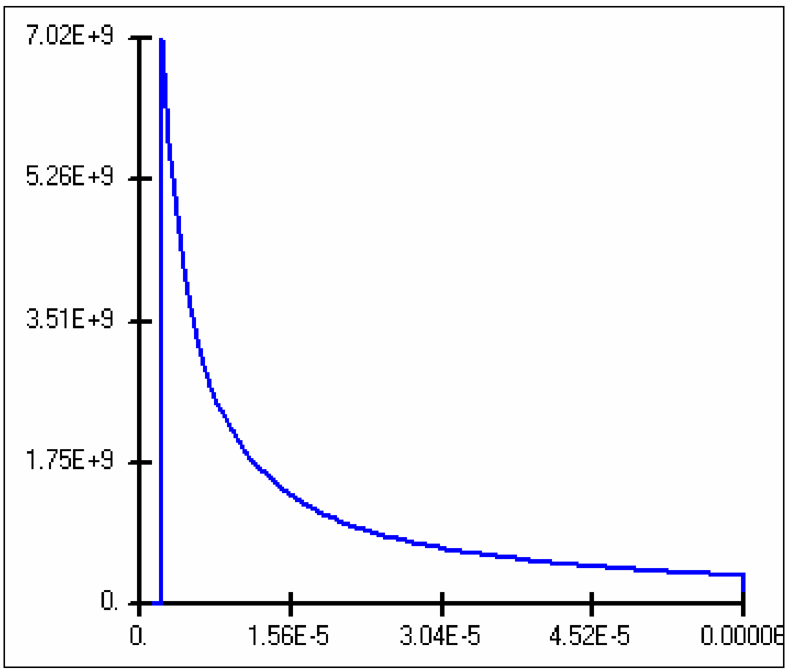


Figure 5-4 Cover Soil Erosion Rate (VCV)

5.3 DESCRIPTION OF THE EXPOSURE SCENARIOS

The site is located in a vast, freshwater marsh and is surrounded by ponded water and supersaturated soils. Other than passive recreational uses, past use of the land at the site

13 According to the *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil* (Yu 1993), soil erosion rates for sites in humid areas, with a 2% slope, and natural succession vegetation are estimated to range between 8 x 10^{-7} and 3 x 10^{-6} m/y (based on model site calculations using the Universal Soil Loss Equation method). MDNR has allowed the soil erosion rate to range to a maximum value of 6 x 10^{-5} m/y, the highest cited value recommended for use in RESRAD (Yu 1993) for a site with 2% slope and for which it can be reasonably shown that the site is, and will continue to be, unsuitable for agricultural use.

has been limited to industrial-waste land disposal. Within the immediate vicinity of the site, development of the marshland for residential, commercial, or agricultural uses has not been undertaken. Land in the surrounding area is also largely undeveloped and is sparsely populated with a mixture of single-family residential dwellings and some small commercial facilities. There is no apparent trend in the land use in the immediate area surrounding the Site. The only noteworthy development of land in the vicinity of the site is more than 1 mile away along Highway 13. The lack of substantive land development in the immediate vicinity of the site coupled with the downward trend in population in Bay County, supports the premise that Site uses into the foreseeable future will be consistent with present uses. Land that is far more suitable for development than that which exists at the Site, is available in the surrounding vicinity. The MDNR site does not have the necessary infrastructure (e.g. roadways, utilities) required to support development of the land while the area in the surrounding vicinity already has an infrastructure in place with a considerable amount of vacant land suitable for development.

As to the suitability of the land for different uses (involving land development), a number of physical factors present significant limitations:

5.3.1 Soil Properties

U.S. Department of Agriculture, Soil Conservation Service's Soil Survey of Bay County, Michigan (USDA 1977) indicates the soil at and around the site is classified as the Belleville series. Belleville soil is characterized by a dark gray, loamy surface layer with grayish-brown sand subsoil. The substratum is multicolored clay loam and loam. Permeability is high in the sandy upper part and low in the loamy lower part. In most Belleville soil areas, and wetlands (ponded water, marsh vegetation) are present. It has potential for development as habitat for wetland wildlife. Due to the soil characteristics, other development options are economically infeasible or impractical. Belleville soils are either not suitable for growing typical agricultural products or these products are generally not grown in Belleville soils. Belleville soils have severe limitations for the following construction activities:

- shallow excavations
- dwellings with or without basements
- small commercial buildings
- local roads and streets
- lawns and landscaping

A severe limitation indicates that one or more soil properties or site features are so unfavorable or difficult to overcome that a major increase in construction effort, special design, or intensive maintenance is required. Belleville soils have severe limitations for use as sanitary facilities such as septic tank adsorption fields or sewage lagoons. Belleville soils are considered poor to unsuitable options for use as road fill, sand, gravel, or topsoil.

Soil properties of the clay cover material are likewise unsuitable for producing crops or gardens (section 5.2.2).

5.3.2 Utilities Upgrade Limitations

Currently, the site is accessed by using a perimeter road that surrounds the Waste Management landfill that is located south of the site. The remainder of the site is bordered by the Tobico Marsh State Game Area, and no roads access the site through the game area. Those desiring access will need to acquire the land, or rights to use the land, for the construction of an approximately 1-mile long access or improved road to the site. The current state of the landfill perimeter road is acceptable for sporadic, recreational use only.

Residential or commercial use of the Site would require significant widening and reconstruction of the current access road. The cost of road rehabilitation is highly dependent upon the finish material. A new 1-mile gravel road (the least expensive alternative to a paved road) built to County road standards would cost approximately $240,000. A reconstructed road or one constructed to a lesser standard would be marginally less expensive. The access road cost alone would likely cause a potential buyer to purchase land elsewhere in the area that has existing suitable access. With the price of tiled agricultural land estimated at $2,000 or less per acre (MSU 2001), the cost of road building would be prohibitive for agricultural use.

Typical low-cost drainage measures, such as seeded ditches, would be difficult to install at this site. The soil type and soil wetness would cause ditch sidewalls to slump as they are excavated, making proper excavation to required depths infeasible. Alternative ditch construction methods, including excavation shoring and concrete/riprap installation, would raise construction costs to prohibitive levels. Without adequate drainage, flooding and wetness would prohibit proper construction, operation, and maintenance of permanent structures and prevent the growing of crops. MDNR believes that the cost of drainage installation, especially when added to the capital costs of road installation, would prevent the reuse of the land for agricultural, commercial, or residential purposes.

5.3.3 Agricultural Improvement Limitations

The site presents many disadvantages that make agricultural use of the land very unlikely. The costs associated with access road construction, excavation of drainage ditches, installation of culverts, and clearing land make this property extremely unattractive to prospective farmers. It is much more likely that a buyer interested in agricultural land would purchase other land in the area that already is being used for this purpose. A 2001 land survey estimates land values in this area of Michigan at approximately $2,000 per acre for tiled agricultural land. Access road construction costs alone for this 3-acre site would far exceed the $6,000 required to purchase 3 acres of agricultural land in the surrounding area.

A soil survey (USDA-Soil Conservation Service in cooperation with Michigan Agricultural Experiment Station, 1980) indicates that the soil types at the site are some of the poorest agriculture producing soil types in Bay County. It is also unlikely that an agricultural user would purchase and develop a site for use that has a maximum production area of only 3 acres. Water well yield is traditionally low throughout the area, making installation of multiple, deep water wells for irrigation unlikely (MDEQ-Bay City).

In addition, more suitable farmland is located in the surrounding areas. Advantages to farming the surrounding area lands include:

- Soil that is more suitable for farming;
- Easier access due to an existing infrastructure;
- Less expense to "prepare" land for farming (i.e. draining); and
- Population higher in surrounding area, therefore larger "consumer base".

5.3.4 Commercial Use Limitations

Commercial use of the land would face the same infrastructure requirements as those required for agricultural use. Notable additions would be adequate power and water supply.

Frequent flooding and wetness of the site would require extensive and well-maintained drainage systems and may be cost prohibitive as well as physically prohibitive to the construction of large commercial buildings. Power supply would require the installation of approximately 1 mile of poles and wire at a current value cost of approximately $80,000. Water supply in the area is obtained from depths of approximately 150 feet below ground surface; however, low yields are common and may be a significant issue depending upon the water usage requirements of the intended commercial use. Installation of a deep well, pumps, water lines, and associated equipment would cost approximately $8,000 to $10,000. The high water table also presents problems with septic systems and required septic field sizes.

5.3.5 Residential Use Limitations

MDNR does not believe it likely that any sort of residential use would be attempted at this property. Numerous infrastructure costs make this property unattractive in comparison to other available land in the area. Also, residents of this property may be required to travel through or next to a landfill to get to the nearest public roadway. The parcel offers little aesthetic value, other than isolation, with few large trees on the perimeter and is surrounded by a wetland that provides excellent breeding sites for nuisance insects. Other disadvantages previously noted that would be applicable to residential use include power supply, water supply, drainage, and septic installation.

5.3.6 Recreational Use Limitations

Typical recreational opportunities that provide value to vacant land – access to lakes and streams – are not present at this site. With its proximity to a State Game Area, however, the site does provide a potential use for hunters. Since hunters would use the site only sporadically, they would likely avoid the development costs associated with road construction.

Beyond road access, the level of site development required by hunters would be entirely dependent upon the potential owner's desires. Placement of more permanent facilities such as a water well and/or rustic cabin would likely be more expensive at the site than at another property within the area; however, the cost of property nearer the more developed areas may be higher than at the subject site. Such developments would, however, face the same prohibitive challenges as residential reuse.

MDNR believes that recreational users would not attempt to establish permanent structures or perform excavation for any reason. If installed, water wells would, by typical yield rates and by rule, have to be screened below the contaminated zones.

Table 5-2 summarizes the advantages/disadvantages of potential land reuse at the Site.

Table 5-2 Site Land Reuse Advantages/Disadvantages

Possible Land Uses	Minimum Development Requirements	Relative Cost	Site Advantages	Site Disadvantages	Relative Likelihood
Agricultural	Access Road Construction, Site Drainage, Land Clearing, Site Work, Water Supply, Building Construction, Soil Importing and Amendments	Very High	None	Existing soil types are poor producers, flooding, wetness, small acreage, access	Extremely Low
Recreational	Access Road Construction, Site Drainage*, Land Clearing*, Site Work*, Water Supply*, Building Construction*	Moderate	Bordered by State Game Area	No lake/river recreation, limited to hunting only	Low
Commercial	Access Road Construction, Site Drainage, Land Clearing, Site Work, Water Supply, Building Construction	Very High	Railroad nearby	Site is far from existing roads, limited acreage, excavations not possible, flooding	Extremely Low
Residential	Access Road Construction, Site Drainage, Land Clearing, Site Work, Water Supply, Building Construction	Very High	Isolated	Site is far from existing roads, basements not possible, flooding, septic difficult, deep well required, access, utility infrastructure	Extremely Low
(asterisk indicates it may be optional)					

Based upon these limiting site physical characteristics, societal trends, and significantly unfavorable economic factors, and without regard to the multiple agency impediments to future development, MDNR considers the future use of the site for farming or residential/commercial development to be highly unlikely. However, given the potential low cost of development for recreational use, MDNR believes that it may be possible to reuse the site for publicly sponsored recreational (primarily hunting) purposes.

While hunters may be among the most likely recreational uses to be exposed at the site, it is also credible to consider that fishing may occur in the surface waters in the proximity of the site. The possibility also exists that naturalists, such as bird watchers or other nature enthusiasts, might visit the site because such activities are encouraged and supported within the Tobico Marsh State Game Area. Each of these variants on a recreational land use represents a discrete and different scenario since different exposure pathways are involved (Figure 5-5). A fourth, composite recreational land user has also been envisioned in which the recreational user engages in all three forms of recreational activity at the site. This composite receptor provides a reasonable upper bound on the potential annual radiation dose that a receptor may be exposed to while engaging in recreational activities at the site.

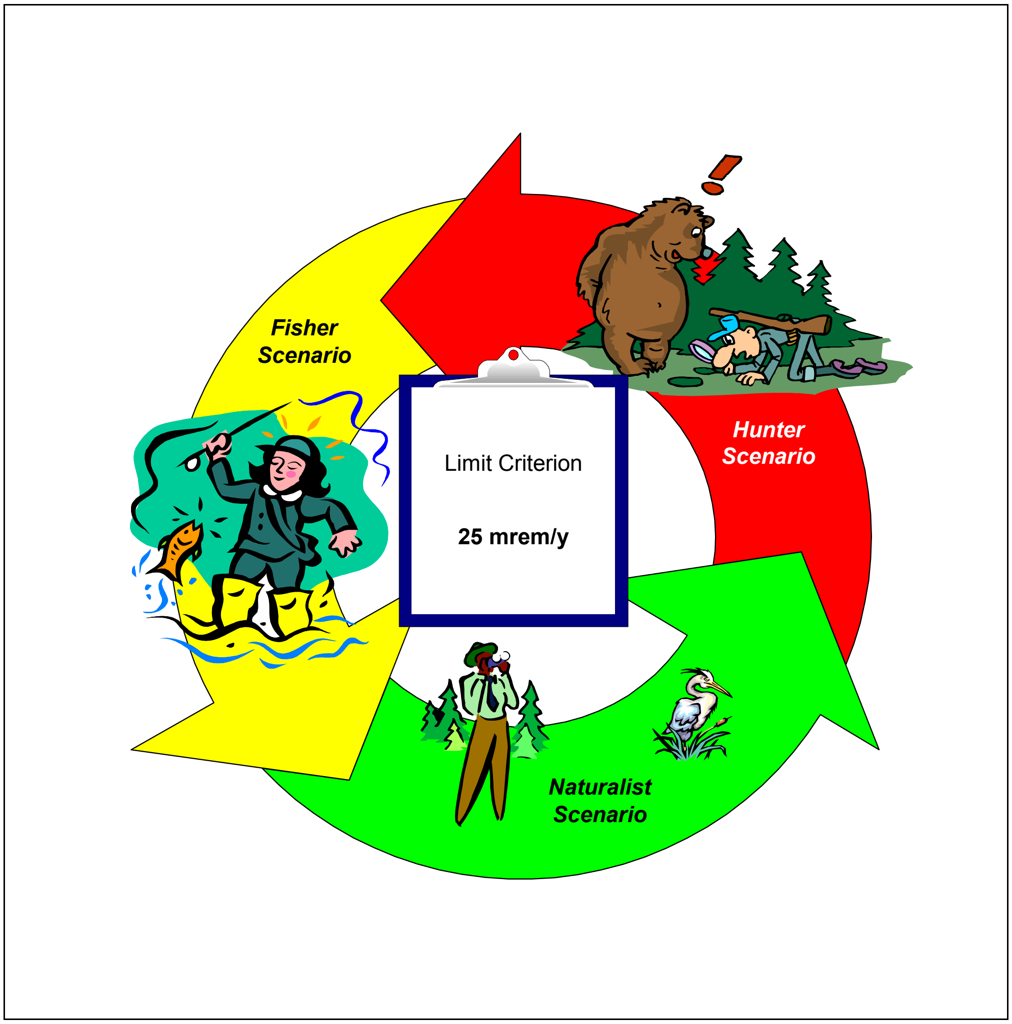


Figure 5-5 Exposure Scenarios Evaluated at the Tobico Marsh SGA

5.4 RECREATIONAL HUNTER SCENARIO

5.4.1 Description of the Critical Group

The critical exposure group for the recreational hunter scenario is described by hypothetical subpopulation that frequently hunts recreationally and consumes a considerable amount of game meat culled from the site. This hunter (as conservatively described) is likely to spend a large fraction of his available outdoor recreational time engaged in hunting and who returns to the MDNR site each time rather than visiting other sites or roaming about the vast non-impacted Tobico Marsh State Game Area lands in search of prey.

5.4.2 Pathways Included in the Recreational Hunter Scenario

Table 5-3 identifies the pathways that have been retained for the analysis and provides explanation for those pathways that were not retained.

Table 5-3 Evaluation of Pathways for the Recreational Hunter Scenario

Pathway	Retained	Remark
Direct Exposure	Yes	The source term found in the Site soils produces penetrating gamma radiation. Exposure from direct penetrating radiation is expected to be a significant contributor to the overall potential dose.
Particulate Inhalation	Yes	Allowance is made for soils containing radiological constituents of the source being liberated and suspended in the breathing air of the recreational hunter.
Radon	No	Radon is specifically excluded from consideration within the framework of the governing regulations. In addition, the source term found is not a significant producer of radon due to the relatively long half-life of the thorium isotopes found in the slag.
Plant Ingestion	No	Ingestion of plant foods addresses those plant foods grown in the radioactivity or irrigated with water containing radioactivity from on Site. Since recreational hunters are not expected to glean edible plant parts grown on site for food consumption, this pathway is incomplete.
Drinking Water	No	Surface water on site is unfit for consumption as drinking water. No on-site sources of groundwater have been developed for drinking water.
Meat Ingestion	Yes	Recreational hunters are expected to consume meat from animals culled from the site.
Milk Ingestion	No	Milk ingestion pathway is incomplete since it is incredible to consider that recreational hunters would graze milk cows on this Site.
Aquatic Foods Ingestion	No	Recreational hunters are not expected to spend time fishing the surface water bodies surrounding the Site.
Direct Ingestion	Yes	Hunters on the Site may ingest relatively small amounts of soil through incidental oral contact with their hands.

5.4.3 Description of the Parameters Used in the Analysis

The recreational hunter scenario involves relatively conservative exposure factors attributable to members of the critical group, hunting enthusiasts, who may spend a considerable amount of time hunting and whose annual diet of meat is composed of a large fraction of game culled from the site. Key parameters used to define the recreational hunter exposure scenario are presented in Table 5-4 along with specific remarks explaining the values' selection[14]. Table 5-4 is organized such that the key parameters describing the receptor's exposure and behavioral patterns (e.g., exposure time, inhalation rate, etc.) are presented first, followed by the site's general and weather-related parameters, geotechnical parameters for each layer described in the physical abstraction of the site, and then parameters describing the source term itself.

14 An exhaustive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for each scenario is provided in the RESRAD output files (reports) in appendices A–D.

Table 5-4 Key Parameters—Recreational Hunter Scenario

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Receptor Exposure Factors						
Exposure Frequency (Total)	EF	Days per year	25	EF and ET are not input parameters used by RESRAD. They are presented here to disclose the calculation used to arrive at the parameters RESRAD uses to account for exposure frequency, FIND & FOTD.		Assumes weeks per year of time spent hunting specifically on the Tobico Site.
Exposure Time	ET	Hours per Day	10			Conservatively assumes that each day spent hunting on site is 10-hours long.
Indoor Time Fraction	FIND	Unitless, 0 to 1	0	Point estimate		The fraction of a total year (8760 hr) that is spent indoors on Site. Assumes that all exposures occur outdoors. There are no habitable structures on the site.
Outdoor Time Fraction	FOTD	Unitless, 0 to 1	0.0285	Triangular	Range: 0 to 0.057	The fraction of a total year (8760 hr) that is spent outdoors on Site. Equals 250 hrs outdoors on Site divided by 8760 hours. The probabilistic distribution ranges to twice the CT value (500 hrs per year spent hunting on the site).
Inhalation Rate	INHALR	m^3/yr	8400	Triangular	Range: 4380 to 13100	RESRAD Default (Yu 2001). Inhalation rate based on geometric mean rate for short-term exposure to adult males (EPA 1997a).
Contaminated Fraction of Meat	FMEAT	Unitless, 0 to 1	0.3	Triangular	Range: 0 to 0.5	The fraction of the annual meat diet that is obtained from game harvested from off the site. The number is conservative in that the size of the site is small relative to the grazing land required to support game habitat. The use of the triangular distribution results in a more conservative estimate than does the RESRAD default for this site (EPA 1997b).

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Mass Loading for Inhalation	MLINH	g/m^3	0.00003	Continuous Linear	0.000000: 0.0000 0.000008: 0.0151 0.000016: 0.1365 0.000030: 0.8119 0.000040: 0.9495 0.000060: 0.9937 0.000076: 0.9983 0.000100: 1.0000	RESRAD Default. Mass loading in air describes the airborne dust loading conditions on the Site (Yu 2001).
Soil Ingestion Rate	SOIL	g/y	18.3	Triangular	Range: 0 to 36.5	RESRAD Default. USEPA default value for adults engaged in non-contact intensive activities (50 mg/day). (Yu 2001, EPA 1997a).
Site General and Weather Related Parameters						
Evapotranspiration Coefficient	EVAPTR	Unitless, 0 to 1	0.625	Uniform	Range: 0.5 to 0.75	RESRAD Default. Typical values in humid climates east of the Mississippi River are approximately 0.7 (Yu 2001).
Average Annual Wind Speed	WIND	m/sec	4.25	Bounded Lognormal-N	μ Normal: 1.445 σ Normal: 0.2419 Min: 1.4 Max: 13.0	RESRAD Default. The five-year (1987-1991) site-specific annual average value (4.18 m/s) is nearly equal to the RESRAD default value (NOAA).
Precipitation Rate	PRECIP	m/year	0.71	Point Estimate		Annual average in Midland–Bay City–Saginaw area. Equals 28 inches per year (NOAA).
Irrigation Rate	RI	m/year	0.0	Point Estimate		No irrigation is considered in the future uses of the site.

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Runoff Coefficient	RUNOFF	Unitless, 0 to 1	0.45	Uniform	Range: 0.1 to 0.8	The fraction of total annual precipitation that sheds off the surface and drains to Site watershed drainage without percolating through the soil. Typical value is approximately 0.3 to 0.5, but is likely much higher for the Tobico Site due to the topography, drainage features of the Site, and engineered clay cover which has a very low hydraulic conductivity (Yu 2001).
Watershed Area for Nearby Stream or Pond	WAREA	m	10000	Point Estimate		RESRAD Default. The watershed area is used to calculate dilution factors for contaminant concentrations in surface water bodies in the vicinity of the site. The watershed area for the Tobico Marsh is vastly larger than the default (it includes the entire Saginaw Bay watershed) making the default conservative (Yu 2001).
Depth of Soil Mixing Layer	DM	m	0.15	Triangular	Range: 0 to 0.6	RESRAD Default (Yu 2001).
Calculation Times	T(n)	Yrs.	0 1 10 30 100 300 1000	NA		Evaluation at these time segments allows for consideration of the potential for conditions at the Site to evolve from the initial conditions specified (e.g., soil erosion impacts the cover thickness) and projects the changing Site conditions to the required 1000-year outlook (NRC 1997a, NRC 2000).
Geotechnical Parameters—Cover						

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Cover Depth (thickness)	COVER0	m	1.52	Triangular	Range: 1 to 2	From geotechnical logging performed in support of the scoping and characterization surveys, the engineered clay cover is shown to be between 1 and 2 meters (4 to 7 feet) thick over the portion of the cap circumscribed by the slurry walls. It has a typical thickness of approximately 1.52 meters (5 ft)
Cover Density	DENSCZ	g/cm^3	1.97	Truncated Normal	μ Normal: 1.97 σ Normal: 0.23 Quantile, min: 0.05 Quantile, max: 0.95	Measured density for clay-bearing materials present at the Site (Cabrera 2001).
Cover Erosion Rate	VCZ	m/yr	0.000003	Continuous Logarithmic	0.0000008 0.00 0.000003 0.50 0.00006 1.00	Typical value for soil erosion rates for sites in humid areas, with a 2% slope, and natural succession vegetation are estimated to range between 8×10^{-7} and 3×10^{-6} m/y (based on model site calculations using the Universal Soil Loss Equation method. MDNR has allowed the soil erosion rate to range to a maximum value of 6×10^{-5} m/y, the highest cited value recommended for use in RESRAD (Yu 1993) for a site with 2% slope and for which it can be reasonably shown that the site is, and will continue to be, unsuitable for agricultural use.
Depth of Roots	DROOT	m	0.15	Lognormal-N	μ Normal: -1.9 σ Normal: 0.6	The engineered cover is composed of dense clay material that is designed to shed water. It does not readily support a typical plant root zone. To further resist erosion, a thin (≈6 inch) layer of soil was placed over the cover and seeded with native grasses. The root depth is nominally limited to the 0.15 m (6 in.) thickness of the seeded soil layer. The fit of the lognormal-N distribution allows for root depths of up to approximately 1 meter.

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Geotechnical Parameters—Contaminated Zone						
Area of Contaminated Zone	AREA	m^2	791	Loguniform	Range: 791 to 5725	Most likely area corresponds to the area in which elevated radioactivity was detected during characterization surveys. The maximum area corresponds to the entire footprint of the cell within the slurry walls (Cabrera 2001).
Thickness of Contaminated Zone	THICK0	m	1.22	Bounded Lognormal-N	μ Normal: 0.20 σ Normal: 0.75 Min: 0.3 Max: 3.0	Site characterization data indicates that the residual radioactivity in soil lies below the thickness of the cover and generally terminates at a thickness of approximately 1.22 meters (4 ft.). To accommodate the localized variability in the depth of contamination, the source term thickness has been modeled to range from 0.3 to 3.0 meters (Cabrera 2001).
Contaminated Zone Density	DENSCZ	g/cm^3	1.65	Truncated Normal	μ Normal: 1.65 σ Normal: 0.23 Quantile, min: 0.05 Quantile, max: 0.95	The Contaminated Zone Density is assumed to be equal to the density of native sand materials present at the Site (Cabrera 2001).
Contaminated Zone Erosion Rate	VCZ	m/yr	0.000003	Continuous Logarithmic	0.0000003 0.00 0.000003 0.25 0.00003 0.50 0.0003 0.75 0.003 1.00	The same erosion rate predicted for the cover is conservatively used for the Contaminated Zone.
Contaminated Zone Total Porosity	TPCZ	Unitless, 0 to 1	0.4	Point Estimate		RESRAD Default (Yu 2001).
Contaminated Zone Field Capacity	FCCZ	Unitless, 0 to 1	0.2	Point Estimate		RESRAD Default (Yu 2001).

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Contaminated Zone Hydraulic Conductivity	HCCZ	m/yr	2000	Bounded Lognormal-N	μ Normal: 7.6 σ Normal: 0.75 min: 200 max: 20000	The central tendency value, 2,000 m/yr (6.4E-3 cm/sec), corresponds to the measured hydraulic conductivity in sandy soils found at the site. The value is assumed to range over two orders of magnitude from 200 to 20,000 m/yr (Cabrera 2001).
Contaminated Zone B-Parameter	BCZ	Unitless	2.88	Bounded Lognormal-N	μ Normal: 1.06 σ Normal: 0.66 min: 0.5 max: 30	RESRAD Default (Yu 2001).

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
K_d (Thorium)	DCACT (n)	cm^3/g	60000	Bounded Lognormal-N	μ Normal: 11.0 σ Normal: 1.0 min: 3200 max: 89000	Classically, K_d is an expression of the sorption characteristics of a soil saturated with a soluble (e.g., thorium) material in solution. This would assume, in this case, that the thorium in the source term is completely solvent, a condition not present at the site. The use of an effective or desorption K_d for thorium is warranted. The physical and chemical characteristics of the thorium bearing slag materials disposed at the Site are: 1. Thorium is not very soluble, and 2. Radionuclides do not readily leach from the slag matrix. These factors support the use of much higher values of K_d than might be found in literature searches or bench testing of soil samples using standard methods. Still, a K_d value for thorium in the Contaminated Zone of 60,000 (the RESRAD deterministic module default) is conservatively recommended as the median value, bounded with the highest and lowest geometric mean values from literature (Yu 1993) .
K_d (Lead)	DCACT (n)	cm^3/g	100	Point Estimate		RESRAD Default (Yu 2001).
K_d (Radium)	DCACT (n)	cm^3/g	70	Point Estimate		RESRAD Default (Yu 2001).
Geotechnical Parameters—Unsaturated Zone (1)						

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Thickness, Unsaturated Zone 1	H1	m	1.22	Bounded Lognormal-N	μ Normal: 0.42 σ Normal: 0.5 Min: 0.5 Max: 4.0	Site characterization data indicates that the typical depth from just below the cover to the interface of the native clay-bearing till layer is approximately 2.75 m (9 ft) with some variability observed. Maximum depth observed was approximately 4 meters (14 ft.). This total thickness is shared by the contaminated layer and the uppermost unsaturated layer with the two thicknesses being inversely correlated with each other (Cabrera 2001).
Density, Unsaturated Zone 1	DENSUZ (1)	g/cm^3	1.65	Truncated Normal	μ Normal: 1.65 σ Normal: 0.23 Quantile, min: 0.05 Quantile, max: 0.95	Unsaturated Zone 1 is the sand cover layer placed over the site prior to disposal of thorium bearing slag. The density is assumed to be equal to the density of native sand materials present at the Site (Cabrera 2001).
Total Porosity, Unsaturated Zone 1	TPUZ(1)	Unitless, 0 to 1	0.4	Point Estimate		RESRAD Default (Yu 2001).
Effective Porosity of Unsaturated Zone 1	EPUZ(1)	Unitless, 0 to 1	0.2	Point Estimate		RESRAD Default (Yu 2001).
Field Capacity Unsaturated Zone 1	FCUZ(1)	Unitless, 0 to 1	0.2	Point Estimate		RESRAD Default (Yu 2001).
Hydraulic Conductivity Unsaturated Zone 1	HCUZ(1)	m/yr	2000	Bounded Lognormal-N	μ Normal: 7.6 σ Normal: 0.75 min: 200 max: 20000	The central tendency value, 2000 m/yr (6.4E-3 cm/sec), corresponds to the measured hydraulic conductivity in sandy soils found at the site. The value is assumed to range over two orders of magnitude from 200 to 20000 m/yr (Cabrera 2001).
Unsaturated Zone 1, B-Parameter	BUZ(1)	Unitless	5.3	Point Estimate		RESRAD Default (Yu 2001).

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
K_d (Thorium)	DCUCU (1,n)	cm^3/g	5885	Lognormal-N	μ Normal: 8.68 σ Normal: 3.62	RESRAD Default (Yu 2001).
K_d (Lead)	DCUCU (1,n)	cm^3/g	100	Point Estimate		RESRAD Default (Yu 2001).
K_d (Radium)	DCUCU (1,n)	cm^3/g	70	Point Estimate		RESRAD Default (Yu 2001).
Geotechnical Parameters—Unsaturated Zone (2)						
Thickness, Unsaturated Zone 2	H2	m	18.3	Bounded Lognormal-N	μ Normal: 2.9 σ Normal: 0.25 Min: 15.25 Max: 30.5	Local geotechnical logging indicates that the clay bearing glacial till layer is 50 to 100 feet in thickness with a typical thickness of approximately 60 feet. The slurry walls are keyed into the undisturbed native clay-bearing till layer to form a cell that contains the waste.
Density, Unsaturated Zone 2	DENSUZ (2)	g/cm^3	1.97	Truncated Normal	μ Normal: 1.97 σ Normal: 0.23 Quantile, min: 0.05 Quantile, max: 0.95	Unsaturated Zone 2 is the undisturbed native till layer underlying the entire site. The density is measured to be 1.97 g/cm^3 (Cabrera 2001).
Total Porosity, Unsaturated Zone 2	TPUZ(2)	Unitless, 0 to 1	0.4	Point Estimate		RESRAD Default (Yu 2001).
Effective Porosity, Unsaturated Zone 2	EPUZ(2)	Unitless, 0 to 1	0.2	Point Estimate		RESRAD Default (Yu 2001).
Field Capacity Unsaturated Zone 2	FCUZ(2)	Unitless, 0 to 1	0.2	Point Estimate		RESRAD Default (Yu 2001).

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Hydraulic Conductivity Unsaturated Zone 2	HCUZ(2)	m/yr	0.017	Bounded Lognormal-N	μ Normal: -4.08 σ Normal: 0.75 min: 0.0017 max: 0.17	The central tendency value, 0.017 m/yr (5.4E-8 cm/sec), corresponds to the measured hydraulic conductivity in native clay bearing soils found at the site. The value is assumed to range over two orders of magnitude from 0.0017 to 0.17 m/yr (Cabrera 2001).
Unsaturated Zone 2, B-Parameter	BUZ(2)	Unitless	5.3	Point Estimate		RESRAD Default (Yu 2001).
K_d (Thorium)	DCUCU (2,n)	cm^3/g	5885	Lognormal-N	μ Normal: 8.68 σ Normal: 3.62	RESRAD Default (Yu 2001).
K_d (Lead)	DCUCU (2,n)	cm^3/g	100	Point Estimate		RESRAD Default (Yu 2001).
K_d (Radium)	DCUCU (2,n)	cm^3/g	70	Point Estimate		RESRAD Default (Yu 2001).
Geotechnical Parameters—Saturated Zone						
Density, Saturated Zone	DENSAQ	g/cm^3	1.52	Truncated Normal	μ Normal: 1.52 σ Normal: 0.23 Quantile, min: 0.001 Quantile, max: 0.999	RESRAD Default (Yu 2001).
Total Porosity, Saturated Zone	TPSZ	Unitless, 0 to 1	0.4	Point Estimate		RESRAD Default (Yu 2001).
Effective Porosity, Saturated Zone	EPSZ	Unitless, 0 to 1	0.2	Point Estimate		RESRAD Default (Yu 2001).
Field Capacity, Saturated Zone	FCSZ	Unitless, 0 to 1	0.2	Point Estimate		RESRAD Default (Yu 2001).

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Hydraulic Conductivity, Saturated Zone	HCSZ	m/yr	10	Bounded Lognormal-N	μ Normal: 2.3 σ Normal: 2.11 min: 0.004 max: 9250	RESRAD Default (Yu 2001).
Hydraulic Gradient	HGWT	Unitless	0.006	Bounded Lognormal-N	μ Normal: -5.11 σ Normal: 1.77 min: .00007 max: 0.5	RESRAD Default (Yu 2001).
Saturated Zone B-Parameter	BSZ	Unitless	2.88	Bounded Lognormal-N	μ Normal: 1.06 σ Normal: 0.66 min: 0.5 max: 30	RESRAD Default (Yu 2001).
Source Term Factors						
Dose Conversion Factors	DCFX(n)	mrem/pCi	All DCFs used are RESRAD defaults			RESRAD defaults from FGR #11 (EPA 1988a) and FGR #12 (EPA 1993) and are derived using ICRP 30 dosimetry model. Short-lived (<180 days) radioactive progeny isotopes are accounted for through the use of the "parent+D" DCFs.
Source Isotopes			Thorium-bearing Slag Isotopic Mix (% of total activity)			This isotopic mix is derived from Site-specific data and assumes that the volume weighted average Th-230:232 ratio is 3.1:1 as calculated. The typically observed ratio during characterization sampling was found to be approximately 1:1, but as noted, two discrete locations exhibited ratios of approximately 10:1 (Cabrera 2001). Even if a wildly conservative 10:1 ratio were used to define the expected radionuclide profile in the mixture, the source term would be limited by the specific activity
Pb-210	S1(1)	pCi/g	3.4E3	Point Estimate	0.5%	
Ra-226	S1(2)	pCi/g	7.48E3	Point Estimate	1.1%	
Ra-228	S1(3)	pCi/g	1.09E5	Point Estimate	16.1%	
Th-228	S1(4)	pCi/g	1.09E5	Point Estimate	16.1%	
Th-230	S1(5)	pCi/g	3.40E5	Point Estimate	50.0%	

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Th-232	S1(6)	pCi/g	1.09E5	Point Estimate	16.1%	limit of Th-232. Ra-226 and Pb-210 activities are derived from 50-year ingrowth calculations and exhibit good agreement with measured ratios. All percentages calculated as the fraction of total activity of radionuclides in the mixture with half-lives greater than 180 days.
An exhaustive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for the Recreational Hunter Scenario is provided in the RESRAD output files (reports) in Appendix A.						

5.5 RECREATIONAL FISHER SCENARIO

5.5.1 Description of the Critical Group

The critical exposure group for the recreational fisher scenario is described by hypothetical subpopulation that frequently fishes recreationally on the site and consumes a considerable amount of fish harvested from surface waters impacted by residual radioactivity from the site. This fisher (as conservatively described) is likely to spend a large fraction of his available outdoor recreational time engaged in fishing and returns to the MDNR site each time rather than visiting other sites or roaming about the vast non-impacted Tobico Marsh State Game Area lands in search of fishing spots.

5.5.2 Pathways Included in the Recreational Fisher Scenario

Table 5-5 identifies the pathways that have been retained for the analysis and provides explanation for those pathways that were not retained.

Table 5-5 Evaluation of Pathways for the Recreational Fisher Scenario

Pathway	Retained	Remark
Direct Exposure	Yes	The source term found in the Site soils produces penetrating gamma radiation. Exposure from direct penetrating radiation is expected to be a significant contributor to the overall potential dose.
Particulate Inhalation	Yes	Allowance is made for soils containing radiological constituents of the source being liberated and suspended in the breathing air of the recreational fisher.
Radon	No	Radon is specifically excluded from consideration within the framework of the governing regulations. In addition, the source term found is not a significant producer of radon due to the relatively long half-life of the thorium isotopes found in the slag.
Plant Ingestion	No	Ingestion of plant foods addresses those plant foods grown in the radioactivity or irrigated with water containing radioactivity from on Site. Since recreational fishers are not expected to glean edible plant parts grown on site for food consumption, this pathway is incomplete.
Drinking Water	No	Surface water on site is unfit for consumption as drinking water. No on site sources of groundwater have been developed for drinking water.
Meat Ingestion	No	Recreational fishers are not expected to consume meat from game animals culled from the site.
Milk Ingestion	No	Milk ingestion pathway is incomplete since it is incredible to consider that recreational fishers would graze milk cows on this Site.
Aquatic Foods Ingestion	Yes	Recreational fishers are expected to spend time fishing and to consume fish caught in the surface water bodies surrounding the site.
Direct Ingestion	Yes	Fishers on the site may ingest relatively small amounts of soil through incidental oral contact with their hands.

5.5.3 Description of the Parameters Used in the Analysis

The recreational fisher scenario involves relatively conservative exposure factors attributable to members of the critical group, fishing enthusiasts, who may spend a considerable amount of time fishing and whose annual diet of aquatic foods is composed of a large fraction of fish caught while fishing on adjoining ponds/streams to the site. Key parameters used to define the recreational fisher exposure scenario are presented in Table 5-6 along with specific remarks explaining the values' selection. Table 5-6 contains only the key parameters describing the fisher's exposure and behavioral patterns (e.g., exposure time, inhalation rate, etc.) as all of the other site parameters—those describing the site in general, its weather, the geotechnical or physical abstraction, and the source term itself—are unchanged from the those identified for the recreational hunter and presented in Table 5-4.

Table 5-6 Key Parameters—Recreational Fisher Scenario

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Receptor Exposure Factors						
Exposure Frequency (Total)	EF	Days per year	25	EF and ET are not input parameters used by RESRAD. They are presented here to disclose the calculation used to arrive at the parameters RESRAD uses to account for exposure frequency, FIND & FOTD.		Assumes 25 days per year spent fishing specifically on the Tobico Site.
Exposure Time	ET	Hours per Day	10			Conservatively assumes that each day spent fishing on site is 10-hours long.
Indoor Time Fraction	FIND	Unitless, 0 to 1	0	Point estimate		The fraction of a total year (8760 hr) that is spent indoors on Site. Assumes that all exposures occur outdoors. There are no habitable structures on the site.
Outdoor Time Fraction	FOTD	Unitless, 0 to 1	0.0285	Triangular	Range: 0 to 0.057	The fraction of a total year (8760 hr) that is spent outdoors on Site. Equals 250 hrs outdoors on Site divided by 8760 hours. The probabilistic distribution ranges to twice the CT value (500 hrs per year spent fishing on the site).
Inhalation Rate	INHALR	m^3/yr	8400	Triangular	Range: 4380 to 13100	RESRAD Default. Inhalation rate based on geometric mean rate for short-term exposure to adult males (Yu 2001, EPA 1997a).
Contaminated Fraction of Aquatic Foods	FR9	Unitless, 0 to 1	0.39	Triangular	Range: 0 to 1.0	RESRAD Default. The fraction of the annual aquatic foods diet that is obtained from surface waters in the vicinity of the site. The number is conservative in that it includes edible shell fish which are not part of the local aquatic habitat and because it requires that up to 100% of the aquatic foods diet is harvested from surface water bodies immediately impacted by the site (Yu 2001, EPA 1997b).

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Mass Loading for Inhalation	MLINH	g/m^3	0.00003	Continuous Linear	0.000000: 0.0000 0.000008: 0.0151 0.000016: 0.1365 0.000030: 0.8119 0.000040: 0.9495 0.000060: 0.9937 0.000076: 0.9983 0.000100: 1.0000	RESRAD Default. Mass loading in air describes the airborne dust loading conditions on the Site. The RESRAD default CT value is nominally 2 to 5 times higher (more conservative) than typical annual average total dust loading in non-arid regions (Yu 2001).
Soil Ingestion Rate	SOIL	g/y	18.3	Triangular	Range: 0 to 36.5	RESRAD Default. USEPA default value for adults engaged in non-contact intensive activities (50 mg/day) (Yu 2001, EPA 1997a).
An exhaustive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for the Recreational Fisher Scenario is provided in the RESRAD output files (reports) in Appendix B.						

5.6 NATURALIST SCENARIO

5.6.1 Description of the Critical Group

The critical exposure group for the naturalist scenario is described by a hypothetical subpopulation that frequently visits the site to observe the natural surroundings (e.g., bird watching). The naturalist is assumed to consume some edible plants or berries that may be growing wild on the site. This naturalist (as conservatively described) is likely to spend a large fraction of his available outdoor recreational time engaged in nature viewing and returns to the MDNR site each time rather than visiting other sites or roaming about the vast non-impacted Tobico Marsh State Game Area lands in search of other spots from which to enjoy to the natural surroundings.

5.6.2 Pathways Included in the Naturalist Scenario

Table 5-7 identifies the pathways that have been retained for the analysis and provides explanation for those pathways that were not retained.

Table 5-7 Evaluation of Pathways for the Naturalist Scenario

Pathway	Retained	Remark
Direct Exposure	Yes	The source term found in the Site soils produces penetrating gamma radiation. Exposure from direct penetrating radiation is expected to be a significant contributor to the overall potential dose.
Particulate Inhalation	Yes	Allowance is made for soils containing radiological constituents of the source being liberated and suspended in the breathing air of the naturalist.
Radon	No	Radon is specifically excluded from consideration within the framework of the governing regulations. In addition, the source term found is not a significant producer of radon due to the relatively long half-life of the thorium isotopes found in the slag.
Plant Ingestion	Yes	Ingestion of plant foods addresses those plant foods grown in the radioactivity or irrigated with water containing radioactivity from on Site. Naturalist visitors to the site may conceivably consume edible plant parts grown on site.
Drinking Water	No	Surface water on site is unfit for consumption as drinking water. No on site sources of groundwater have been developed for drinking water.
Meat Ingestion	No	Naturalists are not expected to consume meat from game animals culled from the site.
Milk Ingestion	No	Milk ingestion pathway is incomplete since it is incredible to consider that milk cows would graze on this Site.
Aquatic Foods Ingestion	No	Naturalists are not expected to spend time fishing the surface water bodies surrounding the Site.
Direct Ingestion	Yes	Naturalists on the site may ingest relatively small amounts of soil through incidental oral contact with their hands.

5.6.3 Description of the Parameters Used in the Analysis

The naturalist scenario involves relatively conservative exposure factors attributable to members of the critical group, nature enthusiasts, who spend a considerable amount of time observing the natural surroundings and who, while visiting, consume plant food gleaned from wild plants growing on the site. Key parameters used to define the naturalist exposure scenario are presented in Table 5-8 along with specific remarks explaining the values' selection. Table 5-8 contains only the key parameters describing the naturalist's exposure and behavioral patterns (e.g., exposure time, inhalation rate, etc.) as all of the other site parameters—those describing the site in general, its weather, the geotechnical or physical abstraction, and the source term itself—are unchanged from the those identified for the recreational hunter and presented in Table 5-4.

Table 5-8 Key Parameters—Naturalist Scenario

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	**Code**	**Unit**		**Distribution**	**Range & Fit**	
Receptor Exposure Factors						
Exposure Frequency (Total)	EF	Days per year	25	EF and ET are not input parameters used by RESRAD. They are presented here to disclose the calculation used to arrive at the parameters RESRAD uses to account for exposure frequency, FIND & FOTD.		Assumes 25 days per year spent viewing nature specifically on the Tobico Site.
Exposure Time	ET	Hours per Day	10			Conservatively assumes that each day spent on site is 10-hours long.
Indoor Time Fraction	FIND	Unitless, 0 to 1	0	Point estimate		The fraction of a total year (8760 hr) that is spent indoors on Site. Assumes that all exposures occur outdoors. There are no habitable structures on the site.
Outdoor Time Fraction	FOTD	Unitless, 0 to 1	0.0285	Triangular	Range: 0 to 0.057	The fraction of a total year (8760 hr) that is spent outdoors on Site. Equals 250 hrs outdoors on Site divided by 8760 hours. The probabilistic distribution ranges to twice the CT value (500 hrs per year spent viewing nature on the site).
Inhalation Rate	INHALR	m^3/yr	8400	Triangular	Range: 4380 to 13100	RESRAD Default. Inhalation rate based on geometric mean rate for short-term exposure to adult males (EPA 1997a, Yu 2001).

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Contaminated Fraction of Plant Food	FPLANT	Unitless, 0 to 1	0.0285	Triangular	Range: 0 to 0.057	The fraction of the annual plant foods diet that is obtained from edible, natural succession vegetation grown on the site. The fraction is consistent with the time spent on site but is thought to be very conservative in that it assumes that a relatively large, naturally sustainable, and edible plant population is present on the cover of the cell. As described earlier, the soil cover over the engineered clay cap is very thin and does not readily support native plants aside from grasses.
Mass Loading for Inhalation	MLINH	g/m^3	0.00003	Continuous Linear	0.000000: 0.0000 0.000008: 0.0151 0.000016: 0.1365 0.000030: 0.8119 0.000040: 0.9495 0.000060: 0.9937 0.000076: 0.9983 0.000100: 1.0000	RESRAD Default. Mass loading in air describes the airborne dust loading conditions on the Site. The RESRAD default CT value is nominally 2 to 5 times higher (more conservative) than typical annual average total dust loading in non-arid regions (Yu 2001).
Soil Ingestion Rate	SOIL	g/y	18.3	Triangular	Range: 0 to 36.5	RESRAD Default. USEPA default value for adults engaged in non-contact intensive activities (50 mg/day) (Yu 2001; EPA 1997a).
An exhaustive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for the Naturalist Scenario is provided in the RESRAD output files (reports) in Appendix C.						

5.7 COMPOSITE RECREATIONAL USER SCENARIO

In order to address the rather remote possibility that a single receptor might engage to a significant extent in all three forms of recreational land use and involving consumption of some meat, fish, and plant foods derived from the site, MDNR has also considered a "composite" recreational user scenario.

5.7.1 Description of the Critical Group

The critical exposure group for the composite recreational user scenario is described by the hypothetical subpopulation that frequently visits the site to hunt, fish, and observe the natural surroundings at the site. The composite recreational user is assumed to consume a considerable amount of game meat, fish, and edible plant foods harvested from the site. This user (as conservatively described) is likely to spend a large fraction of his available outdoor recreational time engaged in hunting, fishing, and nature viewing activities and returns to the MDNR site each time rather than visiting other sites or roaming about the vast non-impacted Tobico Marsh State Game Area lands in search of other spots from which to enjoy these activities.

5.7.2 Pathways Included in the Composite Recreational User Scenario

Table 5-9 identifies the pathways that have been retained for the analysis and provides explanation for those pathways that were not retained.

Table 5-9 Evaluation of Pathways for the Composite Recreational User Scenario

Pathway	Retained	Remark
Direct Exposure	Yes	The source term found in the Site soils produces penetrating gamma radiation. Exposure from direct penetrating radiation is expected to be a significant contributor to the overall potential dose.
Particulate Inhalation	Yes	Allowance is made for soils containing radiological constituents of the source being liberated and suspended in the breathing air of the composite recreational user.
Radon	No	Radon is specifically excluded from consideration within the framework of the governing regulations. In addition, the source term found is not a significant producer of radon due to the relatively long half-life of the thorium isotopes found in the slag.
Plant Ingestion	Yes	Ingestion of plant foods addresses those plant foods grown in the radioactivity or irrigated with water containing radioactivity from on Site. Visitors to the site may conceivably consume edible plant parts grown on site.
Drinking Water	No	Surface water on site is unfit for consumption as drinking water. No on site sources of groundwater have been developed for drinking water.
Meat Ingestion	Yes	Composite recreational users are assumed to engage in hunting and are expected to consume meat from animals culled from the site.
Milk Ingestion	No	Milk ingestion pathway is incomplete since it is incredible to consider that milk cows would graze on this Site.
Aquatic Foods Ingestion	Yes	Composite recreational users are assumed to engage in fishing and are expected to consume fish caught in the surface water bodies surrounding the site.
Direct Ingestion	Yes	Composite recreational users on the site may ingest relatively small amounts of soil through incidental oral contact with their hands.

5.7.3 Description of the Parameters Used in the Analysis

The composite recreational user scenario involves very conservative exposure factors attributable to members of the critical group, "composite" recreational land users, who hypothetically spend a considerable amount of time hunting, fishing, and observing the natural surroundings at the site and who, while visiting, consume plant food gleaned from wild plants growing on the site. They are also assumed to consume game meat and fish harvested from or adjoining the site. Key parameters used to define the composite recreational user scenario are presented in Table 5-10 below along with specific remarks explaining the values' selection. Table 5-10 contains only the key parameters describing the composite recreational land user's exposure and behavioral patterns (e.g., exposure time, inhalation rate, etc.) as all of the other site parameters—those describing the site in general, its weather, the geotechnical or physical abstraction, and the source term itself—

are unchanged from the those identified for the recreational hunter presented in Table 5-4 above.

Table 5-10 Key Parameters—Composite Recreational User Scenario

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	**Code**	**Unit**		**Distribution**	**Range & Fit**	
Receptor Exposure Factors						
Exposure Frequency (Total)	EF	Days per year	25	EF and ET are not input parameters used by RESRAD. They are presented here to disclose the calculation used to arrive at the parameters RESRAD uses to account for exposure frequency, FIND & FOTD.		Assumes 25 days per year spent viewing nature specifically on the Tobico Site.
Exposure Time	ET	Hours per Day	10			Conservatively assumes that each day spent on site is 10-hours long.
Indoor Time Fraction	FIND	Unitless, 0 to 1	0	Point estimate		The fraction of a total year (8760 hr) that is spent indoors on Site. Assumes that all exposures occur outdoors. There are no habitable structures on the site.
Outdoor Time Fraction	FOTD	Unitless, 0 to 1	0.0285	Triangular	Range: 0 to 0.057	The fraction of a total year (8760 hr) that is spent outdoors on Site. Equals 250 hrs outdoors on Site divided by 8760 hours. The probabilistic distribution ranges to twice the CT value (500 hrs per year spent viewing nature on the site).
Inhalation Rate	INHALR	m^3/yr	8400	Triangular	Range: 4380 to 13100	RESRAD Default. Inhalation rate based on geometric mean rate for short-term exposure to adult males (EPA 1997a, Yu 2001).
Contaminated Fraction of Plant Food	FPLANT	Unitless, 0 to 1	0.0285	Triangular	Range: 0 to 0.057	The fraction of the annual plant foods diet that is obtained from edible, natural succession vegetation grown on the site. Equals the fraction used to describe the naturalist receptor's diet.

Parameter			Central Tendency Value	Description of Parameter Distribution		Remark
Description	Code	Unit		Distribution	Range & Fit	
Contaminated Fraction of Meat	FMEAT	Unitless, 0 to 1	0.3	Triangular	Range: 0 to 0.5	The fraction of the annual meat diet that is obtained from game harvested from off the site. Equals the fraction used to describe the hunter receptor's diet (EPA 1997b).
Contaminated Fraction of Aquatic Foods	FR9	Unitless, 0 to 1	0.39	Triangular	Range: 0 to 1.0	RESRAD Default. The fraction of the annual aquatic foods diet that is obtained from surface waters in the vicinity of the site. Equals the fraction used to describe the fisher receptor's diet (EPA 1997b, Yu 2001).
Mass Loading for Inhalation	MLINH	g/m^3	0.00003	Continuous Linear	0.000000: 0.0000 0.000008: 0.0151 0.000016: 0.1365 0.000030: 0.8119 0.000040: 0.9495 0.000060: 0.9937 0.000076: 0.9983 0.000100: 1.0000	RESRAD Default. Mass loading in air describes the airborne dust loading conditions on the Site. The RESRAD default CT value is nominally 2 to 5 times higher (more conservative) than typical annual average total dust loading in non-arid regions (Yu 2001).
Soil Ingestion Rate	SOIL	g/y	18.3	Triangular	Range: 0 to 36.5	RESRAD Default. USEPA default value for adults engaged in non-contact intensive activities (50 mg/day) (Yu 2001, EPA, 1997a).
An exhaustive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for the Composite Recreational User Scenario is provided in the RESRAD output files (reports) in Appendix D.						

5.8 UNCERTAINTY ANALYSIS

5.8.1 Managing Uncertainty

There is an inherent uncertainty in any projection of a future condition. Thus, scientists, statisticians, and even weather forecasters have developed tools to help them model or project a future condition and to understand the uncertainty associated with such projections.

In the past, dose assessments in support of USNRC decommissioning requirements relied primarily on the use of deterministic (single point estimate) analyses. The deterministic approach has the advantage of being simple to implement and easy to communicate to a non-specialist audience. However, it has a significant drawback in not allowing consideration of the combined effects of input parameters. It also fails to provide information on the degree of uncertainty in the results, which would be helpful to the decision maker. To overcome these weaknesses and to ensure that a deterministic analysis had a high probability of erring conservatively, dose/risk assessors often relied on the use of pessimistic (grossly conservative) estimates of each parameter of the model, typically leading to overly conservative evaluations and unnecessarily restrictive DCGLs.

The alternative to the deterministic approach is the probabilistic approach in which the overall uncertainty in the assessment is evaluated to arrive at a better estimate of the correspondence between residual radioactive concentration and the extent of incremental dose to an exposed receptor. Uncertainty analysis imparts more information to the decision maker than deterministic analysis. It characterizes a range of potential doses and the likelihood that a particular dose would be exceeded.

Regardless of the method, uncertainty is inherent in all dose and risk assessment calculations and should be considered in determining whether a selected DCGL concentration will satisfy the regulatory decision-making criteria. In general, there are three primary sources of uncertainty in a dose/risk assessment (Bonano et.al., 1988, and Kozak et al., 1991):

- Uncertainty in the models;
- Uncertainty in scenarios; and
- Uncertainty in the parameters.

Models are simplifications of reality and, in general, several alternative models may be consistent with available data. Computer modeling software codes have permitted the analyst to increasingly refine the models they use because the computer is handling the complex calculations that result. The RESRAD dose modeling code used in this evaluation has been developed and maintained using a stringent version control process. The models (or components of them) are tested for mathematical correctness, verified, and benchmarked against comparable models, when available. Modeling in and of itself implies a degree of uncertainty in that direct measurements or standards are typically not available to compare to modeled results. It is in such cases that risk-managers resort to models. Perhaps the most important factor in building confidence in the predictions of a model is selecting the model that most closely approximates the scenario to be evaluated.

Uncertainty in scenarios is the result of our lack of absolute knowledge about the future uses of the Site. It is important to recognize that the outlook evaluation time criterion (1,000 years) is not intended to predict future scenarios for the next 1,000 years, but to evaluate the continued protectiveness of a given DCGL for 1,000 years into the future given the reasonable and plausible future uses of the Site in today's social and economic conditions.

Parameter uncertainty results from incomplete knowledge of the coefficients that describe the model. However, with the selection of a suitable model for the Site conditions and scenarios to be considered, and configuring the model with realistic and most probable input parameters, the risk-manager may be reasonably confident in the model's predictions.

The current regulatory philosophy is to evaluate the uncertainty in an estimate along with the severity of consequence and probability of exceeding a deterministic regulatory limit. Such a decision method is termed "risk-informed decision making." The advent of powerful personal computers and increasingly capable software tools coupled with increased knowledge of key physical, behavioral, and metabolic parameters used to make dose/risk assessments, have brought probabilistic analysis to the state of the art. While not all regulating agencies currently expect that assessments will employ the probabilistic approach, with a quantitative assessment of the associated uncertainties, the USNRC has adopted a risk-informed approach to regulatory decision-making-suggesting that an assessment of uncertainty be included in dose assessments (NRC 2000). The USNRC's Probabilistic Risk Assessment (PRA) Policy Statement (NRC 1995) states, in part, *"The use of PRA technology should be increased in all regulatory matters to the extent supported by the state of the art in PRA methods and data, and in a manner that complements the USNRC's deterministic approach…."*

Even with the use of probabilistic analyses, it should be recognized that not all sources of uncertainty could be, or need to be, considered in a dose assessment. The primary emphasis in uncertainty analysis is to identify the important assumptions and parameter values that, when altered, could change the decision.

Sensitivity analysis performed in conjunction with the uncertainty analysis is used to identify parameters and assumptions that have the largest effect on the overall result and provides a tool for understanding and explaining the influence of these key assumptions and parameter values on the variability of the estimated dose.

5.8.2 Addressing Sources of Uncertainty

As mentioned above, an important issue in uncertainty and sensitivity analysis is that not all sources of uncertainty can be easily quantified. Of the three primary sources of uncertainty in dose assessment analyses, parameter uncertainty analysis is most mature and will be dealt with quantitatively in this section.

However, mathematical approaches for quantifying the uncertainty in the site conceptual models and future use scenarios are not well developed. For example, it is difficult to predict with absolute certainty the characteristics of a future society. For these reasons, no attempt to formally quantify model or scenario uncertainty is made. To confront these uncertainties an acceptably complete suite of scenarios capturing the plausible range of future uses for this site, given the nature and site-specific impediments to future land development, has been developed and is considered in the assessment (Flavelle 1992). In addition, conceptual site models have been designed and selected to represent the existing features at the Site and to conservatively represent the conditions that might be encountered in each scenario. A notable example of this strategy is seen in the decision to depict receptors exposed in the recreational land use scenarios who obtain substantially large fractions of their diet (meat, fish, plant) from potentially impacted onsite sources, even though the site has a very low ability to sustain sufficient quantities of meat, fish, and plant foods required to match the intake assumed in the various scenarios.

In reality, the uncertainties in the conceptual site model and the scenario selections are captured, to a certain extent, in the parameter uncertainty analysis.

5.8.3 Method of Addressing Uncertainty

MDNR has selected the most current version of the RESRAD dose modeling code (version 6.21, September 2002) to evaluate uncertainty in accordance with USNRC guidance (NRC 2000). It contains a probabilistic module that is used to assess the uncertainty in the relationship between a concentration of radioactivity in soil and the dose it might produce. It uses an enhanced random sampling algorithm called Latin Hypercube sampling in which input parameter values are selected randomly from probability distribution functions (PDF). The uncertainty module in the code permits the analyst to define the PDF for each variable of interest by selecting the distribution and its parameters, and to identify the parameter as either independent or correlated to other input variables.

The following describes the process used to evaluate uncertainty:

1. Each scenario was evaluated using the deterministic module to identify a concentration in soil corresponding to the deterministic regulatory limits. Additionally, coarse scale sensitivity analysis was performed to zero in on the parameters that had the greatest potential to impact the dose.
2. Pathways of interest were identified through preliminary runs of the deterministic module in the code for all the scenarios. These identified the scenario specific pathways that most significantly contributed to dose. The direct exposure

pathway, or "ground" pathway was consistently the dominant pathway for exposure to the source term, and by a significant margin.

3. Where site-specific knowledge was lacking, where the dose response was not sensitive to variability in a given parameter, or where the default parameter distributions were reasonably representative of site conditions or conditions being portrayed in the exposure scenario, the default was used. Where no default distribution is recommended or where discreet knowledge of site-specific conditions exists, an appropriate distribution considering the degree of knowledge of site-specific conditions was selected.
4. The Latin-Hypercube sampling algorithm (a variant of the Monte Carlo sampling technique which has an advantage in that it forces the sampling to occur over the entire range of possible values in the PDF rather than rely on pure random sampling) was set to obtain fifteen hundred samples (300 samples, repeated five times).

5.8.4 Parameter Distributions

Parameters to which probability density functions were assigned in order to evaluate their impact on uncertainty are presented in this section. They are organized such that the receptor exposure parameters are presented first, followed by general site and meteorological parameters, and then the geotechnical parameters describing the various soil layers starting with the cover and concluding with the saturated layer.

5.8.4.1 Outdoor Time Fraction (FOTD)

RESRAD uses fractions of a whole year spent on site to calculate annual dose to a receptor. The total fraction of a year spent on site is divided between two parameters: indoor time fraction (FIND) and outdoor time fraction (FOTD). Fractions of time spent on site are wholly dependent upon the scenario under consideration. Each of the four scenarios evaluated in the derivation of the site-specific soil DCGL assumes that the indoor time fraction is zero, denoting that all exposure on site occurs outdoors. The value used to describe the on site, outdoor time fraction for each of the recreational use scenarios is derived from conservative assumptions attributed to members of the critical exposure group and designed to be conservative for the general population of potentially exposed individuals.

Sensitivity analysis indicates that total annual dose is sensitive to variability in the FOTD parameter as the penetrating gamma (ground) exposure pathway dominates and is strongly dependent on exposure duration. In setting up the uncertainty analysis, the FOTD parameter is represented with a triangular distribution. Figure 5-6 graphically illustrates the distribution from which values of outdoor time fractions are sampled.

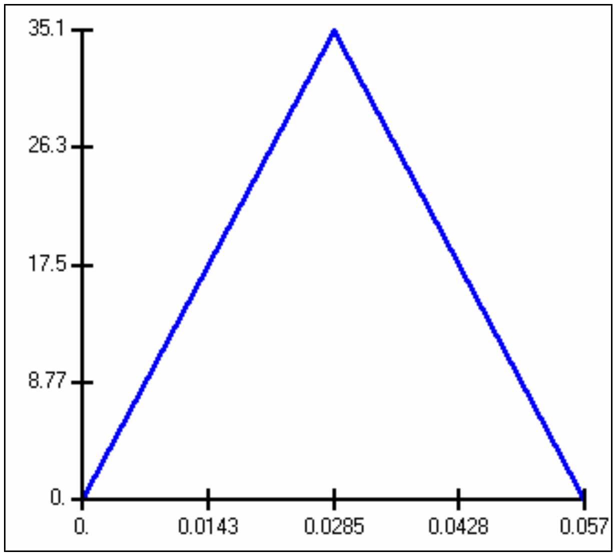


Figure 5-6 Outdoor Time Fraction—All Scenarios (unitless)

5.8.4.2 Inhalation Rate

Inhalation rate (INHALR) is the air intake in m^3 per year. It is used to calculate the dose from the inhalation pathway. The parameter represents the annual average breathing rate for a receptor from the critical exposure group subpopulation performing tasks under evaluation in a given scenario.

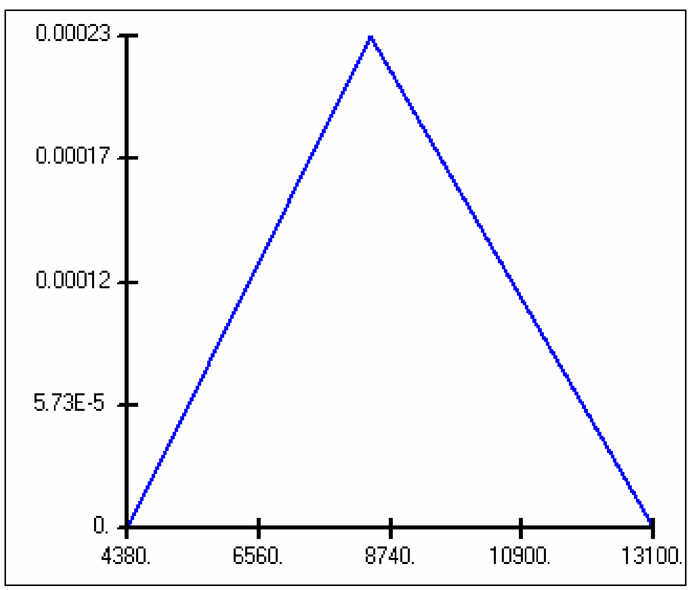


Figure 5-7 Inhalation Rate—Adults, Outdoor Activities (m^3/y)

Population normalized inhalation rates vary depending upon the tasks that are being performed. For the recreational land user, the inhalation rate used is the RESRAD default, which is derived from International Commission on Radiological Protection (ICRP) and EPA recommendations for adults engaged in short-term (episodic) exposure scenarios (ICRP 1981, EPA 1985, EPA 1997a). Sensitivity analysis shows that the total annual dose is not sensitive to this parameter, because the inhalation pathway is not a significant contributor to total annual dose. Inhalation rate is represented with a triangular distribution (the RESRAD default). Figure 5-7 graphically illustrates the distribution from which values of inhalation rate are sampled.

5.8.4.3 Contaminated Fraction of Meat Diet

The meat ingestion pathway is unique to the hunter and "composite" recreational user scenarios. Evaluation of the potential dose from this pathway considers both the annual consumption of meat and poultry, DIET(4) (using the RESRAD default value of 63 kilograms per year), and the fraction of that annual meat diet that is potentially impacted with residual radioactivity from the site (FMEAT).

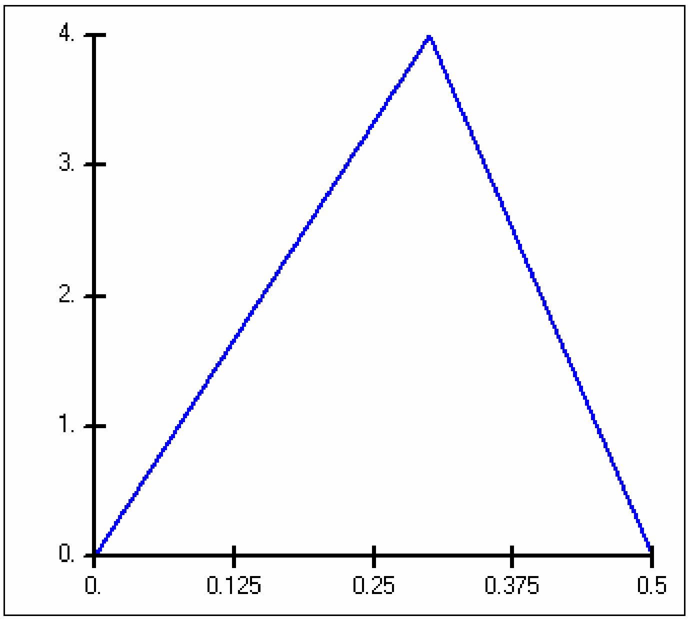


Figure 5-8 Contaminated Fraction of Meat (unitless)

A triangular distribution was selected to represent the range and variability in the fraction of the receptor's meat diet that might have been culled from among game animals that grazed on the site. The mode of the distribution (the most likely value) was selected based upon the typical dressed weight of a white-tail deer (~40 lbs., 19 kg), the most abundant game species in the area. The contaminated fraction is estimated to range between 0 (no game meat harvested) and 0.5 (half of the entire annual meat diet consumed is derived from game grazed on the Tobico site). The fraction modeled is conservative in that the size of the site is small relative to the grazing land required to support game habitat. Sensitivity analysis shows that the total annual dose is not sensitive to this parameter, because the meat ingestion pathway is not a significant contributor to total annual dose. Figure 5-8 graphically illustrates the distribution from which values of the contaminated fraction of meat is sampled.

5.8.4.4 Contaminated Fraction of Aquatic Foods Diet

The aquatic foods pathway is unique to the fisher and “composite” recreational user scenarios. Evaluation of the potential dose from this pathway considers both the annual consumption of fish, DIET(5) and DIET(6) (using the RESRAD default values of 5.4 and 0.9 kilograms per year respectively), as well as the fraction of that annual aquatic foods diet that is potentially impacted with residual radioactivity from the site (FR9). A triangular distribution was selected to represent the range and variability in the fraction of the receptor’s aquatic foods diet (fish) that might have been caught from surface waters impacted by residual radioactivity from the site. The RESRAD default distribution (triangular, with mode of 0.39 and a range of 0 to 1.0) was selected. The fraction modeled is conservative in that it assumes that the entire annual aquatic foods diet is derived from freshwater fish consumption only. In reality, a relative large fraction of the annual aquatic foods diet for a typical receptor is made up of a large portion of sea food and shellfish species not available at the site. Figure 5-9 graphically illustrates the distribution from which values of the contaminated fraction of aquatic foods is sampled.

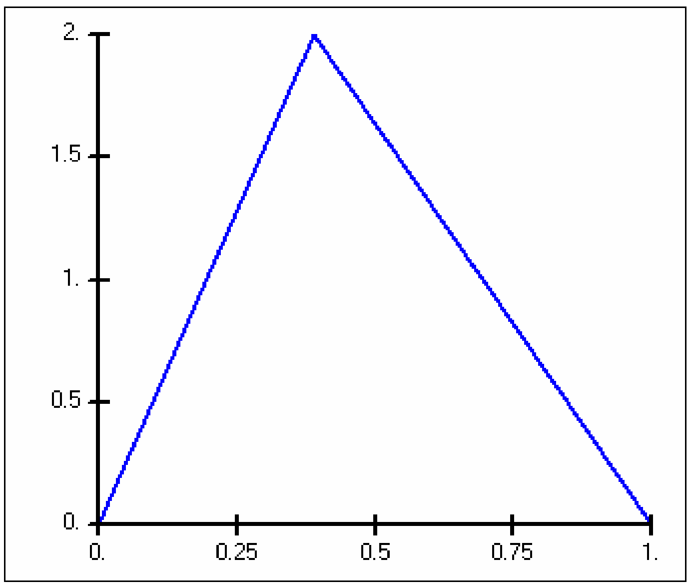


Figure 5-9 Contaminated Fraction of Aquatic Foods (unitless)

Sensitivity analysis shows that neither the aquatic foods ingestion pathway, nor the total annual dose is sensitive to this parameter because the isotopes of concern at the Site are relatively insoluble and immobile in soil.

5.8.4.5 Contaminated Fraction of Plant Food Diet

The plant foods pathway is unique to the naturalist and “composite” recreational user scenarios. Evaluation of the potential dose from this pathway considers both the annual consumption of plant foods, DIET(1) and DIET(2) (using the RESRAD default values of 160 and 14 kilograms per year respectively), as well as the fraction of that annual plant foods diet that is potentially impacted with residual radioactivity from the site (FPLANT).

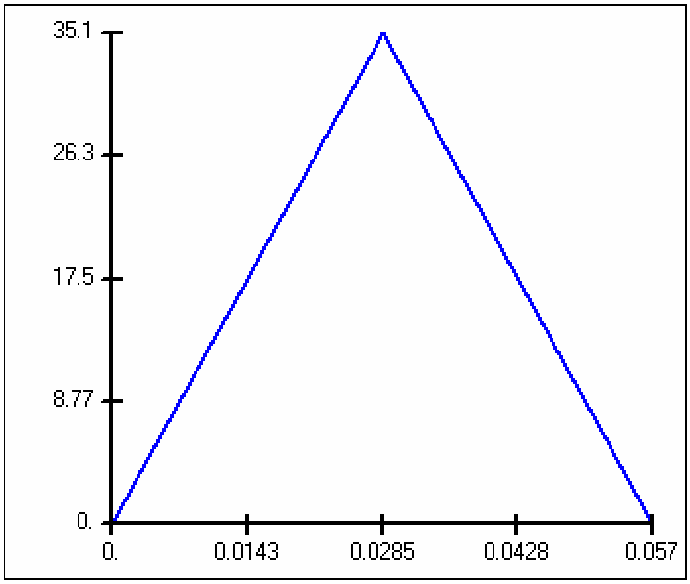


Figure 5-10 Contaminated Fraction of Plant Food (unitless)

A triangular distribution was selected to represent the range and variability in the fraction of the receptor's annual plant food diet that is derived from edible plants, sustained by natural succession, and which grew on and in the clay cover of the cell. RESRAD does not offer a default distribution for the FPLANT parameter as it is highly dependent upon the scenario and the ability of the site to sustain edible plant production. For this evaluation, a triangular distribution was used to represent the fraction of the receptor's plant food diet that might come from the site. The range and mode are chosen to correspond with the probability density function describing the fraction of time on site (FOTD) with the idea that plant food consumption would occur as a result of gleaning edible, natural succession plants while on site observing nature. Logically, then, the mode of the triangular distribution is 0.0285 with a range of 0 to 0.057, allowing for 0 to 5.7% of the receptor's annual plant food diet to be derived from plants grown on the site. The fraction modeled is conservative in that the cover is designed to support plants with very shallow root depths such as species of native grasses (for erosion control). Figure 5-10 graphically illustrates the distribution from which values of the contaminated fraction of plant food is sampled.

Sensitivity analysis shows that neither the plant foods ingestion pathway, nor the total annual dose are sensitive to this parameter because the sustainable root depth is shallow and the thickness of the engineered clay cover layer effectively isolates plants from contact with the residual radioactivity in soil.

5.8.4.6 Mass Loading for Inhalation

Mass loading for inhalation (MLINH) is the soil/air concentration ratio. It is used to calculate the dose from the particle inhalation pathway. The parameter represents the dust (mass) loading on site conservatively assuming that all airborne dust is generated on Site and is radioactive. Other parameters, derived by the RESRAD code and based upon the site-specific parameters input, are used to modify this assumption, as appropriate. Mass loading does vary from season to season and depends upon the tasks that are being performed at the Site. The RESRAD default continuous liner distribution and fit with a CT value of 0.00003 g/m^3 (30 µg/m^3) and ranging up to 100 µg/m^3 are used for each of the recreational visitor scenarios evaluated. The use of the RESRAD default is conservative as PM_{10} monitoring in the Midland–Bay City–Saginaw area indicates annual average dust loading to be approximately 10 µg/m^3 (MDEQ 2000), one third those used in the default.

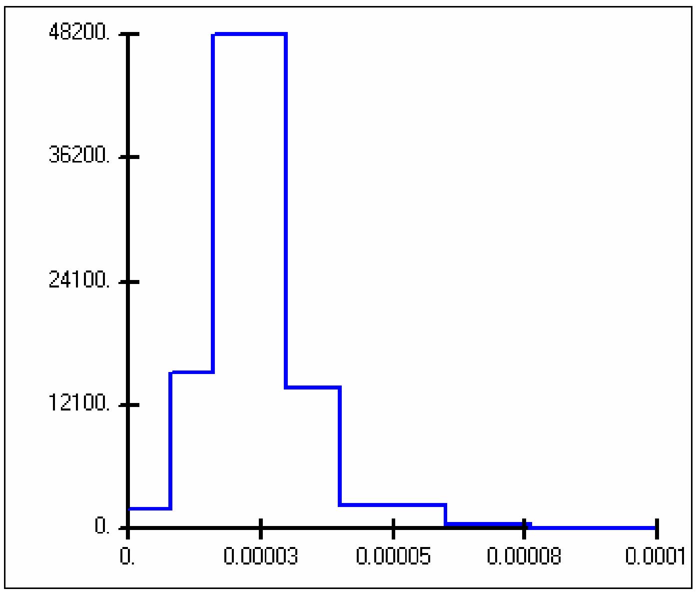


Figure 5-11 Mass Loading for Inhalation (g/m^3)

Sensitivity analysis shows that the inhalation pathway and total annual dose are insensitive to this parameter because the radioactivity is effectively isolated from the receptor by the in place cover material. Figure 5-11 graphically illustrates the distribution from which values of mass loading in air are sampled.

5.8.4.7 Soil Ingestion Rate

RESRAD uses the annual average soil ingestion rate (SOIL) to calculate the dose from the direct soil ingestion pathway. The soil ingestion rate used in deriving the soil DCGL for the site is represented by a triangular distribution centered at 18.3 g/y (50 mg/d) and ranging from 0 to 36.5 g/y (0 to 100 mg/d), the RESRAD default.

Sensitivity analysis again shows that neither the soil ingestion pathway nor the annual effective dose equivalent is sensitive to this parameter because the radioactivity is effectively isolated from the receptor by the in place cover material. Figure 5-12 graphically illustrates the distribution from which values of soil ingestion rate (SOIL) are sampled.

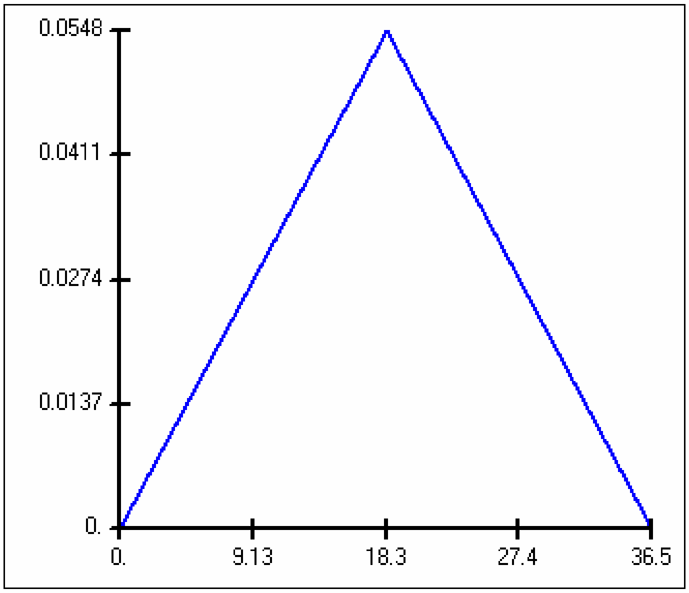


Figure 5-12 Soil Ingestion Rate (g/y)

5.8.4.8 Evapotranspiration Coefficient

The evapotranspiration coefficient (EVAPTR) is the fraction of total precipitation that is released back to the atmosphere via plant "respiration." Evapotranspiration varies with geographic region and to some extent with soil type. Evapotranspiration rates in the Midland/Bay City/Saginaw (MBS), Michigan region are estimated to be approximately 24 inches per year (Yu 1993), corresponding to a most likely evapotranspiration coefficient of approximately 0.85 (average annual precipitation in the region is 28.5 inches, (National Climatological Data Center, NOAA)).

The Evapotranspiration coefficient is conservatively represented with a uniform distribution ranging between 0.5 and 0.75 (the RESRAD default). Sensitivity analysis showed that annual dose is insensitive to values of evapotranspiration coefficient over the entire RESRAD default range. Figure 5-13 graphically illustrates the distribution from which values of evapotranspiration coefficient are sampled.

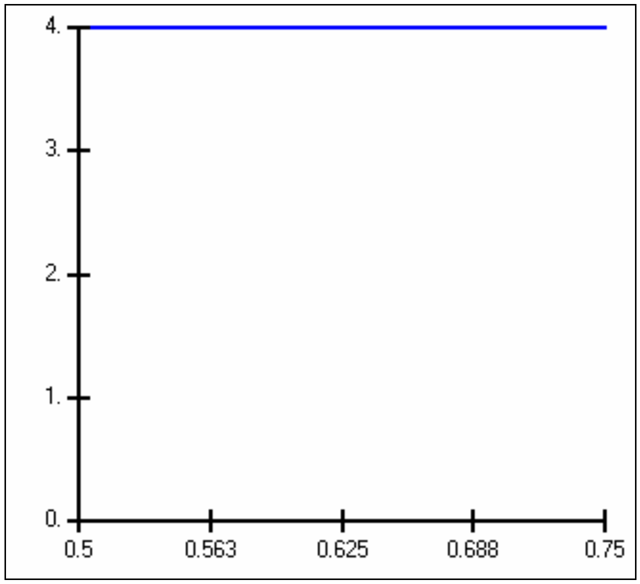


Figure 5-13 Evapotranspiration Coefficient (dimensionless)

5.8.4.9 Wind Speed

Average annual wind speed is used to calculate the dose from the inhalation pathway. The wind speed is used to transport airborne dust generated on Site in a standard air dispersion model. Through the transport calculations, the radioactive fraction of the total dust loading in air is derived. The fraction is then used to calculate particle inhalation intake. While wind speeds do vary from day-to-day and season-to-season, the annual average wind speed is reasonably steadfast. Sensitivity analysis shows that the inhalation pathway is insensitive to this parameter because, the residual radioactivity is effectively isolated by the covering layer such that radioactive particle suspension is minor. As a result, the inhalation pathway is not a significant contributor to total annual dose. Wind speed is represented with the RESRAD default, bounded lognormal-N distribution. The default data fit to the distribution was also used as the site specific wind speed data is closely approximated by the RESRAD default. For example, the site specific annual mean wind speed is reported to be 4.18 m/sec (National Climatological Data Center, NOAA) near perfect match to the 4.24 m/sec value described by the RESRAD default. Figure 5-14 graphically illustrates the distribution from which values of annual average wind are sampled.

5.8.4.10 Runoff Coefficient

The runoff coefficient is one of a number of parameters used to calculate radionuclide leaching from the contaminated zone. It is the fraction of precipitation that does not penetrate the top soil layer. The runoff coefficient (RUNOFF) varies with topography, amount of pavement, precipitation patterns in the region, and soil type. Runoff coefficient is represented with RESRAD default parameter distribution, a uniform distribution ranging between 0.1 and 0.8 (10% to 80% of precipitation runs off without penetrating the surface). Considering the mounded topography of the site and the presence of the engineered clay soil cover over the cell, the true range is likely to be much narrower and near the maximum value (80%) considered in the probability distribution. Sensitivity analysis showed that annual dose is insensitive to values of runoff coefficient over the entire range of plausible values. Figure 5-15 graphically illustrates the distribution from which values of runoff coefficient are sampled.

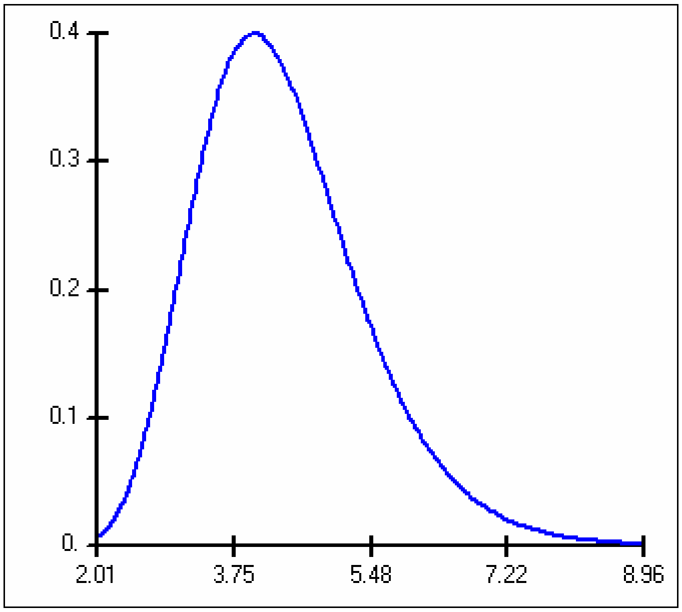


Figure 5-14 Average Annual Wind Speed (m/sec)

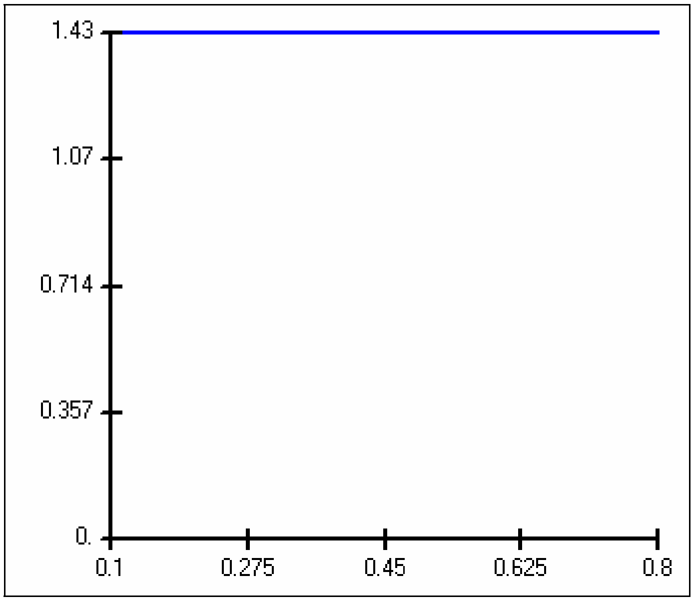


Figure 5-15 Runoff Coefficient (dimensionless)

5.8.4.11 Depth of Soil Mixing Layer

This parameter (DM) is used in calculating the depth factor for the dust inhalation and soil ingestion pathways and for foliar deposition for the ingestion pathways. The depth factor is the fraction of resuspendable soil particles at the ground surface that are contaminated, which is calculated by assuming that mixing of the soil will occur within a layer of thickness, DM, at the surface. The RESRAD default distribution (triangular) and range was used. Figure 5-16 graphically illustrates the distribution from which values of the depth of the soil mixing layer is sampled.

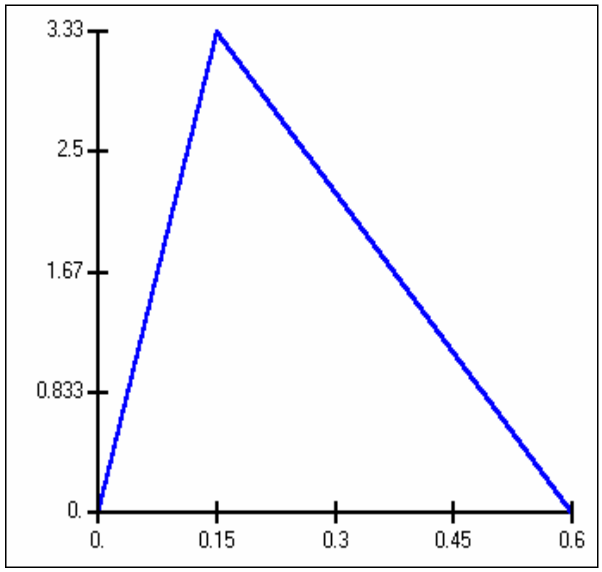


Figure 5-16 Depth of Soil Mixing Layer (m)

5.8.4.12 Cover Depth (Thickness)

The cover depth (thickness) is a key parameter in assessing the protectiveness of the chosen decommissioning alternative as it provides a barrier to potential physical contact with residual radioactivity in the slag materials located within the cell, and a substantial degree of gamma radiation attenuation for the penetrating gamma radiation exposure pathway, the dominant, or critical dose pathway. From geotechnical logging performed in support of the scoping and characterization surveys, the engineered clay cover is shown to be between 4 to 7 feet (1 and 2 meters) thick over the portion of the cap circumscribed by the slurry walls. It has a typical thickness of approximately 1.52 meters (5 ft). RESRAD does not suggest a default probability distribution for cover depth (COVER0) as it is highly dependant upon site-specific conditions and for many sites does not exist at all. Thus MDNR has conservatively chosen to represent this parameter with a triangular distribution ranging between 1 and 2 meters thick and with a most likely value of 1.52 meters (5 ft.). This representation is conservative in that the cover tends to be thicker near the center/middle of the cell, thinning as it extends beyond the slurry wall. Nor does it take credit for the attenuating effect of the thin (~6 inch thick) top soil layer placed over the cover in order to support natural succession vegetation as an erosion control mechanism. Sensitivity analysis reveals that the "cover penetrating gamma radiation dose" pathway, and as a result the total annual effective dose equivalent, is sensitive to this parameter. As an added measure of conservatism, owing to its potential impact on dose, the cover thickness was modeled with a potential range extending down to 1 meter (almost one foot thinner than the minimum thickness measured). Figure 5-17 graphically illustrates the distribution from which values of cover depth were sampled.

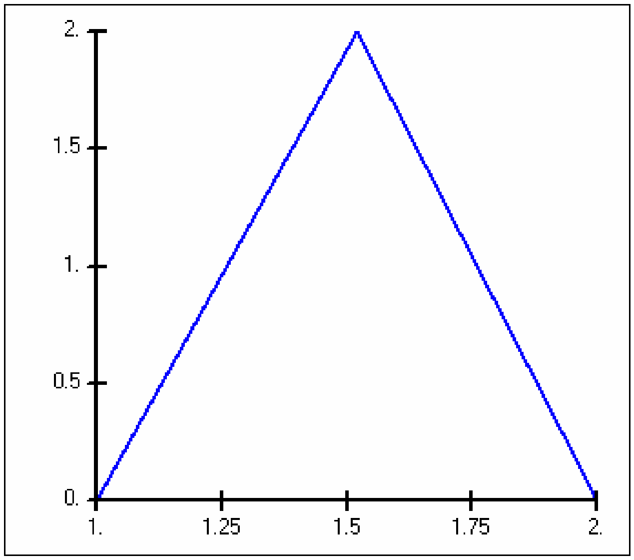


Figure 5-17 Cover Depth (m)

5.8.4.13 Cover Soil Density

The engineered cover is comprised of compacted clay soils. The soil density of native clay bearing soils at the site was measured to arrive at a site-specific estimate of the soil density of both the clay cover material and the undisturbed, clay-bearing, native till layer underlying the Site (unsaturated zone 2). The measured soil density was found to be 1.97 g/cm^3, a number typical of high clay content soils. Sensitivity analysis showed that annual dose was insensitive to a wide range of soil densities. Since site-specific data was available for the density of the clay bearing materials at the site, these were used to describe the density of the cover soil layer. Cover soil density (DENSCV) was represented with a truncated normal distribution (the RESRAD default). The Mean was set equal to the measured density of 1.97 g/cm^3 and allowed to range between approximately 1.6 and 2.4 g/cm^3. Figure 5-18 graphically illustrates the distribution from which values of cover soil density were sampled.

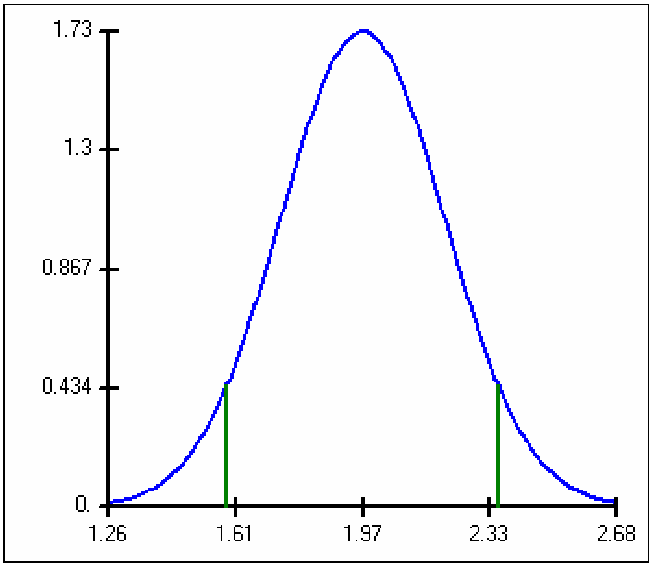


Figure 5-18 Cover Soil Density (g/cm^3)

5.8.4.14 Cover (Surface Soil) Erosion Rate

The conceptual site model used to describe the conditions at the Site involves a relatively thick cover layer, as has been described, engineered to resist the forces of erosion. The Site has very little topographical variation because it is in the freshwater marsh (delta) formed by the outflow of the Saginaw River into the Saginaw Bay. The cell itself is slightly elevated in comparison to the immediately surrounding landscape by approximately 5 to 6 feet. Generally, the Site is characterized by relatively flat features (<2% grade).

Sensitivity analysis shows that all pathways are sensitive to this parameter when represented with chronic and extreme erosion values such as those that might be observed in arid desert climates or where continual loosening of the surface soils occurs, such as might be expected for land used for agricultural purposes. In every scenario, the greatest annual dose occurs in the out years (year 1,000) when the cumulative effect of long-term soil erosion impacts the thickness of the cover layer and thus its attenuating affect. The surface (cover) soil erosion rate (VCV) has been conservatively estimated with a range of possible values to represent the likely and extreme erosion rates typical for conditions and activities expected at the site. Surface soil erosion is represented with a continuous logarithmic distribution (the RESRAD default) and ranging over approximately two decades from 8 x 10^{-7} to 6 x 10^{-5} m/year (Figure 5-19). The most probable range for a site in a humid climate, with a slope of approximately 2%, and natural succession vegetation extends from 8 x 10^{-7} to 3 x 10^{-6} m/year. Extreme surface soil erosion potential has been accounted for by estimating that there is as much as a 50% probability that the soil erosion rate will exceed this range, with estimates ranging to 6 x 10^{-5} m/year (the predicted maximum for sites used for permanent pasture) (Yu 1993).

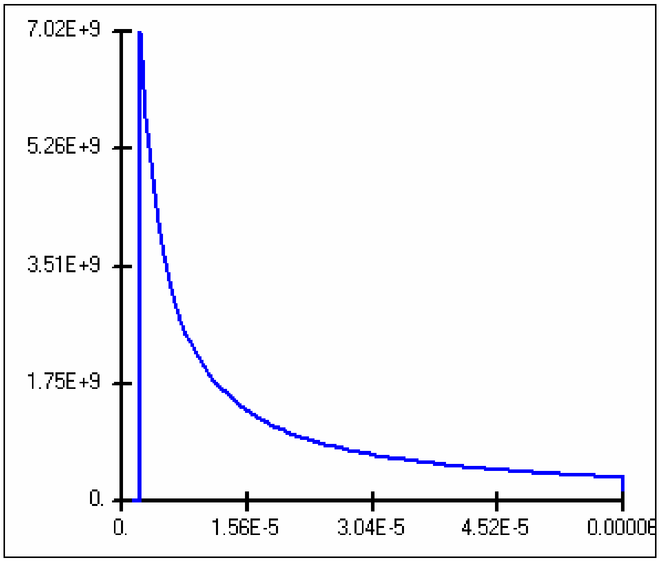


Figure 5-19 Soil Erosion Rate (m/y)

5.8.4.15 Depth of Plant Roots

The depth of plant roots is important only for the naturalists and composite recreational user scenarios (scenarios in which ingestion of plants grown on site is considered) as it is one of several parameters used to calculate dose from the intake of produce grown in soils having residual radioactivity. The depth of roots in these scenarios is effectively constrained by the fact that only a very thin layer of cover soil suitable for plant growth (≈6 inches) is actually in-place over the engineered clay cover layer. The engineered clay cover resists root penetration. Sensitivity analysis showed that the plant ingestion pathway was somewhat sensitive to root depth, but only in the out years of the analysis after the cumulative effects of long-term soil erosion have reduced the soil cover thickness to its projected minimum value. Even then, the plant ingestion dose is small when compared with the external penetrating radiation pathway. Root Depth (DROOT) is represented with a lognormal-N distribution and a central tendency estimate of 0.15 m (6 inches). The majority of root depth values as described in the distribution range from 1 to 12 inches with the maximum root depth ranging to depths as deep as approximately 1 meter (40 inches). Figure 5-20 graphically illustrates the distribution from which values of root depth were sampled.

5.8.4.16 Weathering Removal Constant

The weathering removal constant is used to account for the natural removal of soil and dust that have been deposited on consumable plants. It is relevant only for the naturalist and composite recreational user scenarios (scenarios in which the consumption of plants is considered). Sensitivity analysis showed that annual dose was insensitive to the weathering removal constant (WLAM), thus the RESRAD default distribution (triangular) and range were used. Figure 5-21 graphically illustrates the distribution from which values of the weathering removal constant parameter are sampled.

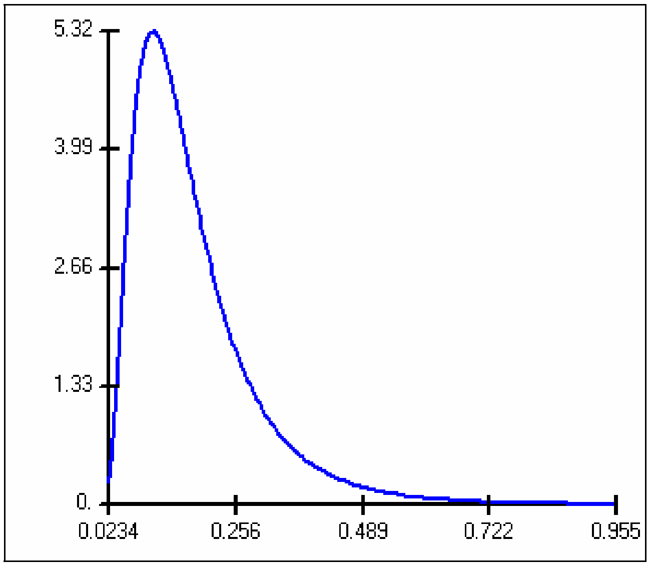


Figure 5-20 Depth of Plant Roots (meters)

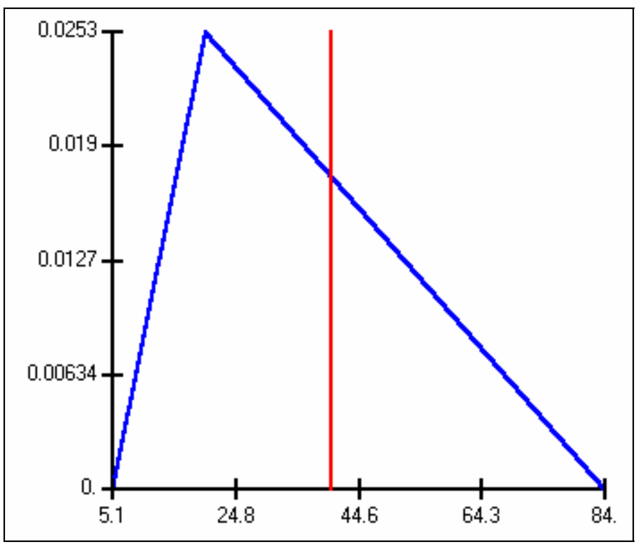


Figure 5-21 Weathering Removal Constant (dimensionless)

5.8.4.17 Area of Contaminated Zone

The area of the contaminated zone (AREA) describes the areal size, in meters, of the region in which elevated concentrations of residual radioactivity are located. Radiological sampling and measurement data from numerous radiological surveys performed at the site confirm that elevated radioactivity is confined to within the area circumscribed by the slurry walls of the cell. The Characterization Survey Report further delineates the region where elevated measurements occur, concluding that elevated activity is located principally along the trace of the former dirt road through the site and within an area of 791 m^2 (Cabrera 2001). In defining the probability density function for the AREA parameter, it was conservatively assumed that the contaminated zone area is no smaller than the 791 m^2 estimate derived from characterization survey data, but might be as large as the entire area circumscribed by the slurry wall, 5,725 m^2. RESRAD does not offer a default distribution for this parameter. A loguniform distribution ranging from the most likely value, 791 m^2, to a maximum value of 5,725 m^2 was selected to represent the area of the contaminated zone within the probabilistic module of RESRAD. Sensitivity analysis showed that annual dose was insensitive to the area of the contaminated zone. Figure 5-22 graphically illustrates the distribution from which values of the area of the contaminated zone parameter are sampled.

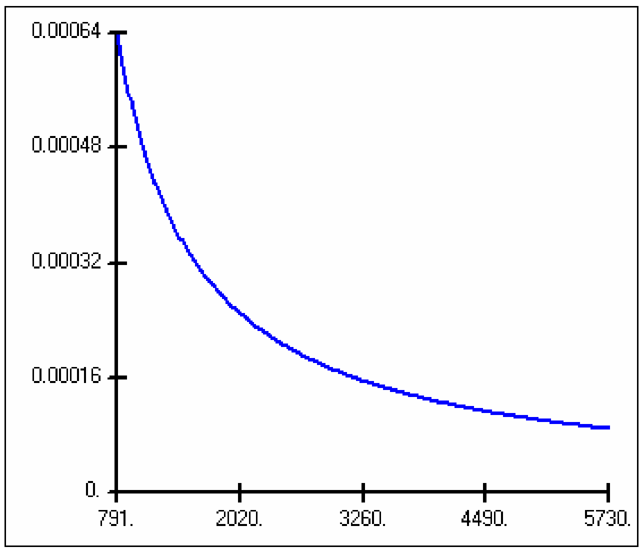


Figure 5-22 Area of Contaminated Zone (m^2)

5.8.4.18 Contaminated Zone Thickness

Thickness of the contaminated zone (THICK0) describes the depth profile of the residual radioactivity. Vertically, the radiologically significant material is located just beneath the cover (approximately 5 feet bgs) and lies in a lens that is nominally about 4 feet (1.2 meters) thick (Figure 5-2). The amount of source material deposited rapidly depletes as the depth increases and terminates at a maximum thickness of approximately 15 feet in one location. RESRAD does not offer a recommended (or default) distribution for the thickness of contaminated zone parameter (THICK0).

A lognormal-N distribution describes best the observed variability in the depth profile and thus the thickness of the contaminated zone or source term. In describing the source term for input to RESRAD, the thickness parameter is represented by a bounded lognormal-N distribution, with the central tendency (CT) value conservatively set to a thickness of 4 feet (1.22 meters). This thickness is conservative in that the mean source thickness over the entire footprint of the cell, the impacted area, is considerably less than

4 feet. It is only within the region along the former haul road (the most heavily contaminated area) that the thickness averages approximately 4 feet. The distribution is bounded at a minimum value of 0 feet (0 meters), and a maximum value of 15 feet (4.5 meters). Sensitivity analysis showed that annual dose was insensitive to the thickness of the contaminated zone. This is the result of the self-attenuating effect of source thicknesses greater than approximately 12 inches (0.3 meters) coupled with the attenuating capacity of the engineered clay cover. Figure 5-23 graphically illustrates the distribution from which values of the contaminated zone thickness parameter are sampled.

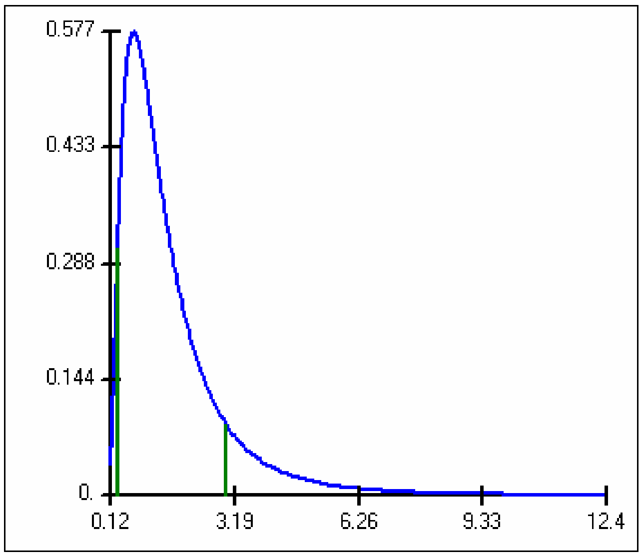


Figure 5-23 Contaminated Zone Thickness (m)

5.8.4.19 Contaminated Zone Density

The contaminated zone is comprised of thorium-bearing slag materials interspersed with other debris and sandy materials associated with the sand cover layer. The density of the native sand materials found at the site was measured to arrive at a site-specific estimate of the sand layer soil density. It is conservatively assumed that the contaminated layer has a soil density (and other hydrogeologic soil properties) equal to that of the native sand materials at the site. The measured sandy soil density was found to be 1.65 g/cm^3, a number typical of sandy soils. Sensitivity analysis showed that annual dose was insensitive to a wide range of soil densities. The contaminated zone soil density (DENSCZ) was represented with a truncated normal distribution (the RESRAD default). The Mean was set equal to the measured density of sandy materials at the site (1.65 g/cm^3) and allowed to range between approximately 1.25 and 2.05 g/cm^3. Figure 5-24 graphically illustrates the distribution from which values of contaminated zone soil density were sampled.

5.8.4.20 Contaminated Zone Erosion Rate

Contaminated zone erosion rate comes into play only when and if the cover is eroded. If erosion is severe enough to completely erode the cover, the same phenomenon would also subsequently act on the contaminated layer itself. The contaminated layer erosion rate is represented with the same range of parameters and continuous logarithmic distribution used to describe the cover erosion rate (see Figure 5-19).

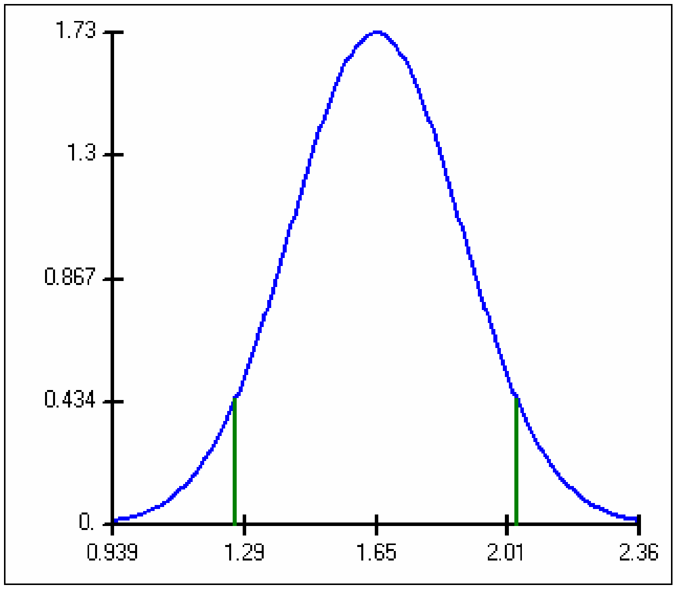


Figure 5-24 Soil Density (g/cm^3)

5.8.4.21 Contaminated Zone Hydraulic Conductivity

RESRAD uses vertical hydraulic conductivity to model the potential vertical movement of water through the four strata below the cover layer. Hydraulic conductivity is a key parameter used to calculate the migration of radioactivity from the source to groundwater. Sensitivity analysis showed that annual dose was insensitive to a wide range of hydraulic conductivities, largely because the thorium and other radionuclides in the contaminated zone are physically and chemically bound up in the slag and because the slag is very insoluble. Hydraulic conductivity was specifically measured for the native sand materials found at the site and was determined to be 6.4 x 10^{-3} cm/s (≈2000 m/y). Hydraulic conductivity in the contaminated zone (HCCZ) and the underlying unsaturated zone 1 (HCUZ(1)) are represented with bounded lognormal-N distributions (the RESRAD default) having central tendency values at 2,000 meters per year and with values conservatively ranging over two decades between 200 and 20,000 meters per year (Figure 5-25).

5.8.4.22 Soil Specific b-Parameter

The soil-specific exponential b-parameter is one of several hydrogeologic parameters used to calculate radionuclide transport from the contaminated zone. Sensitivity analysis showed that annual dose was insensitive to the contaminated zone b-parameter (BCZ) thus the RESRAD default distribution (bounded lognormal-N) and parameters were used. Figure 5–26 graphically illustrates the distribution from which values of the contaminated zone soil b-parameter are sampled. The soil b-parameter is physically limited to values less than approximately 15 (as represented by the vertical red line in Figure 5-26).

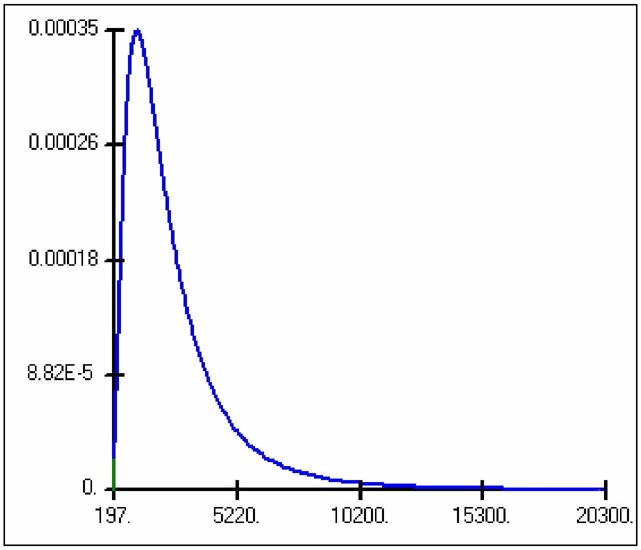


Figure 5-25 Hydraulic Conductivity (m/y)

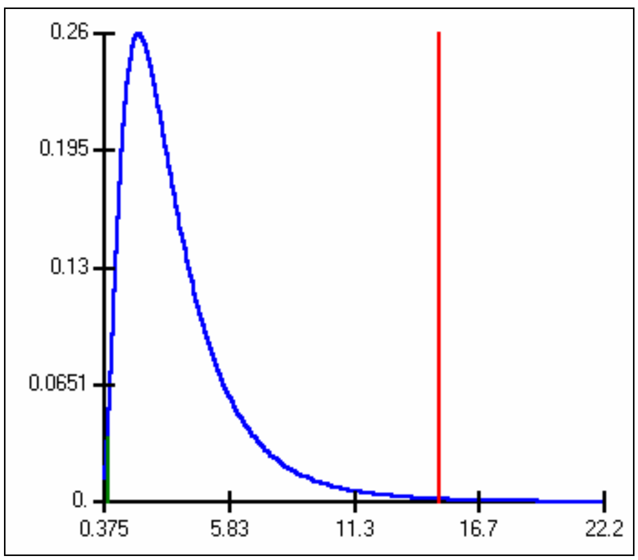


Figure 5-26 Soil Specific b-Parameter (dimensionless)

5.8.4.23 Thorium Distribution Coefficient, Contaminated Zone

Distribution coefficients (K_d) describe the partitioning of soluble concentrations of radionuclides introduced to a soil column between solid (soil) and liquid phases. It is a key parameter influencing the migration of radioactivity from surface soils to groundwater. Distribution coefficients for a given chemical species (e.g., uranium) can vary over many orders of magnitude depending on the soil type, pH, redox potential, and presence of other ions. Observed K_d values for thorium are somewhat less subject to extreme variability.

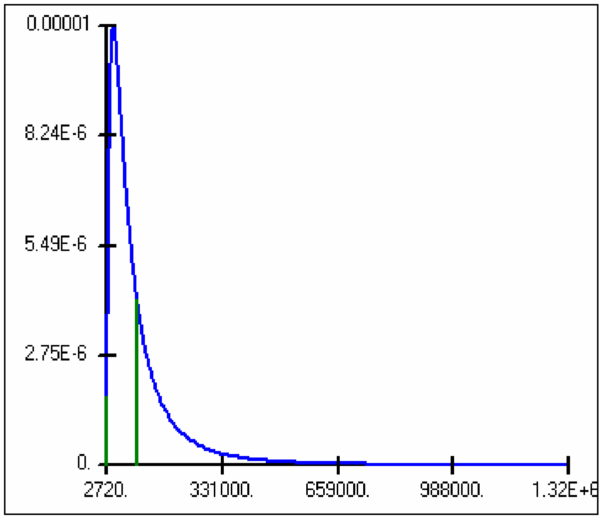


Figure 5-27 Distribution Coefficient—Thorium (cm3/g)

The distribution coefficient, K_d, is the ratio of the mass of solute species adsorbed or precipitated on the solids per unit of dry mass of the soil to the solute concentration in liquids within the pore spaces in the soil. The key component of this definition as it relates to the site-specific conditions at the site and the RESRAD groundwater transport model is that it assumes that the radionuclide is introduced to the soil column as a *solute*. While this classical approach may be appropriate to describe the retardation of soluble contaminant migration in the soil column beneath the contaminated soil layer, it fails to address the situation encountered for the so called "contaminated zone." The site-specific condition encountered at the Tobico Site is that the physical composition of the contaminant is a vitreous slag that is essentially insoluble even under the most extreme in-situ conditions that might reasonably be encountered.

As discussed previously in Section 3 of this Decommissioning Plan, leachability studies performed on comparable thorium-bearing slag found at other locations affirm that very little thorium is expected to be leached out of the slag in the environment. In addition, radiological analysis of leachate samples collected from within the engineered cell support the conclusion that thorium is not readily leached from the slag found at the MDNR site. Given that radio-analytical measurements of the leachate in the cell indicate that radiological contaminants are not present in concentrations greater than that found naturally occurring in unaffected groundwater, the effective K_d value of the contaminated zone is judged to be substantially greater than the RESRAD default value which is derived from data based upon adsorption measurements.

The K_d value for thorium in the contaminated layer is described using the typical, and RESRAD default, lognormal-N distribution function, except that bounds have been established on the range of values sampled during probabilistic analysis (a bounded lognormal-N distribution). The central tendency value for the distribution has been set to match the default, single-point estimate used in the RESRAD deterministic module, 60,000 cm^3/g (Yu 1993, NRC 1980). Probabilistic sampling is bounded between 3,200 and 89,000 cm^3/g, the lowest and highest geometric mean values for various soils as reported in literature and summarized in the *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil* (Yu 1993). Treatment of the contaminated zone K_d value for thorium in this manner is only slightly less conservative than the default treatment of this parameter in RESRAD's probabilistic module and is at least as conservative as the default treatment in RESRAD's deterministic module. A graphic representation of the probability density function describing the thorium K_d parameter for the contaminated zone in the RESRAD probabilistic module is offered in Figure 5-27. The vertical green lines represent the bounding conditions at 3,200 and 89,000 cm^3/g as described. Annual effective dose equivalent is not sensitive to variability in thorium K_d over the wide range considered in the probabilistic assessment.

5.8.4.24 Thickness of the Unsaturated Zone 1

Unsaturated zone 1 is comprised of the sand cover layer and the non-radiological waste materials lying above the undisturbed native till. The sand layer was placed over existing waste materials at the direction of the State of Michigan and prior to slag disposal at the site. From a modeling perspective, the hydro-geologic properties of this layer are characterized as consistent with the sand material, as this represents the most conservative characterization of the layer. Further, the layer is actually saturated as opposed to unsaturated as its name implies.[15] The thickness of unsaturated zone 1 varies inversely with the thickness of the contaminated zone such that the combined thickness of the contaminated zone and unsaturated zone 1 totals approximately 4 meters (13 feet). Sensitivity analysis showed that the annual dose was not sensitive to unsaturated zone thickness. Unsaturated zone 1 thickness (H(1)) is represented with a bounded lognormal-N distribution (the RESRAD default), with a most likely value of 1.52 meters (5 feet) and a range of 0.5 to 4 meters. The H(1) and THICK0 parameters have been inversely correlated in the RESRAD uncertainty analysis (a conservative treatment) to force thinner thicknesses of the underlying unsaturated layer when the contaminated layer is

15 RESRAD accommodates only one "saturated" layer, at least in name. This is, in part, because RESRAD is not designed nor intended to be a comprehensive groundwater fate and transport model and does not seek to model the lateral dispersion of radionuclides. Rather, RESRAD seeks to model the vertical migration of radionuclides from the source term (contaminated zone) through intermediate "unsaturated layers" and into the "saturated layer" from which it is assumed that drinking water may be drawn. This is ideal as long as the groundwater nearest to the ground surface (the uppermost saturated layer) is a potential source is drinking water. This is not the case at the Tobico Marsh Site where the near surface soils are actually saturated and yet are not a viable source of drinking water. RESRAD can easily accommodate this situation by modeling intermediate layers with hydraulic parameters that are characteristic of saturated zones even though RESRAD names such a layer as an "unsaturated zone." This is what has been done in the case of the Tobico Marsh SGA site modeling.

thicker. Figure 5-28 graphically illustrates the distribution from which values of unsaturated zone 1 thickness are sampled.

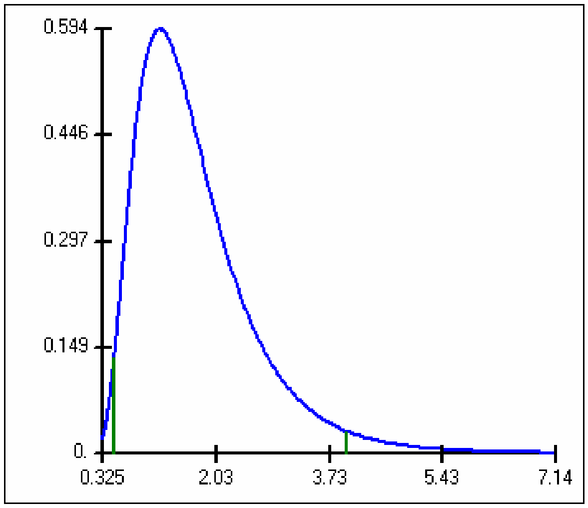


Figure 5-28 Thickness of Unsaturated Zone 1 (m)

5.8.4.25 Density, Unsaturated Zone 1

As described above, Unsaturated Zone 1 is comprised in part of sand materials placed over non-radioactive waste materials. The density of this layer is conservatively estimated to be equal to the measured density of native sand materials at the site, 1.65 g/cm^3 (Cabrera 2001). The same truncated normal distribution used to describe the density of the contaminated zone (see Figure 5-24) is again used to describe the density of unsaturated zone 1 (DENSUZ(1)). Projected annual dose equivalent is insensitive to variation in the density of the unsaturated zone 1 over a wide range of reasonable soil densities.

5.8.4.26 Hydraulic Conductivity, Unsaturated Zone 1

The hydraulic conductivity of unsaturated zone 1 (HCUZ(1)) is also conservatively linked to the measured hydraulic conductivity of the native sand materials. Again, the same bounded lognormal-N distribution used to describe the hydraulic conductivity of the contaminated zone (see Figure 5-25) is used to describe the hydraulic conductivity of unsaturated zone 1. The most likely value described by the distribution is 2,000 meters per year. Projected annual dose equivalent is insensitive to variation in the density of the unsaturated zone 1 over a two decade range of values from 200 to 20,000 m/y.

5.8.4.27 Thorium Distribution Coefficient, Unsaturated Zone 1

The thorium distribution coefficient for all layers underlying the contaminated layer (including unsaturated zone 1) has been set to the RESRAD default distribution and values. The default provides a wide range of possible values from which the uncertainty analysis is performed with a central tendency of approximately 6,000 cm^3/g (an order of magnitude more conservative than the RESRAD deterministic module default value of 60,000 cm^3/g). Sensitivity analysis showed that the annual dose was not particularly sensitive to variability in the thorium distribution coefficient within either of the unsaturated zones or the saturated zone. Figure 5-29 graphically illustrates the range from which values of thorium distribution coefficient within unsaturated zone 1 and 2 as well as the saturated zone [(DCACTU(1), DCACTU(2), and DCACTS] are sampled.

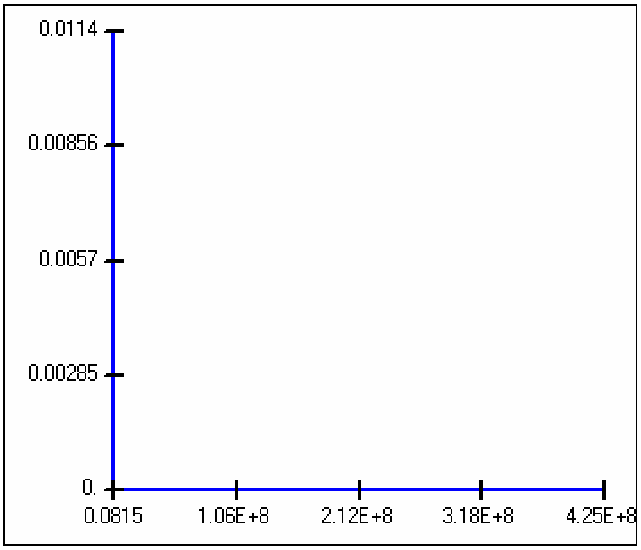


Figure 5-29 Distribution Coefficient—Thorium (cm^3/g)

5.8.4.28 Thickness of the Unsaturated Zone 2

The thickness of unsaturated zone 2 (H(2)) varies from ≈50 to 100 feet (15.25 to 30.5 meters) with a central tendency value conservatively set near the low end of the range at ≈60 feet (18.2 meters). Sensitivity analysis showed that annual dose equivalent was insensitive to unsaturated zone 2 thickness. The thickness is represented with a bounded lognormal-N distribution (the RESRAD default), with a most likely value (18.2 meters) near the lower end of the range that extends from 15.25 to 30.5 meters. Figure 5-30 graphically illustrates the distribution from which values of unsaturated zone 2 thickness are sampled.

5.8.4.29 Density, Unsaturated Zone 2

As described earlier, unsaturated zone 2 is comprised of the undisturbed glacial till layer underlying the entire area. This layer is very dense with clay soils. The soil density of native clay bearing soils at the site was measured to arrive at a site-specific estimate of the soil density of the undisturbed, clay-bearing, native till layer underlying the Site (unsaturated zone 2). The measured soil density was found to be 1.97 g/cm^3, a number typical of high clay content soils (Cabrera 2001). Sensitivity analysis showed that annual dose was insensitive to a wide range of soil densities. Since site-specific data was available for the density of the clay bearing materials at the site, it was used to describe the density of the native till layer. Unsaturated zone 2 soil density (DENSUZ(2)) was represented with a truncated normal distribution (the RESRAD default). The Mean was set equal to the measured density of 1.97 g/cm^3 and allowed to range between approximately 1.6 and 2.4 g/cm^3. This is the same distribution used to represent the soil density of the engineered clay cover and is presented in Figure 5-18.

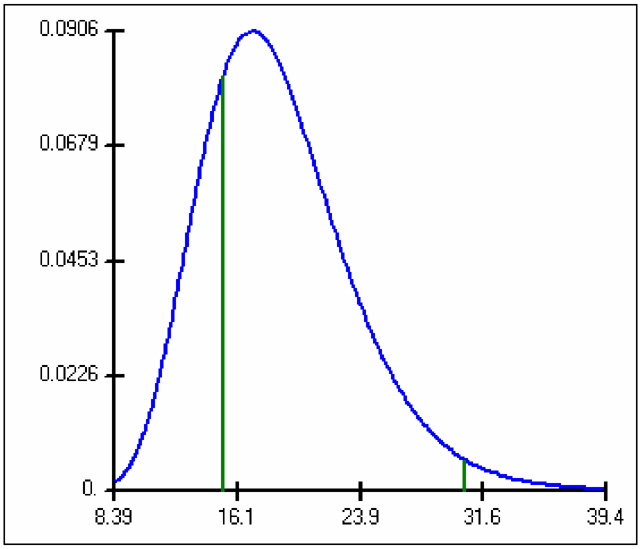


Figure 5-30 Thickness of Unsaturated Zone (m)

5.8.4.30 Hydraulic Conductivity, Unsaturated Zone 2

Hydraulic conductivity was specifically measured for the native clay-bearing materials found at the site and was determined to be 5.4 x 10^{-8} cm/s (≈0.017 m/y) (Cabrera 2001). Hydraulic conductivity in unsaturated zone 2 (HCUZ(2)) is represented with a bounded lognormal-N distribution (the RESRAD default) having a central tendency value at 0.017 meters per year and with values conservatively ranging over two decades between 0.17 and 17 centimeters per year (Figure 5-30). Sensitivity analysis showed that annual dose was insensitive to a wide range of hydraulic conductivities, largely because the thorium and other radionuclides in the contaminated zone are physically and chemically bound up in the slag and because the slag is very insoluble.

5.8.4.31 Thorium Distribution Coefficient, Unsaturated Zone 2

As described in section 5.8.4.27, the thorium distribution coefficient for unsaturated zone 2 is represented with the RESRAD default distribution and fit. See Figure 5-29.

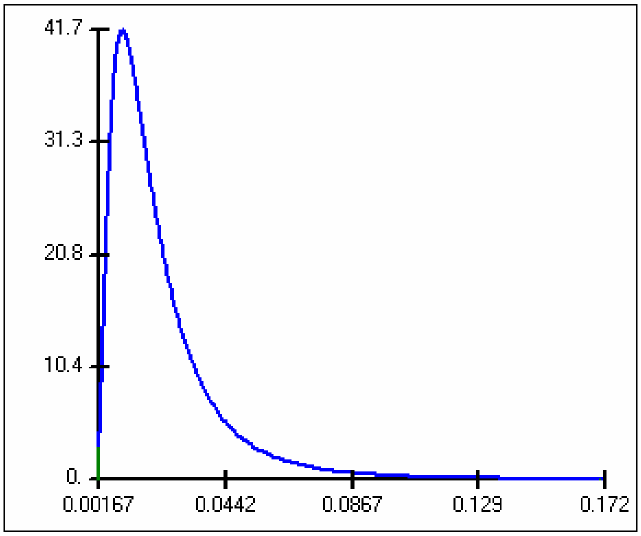


Figure 5-31 Hydraulic Conductivity, Unsaturated Zone 2 (m/y)

5.8.4.32 Density, Saturated Zone

The RESRAD default distribution and fit for the saturated zone density is used in the uncertainty analysis because no site specific data was collected explicitly for this parameter. The truncated normal distribution is centered at the most likely value of 1.52 g/cm^3 and ranges between values of less than 1 and 2.2 g/cm^3. Variability in the saturated zone soil density was shown to have no affect on the projected annual dose in the uncertainty analysis. Figure 5-32 graphically illustrates the distribution from which values of saturated zone density are sampled.

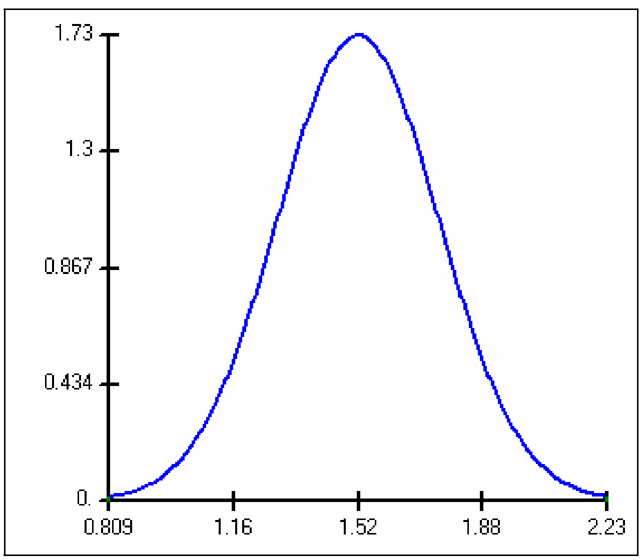


Figure 5-32 Saturated Zone Soil Density (g/cm^3)

5.8.4.33 Hydraulic Conductivity, Saturated Zone

The RESRAD default distribution and fit for the saturated zone hydraulic conductivity (HCSZ) is used in the uncertainty analysis as no site-specific data was collected explicitly for this parameter. The bounded lognormal-N distribution is centered at the most likely value of 10 meters per year and ranges over more than five decades of possible values between approximately 1.5 cm/y and more than 6,700 m/y. Variability in the saturated zone hydraulic conductivity was shown to have no measurable impact on the projected annual dose in the uncertainty analysis. Figure 5-33 graphically illustrates the distribution from which values of saturated zone hydraulic conductivity are sampled.

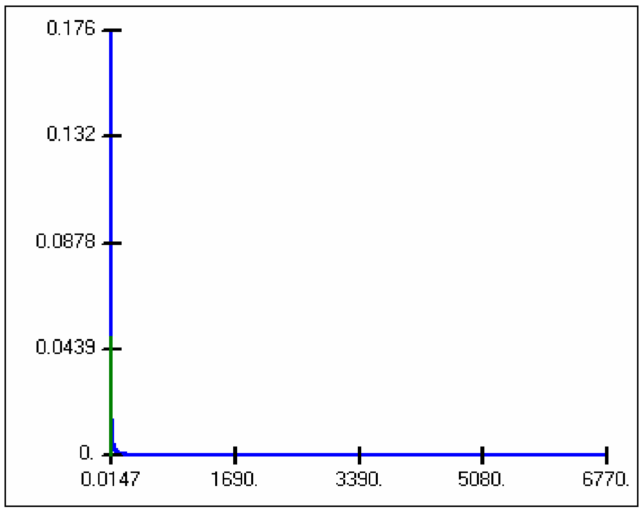


Figure 5-33 Hydraulic Conductivity, Saturated Zone (m/y)

5.8.4.34 Thorium Distribution Coefficient, Saturated Zone

As described in section 5.8.4.27, the thorium distribution coefficient for the saturated zone (DCACTS) is represented with the RESRAD default distribution and fit. (See Figure 5-29).

5.8.4.35 Soil Specific b-Parameter, Saturated Zone

Sensitivity analysis on the effect of variability in the soil-specific exponential b-parameter for the saturated zone (BSZ) showed that annual dose was insensitive to the b-parameter, thus the RESRAD default distribution (bounded lognormal-N) and parameters were used to represent the range of possible values for this parameter in the uncertainty assessment. This is the same distribution that was used to represent the b-parameter within the contaminated zone and presented in section 5.8.4.22 (see Figure 5-26).

5.8.4.36 Saturated Zone Hydraulic Gradient

The hydraulic gradient is one of several hydrogeologic parameters used to calculate radionuclide transport from the contaminated zone. Sensitivity analysis showed that annual dose was insensitive to the hydraulic gradient parameter (HGWT), thus the RESRAD default distribution (bounded lognormal-N) and parameters were used. The central tendency value is estimated to be 0.006 and the distribution is allowed to range over approximately 4 decades from 0.00007 to 0.5. Figure 5-34 graphically illustrates the distribution from which values of the hydraulic gradient parameter are sampled.

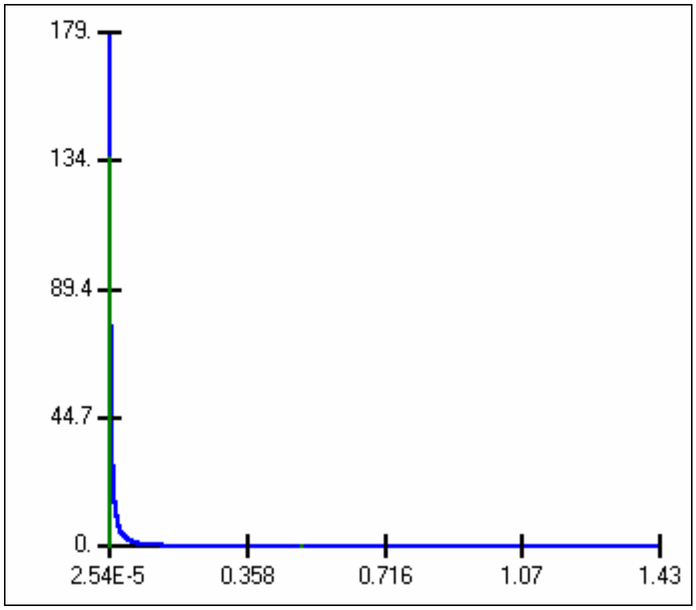


Figure 5-34 Hydraulic Gradient (dimensionless)

5.8.5 Interpreting Uncertainty Analysis Results

Since the result of the uncertainty analysis provides a distribution of annual doses, it must be recognized that some percentage of the calculated doses may exceed the regulatory limit. At the same time, because not all parameter distributions are symmetrical and because some parameters are correlated, the mean dose calculated in the uncertainty analysis is not necessarily equal to a deterministic dose calculated using single point estimates of the various parameters. A further phenomenon observed in the probabilistic modeling is that the mean dose for a particular series of repetitions is frequently higher than the 90^{th} or even the 95^{th} percentile estimates of probable dose. This results when all but the rarest combinations of very conservative estimates of the individual parameters result in little or no dose. In the very few cases in which the Monte Carlo sampling technique selects combinations of values from the outermost extremes of the proposed parameter distributions, projected annual dose is large compared to the majority of cases sampled. The resulting cumulative probability density curve reveals an extremely skewed distribution of projected future dose. An example of this phenomenon as seen in the probabilistic dose modeling of the composite recreational user scenario is evident in Figure 5-35. Here the cumulative probability for annual dose from all nuclides and all pathways is essentially 100% at an annual dose of nearly zero. Yet, there are four samples (out of 1,500 combinations tested) that yielded an estimate of annual dose between 2 and 5 mrem per year. The mean dose is highly influenced by these four results, which themselves represent less than 1% of the estimates. In the case of the composite recreationally user scenarios the mean annual dose is calculated to be 9.3 x10^{-3} mrem/year while the 90th and 95th percentile estimates are 8.4 x10^{-4} and 2.3 x 10^{-3} mrem/year, both substantially less than the calculated and reported mean.

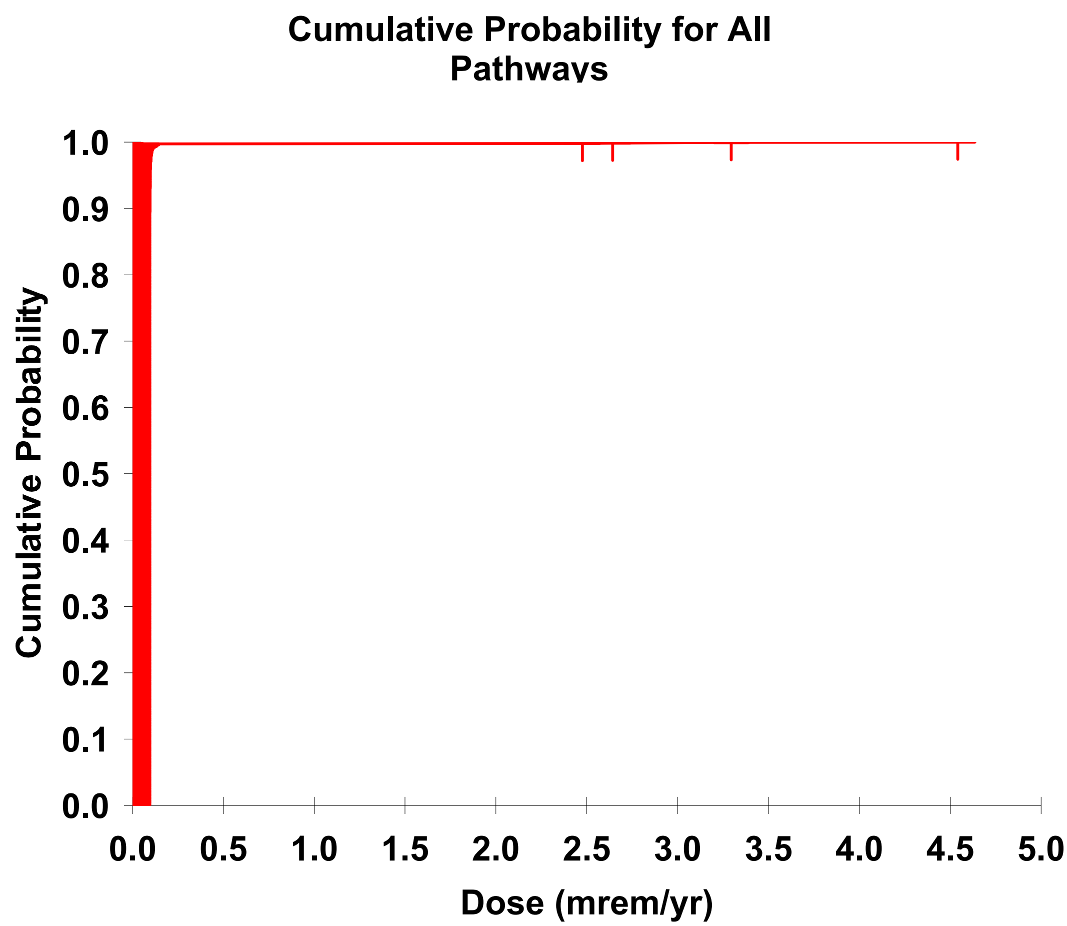


Figure 5-35 Cumulative Probability Plot—Annual Dose, All Pathways (Composite Recreational User Scenario)

A key issue that must be addressed in the treatment of uncertainty is specifying how to interpret the results from an uncertainty analysis in the context of the deterministic regulatory limit. There is no such thing as absolute assurance that the regulatory limit will be met, so regulatory compliance must be stated in terms of a metric of the distribution. Even for a deterministic analysis, it should be recognized that the reported dose is simply one of a range of possible doses that could be calculated for the Site and scenario. In this analysis, the peak of the mean dose for the critical exposure group (the most exposed subpopulation) is presented for comparison with the deterministic regulatory limit as required by regulation. But, since the severely skewed cumulative distribution phenomenon occurs repeatedly in the annual dose modeled for the Tobico

Site using the probabilistic approach, a suite of projected annual doses corresponding to the 50^{th}, 90^{th}, 95^{th}, and maximum is reported along with the traditional compliance measure, peak mean annual dose. In addition, the deterministic estimate of projected annual dose is provided for comparison.

Risk managers should keep in mind that the parameters used to perform the assessment were selected to represent the critical exposure group (analogous to the Reasonable Maximum Exposure concept), and as such already overstate the expected dose to the average receptor at the Site. Results of both the deterministic and probabilistic dose modeling including an evaluation of the uncertainty analysis are presented in sections that follow.

5.9 RESULTS OF COMPUTER MODELING

In order to evaluate the DCGLs, the computer modeling codes were run for each of the selected scenarios using the maximum that are physically possible uniform mean concentrations of residual radioactivity in soil to arrive at the peak mean annual dose estimate in mrem to a single receptor in the critical exposure group. The computer code was set up to model each scenario with the input parameters identified and explained in this section.

The following sections present the results of the computer modeling relating Th-232 source concentrations in soil with potential future doses in each of the four scenarios evaluated.

5.9.1 Recreational Hunter Scenario

The recreational hunter scenario is considered, perhaps, to be the most likely among the future use scenarios considered for this site. Whereas the variety of persons who engage in recreational hunting on the site might spend little time actually on the site, the critical exposure group receptor for this scenario is a conservatively assumed to spend a relatively large fraction of his/her available recreational hunting time actually on the site where the greatest exposure potential occurs. This naturally provides a conservative evaluation of the potential future dose for a more typical hunter making use of the site.

Table 5-11 summarizes the results of modeling the projected future exposure potential for the scenario involving exposure while engaged in recreational hunting at the Site. The isotope mixtures used are typical of, and consistent with, the measured isotopic mixture in soil at the site (Cabrera 2001).

Table 5-11 Recreational Hunter Scenario

Statistic	Projected Annual Dose (mrem/year)
Annual Dose Limit (10 CFR 20.1401, 1402)	25.0
Peak Mean Annual Dose	0.000752
50^{th} Percentile	0.00000792
90^{th} Percentile	0.000811
95^{th} Percentile	0.00269
Maximum Annual Dose	0.0792
Deterministic Estimate, Peak Annual Dose	5.8×10^{-6}
Computer printouts showing source term, dose, and radionuclide contribution distributions are in Appendix A.	

A review of the computer modeling printouts for the recreational hunter scenario (Appendix A) reveals that exposure from gamma radiation dominates the potential future dose and is thus the significant exposure pathway. The Th-232 and Th-228 isotopes are the most significant contributors to total effective annual dose. Figure 5-36 and Figure 5-37 illustrate the relative pathway and isotopic contributions to total effective dose equivalent for the recreational hunter scenario.

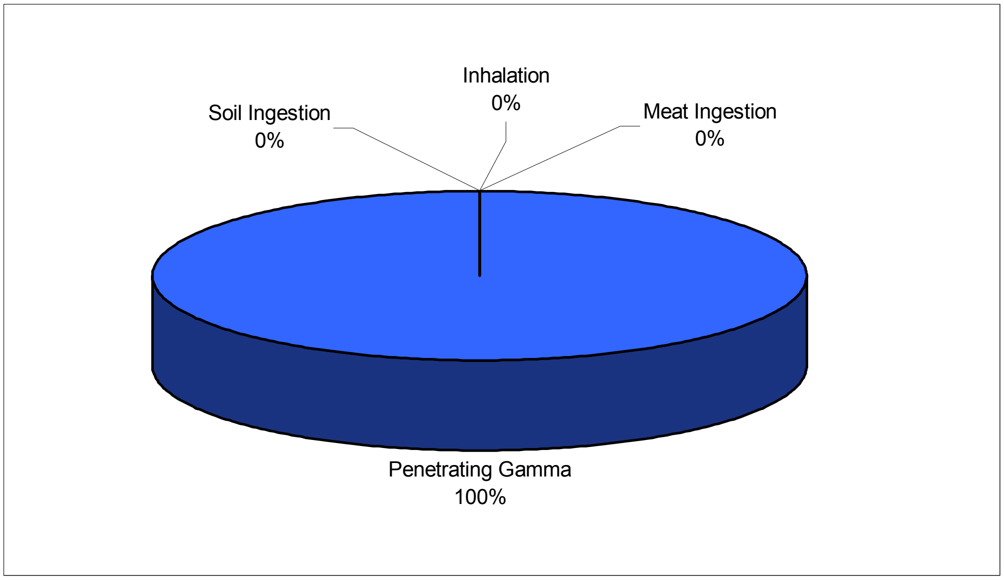


Figure 5-36 Pathway Contributions to Total Effective Dose Equivalent—Recreational Hunter

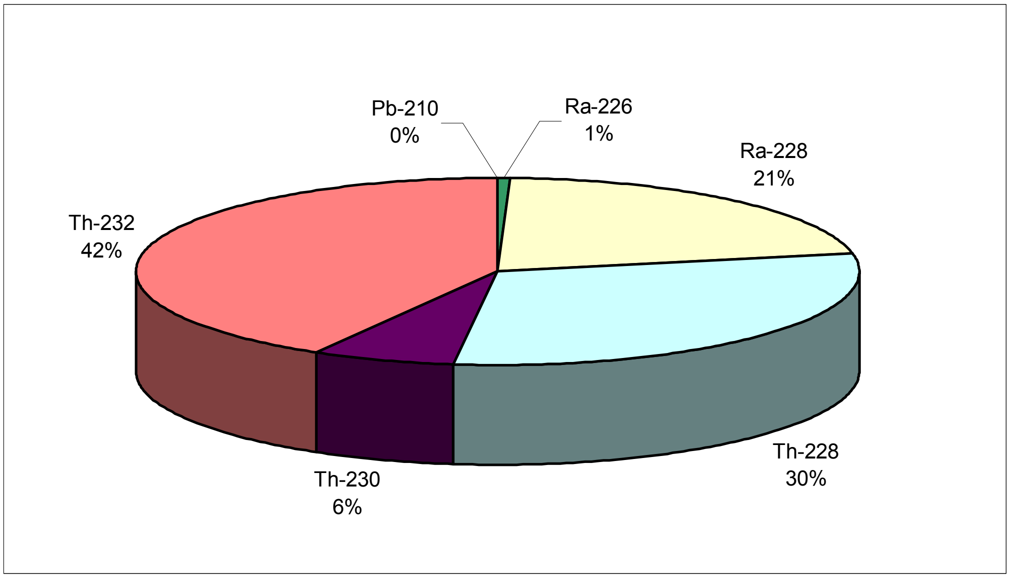


Figure 5-37 Isotopic Contributions to Total Effective Dose Equivalent—Recreational Hunter

5.9.2 Naturalist Scenario

Table 5-12 summarizes the results of modeling the projected future exposure potential for the scenario involving exposure while engaged in nature viewing at the site. The isotope mixtures used are consistent from one scenario to the next and consistent with the measured isotopic mixture in soil at the site.

Table 5-12 Naturalist Scenario

Statistic	Projected Annual Dose (mrem/year)
Annual Dose Limit (10 CFR 20.1401, 1402)	25.0
Peak Mean Annual Dose	0.000752
50^{th} Percentile	0.00000792
90^{th} Percentile	0.000811
95^{th} Percentile	0.00269
Maximum Annual Dose	0.0792
Deterministic Estimate, Peak Annual Dose	5.8×10^{-6}
Computer printouts showing source term, dose, and radionuclide contribution distributions are in Appendix B.	

A review of the computer modeling printouts for the naturalist scenario (Appendix B) reveals that exposure from gamma radiation again dominates the potential future dose and is thus the significant exposure pathway. The Th-232 and Th-228 isotopes are the most significant contributors to total effective annual dose. In fact, the relative contributions to total annual dose by isotope are consistent with the results from the recreational hunter scenario because neither the meat ingestion pathway nor the plant ingestion pathway contributes significant dose to either total. Figure 5-38 and Figure 5-39 illustrate the relative pathway and isotopic contributions to total effective dose equivalent for the naturalist scenario.

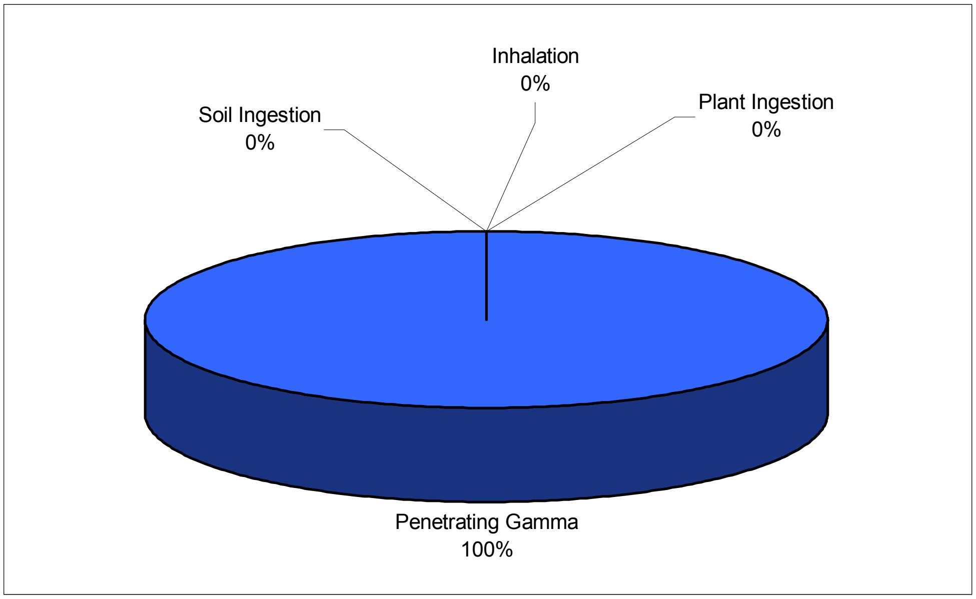


Figure 5-38 Pathway Contributions to Total Effective Dose Equivalent—Naturalist

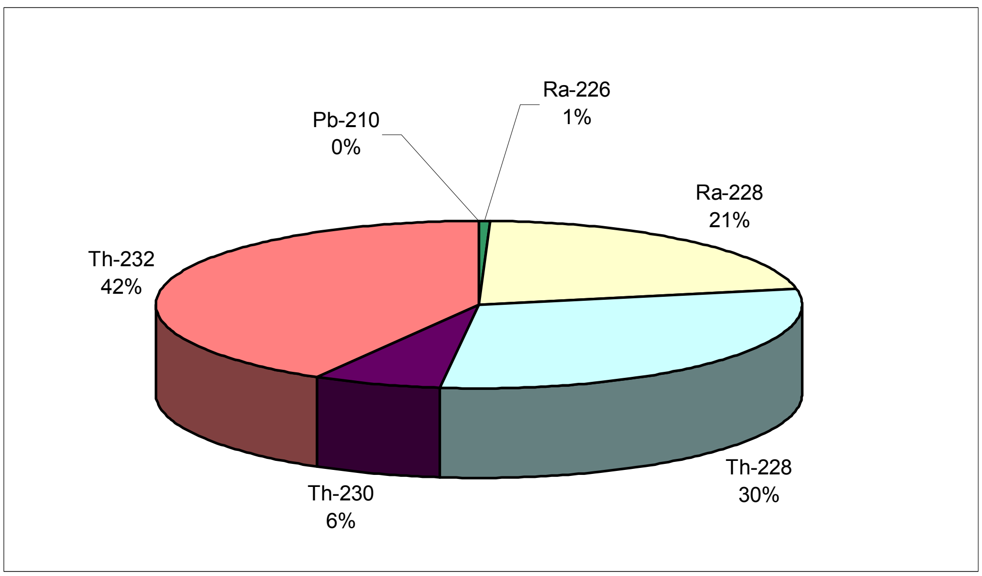


Figure 5-39 Isotopic Contributions to Total Effective Dose Equivalent—Naturalist

5.9.3 Recreational Fisher Scenario

The recreational fisher scenario evaluates the potential exposure to receptors that could be expected to frequent the property to fish. It was conservatively assumed that as much as 100% of the fisher's aquatic foods diet could be derived from waters on the site that are impacted with residual radioactivity.

Table 5-13 summarizes the results of modeling the projected future exposure potential for the scenario involving exposure while engaged in recreational fishing at the site. The isotope mixtures used are consistent from one scenario to the next and consistent with the measured isotopic mixture in soil at the site.

Table 5-13 Recreational Fisher Scenario

Statistic	Projected Annual Dose (mrem/year)
Annual Dose Limit (10 CFR 20.1401, 1402)	25.0
Peak Mean Annual Dose	0.0301
50th Percentile	0.00000807
90th Percentile	0.000841
95th Percentile	0.00298
Maximum Annual Dose	23.3
Deterministic Estimate, Peak Annual Dose	5.8×10^{-6}
Computer printouts showing source term, dose, and radionuclide contribution distributions are in Appendix C.	

A review of the computer modeling printouts for the recreational fisher scenario (Appendix C) reveals that exposure from gamma radiation is consistent with that calculated in the recreational hunter and naturalist scenarios but that dose from the aquatic foods ingestion pathway is significant when the considering the extreme quantile estimates (>99th percentile) of dose. In fact, because of the extreme skewness in projected dose from the aquatic foods ingestion pathway, both the maximum and peak annual dose is dominated by the aquatic foods ingestion pathway in the out years approaching 100 years. Th-232 is the most significant contributor to total effective annual dose. Figure 5-40 and Figure 5-41 illustrate the relative pathway and isotopic contributions to total effective dose equivalent for the recreational fisher scenario.

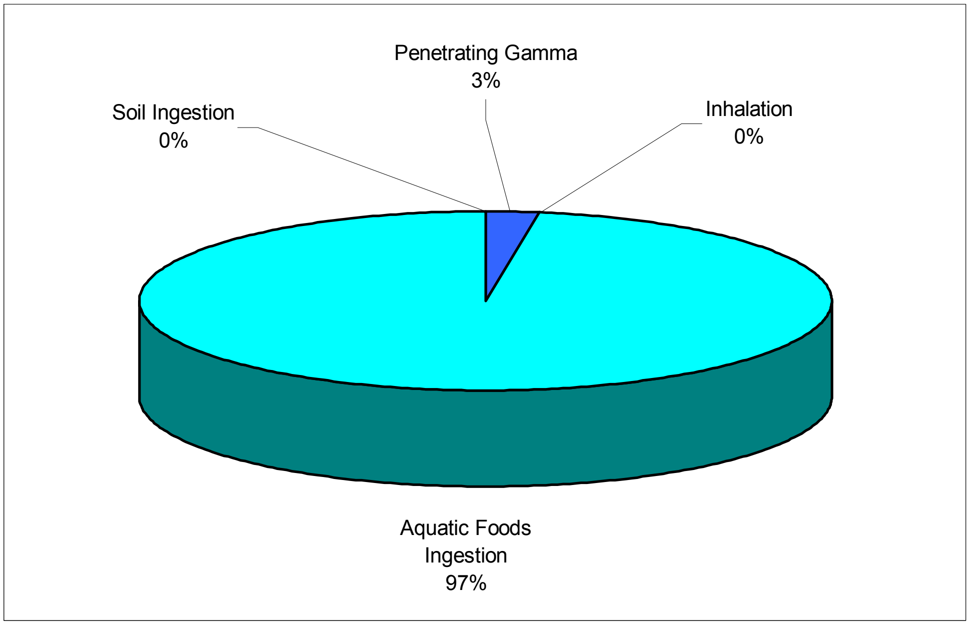


Figure 5-40 Pathway Contributions to Total Effective Dose Equivalent—Recreational Fisher

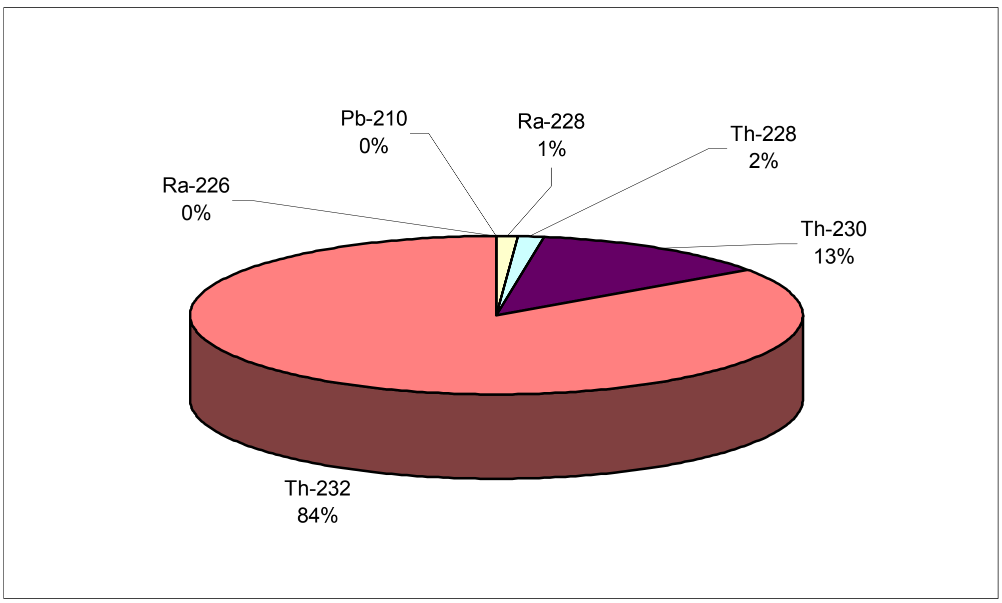


Figure 5-41 Isotopic Contributions to Total Effective Dose Equivalent—Recreational Fisher

5.9.4 Composite Recreational User Scenario

The composite recreational user scenario serves as a bounding condition scenario and evaluates the potential exposure to receptors that could be expected to frequent the site to hunt, fish, and view nature. The hypothetical receptor consumes plant food grown on the site, meat harvested from the site, and aquatic foods caught from the waters of the site.

Table 5-14 summarizes the results of modeling the projected future exposure potential for the scenario involving exposure while engaged in multiple recreational activities at the site. The isotope mixtures used are consistent from one scenario to the next and consistent with the measured isotopic mixture in soil at the site.

Table 5-14 Composite Recreational User Scenario

Statistic	Projected Annual Dose (mrem/year)
Annual Dose Limit (10 CFR 20.1401, 1402)	25.0
Peak Mean Annual Dose	0.0093
50^{th} Percentile	0.00000799
90^{th} Percentile	0.000856
95^{th} Percentile	0.00245
Maximum Annual Dose	4.54
Deterministic Estimate, Peak Annual Dose	5.8×10^{-6}
Computer printouts showing source term, dose, and radionuclide contribution distributions are in Appendix D.	

A review of the computer modeling printouts for the recreational hunter scenario (Appendix A) reveals that exposure from gamma radiation dominates the potential future dose and is thus the significant exposure pathway. The Th-232 and Th-228 isotopes are the most significant contributors to total effective annual dose. Figure 5-42 and Figure 5-43 illustrate the relative pathway and isotopic contributions to total effective dose equivalent for the composite recreational user scenario.

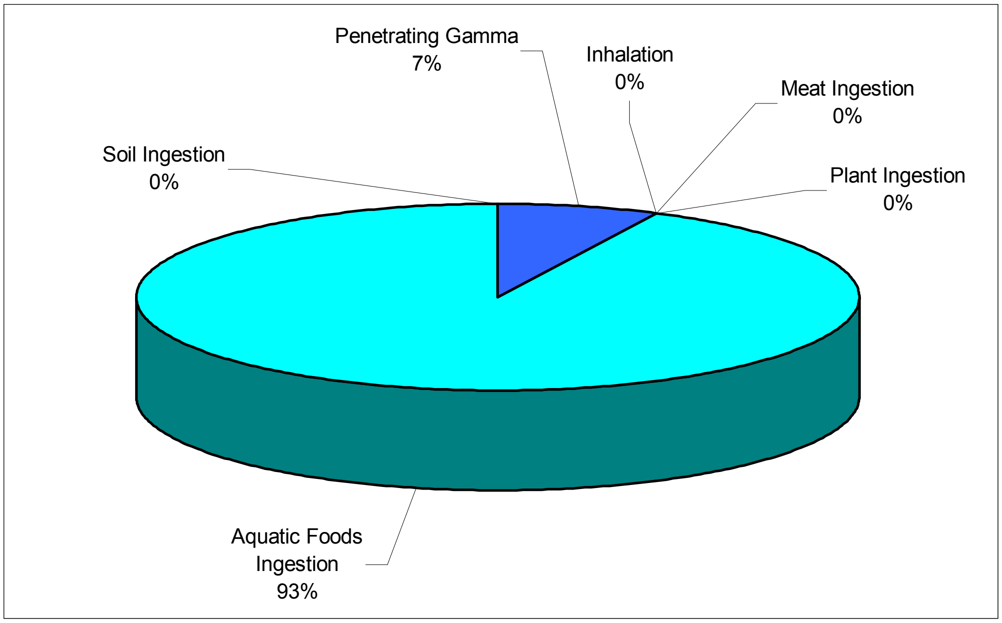


Figure 5-42 Pathway Contributions to Total Effective Dose Equivalent—Composite Recreational User

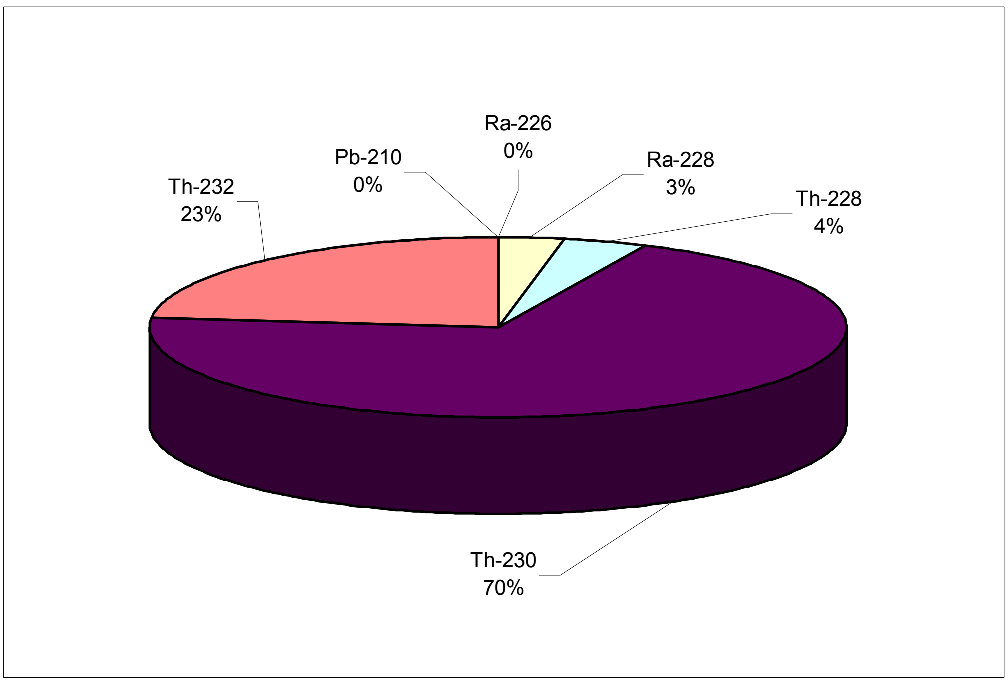


Figure 5-43 Isotopic Contributions to Total Effective Dose Equivalent—Composite Recreational User

5.9.5 Potential for the Migration of Radioactivity Offsite

The radioactivity at the Tobico Marsh SGA Site has been shown (at present) to be confined laterally to the area circumscribed by the installed slurry walls and vertically to the contaminated layer just beneath the cover. Still, there is need to provide assurance that the radioactivity will remain (over the next 1,000 years) confined to a satisfactory degree such that the potential dose impacts to a receptor offsite will also be within the acceptable public dose limits.

The potential for dose to an offsite receptor resulting from the migration of radioactivity offsite is constrained by the surface soil erosion rate (coupled with the cover thickness) and by the ability of radioactivity to migrate through groundwater.[16] By considering the radionuclide concentrations in various media (e.g., surface water, surface soil, etc.) projected for 1,000 years into the future, the potential for offsite dose can reasonably be eliminated. The RESRAD output reports (Part IV) for each of the four scenarios evaluated (See Appendices A-D, Part IV, *Detailed Concentrations and Radionuclides Report*) shows that at no time over the 1,000 year outlook period are concentrations of radionuclides projected to be present in either environmental media or in foodstuffs. The absence of radioactivity in these media, while taking into account the potential erosion of the cover and the mobility of radionuclides in groundwater, suggest that offsite dose is not a concern even if the slurry walls should leak. Sampling from within the cell itself has shown that concentrations of radioactivity in the leachate are not different from those in unaffected background groundwater samples.

5.10 SUMMARY OF MODELING RESULTS

The estimates of peak mean dose to the critical exposure groups in each of the foregoing scenarios have been derived with industry standard modeling tools specifically designed to assess exposures to residual radioactivity. The RESRAD modeling code is recognized as an industry standard, and is accepted for use by the USNRC, USDOE, and USEPA for modeling dose and risk to individuals exposed to radioactivity originating in soils.

Conservatism has been built into the modeling by conscientiously selecting exposure factor values that err on the side of safety when confronted with uncertainty in the selection of input parameters. In order to provide the risk managers and decision makers with insight as to the degree of conservatism associated with the dose modeling, projected annual doses have been calculated with both deterministic and probabilistic techniques.

Based on the results presented above, each of the scenarios considered is projected to produce a peak mean annual dose well below the annual public dose limits identified by the USNRC (10 CFR 20.1402).

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16 It is important to note that the RESRAD dose modeling performed takes no credit for the ability of the slurry walls to impede or retard lateral movement of radioactivity through groundwater.

The dose evaluation described in this report provides the risk managers and decision makers with the substantive basis necessary to set and approve site-specific permissible concentration standards, the DCGLs, derived from the applicable regulatory limits for public dose.

The projected annual dose at the physically limiting specific activity for Th-232 is not constrained by the permissible decommissioning dose standard of 25 mrem/y. That the residual radioactivity concentration could safely excursion to the specific activity limit without impacting compliance, provides the risk managers and decision makers with clear margin of safety upon which to evaluate public health impacts resulting from exposure to residual radioactivity at the site. Additionally, the projected peak annual dose for each scenario has been derived with a level of conservatism commensurate with the extent of the hazard and uncertainty in the estimation tools.

6.0 ALTERNATIVES ANALYSIS

The preferred alternative chosen by MDNR, as described in the Tobico Marsh SGA Site Decommissioning Plan, is essentially the No Action Alternative in that it does not result in the removal of source term. Two additional decommissioning alternatives were identified and considered for the decommissioning plan. These alternatives include: 1) complete removal of waste cell contents (both radiological and chemical hazards) and, 2) removal of only the radiological hazard from the waste cell.

The rationale behind consideration of the 2 "action" alternatives is positive in theory, in that both alternatives effectively removes the radioactive source term from the site and obviates the need to consider any future exposure potential from residual radioactivity to a receptor at the site.

However, during the consideration of the alternatives listed above, it was determined that neither alternative was identified as an environmentally sound option, and were rejected as viable alternatives. Either alternative would have required the degradation of the currently installed clay cover, thus exposing workers, residents of the area, or the environment to the chemical hazards buried within the waste cell. In addition, access roads would be required to be constructed, or improved, to facilitate the movement of heavy equipment and materials to and from the site, scaring the pristine landscape of the SGA. The construction of a rail spur, necessary for waste shipment, would be required to transport hazardous waste to an off-site waste repository, increasing the magnitude of damage and scaring of SGA lands. Hypothetical spills during the transport of chemical or radioactive waste removed from the waste cell would negatively impact the currently unaffected landscape and require additional remediation activities of previously unaffected land. Local wildlife and its habitat would be temporarily disturbed during the construction of access roads and the rail spur, as well as during remediation of the waste cell.

The environmental impact presented by the release of the chemical constituents buried and contained within the waste cell, realized or potential, limited the serious evaluation of either of the two alternatives. The preferred alternative, as described in this decommissioning plan, offers the most technically feasible and environmentally responsible option of all the creditable decommissioning alternatives offered. It also eliminates the unacceptable risk of damage to the environment from chemical contamination, for a net gain of source term removal from the waste cell.

7.0 ALARA ANALYSIS

This As Low As Reasonably Achievable (ALARA) analysis is provided to demonstrate that the dose criteria in Subpart E of 10 CFR Part 20 (NRC 1997a) has been met and concludes whether it is reasonable to further reduce the levels of residual radioactivity to levels below those necessary to meet the dose criteria (i.e., to levels that are ALARA).

It is MDNR's intention to terminate and remove above grade components and piping of the LCTS and to perform a final status survey of the single building structure located on site, such that it meets the unrestricted use criteria presented in 10 CFR 20.1402 (NRC 1997a). The only other credible remedial activity available is the removal of subsurface soils from the site with shipment to a low-level waste disposal facility.

Based on the licensee's decision to perform remedial activities to meet unrestricted use criteria limits, and using appropriate dose modeling to relate concentrations to dose, the licensee can take advantage of the allowance given in Section 1.5, Appendix D of NUREG-1727 (NRC 2000) which states "In certain circumstances, the results of an ALARA analysis are known on a generic basis and an analysis is not necessary. For residual radioactivity in soil at sites that will have unrestricted release, generic analysis show that shipping soil to a low-level waste disposal facility is unlikely to be cost effective for unrestricted release, largely because of the high cost of waste disposal. Therefore shipping soil to a low level waste disposal facility generally does not have to be evaluated for unrestricted release." In this regard, the results of an ALARA analysis are "known on a generic basis and an analysis is not necessary."

8.0 PLANNED DECOMMISSIONING ACTIVITIES

One building, constructed after the slurry walls and clay cover were installed, is present at the site. The building was designed to house equipment and controls associated with a LCTS that was installed within the slurry walls. The LCTS, designed by the MDEQ to address non-radiological contaminants, was never on-line and operational.

The building was used as a staging area and shelter during the performance of site characterization surveys and to temporarily store containerized, potentially contaminated personal protective equipment (PPE) and sampling-derived waste. The location of the building is identified on the site map, Figure 8-1.

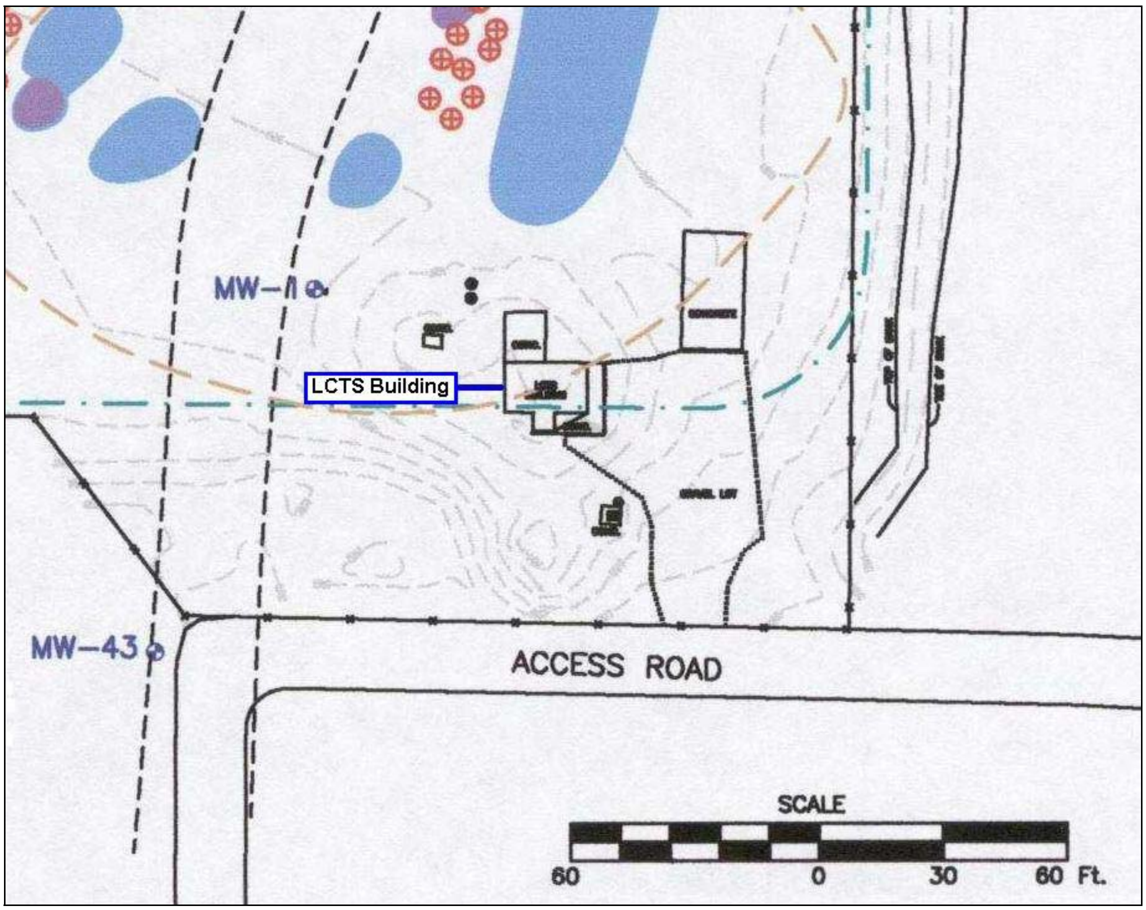


Figure 8-1 LCTS Building Location

Quarterly radiological surveys performed on site, including surveys of the building and its contents, have provided evidence that the building and its contents are not radiologically contaminated.

The scope of this Decommissioning Plan includes the removal of above grade components so as to render it inoperable and to preclude access to the environment below the engineered clay cover where radioactive material is located. In addition to isolation, sealing, and abandonment (just below grade level) of the LCTS, the final status radiological survey of the LCTS building located on site is planned. It is the objective of MDNR to perform this scope of work such that the Tobico Marsh SGA site will meet the criteria for unrestricted use as specified by 10 CFR 20.1402.

8.1 CONTAMINATED STRUCTURES

There are no contaminated structures located on site, and remediation activities are not planned. The LCTS building has been used to store used PPE and sample-derived wastes from previous sampling events in containerized packaging. Radioactive contamination is not known or expected to be present on building surfaces.

8.2 CONTAMINATED SYSTEMS AND EQUIPMENT

There are no contaminated systems or equipment on site, and remediation activities are not planned.

8.3 SOIL

There are no soils at the site (and within the cell) that exceed the 1.09 $x10^{-1}$ μCi/g derived soil DCGL for Th-232.

8.4 SURFACE AND GROUNDWATER

There is no surface water or groundwater that contains residual radioactivity in excess of site background levels, and remediation activities are not planned.

8.5 USE OF APPROVED PROCEDURES

MDNR commits to conducting decommissioning activities in accordance with written and approved procedures.

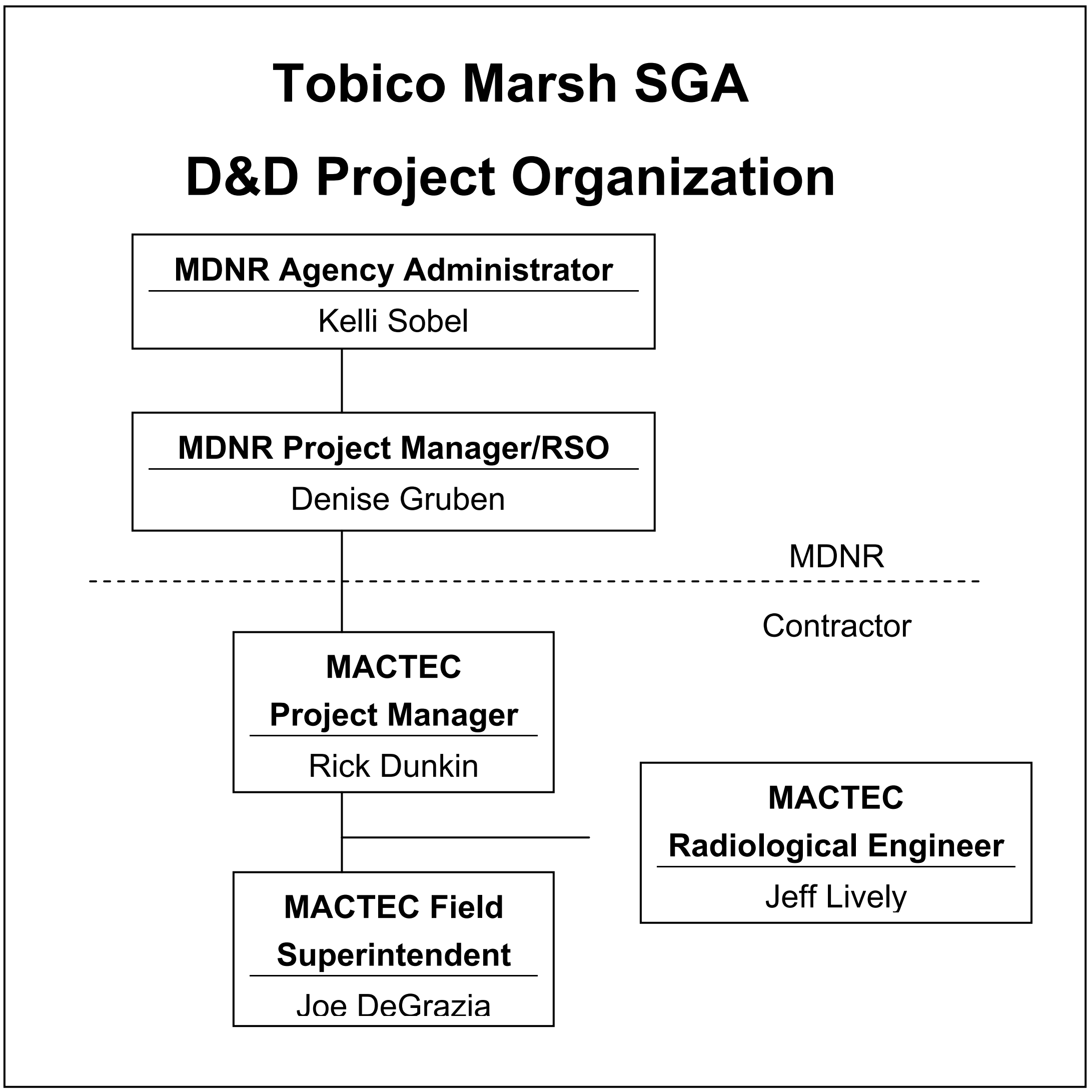
8.6 SCHEDULES

Removal of the LCTS and the performance of a final status survey of the building are scheduled (Figure 8-2) for completion December 2003 whether or not this plan has been approved by the NRC.

9.0 PROJECT MANAGEMENT AND ORGANIZATION

9.1 DECOMMISSIONING MANAGEMENT ORGANIZATION

The functional organization for the completion of decommissioning activities includes the Project Manager; Site Manager; Site Health, Safety Officer; Quality Assurance Manager; Radiation Safety Officer; and support personnel, as required. Figure 9-1 shows the functional organization and the relationship to MDNR.



9.2 DECOMMISSIONING TASK MANAGEMENT

Activities involving licensed material shall be conducted in accordance with approved, written procedures, and/or radiation work permits (RWP). Decommissioning tasks shall be managed through procedures and/or RWPs.

RWPs are managed in accordance with a written procedure. The procedure addresses request, initiation, development, issuance, and termination of an RWP. The RWP will normally be requested by the supervisor of a particular activity. The request will include a description of the activity to be performed and authorized users of the RWP. Subsequently, the supervisor or Health and Safety Officer shall initiate the RWP and provide description on the RWP of existing and/or anticipated radiological conditions.

After initiation, the supervisor or Health and Safety Officer shall develop the RWP. The development effort includes specific identification of the radiological conditions and radiological protection requirements (e.g. clothing, respiratory protection, dosimetry, monitoring, training). In addition, hold points and special instruction may be described on the RWP. The development effort also includes creating a sign-in/out sheet for use by the authorized users. The development effort ends with approval of the RWP by the RSO or his/her designee. Following development, the RWP is issued to the authorized users. The RWP form contains the job description, location, known radiological conditions, protective clothing requirements, respiratory protection, dosimetry, training, HP monitoring requirements, and any other special instructions. Issuance includes a review of RWP with the authorized users, as required. A pre-job meeting may be prerequisite to issuance of the RWP. During use, a copy of the RWP is maintained at the worksite, and authorized users are required to sign-in/out when participating in the subject activity, indicating their understanding of the requirements of the RWP. The RWP is terminated upon completion of the subject activity. Termination is identified by signature on the RWP and completion of a checklist indicating reason for termination and confirmation of final radiological survey of the activity or area. Upon termination of the RWP, a package is completed and filed. The package contains the RWP, RWP request form, sign-in sheets, applicable radiological surveys, and any other documents pertinent to the job. If radiological conditions or requirements change, a new or revised RWP will be issued.

9.3 DECOMMISSIONING MANAGEMENT POSITIONS AND QUALIFICATIONS

9.3.1 Project Manager

The Project Manager (PM) has overall responsibility for the safe conduct of the project. This individual provides the senior project management oversight for implementation and execution of a project specific Quality Assurance program, a project-specific radiological health and safety program, and for compliance with all local, state, and federal regulations. The Project Manager has further assigned these responsibilities to the Site Manager, the Site Health & Safety Officer, and the Quality Assurance Manager.

9.3.1.1 Experience and Qualifications

The Project Manager will hold a degree in science or engineering or have equivalent knowledge, and shall have a minimum 15 years of experience, at least 5 years of which shall be in a project management role.

9.3.2 Site Manager

The Site Manager is responsible for all operational aspects of decommissioning project performance. This individual is responsible for implementation and oversight of the decontamination and dismantlement activities including waste management and engineering support. The Site Manager is responsible for ensuring that Safe Work Plans are approved and current for each specific work activity, the labor workforce possesses and maintains the project, and site-specific training required to complete the project safely.

9.3.2.1 Qualifications and Experience

The Site Manager will hold a degree in science or engineering or have equivalent knowledge, and have at least 10 years supervisory or management experience, with at least 5 years decontamination and decommissioning experience, and 10 years of construction experience.

9.3.3 Site Health & Safety Officer

The Site Health & Safety Officer (HSO) is responsible for the implementation of on site health and safety including appropriate implementation of radiological health and safety, and regulatory compliance[17]. The HSO will perform routine safety inspections to ensure compliance with all regulatory requirements, review and validate analytical and air monitoring data, and perform monthly and quarterly self-assessments. In addition, the

17 The Site Health & Safety Officer will have professional level health physics support (as necessary) to assure the proper implementation of the radiation protection program for decommissioning activities and the safe conduct of work involving radioactive materials at the site.

HSO will develop, implement, and maintain a training matrix for personnel assigned to the project and ensure that required qualifications are maintained current through timely notification of training requirements and scheduled training to the Site Manager. The HSO will keep the RSO informed of issues related to the radiological status of the site and activities performed at the site.

9.3.3.1 Experience and Qualifications

The HSO shall hold a degree in science or engineering or have equivalent knowledge, and have at least 5 years experience in areas such as radiation safety, radiation monitoring, emergency preparedness, industrial safety, and personnel exposure evaluation. The HSO shall have demonstrated a proficiency to conduct specified radiation safety programs, recognize potential radiation and chemical safety problem areas in operations and advise operation supervision on radiation protection matters. The HSO shall be capable of directing the surveillance activities of the Health Physics Technicians.

The duties and responsibilities of the HSO include, but are not limited to:

- Surveillance of overall activities involving radioactive material, including monitoring and surveys of all areas in which radioactive material is used.

- Determine compliance with rules and regulations, and license conditions.

- Monitor and maintain absolute and other special filter systems associated with the use, storage, and disposal of radioactive material.

- Provide necessary information on all aspects of radiation protection to personnel at all levels of responsibility, pursuant to 10 CFR 19, and 10 CFR 20.

- Proper delivery, receipt, and conduct of radiation surveys of all shipments of radioactive material arriving at or leaving the site within the scope of this license, including proper packaging and labeling of that radioactive material.

- Distribute and process personnel monitoring equipment, determine the need for evaluation of bioassays, monitor personnel exposure and bioassay records for trends and high exposures, and notify individuals and their supervisors of exposures approaching maximum permissible amounts and recommend appropriate remedial action.

- Conduct or provide oversight of training programs and otherwise instruct personnel in the proper procedures for the use of radioactive material prior to use, at periodic intervals (refresher training) and as required by changes in procedures, equipment and regulations, etc.

- Supervise and coordinate the radioactive-waste disposal program, including effluent monitoring and maintenance of waste storage and disposal records.
- Store radioactive materials not in current use, including wastes.
- Perform or arrange for calibration of radiation survey instruments.
- In conjunction with the site RSO, maintain an inventory of all radioisotopes on site and limit the quantity of radionuclides on site to the amounts authorized by the license.
- Immediately terminate any activity that could pose a threat to public, workers or the environment.
- Supervise decontamination, renovation, material control, remediation, and decommissioning operations.
- Maintain other records not specifically designated above, e.g., receipt, transfer, and survey records as required by 10 CFR 30.51, "Records," and 10 CFR Part 20, Subpart L, "Records" (NRC 1992b).
- Conduct periodic meetings with and reports to project management, MDNR management, and the RSO.
- Designate and maintain a list of qualified supervisors and users of licensed materials. Qualified individuals will be identified through evaluation of previous job experiences, education, and/or site-specific training programs.
- Develop and maintain training programs in accordance with 10 CFR Part 19.12.
- Develop and maintain operational Radiation Protection procedures to ensure program implementation and compliance with regulatory requirements.
- Maintain records of licensed material accumulation and transfer as required to support inventory and accountability.

9.3.4 Quality Assurance Manager

The Quality Assurance Manager is responsibility for the implementation and execution of Quality Assurance and Control procedures and practices including supervision of the project's Document Control procedures. This individual is also responsible for preparation, implementation, and oversight of the Self-Assessment and Audits procedures, including identification of deficiencies and improvements, corrective actions, and feedback.

9.3.4.1 Qualifications and Experience

The Quality Assurance Manager shall hold a degree in science or engineering and have a minimum of 5 years experience in management, with a minimum of 2 years experience in oversight and responsibility for quality assurance and quality control issues.

9.3.5 Radiation Safety Officer

The duties, responsibilities, qualification and experience requirements for the Radiation Safety Officer are defined in the NRC issued radioactive materials license No. SUC-1581 (NRC 1999a).

9.4 TRAINING

Training will be performed in accordance with the applicable material license and all regulatory requirements.

10.0 RADIATION PROTECTION PROGRAM DURING DECOMMISSIONING

This program and associated operating procedures are the primary means used to administratively establish safe radiation work practices and ensure compliance with the requirements of the NRC.

10.1 RADIATION SAFETY CONTROLS AND MONITORING FOR WORKERS

10.1.1 Workplace Air Sampling Program

Concentrations of radioactive material in air will be determined, as needed, by sampling the air. Air sampling shall be conducted in accordance with (or equivalent to) the guidance provided in NRC Regulatory Guide 8.25, "Air Sampling in the Workplace", July 1992 (NRC 1992a). The samples will be collected under known physical conditions (e.g. filter, sample time, flow rate). The flow meters of air samplers shall be calibrated at least annually. Calibration shall also be performed after repair or modification of the flow meter.

Air samples will be collected from general and localized areas when and/or where there is potential for generation of airborne radioactive material. These samples will be used to verify that the confinement of radioactive material is effective, and provide warning of elevated concentrations for planning or response actions. In each case, the sampling point will be located in the airflow pathway near the known or suspected release point(s). As necessary, more than one air sample location may be used in order to provide a reasonable estimate of the general concentration of radioactive material in air.

The RSO shall apply professional judgment and experience to identify air sampling appropriate for the specific situation. Such judgment will be based on historical air sampling and characterization results, quantity of contamination of the material being handled, potential for release of contaminants based on physical form and activity, type of confinement or containment, and other factors specific to the activity.

Air sampling of the workplace will also be conducted under the following two conditions:

A. Areas with removable contamination greater than 1,000 dpm/100cm^2 and the worker is actively working in the area for greater than one hour during that workday; or

B. Areas with total contamination greater than 5,000 dpm/100 cm^2 and the work involves invasive activities such as drilling, scabbling, digging, or otherwise causing the release of contaminants or contaminated material into the air.

As familiarity with work activities increases, the RSO may modify the aforementioned conditions. Any modification will be explained and justified in writing by the RSO.

An administrative action level shall be established for breathing zone air samples of one derived air concentration (DAC); air sample results greater than this administrative action level shall be reported to the RSO. An administrative limit shall be established for breathing zone air samples of 12 DAC-hours per week; individual exposure greater than this action level shall require the individual to be restricted from work involving potential exposure to airborne radioactive material unless approved by the RSO.

10.1.2 Respiratory Protection Program

The respiratory protection program (program) provides guidance and instruction regarding protection of workers from occupational injury and illness due to exposure to airborne radioactive material. The program is implemented by written procedures. The program and implementing procedures are the primary means used to administratively establish safe respiratory protection practices and compliance with requirements of the NRC.

The program covers routine use of respiratory protection equipment. The functional areas of the program include medical evaluation; fit testing, selection, issue, inspection, use, cleaning, maintenance, storage, and training.

- Medical

  Prior to the initial fit test, and at least every 12 months thereafter, an evaluation will be made of each worker required to wear respiratory protection equipment as part of the worker's duties as to whether or not the worker can wear the required respirator without physical risk. A worker will not be allowed to wear a particular type of respirator if, in the opinion of a physician, the worker might suffer physical harm due to wearing the respirator. A worker shall not be allowed to use a respirator without a current medical evaluation.

- Fit Test

  All workers required to wear respiratory protection equipment shall be required to successfully complete a fit test prior to initial use of the equipment. The fit test shall be repeated at least annually. A worker shall not be allowed to wear a respirator without a current successful fit test.

- Selection

  Respirators shall be selected from those approved by the National Institute for Occupational Safety and Health for the contaminant or situation to which the worker may be exposed. Health Physics shall select the respirator type. Selection shall be based on the physical, chemical, and physiological properties of the contaminant, the contaminant concentration likely to be encountered, and the likely physical conditions of the workplace environment in which the respirator will be used.

- Issue

  Respirators, when it is determined to be necessary, shall only be assigned or issued to workers qualified, with respect to the program, to use respiratory protection equipment. The type of respirator selected shall be documented on the Radiation Work Permit.

- Inspection

  All respirators shall be inspected with regard to operability before, and routinely after, each use, and after cleaning.

- Cleaning

  Respiratory protection equipment that is used routinely shall be cleaned after each use. Respiratory protection equipment that is used by more than one worker shall be cleaned and disinfected after each use. The need for cleaning shall also be based on contamination surveys of the work area and of the respiratory protection equipment.

- Maintenance

  Respiratory protection equipment shall be maintained to retain its original effectiveness. Replacement or repair shall be done only by experienced persons, with parts designed for the respirator. No attempt shall be made to replace components or to make adjustments or repairs beyond the manufacturer's recommendations. Reducing valves or admission valves on regulators shall be returned to the manufacturer or equivalent for repair.

- Storage

  Respirators shall be stored to protect against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals. Respirators shall be stored in dedicated carrying cases or cartons that protect from dirt and damage.

- Training

  All workers required to use respiratory protection equipment shall be instructed in the content and applicability of the program and implementing procedures, and especially in the proper use of the equipment and its limitations. Refresher training shall be conducted annually. A worker shall not be allowed to use a respirator without current successful completion of training.

10.1.3 External Exposure Monitoring Program

Individual monitoring devices shall be provided to workers who require monitoring for external exposure pursuant to 10 CFR 20.1502(a). External monitoring shall be conducted in accordance with (or equivalent to) NRC Regulatory Guide 8.34, "Monitoring Criteria and Methods to Calculate Occupational Radiation Doses", July 1992 (NRC 1992c).

External exposure monitoring, when required, shall be accomplished using thermoluminescent dosimeters (TLD) worn on the front of the upper torso. For work areas where the external radiation field is non-uniform and external monitoring is required, extremity dosimetry shall also be issued to the worker. Radiological surveys may be performed to supplement personnel monitoring when work is being performed where workers are required to be monitored.

Dosimeters shall be processed at least quarterly by a vendor accredited by NVLAP.

Work restriction shall be implemented for any worker reaching 50% of the annual limits of 10 CFR 20.

10.1.4 Internal Exposure Monitoring Program

Individual monitoring shall be provided for workers who require monitoring of the intake of radioactive material pursuant to 10 CFR 20.1502(b). Monitoring of intake shall normally be conducted by use of air samples, particularly of the breathing zone. Internal dose shall be determined by converting airborne concentrations to intakes in accordance with NRC Guidance (NRC 1992c).

When a potential or actual condition exists where the worker(s) could have received an unmonitored intake of radioactive material, and cannot otherwise be estimated, the intake shall be determined by measurements of quantities of radionuclides excreted from or retained in the body. These measurements shall be made consistent with the guidance provided in NRC Regulatory Guide 8.9 "Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program", July 1993 (NRC 1993).

Determination of radiation dose to the embryo/fetus shall be performed in accordance with NRC Regulatory Guide 8.36 "Radiation Dose to the Embryo/Fetus", July 1992 (NRC 1992d).

10.1.4.1 Summation of External and Internal Exposures

Results of internal and external monitoring shall be used to calculate total organ dose equivalent and total effective dose equivalent to workers for which monitoring is required. Summation of internal and external doses shall be performed in accordance with NRC Guidance (NRC 1992c).

10.1.5 Contamination Control Program

Contamination control shall be managed for exposure control and monitored by radiation surveys in accordance with approved procedures.

10.1.5.1 Exposure Control

Personnel exposure to radioactive material will be controlled by application of engineering, administrative, and personnel protection provisions. The priority of application will be descending with respect to their order of description below.

A. Engineering - Engineering controls will be used, as practicable, to minimize or prevent the presence of uncontained radioactive material. Engineering controls will predominantly be comprised of containment, isolation, ventilation, and decontamination.

B. Administrative - Administrative controls will be used to control work conditions and work practices. Administrative controls will predominantly be comprised of the following:

   i. Access Control: Routine access to work areas will be limited to personnel necessary to accomplish tasks or activities. Access will also be controlled with respect to training and use of specified personnel protection equipment.

   ii. Postings and Barriers: Postings will be used to inform personnel of relevant hazards or conditions and associated access requirements. Barriers may be used to prevent unauthorized access.

   iii. Procedures: Written procedures may be used to describe specific radiation protection requirements necessary for tasks that involve radioactive material.

   iv. Radiation Work Permits: RWPs will be used to describe specific or special worker protection requirements for activities involving radioactive material and not covered by a procedure. RWPs may also be used in conjunction with a procedure.

   v. Contamination Control: Action levels and limits for radiation surveys, described later in this section, will be used to control the levels of radioactivity on equipment and in areas.

C. Personal Protective Equipment - Personal protective equipment will be used to control personnel exposure to radioactive material when administrative controls are not sufficient and engineering controls are not practicable. Personal protective equipment may include head covering, eye protection, respiratory protection, impervious outerwear, gloves, and/or protective shoes or shoe covers.

10.1.6 Radiation Surveys

Radiation surveys will be performed to describe the radiation types and levels in an area or during a task, to identify or quantify radioactive material, and to evaluate potential and known radiological hazards.

The types of radiation surveys and their frequency are described in the following subsections.

A. Contamination Measurements - Measurements will be made of removable alpha, beta, and beta-gamma radiation, as applicable. The measurements will be made by wiping an area with cloth, paper, or tape. The radiation levels will be measured on the wipe. Contamination surveys shall be performed at the end of each workday where invasive demolition of contaminated surfaces was performed.

B. Radiation - Exposure rate measurements will be performed using an ion chamber or equivalent. Measurements will be made at approximately 30 centimeters. Measurements may also be made at contact.

C. Personnel - Personnel will be frisked prior to leaving access-controlled areas.

D. Action Levels - Action levels are established to inform facility personnel when a situation needs to be evaluated so that corrective actions can be taken. Action levels are set so that corrective actions can be made before a regulatory limit is exceeded. Exceedance of action levels requires investigation, including evaluation of preventative and/or corrective action. The investigation, and documentation of such, is completed commensurate with the significance of the condition.

   Radiation levels exceeding the values described in the following subsections will be reduced below the respective levels as soon as practicable.

   i. Removable: The action level for removable alpha or beta-gamma radiation on a surface is 50% of the established removable surface radioactivity limits.

   ii. Exposure Rate: The action level for exposure rate is two millirem per hour at 30 centimeters.

   iii. Personnel: The action level for personnel is the detection of elevated (greater than background) levels.

E. Limits - Limits, as release criteria, are described in Section 14.1. The limits are administered such that when exceeded, action must be taken to reduce the levels or additional controls must be applied.

Items or areas will not be released for unrestricted use until the relevant limits are satisfied.

All accessible surfaces and areas that exceed the respective limits will be decontaminated on a timely basis. In no case will the delay to initiate control exceed one normal workday. In the case of personnel contamination, there will be no delay to initiate decontamination.

10.1.7 Instrumentation Program

Instrumentation that is capable of performing the radiation surveys and measurements of radioactive material required by regulation, license, and procedures shall be maintained. The types and management of radiation detection instrumentation is described in the following sections.

10.1.7.1 Calibration

Calibration, maintenance, repair, and efficiency determination shall be performed according to written procedures, instructions, or other guidance documents reviewed and approved by the RSO, or by a commercial calibration service.

A. Frequency - Instruments shall be calibrated at least annually or following maintenance, repair, or adjustment likely to affect the primary calibration.

B. Radiation Energy - Calibration shall be performed using a source (s) providing radiation fields similar to those in which the instrument will be used.

C. Label - Each instrument shall be labeled or marked with the following information as applicable:

   i. Unique identification (e.g. serial number),

   ii. Initials or specific identifying mark of individual completing the calibration,

   iii. Energy correction factors,

   iv. Graph or table of calibration factors for each type of radiation for which the instrument may be used,

   v. Instrument response to an identified check source,

   vi. Unusual or special use conditions or limitations, and

   vii. Date by which calibration is again required.

D. Standards - Calibration shall be performed using standard sources traceable to NIST. Gamma spectrometry system(s) measurements may be performed using high purity germanium radiation detectors that have been specifically characterized by the vendor to enable a sourceless efficiency calibration methodology. When this method is selected, the vendor's computer software performs a mathematical efficiency calibration without the use of sources.

10.1.7.2 Verification

Instruments in use shall be verified (checked) daily to ensure that the instrument is in proper working condition. An instrument shall be removed from service if the source check is not within ±20 percent of the initial post-calibration value. Laboratory instruments used for radioactivity measurements are evaluated daily before use via check sources and efficiency checks. Maintenance or repair shall be performed if the daily source or background checks are not within prescribed ranges.

10.1.7.3 Sensitivity

Radiation detection systems shall be capable of detecting emissions of radioactivity less than the respective limits. Measurement sensitivity will be determined using industry standard guidance (e.g., NUREG-1507 "Minimum Detectable Concentrations with Typical Radiation Safety Instruments for Various Contaminants and Field Conditions", 1997 (NRC 1997b)).

10.2 HEALTH PHYSICS AUDITS, INSPECTIONS AND RECORD-KEEPING PROGRAM

The radiation safety program shall be subject to an annual audit and periodic inspections. Each are performed to determine if radiological operations are being conducted in accordance with regulations, license conditions, and written procedures.

An audit of the program shall be conducted annually. The audit shall be conducted by the RSO or designee, but shall not be a member of the contractor organization. The audit will consider the basic functional areas of the program; e.g. Radiation Work Permits, Radiation Protection Procedures, radiological surveys and air monitoring, ALARA program, individual and area monitoring results, access controls, respiratory protection program, and training.

The audit shall be conducted in accordance with a specific audit plan developed by the auditor. A written report describing the results shall be generated upon completion of the audit. The report shall be distributed to site management. As necessary, a written corrective action plan shall be prepared to address non-compliance issues. All corrective actions shall be tracked to completion. Once corrective actions have been completed, a written closure report shall be distributed to management documenting the completion of corrective actions.

The periodic inspections shall be conducted by the Health and Safety staff. These inspections shall be routine reviews performed of operations and activities. The inspections shall normally be completed against a pre-established checklist. Checklists may be developed independently for differing periods; e.g. daily, weekly, monthly, etc. The checklist items shall usually be comprised of routine procedural requirements. Any findings discovered during the routine inspection shall be recorded on a tracking log. The log shall be maintained by the RSO. The log shall include a description of planned corrective action and date of completion of corrective action.

11.0 ENVIRONMENTAL MONITORING AND CONTROL PROGRAM

11.1 ENVIRONMENTAL ALARA EVALUATION PROGRAM

There is no Environmental Monitoring and Control Program for the Tobico Marsh SGA Site.

11.2 EFFLUENT MONITORING PROGRAM

There is no Effluent Monitoring Program for the Tobico Marsh SGA Site.

11.3 EFFLUENT CONTROL PROGRAM

There is no Effluent Control Program for the Tobico Marsh SGA Site.

12.0 RADIOACTIVE WASTE MANAGEMENT PROGRAM

12.1 SOLID RADIOACTIVE WASTE

No solid radioactive waste will be generated during D&D activities at the Tobico Marsh SGA Site

12.2 MANAGEMENT OF LLW

LLW currently being stored on site will be packaged in appropriate waste containers and segregated from uncontaminated wastes. If LLW is required to be handled outside of it's packaging, a staging area will be set up for this work. The staging area will have boundary markings and signs will be posted identifying the area.

12.3 WASTE PACKAGING

To the extent practical, the number of waste packages and the number of waste shipments will be minimized. Waste will be packaged in a manner that provides containment and protection for the duration of the anticipated storage period and until disposal is achieved, or until the waste is removed from the packaging. Waste packages will be marked such that their contents can be identified.

A commonly used packaging for shipment of radioactive material will be steel or plastic, open head or closed head, drums (e.g. 55-gallon). All packaging will be inspected prior to use to ensure suitability for intended use.

12.4 DISPOSAL FACILITY

Radioactive waste will be transferred to a recipient who is properly licensed to receive such waste.

12.5 LICENSED MATERIAL INVENTORY AND ACCOUNTABILITY

Inventory and accountability of licensed material is accomplished by keeping track of receipts and outgoing shipments of material in logs. Records will be maintained of licensed material content for waste material accumulated and shipped.

12.6 LIQUID RADIOACTIVE WASTE

No liquid radioactive waste will be generated.

12.7 MIXED WASTE

No mixed waste will be generated.

13.0 QUALITY ASSURANCE PROGRAM

Decommissioning and decontamination activities will be performed under the provisions of the Decommissioning Contractor's, Quality Assurance Plan (QAP) and in the Characterization Plan (CP). The requirements and guidance contained in the QAP/CP are based on the principle that work shall be planned, documented, performed under controlled conditions, and periodically assessed to established work item quality and process effectiveness and to promote improvement. The requirements described in the QAP/CP reflect the responsibilities assigned to management and personnel of all departments and their responsibility for planning, achieving, verifying, and assessing quality and promoting continuous improvement. The QAP/CP further delineate the quality contributions of all personnel and encourages their active participation in accomplishing the quality objectives.

13.1 D&D CONTRACTOR ORGANIZATION

The Decommissioning Contractor's President has ultimate responsibility for the implementation of the Quality Assurance Plan, but has delegated the day-to-day implementation of the Plan to the Project Manager. Appropriately trained and qualified personnel assigned to specific activities perform technical work, including quality-related work.

The Quality Assurance Manager is organizationally independent of cost and schedule to guarantee objectivity, and reports directly to the President. The Quality Assurance Manager is responsible for designing and implementing quality assurance procedures; for monitoring, auditing and inspecting to confirm that quality is being achieved; and for verifying that corrective action, when required, has been effective.

The President, Project Manager, Quality Assurance Manager, Site Manager, Site Health, Safety & Radiological Safety Officer, Radiation Safety Officer, and field personnel have the authority to stop work for cause, real or suspected. Any employee can make work stoppage recommendations to any of those positions, and when there is an imminent danger all employees have the authority to stop work. Work will not resume until the concern is addressed and appropriately resolved.

Personnel and organizations not directly responsible for managing or performing the work verify the achievement of quality.

13.2 QUALITY ASSURANCE PROGRAM

Methods of quality assurance are used during the planning, design, procurement, installation, operation, maintenance, remediation and decontamination/decommissioning of structures, systems, components and project under the management of the Decommissioning Contractor. The Decommissioning Contractor's QAP/CP is documented and maintained in accordance with applicable standards and sound management practices. Activities affecting quality are identified and are made subject to the QAP/CP in the documentation.

13.3 DOCUMENT CONTROL

Documents that specify quality-related requirements and instructions are identified, reviewed, approved, issued, distributed, and maintained as controlled documents in accordance with written procedures. A listing of the type of documents to be maintained as controlled documents is shown in an appendix to the QAP. The controlled document list will be updated as needed, to ensure it is comprehensive, current, and complete.

Changes to controlled documents are reviewed and approved by the same organization that reviewed and approved the documents originally, or by other designated qualified organizations. Disposition of superseded and modified documents is controlled in accordance with written procedures. A master list of controlled documents is maintained to identify the current revision number of instructions, procedures, specifications, drawings, and procurement documents. The list is distributed periodically to those individuals or organizations responsible for maintaining the applicable controlled documents, to prevent the use of outdated or obsolete documents.

Appropriate controlled documents are available in work areas before initiation of and during the performance of activities affecting quality. This availability is verified periodically by Quality Assurance Manager. Changes or revisions to controlled documents are verbally communicated to affected individuals and a required reading program assures awareness of the change.

13.3.1 Instructions, Procedures, and Drawings

Quality-related activities shall be prescribed by and accomplished in accordance with documented and approved instructions, procedures, or drawings. These instructions, procedures and drawings shall contain the necessary detail required by the activity and include or reference appropriate acceptance criteria.

13.3.2 Responsibility

Quality Assurance Manager is responsible for verifying implementation of all quality-related work outlined in controlled documents, procedures, or drawings.

Employees and subcontractors are responsible for implementing the Quality Assurance Plan and applicable instructions, procedures, and drawings.

The cognizant managers and appropriate supervisors are responsible for developing and implementing all quality-related technical documents or procedures.

Technical supervisors are responsible for developing, securing approval for, conducting, and reporting on elements of the work program affecting quality in accordance with the

Quality Assurance Plan and applicable instructions, procedures and drawings. The Cognizant Managers are responsible for ensuring development of all technical documents dealing with quality-related work under their purview, and for ensuring compliance with those documents.

13.3.3 Implementation

A written plan, procedures, and instructions governing implementation of the Quality Assurance Program shall be developed. These documents address requirements concerning scope and purpose, applicability, responsibilities, and records. They are issued and maintained as controlled documents. Approval of the Cognizant Manager and concurrence with Quality Assurance are required before these documents may be issued or revised.

Activities affecting quality are controlled and authorized by documents (e.g. procedures, instructions, drawings). These documents are reviewed as necessary by authorized personnel having appropriate technical, quality, and administrative expertise to ensure adequacy and completeness. Written procedures clearly outline the actions to be accomplished in the preparation, review, approval, and control of procedures, instructions and drawings.

Any errors or deficiencies in instructions, procedures, and drawings are corrected upon discovery. Revisions or changes are made, reviewed, approved, and documented in accordance with written procedures before the revision or change is implemented.

13.4 CONTROL OF MEASURING AND TEST EQUIPMENT

The Decommissioning Contractor's technical staff will use appropriate procedures to ensure adequate control of measuring and test equipment that affect site characterization and the quality of design, construction, or operation. The procedures describe calibration technique, frequency, maintenance, and control of measuring and test equipment.

Measuring and test equipment is labeled, tagged, or otherwise identified and documented to indicate the next calibration due date, as well as to provide traceability to calibration test data. Before measuring and test equipment is used, it is checked by the user to have a current calibration. Equipment is calibrated at specific intervals based on manufacturer's recommendations or on required accuracy and equipment history of drifting, precision, purpose, or any other characteristics that could affect accuracy. If a piece of equipment is found to be out of calibration, evaluations are made to determine the validity and acceptability of any measurements performed subsequent to the last calibration. If items are measured with equipment found to be out of calibration, the items are re-inspected.

Standards for calibration are determined with appropriate reference to nationally accepted standards, manufacturers' instructions, intended uses, and other factors. If national standards do not exist, the basis for calibration is documented. Calibrations are performed immediately prior to use when such action is necessary to maintain or ensure accurate measurements and tests.

Documented calibration records are maintained as Quality Assurance records, in accordance with applicable procedures. Calibration instructions are maintained as controlled documents.

13.5 CORRECTIVE ACTION

Corrective actions are accommodated through written procedures that implement an audit tracking system. Conditions adverse to quality are evaluated via the audit tracking system, and if found to be significant, are investigated to determine root causes, to decide on immediate corrective actions, to project preventive actions, and to define follow-up needs. The evaluations are documented within the audit tracking system.

Follow-up verification by the Quality Assurance Manager or designee ensures that the audit tracking system actions have been implemented in a timely manner and are effective. The Quality Assurance Manager monitors progress and closes audit tracking system actions in a timely manner.

The Quality Assurance Manager reports on audit tracking system actions pending and closed, and on trends related to Nonconformance Reports and Corrective Action Reports, at each management review meeting.

Documentation of Corrective Action Reports will be maintained, as well as actions taken to resolve the condition, and any follow-up audits or actions.

13.6 RECORDS

A records management system for items with quality assurance requirements includes, in part, the following: operating logs, results of reviews, inspections, tests, audits, monitoring of work performance, and material analyses. Records also include closely related data such as qualifications of personnel, training, procedures, equipment records (including calibrations), evaluations and analyses of a quality-related nature.

The types and locations of quality assurance records are identified in a subject-oriented records list. Individual records are classified, designated, validated, and stored in accordance with written procedures. Quality assurance documents are traceable to relevant items and activities, and are identifiable and retrievable. Record retention is in accordance with applicable regulatory requirements.

13.7 AUDITS AND SURVEILLANCES

Audits and surveillances are planned and scheduled according to the type and status of work being performed. Unannounced audits and surveillances are performed as necessary.

The results of audits and surveillances shall be documented. Quality Assurance is responsible for ensuring that audit findings and observations are monitored and closed out in a timely manner. Audit results are documented and reviewed by D&D Contractor management personnel who are responsible for the audited area.

Management personnel shall take appropriate action to identify root causes, correct deficiencies, prevent recurrences, and determine impacts of audit findings in their area of responsibility. Follow-up actions are performed as necessary to ensure that appropriate corrective actions have been implemented in a timely manner and are effective.

13.8 PROGRAM CHANGES

Changes to the key elements of the Quality Assurance Program presented in this Decommissioning Plan will be submitted to the U.S. Nuclear Regulatory Commission for review and approval prior to implementation.

The NRC will be notified of any changes to the organizational elements within 30 days after the announcement of the change is made.

Editorial changes or personnel reassignments of a non-substantive nature do not require NRC notification.

14.0 FACILITY RADIATION SURVEYS

14.1 RELEASE CRITERIA

The radiological criteria for offsite release of structures, equipment, and components for unrestricted use are described in Table 14–1.

Table 14-1 Acceptable Surface Contamination Levels, (dpm/100cm^2)

Radiation Type	Removable	Total, Average	Total, Maximum
Alpha or Beta	200	1000	3000
Surface radioactivity levels derived from U.S. NRC RegGuide 1.86 (NRC 1974)			

Release surveys will be performed and documented in accordance with written procedures. The release criteria will be evaluated by removable and/or scanning radiation surveys. The coverage of the release survey will be based on professional judgment including any applicable history or process knowledge but shall cover at lease 10 percent of the surface area of the survey unit. The radionuclides present will be identified (via historical knowledge of the source term or analytical measurements) to determine the applicable release criteria. If survey results are greater than the release criteria, the item will not be released, or a 100% scan will be completed of the survey unit. The location exceeding the release criteria will be decontaminated and resurveyed, or will not be released.

14.2 CHARACTERIZATION SURVEYS

Any additional radiological characterization deemed to be required will be conducted in accordance with a written plan. The plan will provide details of the characterization methods including measurement and sampling techniques, and measurement system quality issues. Measurement and sample collection, handling, and analyses will be performed in accordance with written procedures to ensure precise, accurate, reproducible, complete, and comprehensive results.

14.3 FINAL STATUS SURVEY DESIGN

This section presents the basic design of any additional sampling and surveys that may be required to demonstrate that the final radiological status of the Tobico Marsh SGA Site is in compliance with the required and approved radiological conditions. The surveys will be designed with the guidance contained in NUREG-1575 "Multi-Agency Radiation Survey and Site Investigation Manual" (NRC 2000b). The surveys will demonstrate that the residual radioactivity in each survey unit satisfies the applicable criteria for unrestricted release. The surveys will provide data to demonstrate that radiological parameters do not, with acceptable confidence, exceed the established DCGLs.

14.3.1 Summary of Statistical Tests

Measurements from a survey unit will be compared statistically to the appropriate concentration guideline level. In general, two types of non-parametric statistical tests may be employed in evaluating compliance for final status survey; a single sample test (such as the Sign Test) or a two sample test (such as the Wilcoxon Rank Sum Test). A single sample test compares the sample results directly to the release standard, whereas a two sample test seeks to determine whether there is a statistically significant difference between the two samples. In the case of a two sample test, the sample from the survey unit under consideration is compared to essentially equivalent measurements from a reference area. In general, the two sample comparison will be to show whether or not the survey unit exceeds the reference area by more than the $DCGL_W$.

In addition, an elevated measurement comparison (EMC) will be performed against each individual measurement in a Class 1 unit to ensure that the measurement result does not exceed the specified investigation level; i.e. the $DCGL_{EMC}$. If any measurement exceeds the $DCGL_{EMC}$, then additional investigation will be completed regardless of the outcome of the statistical test of the central tendency value.

Measurement methods used to generate data during the surveys can be classified into three categories commonly known as scanning surveys, direct measurements, and sampling. These techniques will be combined in an integrated survey design.

14.3.2 Direct and Removable Measurements

Direct and removable measurements will be made to determine average activity in a survey area or unit. Direct and removable measurements will be limited to alpha and beta/gamma measurements.

14.3.3 Sampling

Volumetric sampling is commonly limited to land area surveys and will not be performed.

14.3.4 Control and Handling of Samples for Laboratory Analysis

Sample collection will be conducted in accordance with a written procedure. Laboratory analyses will be conducted in accordance with a written procedure. A written chain-of-custody procedure will be used to ensure integrity of samples and data from sample collection through data reporting.

14.3.5 Final Status Survey Investigation Levels

Radionuclide-specific investigation levels will be used to indicate when additional investigations may be necessary. The investigation levels will also serve as a quality control check for the measurement process.

15.0 FINANCIAL ASSURANCE

A revised decommissioning funding plan (DFP) for the Tobico Marsh SGA Site will be submitted under separate cover. The DFP previously submitted to the NRC by the MDNR was based on the assumption that complete removal of the licensed radioactive material might be required. As a result, the cost estimate provided in the DFP served as a bounding estimate and the basis for the financial assurance vehicle issued by the MDNR.

The previous cost estimate projected that the costs of site characterization would be approximately 2.5 million dollars, and that the cost of complete removal and disposal of the thorium bearing slag materials would be approximately 10 million dollars. With characterization work now completed, approximately 3.5 million dollars have been expended to date. It is estimated that the cost to complete the remaining open items in the preferred decommissioning option is less than 1 million dollars.

The February 3, 1997 Statement of Intent issued by the MDNR assures that a total of 12.5 million dollars would be sought from the Michigan Legislature through the appropriate process. That Statement of Intent is still in effect and in excess of the projected funds needed to complete the decommissioning process for the MDNR's Tobico Marsh SGA site thus assuring that sufficient funding is available.

A revised cost estimate for the preferred decommissioning alternative will be submitted within the revised DFP submittal.

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