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FINAL ENGINEERING EVALUATION AND COST ANALYSIS AT SITE 1 NSWC INDIAN HEAD MD

9/29/2010

TETRA TECH NUS

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PITT-09-10-081

September 29, 2010

Project Number 112G02622

Commanding Office
Naval Facilities Engineering Command, Washington
1314 Harwood Street, SE
Washington Navy Yard, D.C. 20374-5018
Attention: Mr. Nathan Delong

Reference: Clean Contract No. N62470-08-D-1001
Contract Task Order No. JU11

Subject: Final Engineering Evaluation and Cost Analysis (EE/CA)
Site 1 – Thorium Spill
Naval Support Facility, Indian Head, Maryland

Dear Mr. Delong:

Enclosed are two (2) hard copies and one (1) electronic copy on compact disk (CD) of the final EE/CA for Site 1 – Thoriu Spill at the Naval Support Facility Indian Head (NSF-IH), Maryland. If you have any questions regarding this document or need additional copies, please contact me at (412) 921-7134 or via email at scott.nesbit@tetratech.com.

Sincerely,

Scott A. Nesbit

Scott A. Nesbit, P.E.
Project Manager

SAN/clm

Enclosures

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Mr. Curtis DeTore, MDE (1 hard copy, 1 CD)
Mr. Dennis Orenshaw, EPA (1 hard copy, 1 CD)
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Engineering Evaluation and Cost Analysis (EE/CA)

Non-Time-Critical Removal Action for Soil

Site 1 – Thorium Spill

Naval Support Facility Indian Head
Indian Head, Maryland

Naval Facilities Engineering Command
Washington

Contract No. N62470-08-D-1001
Contract Task Order JU11

September 2010

ENGINEERING EVALUATION AND COST ANALYSIS (EE/CA)

NON-TIME-CRITICAL REMOVAL ACTION FOR SOIL

SITE 1 – THORIUM SPILL

NAVAL SUPPORT FACILITY INDIAN HEAD
INDIAN HEAD, MARYLAND

Submitted to:
Naval Facilities Engineering Command Washington
1314 Harwood Street, SE
Washington Navy Yard, D.C. 20374-5018

Submitted by:
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CONTRACT NO. N62470-08-D-1001
CONTRACT TASK ORDER JU11

September 2010

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
ARAR	Applicable or Relevant and Appropriate Requirement
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
COMAR	Code of Maryland Regulations
CTO	Contract Task Order
DoN	Department of the Navy
DPS	disintegrations per second
EE/CA	Engineering Evaluation and Cost Analysis
EOD	explosive ordnance disposal
EPA	U.S. Environmental Protection Agency
FDA	Food and Drug Administration
FFA	Federal Facility Agreement
FID	Flame Ionization Detector
FS	feasibility study
ft	Feet or foot
ft^2	square feet
ft^3	cubic feet
IDW	investigation-derived waste
IHDIV-NSWC	Indian Head Division, Naval Surface Warfare Center
IHIRT	Indian Head Installation Restoration Team
ILCR	incremental lifetime cancer risk
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDE	Maryland Department of Environment
NAVSCOLEOD	Naval School, EOD
NAVSEADET	Naval Sea Systems Command Detachment
NCP	National Contingency Plan
NORM	naturally occurring radioactive material
NSF-IH	Naval Support Facility Indian Head
NTCRA	non-time-critical removal action
piC/g	picoCurie per gram
RAO	Removal Action Objective
RASO	[Navy's] Radiological Affairs Support Office

RI	remedial investigation
SARA	Superfund Amendments and Reauthorization Act of 1986
SSP	Site Screening Process
TCRA	time-critical removal action
TRA	Target Removal Area
USAEC	U.S. Atomic Energy Commission
yd^3	cubic yards

1.0 INTRODUCTION

This Engineering Evaluation/Cost Analysis (EE/CA) was prepared for a non-time-critical removal action (NTCRA) for soil at Site 1 – Thorium Spill at Naval Support Facility Indian Head (NSF-IH) in Indian Head, Maryland (Figures 1 and 2). This document was prepared by Tetra Tech under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. N62470-08-D-1001, Contract Task Order (CTO) JU11. NSF-IH is a Naval Support Activity South Potomac facility within the Naval District Washington Region. Until October 1, 2005, NSF-IH was referred to as Naval District Washington, Indian Head.

A summary of historical activities, investigations, and documents associated with Site 1 is provided in Section 2.2. There are potential unacceptable risks to hypothetical future residents from exposure to site soils impacted by thorium-232. The thorium contamination in soil resulted from historical radiation training exercises by the Naval School, Explosives Ordnance Disposal (NAVSCOLEOD).

This EE/CA will develop, evaluate, and recommend an NTCRA alternative to address the potential human health risk from exposure to thorium-impacted soils.

1.1 REGULATORY BACKGROUND

This document is issued by the U.S. Navy, lead agency responsible for the NTCRA at Site 1, in partnership with the U.S. Environmental Protection Agency (EPA) Region 3 and the Maryland Department of Environmental (MDE)[1] under Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA) of 1986.

Section 104 of CERCLA and SARA allows an authorized agency to provide for remedial action and to remove, or arrange for removal of, hazardous substances, pollutants, or contaminants at any time, or to take any other response measures consistent with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) as deemed necessary to protect public health or welfare and the environment.

The NCP [Title 40 of the Code of Federal Regulations (CFR), Section 300] provides regulations for implementing CERCLA and SARA and regulations specific to removal actions. The NCP defines a removal action as:

[1] The entity of the partnership between the Navy, EPA Region 3, and MDE is called the Tier I Partnering Team.

[The] cleanup or removal of released hazardous substances from the environment, such actions as may be necessary to monitor, assess, and evaluate the threat of release of hazardous substances, the disposal of removed material, or the taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release.

The term includes, "in addition, without being limited to, security fencing or other measures to limit access... and enforcement activities related thereto."

A time-critical removal action (TCRA) is performed when the lead agency determines an immediate risk to public health or welfare of the U.S. or environment, whereas an NTCRA is performed when there is an imminent, but not an immediate, threat, and "...a planning period of at least 6 months exists before onsite activities must be initiated (40 CFR 300.415[b][4])." "NTCRAs may be interim or final actions; they may be the first and only action at a site, or one of a series of planned response actions (EPA, 1993)." The removal being considered for Site 1 to mitigate potential unacceptable human health risk from exposure to thorium-impacted soils is not time-critical.

The NCP requires the lead agency to conduct an EE/CA to evaluate NTCRA alternatives. The goals of an EE/CA are to satisfy environmental review and Administrative Record requirements for removal actions, and to provide a framework for evaluating and selecting the removal action alternative technologies (EPA, 1993).

Community involvement requirements for NTCRAs include making the EE/CA available for public review and comment for a period of 30 days. An announcement of the public comment period is required in a local newspaper. Written responses to significant comments will be provided in a responsiveness summary to be attached to the Navy's Action Memorandum, and will be included in the Administrative Record for NSF-IH. Information in the Administrative Record can be accessed at the following repositories:

Indian Head Town Hall 4195 Indian Head Hwy Indian Head, Maryland (301) 743-5511	Charles County Public Library 2 Garrett Ave La Plata, Maryland (301) 934-9001	Naval Support Facility Indian Head General Library Building 620 (The Crossroads) 4163 N. Jackson Road Indian Head, Maryland

1.2 PURPOSE AND OBJECTIVES

This EE/CA has been prepared in accordance with the EPA (1993) guidance entitled Superfund – Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA. A comparison of developed removal alternatives is presented herein based on their technical feasibility, ability to protect

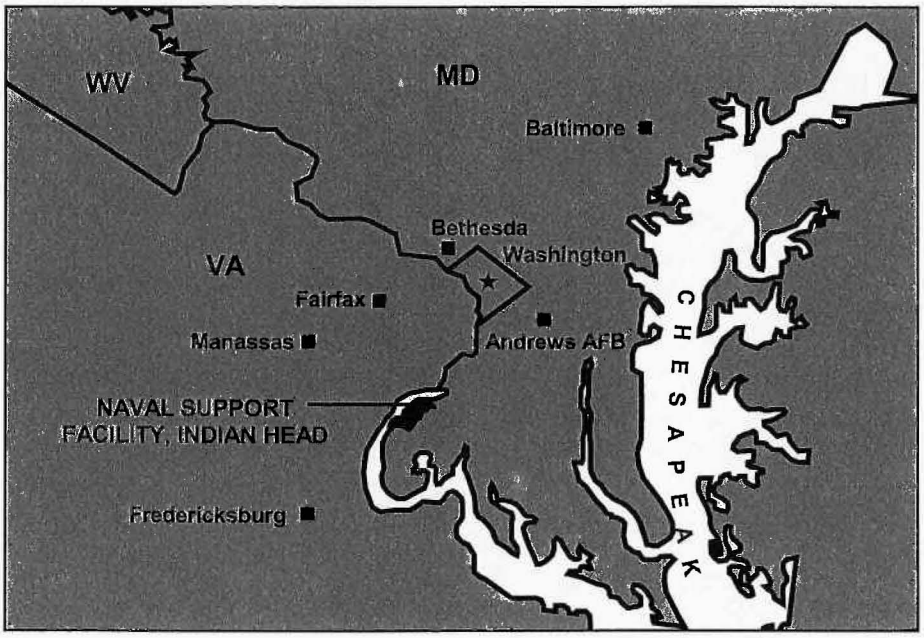
human health and the environment, ability to prevent the potential release of hazardous chemicals or substances, and cost. Submittal of this document fulfills the requirements for planning NTCRAs as defined by the NCP.

The objective of the NTCRA at Site 1 is to reduce or eliminate potential unacceptable human health risk associated with hypothetical residential exposure to thorium-232 in soil. The removal action alternatives evaluated herein are as follows:

- Alternative 1 – No Action
- Alternative 2 – Excavation and Disposal

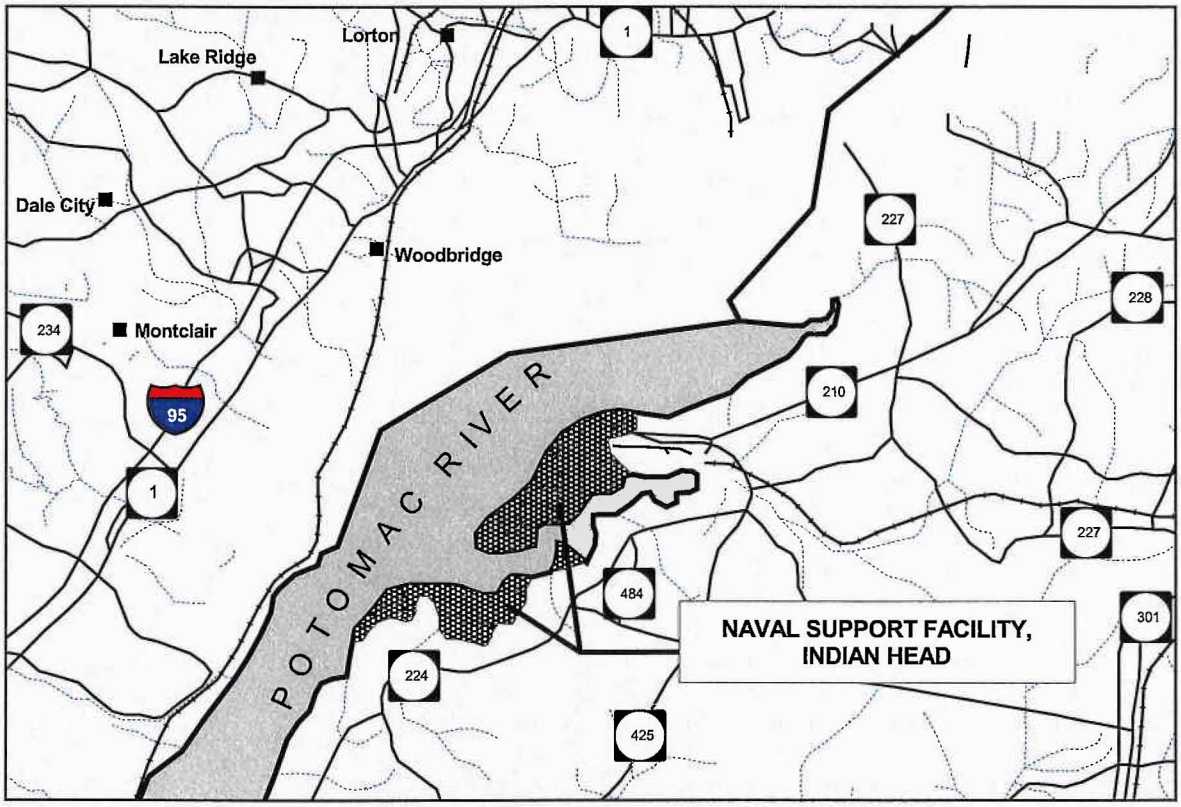
1.3 REPORT ORGANIZATION

This EE/CA was prepared to include the elements specified in EPA (1993) guidance, and is organized as shown in the Table of Contents. Tables and figures are provided at the end of the document.



LEGEND

- City
- Highway
- Railroad
- River



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K. PEILA	3/17/05		2144	005
CHECKED BY	DATE	FACILITY LOCATION MAP	APPROVED BY	DATE
G. LATULIPPE	12/03/07	NAVAL SUPPORT FACILITY, INDIAN HEAD	G LATULIPPE	12/03/07
COST/SCHEDULE-AREA		INDIAN HEAD, MARYLAND	APPROVED BY	DATE
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DRAWN BY K. PEILA	DATE 6/8/04	Tetra Tech NUS, Inc.	CONTRACT NUMBER 2144 / OWNER NUMBER 005
CHECKED BY G. LATULIPPE	DATE 12/11/07	SITE LOCATION MAP SITE 1 - THORIUM SPILL NAVAL SUPPORT FACILITY, INDIAN HEAD INDIAN HEAD, MARYLAND	APPROVED BY G. LATULIPPE / DATE 11/30/07
COST/SCHEDULE-AREA			APPROVED BY — / DATE —
SCALE			DRAWING NO. / REV

2.0 SITE HISTORY AND CHARACTERIZATION

This section provides a summary of background information for NSF-IH and Site 1 – Thorium Spill. Additional information can be found in the Tetra Tech (2009) Site Screening Process (SSP) Investigation Report. This section also summarizes previous environmental investigations and actions that occurred at Site 1.

2.1 FACILITY INFORMATION

2.1.1 Facility Location

NSF-IH is located in northwestern Charles County, Maryland. As shown on Figure 1-1, NSF-IH is approximately 25 miles southwest of Washington, D.C. NSF-IH is a military facility consisting of the Main Area on the Cornwallis Neck Peninsula and the Annex on Stump Neck. As shown on Figure 1-2, the Main Area is bounded by the Potomac River on the northwest, west, and south, Mattawoman Creek to the south and east, and the Town of Indian Head to the northeast. Stump Neck Annex is located across Mattawoman Creek and is not contiguous with the Main Area. The location of Site 1 is shown on Figure 1-2.

2.1.2 Facility Background

The Indian Head peninsula is located in the Atlantic Coastal Plain Physiographic Province, approximately 8 to 10 miles east of the Fall Line that marks the western extent of the physiographic province. Indian Head has gently rolling to undulating topography with elevations ranging from sea level to more than 100 feet (ft) above mean sea level (msl). The higher elevations are on the eastern portion of the facility, and the land surface generally slopes to the southwest and southeast. The portion of NSF-IH along the Potomac River is characterized by 20- to 100-ft bluffs. The portion along Mattawoman Creek is more gently sloping.

The primary mission of NSF-IH consists of the following:

- To provide services in energetics for all warfare centers through engineering, fleet and operation support, manufacturing technology, limited production, and industrial base support.
- To provide research, development, testing, and evaluation of energetic materials, ordnance devices and components, and other related ordnance engineering standards including chemicals, propellants and their propulsion systems, explosives, pyrotechnics, warheads, and simulators.

- To provide support to all warfare centers, military departments, and the ordnance industry for special weapons, explosive safety, and ordnance environmental issues.

In 1951, the Navy was assigned the joint-service explosive ordnance disposal (EOD) responsibilities for basic training and research and development. In 1953, the research and development tasks were established as a separate organization, and redesignated the Naval EOD Technical Center. The training function was renamed the Naval School, EOD (NAVSCOLEOD). From 1955 on, all joint service EOD training was provided at NSF-IH until the school moved to Eglin Air Force Base (AFB). In 1958, the NAVSCOLEOD moved from its Jackson Road location to Strauss Avenue. The NAVSCOLEOD command moved to Eglin AFB in 1993, and the NAVSCOLEOD at NSF-IH was designated as a detachment. The Commanding Officer and the NAVSCOLEOD Headquarters returned to NSF-IH in 1994 while a construction project was being completed at Elgin AFB. In January 1999, the NAVSCOLEOD was consolidated at Elgin AFB. A detachment of EOD personnel remains at NSF-IH.

2.2 SITE INFORMATION

2.2.1 Site Description and Setting

Site 1 is an area of approximately 60 by 135 feet located between Building 1662 and Strauss Avenue (Figure 2-2). The area is currently covered by a parking lot and maintained lawn. Building 1662 is used for electrical and satellite communications. Future land use is expected to be any military, industrial, or commercial use needed to support the NSF-IH mission. It is unlikely that the site area would be developed for residential use while under government control.

2.2.2 Site Background

The Naval Sea Systems Command Detachment (NAVSEADET) Radiological Affairs Support Office (RASO) provided the historical information that served as the basis for site background discussion [see Tetra Tech (2005) Site 1 SSP Work Plan]. The construction of Building 1662 was completed in 1983. Building 900, located northeast of Building 1662, was in place prior to 1962.

Thorium was first placed on the ground at Site 1 in 1962 in connection with radiation training exercises conducted by the NAVSCOLEOD. Thorium ore from approximately five drums of 30- to 50-gallon capacity was spread over the site. No U.S. Atomic Energy Commission (USAEC) license was issued at the time the ore was purchased.

Thorium is a soft, silvery white metal that dissolves slowly in water. Thorium-232 has a half-life of 14 billion years and decays by alpha emission with accompanying gamma radiation. Thorium-232 is at

the top of a long decay series that contains key radionuclides such as radium-228, its direct decay product, and radon-220. Two other isotopes of thorium are thorium-230 and thorium-228. Both belong to other decay series. They also decay by alpha emission with accompanying gamma radiation, and have half-lives of 75,400 years and 1.9 years, respectively (http://www.epa.gov/radiation/radionuclides/thorium.htm).

2.2.3 Site Environmental History

As mentioned above, thorite ore was first placed on Site 1 in 1962. Early in 1967, some of the thorite ore was removed from the site, placed into barrels, and transferred to an unknown destination. The residual soil on the site was then disked and harrowed several times to uniformly incorporate any residual thorite ore into the soil. It was reported that the soil was affected to a depth of 8 to 12 inches.

In 1971, a sample of the thorite ore was assayed for thorium content by the Engineering Division, U.S. Army Engineer Power Group, Fort Belvoir, Virginia. The results were reported as, "Thorium content 2.5 w/o thorium with a specific activity of 100 disintegrations per second (dps) per gram." A radiological survey conducted at Site 1 on March 28, 1972, determined that the affected areas included seven locations covering a total of approximately 600 square feet. The depths of the affected soil ranged from 12 to 18 inches below ground surface (bgs).

In July 1972, the radioactive soil was excavated, placed into fifty 55-gallon drums, and staged at the facility's radiation training area. The drums were shipped in October for disposal at the Nuclear Engineering Company, Inc., in Morehead, Kentucky. Two subsequent radiological surveys, each followed by the removal of radioactive material, occurred on November 1972. The excavated area was backfilled with 18 to 24 inches of clean soil to reestablish original grade.

A final radiological survey of the area was performed by RASO personnel in February 1976. In a March 1976 memorandum, RASO indicated that based on the survey, "the subject area has been returned to background and may be released for unrestricted use." However, in 1983, two buried drums containing thorium material, dirt, and gravel were discovered near the site during construction of Building 1662. The drums were shipped off-site for disposal as low-level radioactive waste.

Prior to constructing an addition to Building 900, a radiological survey was performed in October 2001 along the southeastern side of the building where the site was initially thought to be located. Ten subsurface soil (0.5 to 2 ft bgs) samples were collected. The associated survey report concluded that "based on the laboratory results, no further actions regarding thorium are required at this time. Soil remediation will not be required as part of Building #900 Joint Interoperability Project."

In November 2004, RASO indicated that it considered all known drums of thorium ore to have been accounted for and properly disposed. However, RASO indicated in the same communication that "radiation measurements made in 1972 are not definitive as to the thorium concentrations remaining after the cleanup. Characterization surveys are still necessary." Following a search of historical files, RASO provided a description of the location of Site 1:

Clean soil covers the 60-ft by 90-ft area to a depth of 12 to 18 inches as a result of the 1972 removal of contaminated soil and its replacement with clean soil. No drums currently exist at the site. If contamination exists at the site, it will be found below the 12 to 18 inches of clean soil and within the next 12 inches of depth (i.e., the bottom of the interval in question is 24 to 30 inches bgs).

2.2.4 Previous Site Investigations and Actions

The SSP Investigation at Site 1 began in 2005 to determine whether historical practices resulted in the release of thorium at concentrations of potential environmental concern. During the investigation, soil samples were collected from the RASO-approved Reference Area and from the onsite study area (Figures 2-1 and 2-2). Samples were collected from variable depth intervals (18 to 24, 24 to 30, or 30 to 36 inches bgs) from a 3-inch diameter borehole and sent to a laboratory for thorium-232 analysis using alpha spectroscopy. The appropriate depth interval for laboratory sample selection was based on the highest gross gamma radiation reading in the field from a gamma probe scintillator lowered down each borehole.

The presence or absence of residual contamination at Site 1 was determined by evaluating analytical results between the site and the Reference Area (uncontaminated background conditions). Background conditions, or a *derived concentration guideline level* (DCGL)[1], were/was established by adding 1 picoCurie per gram (pCi/g) to each of the Reference Area data (determined by RASO to be an appropriate incremental concentration by which the site could not exceed the Reference Area). The site and background data sets were compared using the Wilcoxon Rank Sum (WRS) test.

The results of the 2005 effort, along with additional research on historical activities, indicated an expanded study area was required. Subsequently, a larger study area was established and additional soil samples were collected in 2007 and analyzed for thorium-232 [a subset of samples also were analyzed for *naturally occurring radioactive material* (NORM) by gamma spectroscopy].

[1] The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) [Nuclear Regulatory Commission (NRC), 2000] defines the DGL as "a derived, radionuclide-specific activity concentration within a survey unit corresponding to the release criterion." MARSSIM also describes DCGLs as "...average levels of radiation or radioactivity above appropriate background levels."

After evaluating both the 2005 and the expanded 2007 data sets, it was determined that nine sample locations (S01SB011, S01SB014, S01SB020, S01SB021, S01SB023, S01SB031, S01SB032, S01SB039, and S01SB040) exhibited elevated activity considering the DCGL and field measurements (Appendix A and Figure 2-2).

2.2.5 Risk Summary

In addition to the WRS test, MARSSIM (NRC, 2000) states that areas of elevated activity need to be evaluated. For the purpose of the SSP, these areas of elevated activity were simply the individual sample locations where thorium-232 exceeds the developed DCGL, or where field-measured gamma readings were elevated. Therefore, it was necessary to develop a new DCGL to evaluate areas of elevated activity.

To develop the new appropriate DCGL, the RESRAD computer software was used in conjunction with a residential gardener exposure scenario (considered residents who did not raise their own meat, milk, or aquatic food on the property but are exposed to radiation via external gamma radiation, inhalation, plant ingestion, drinking water, and soil ingestion). Several model runs were made using assumed DCGLs from 1 to 4 pCi/g for thorium-232 in soil to determine the resulting cancer risk levels. The goal was to develop a DCGL that corresponded to a cancer risk within the EPA acceptable (or presumably not unacceptable) risk range of 1×10-4 (1 in 10,000) and 1×10-6 (1 in 1,000,000). The maximum DCGL that resulted in a cancer risk less than 1×10-4 is 3 pCi/g. The cancer risk levels resulting from the RESRAD modeling are shown below. The RESRAD modeling run output is provided in Appendix A.

Cancer Risk				
Thorium-232 Concentration in Soil (i.e., DCGL)				
Duration (years)	(pCi/g)			
	1	2	3	4
0	2.59×10^{-5}	5.18×10^{-5}	7.77×10^{-5}	1.04×10^{-4}
1	2.69×10^{-5}	5.39×10^{-5}	8.08×10^{-5}	1.08×10^{-4}
3	2.87×10^{-5}	5.74×10^{-5}	8.61×10^{-5}	1.15×10^{-4}
10	3.17×10^{-5}	6.33×10^{-5}	9.50×10^{-5}	1.27×10^{-4}
30	2.97×10^{-5}	5.93×10^{-5}	8.90×10^{-5}	1.19×10^{-4}
100	1.17×10^{-5}	2.34×10^{-5}	3.50×10^{-5}	4.67×10^{-5}

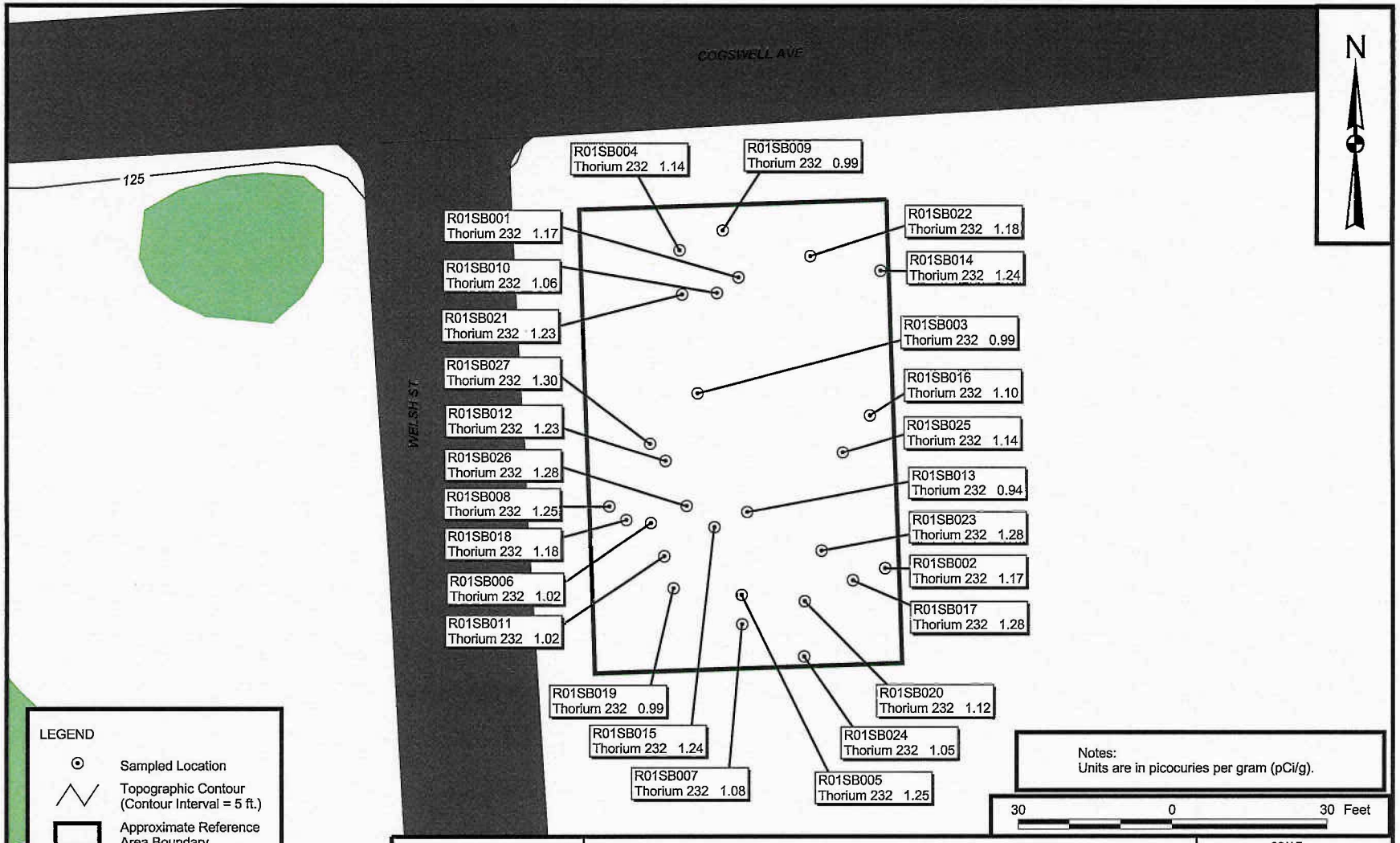
Seven sample locations (S01SB011, S01SB014, S01SB023, S01SB031, S01SB032, S01SB039, and S01SB040) had thorium-232 activity concentrations greater than the revised DCGL of 3 piC/g. Two locations (S01SB020 and S01SB021) with thorium-232 activity concentrations less than 3 piC/g were retained as contributing to unacceptable risk because of elevated down-hole gamma readings.

2.2.6 SSP Investigation Conclusion and Recommendation

Based on exceedances of the DCGL and elevated field readings, there are nine sampling locations within two areas that are candidates for excavation and removal to depths ranging from 24 to 36 inches bgs (Figure 3-1):

- The first area is defined by sample locations S01SB039 and S01SB40 in the northern portion of the site. The estimated area of contamination is 300 square feet, and the depth of contamination is 30 inches (2.5 feet).
- The second area is defined by the remaining sample locations in the central portion of the site. The estimated area of contamination is 775 square feet, and the average depth of contamination is 30 inches (2.5 feet).

The contaminated soil could be removed for offsite disposal. Based on the site history and surface radiation measurements, the upper 18 inches of soil may not be contaminated. If this soil is removed, screened for radiation, and found to be uncontaminated, it could be stockpiled for use as backfill. This would reduce the volume of soil for offsite disposal by more than 50 percent. Another option would be to implement land use controls to prevent residential use.



Tetra Tech NUS, Inc.

SITE 1 - THORIUM SPILL REFERENCE AREA
SAMPLE LOCATIONS AND RESULTS
NAVAL SUPPORT FACILITY, INDIAN HEAD
INDIAN HEAD, MARYLAND

SCALE	
1 = 30	
FILE	
SITE 01 WP	
REV	DATE
—	—
FIGURE NUMBER	
FIGURE 2 - 1	

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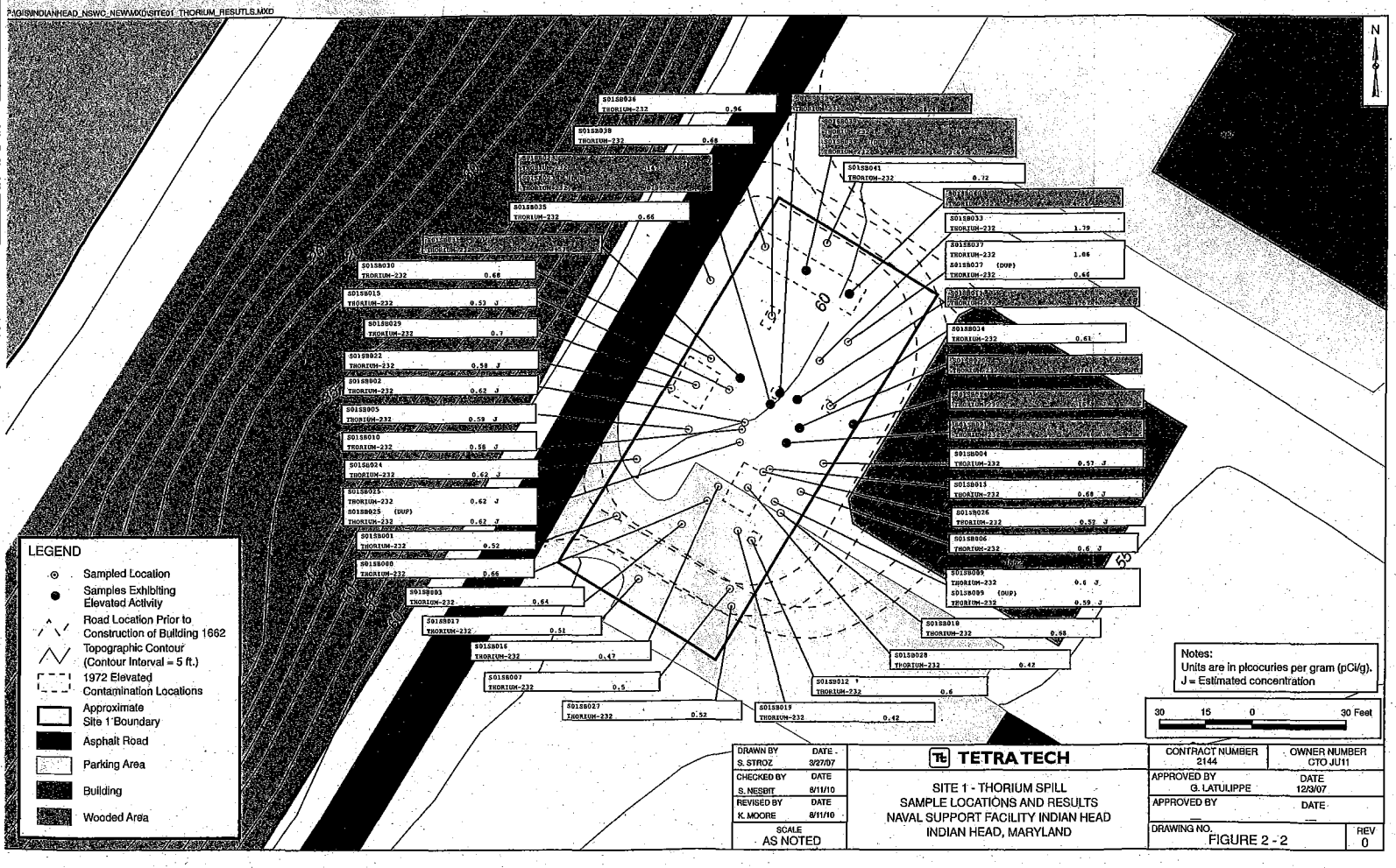

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CHECKED BY S. NESBIT	DATE 8/11/10	SITE 1 - THORIUM SPILL SAMPLE LOCATIONS AND RESULTS NAVAL SUPPORT FACILITY INDIAN HEAD INDIAN HEAD, MARYLAND	APPROVED BY G. LATULIPPE / DATE 12/3/07
REVISED BY K. MOORE	DATE 8/11/10		APPROVED BY / DATE
SCALE AS NOTED			DRAWING NO. FIGURE 2 - 2 / REV 0

3.0 IDENTIFICATION OF REMOVAL ACTION OBJECTIVES

The Removal Action Objectives (RAOs) are developed to provide guidelines for evaluating the removal action and assuring that the action complies with regulatory requirements [e.g., Applicable or Relevant and Appropriate Requirements (ARARs)]. This section presents the RAOs and the removal action scope, schedule, associated statutory limits, and an evaluation of ARARs for the NTCRA.

3.1 STATUTORY LIMITS ON REMOVAL ACTION

The NCP (i.e., 40 CFR 300.415) dictates statutory limits of $2 million and 12 months of EPA fund-financed removal actions, with statutory exemptions for emergencies and actions consistent with the removal action to be taken. However, the removal action evaluated in this EE/CA will not be EPA fund-financed. The Navy ERP does not limit the cost or duration of the removal action; nonetheless, cost-effectiveness is a recommended criterion for the evaluation of removal action alternatives.

3.2 REMOVAL ACTION SCOPE AND OBJECTIVE

3.2.1 Removal Action Target Medium and Contaminants

The results of the SSP Investigation identified thorium-232 in subsurface soil as the site-related contaminant risk driver (Tetra Tech, 2009). Subsurface soil is the medium of concern at Site 1. The proposed measurable removal action cleanup level is the DCGL of 3 piC/g, which corresponds to a cancer risk less than 1×10-4 (see Section 2.2.5). The current limits of the Target Removal Area (TRA) for soil are shown on Figure 3-1.

3.2.2 Removal Action Objective

RAOs are site-specific goals formed considering the site-related contaminants to be addressed and the impacted media, as well as contaminant mobility, exposure routes and receptors, and cleanup goals. The RAO for the NTCRA at Site 1 evaluated herein is as follows:

To reduce or eliminate potential unacceptable human health risk associated with hypothetical residential exposure to thorium-232 in soil to allow for unrestricted site use and unlimited exposure.

3.2.3 Removal Action Scope

In addition to the no-action alternative (Alternative 1), one other alternative was developed to meet the RAO. The scope of each NTCRA alternative is summarized below (see Section 4.0 for identification and evaluation of each alternative):

- Alternative 1 – No Action: The no-action alternative implies that no removal work would be done at this site. This alternative is included as a basis of comparison for the other alternatives.

- Alternative 2 – Excavation and Offsite Disposal: Direct excavation and appropriate offsite disposal of contaminated soil, followed by restoration to pre-existing conditions using clean fill.

3.3 DETERMINATION OF REMOVAL SCHEDULE

The EE/CA will be placed in the Administrative Record, and notice of its availability for public review along with a brief summary will be published in local newspapers. The EE/CA will then be subjected to a 30 day public comment period. A public information session will be held during or immediately following the public comment period if requested. If significant comments are received, Responsiveness Summary will be prepared and attached to the Action Memorandum, which will be included in the NSF-IH Administrative Record.

Since this removal action has been designated non-time-critical, the start date will be determined by factors other than the urgency of the threat. Following public review, the Action Memorandum will be submitted with the final version of the EE/CA, followed by preparation of the Remedial Action Work Plan (RAWP). The removal action timeframe includes the time required for mobilization and setup of equipment, and implementing the selected removal action, all of which are tentatively scheduled for summer 2011. Alternative 2 (excavation) would require 1 month or less of construction activities, and would not require any Post-Removal Site Control (PRSC)—those activities that are necessary to sustain the integrity of a removal action following its conclusion (e.g., long-term administrative controls, operation and maintenance, etc.) (EPA, 1992).

3.4 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The removal action will comply to the extent practicable with ARARs under federal and state environmental laws, as described in 40 CFR 300.415. The evaluation of ARARs for the NTCRA at Site 1 is provided in Appendix B. Other federal and state advisories, criteria, or guidance, as appropriate, will be

considered as appropriate in formulating the removal action. The term ARAR is defined in the NCP as follows:

- Applicable requirements are generally defined as cleanup standards, standards of control, or other substantive environmental protection requirements promulgated under Federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, or location. Only those state standards that are identified by a state in a timely manner and that are more stringent than Federal requirements may be considered as applicable requirements.

- Relevant and appropriate requirements are defined as cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state environmental or facility siting laws that are not directly "applicable" to a hazardous substance, pollutant, contaminant, remedial action, or location, but address situations sufficiently relevant to those encountered at the site that their use is appropriate. Only those state standards that are identified by a state in a timely manner and that are more stringent than Federal requirements may be considered as relevant and appropriate requirements.

- Any promulgated standard, requirement, criterion, or limitation under a state environmental or facility-siting law that is more stringent than the associated Federal standard, requirement, criterion, or limitation.

Federal ARARs are determined by the lead agency, which in this case is the Navy. As outlined by 40 CFR 300.415(j), the lead agency may consider the urgency of the situation and the scope of the removal action to be conducted in determining whether compliance with ARARs is practicable. The NCP, 40 CFR 300.400(g)(2), specifies factors to consider in determining what requirements of other environmental laws are relevant and appropriate:

- The purpose of the requirement in relation to the purpose of CERCLA
- The media regulated by the requirement
- The substance(s) regulated by the requirement
- The actions or activities regulated by the requirement
- Variations, waivers, or exemptions of the requirement
- The type of place regulated and the type of place affected by the release or CERCLA action
- The type and size of the facility or structure regulated by the requirement or affected by the release
- Consideration of the use or potential use of affected resources in the requirement

In some circumstances, a requirement may be relevant to the particular site-specific situation but may not be appropriate because of differences in the purpose of the requirement, the duration of the regulated activity, or the physical size or characteristic of the situation it is intended to address. There is more discretion in the judgment of relevant and appropriate requirements than in the determination of applicable requirements.

Three classifications of requirements are defined by EPA in the ARAR determination process: chemical-specific, location-specific, and action-specific. An evaluation of each of these ARARs is presented in Appendix B.

- Chemical-specific ARARs are health or risk management-based numbers or methodologies that result in the establishment of numerical values for a given media that would meet the NCP "threshold criterion" of overall protection of human health and the environment. These requirements generally set protective cleanup concentrations for the chemicals of concern in the designated media, or set safe concentrations of discharge for remedial activity.

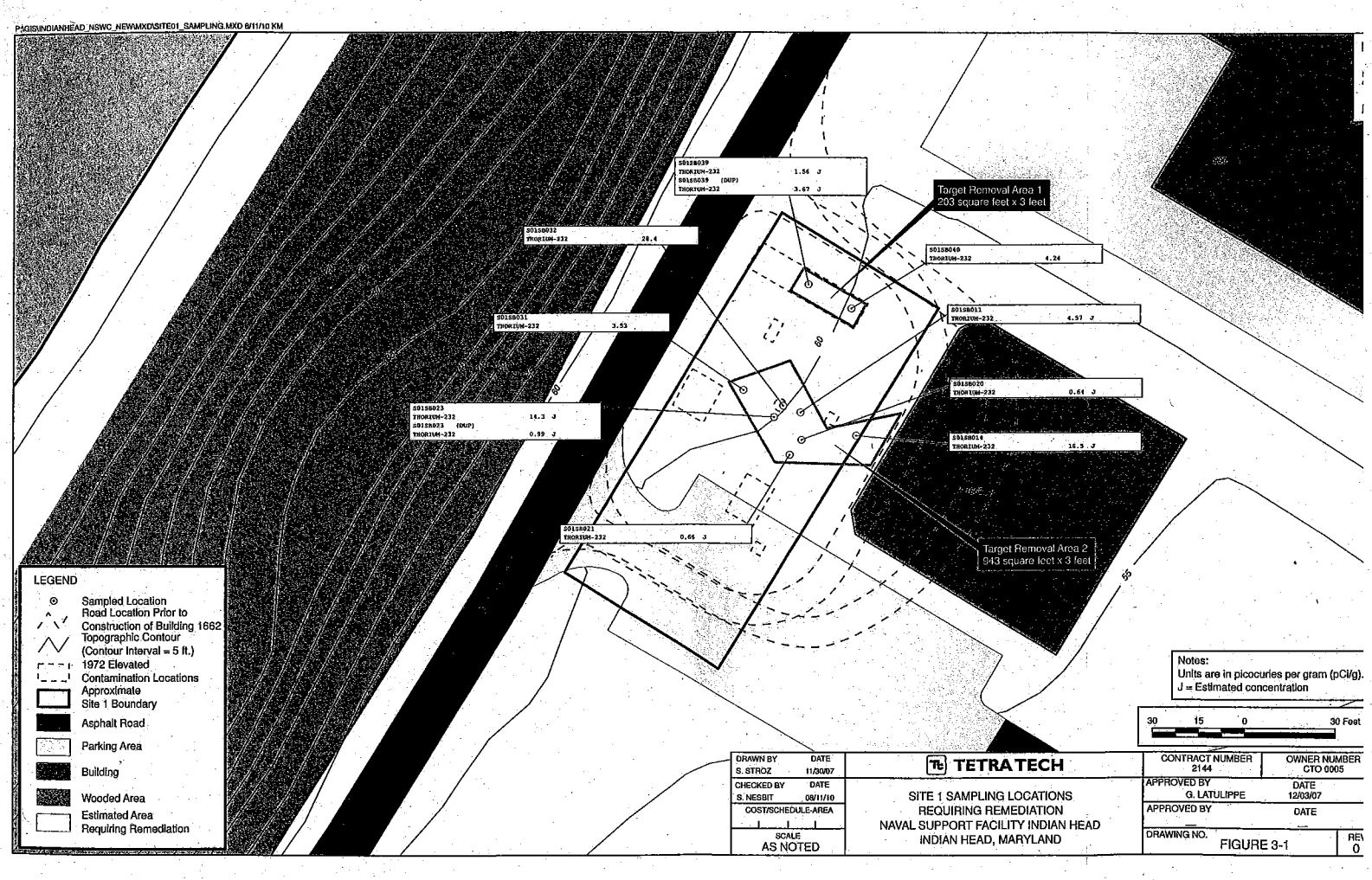
- Location-specific ARARs restrict remedial activities (i.e., removal actions) and media concentrations based on the characteristics of the surrounding environments. Location-specific ARARs may include restrictions on remedial actions within wetlands or floodplains, near locations of known endangered species, or on protected waterways.

- Action-specific ARARs pertain to the implementation of a given remedy. These ARARs control or restrict hazardous substance- or pollutant-related activities. These controls are considered when specific removal activities are planned for a site.

In addition to ARARs, other regulations and guidance may be classified as guidance "To Be Considered" (TBC). TBCs are non-promulgated, non-enforceable guidelines or criteria that may be useful for developing removal actions or necessary for determining what would be protective of human health and/or the environment. TBCs are also evaluated in Appendix B to aid in the evaluation of the removal action.

Section 121(d)(4) of CERCLA identifies circumstances under which ARARs may be waived, including the instance where the selected removal action is an interim remedy and the final remedial action will attain the ARAR upon its completion. As such, the selected removal actions for the sites being addressed under this EE/CA do not necessarily need to comply with all identified ARARs. However, if Alternative 2 (excavation) is selected, it is anticipated that NFA will be necessary at the site to achieve unrestricted use and unlimited exposure (UU/UE) status.

P:\GIS\INDIANHEAD_NSWC_NEW\MXD\SITE01_SAMPLING.MXD 8/11/10 KM



DRAWN BY S. STROZ DATE 11/30/07	TETRA TECH	CONTRACT NUMBER 2144	OWNER NUMBER CTO 0005
CHECKED BY S. NESBIT DATE 08/11/10	SITE 1 SAMPLING LOCATIONS REQUIRING REMEDIATION NAVAL SUPPORT FACILITY INDIAN HEAD INDIAN HEAD, MARYLAND	APPROVED BY G. LATULIPPE	DATE 12/03/07
COST/SCHEDULE-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 3-1	REV 0

4.0 DESCRIPTION AND EVALUATION OF REMOVAL ACTION ALTERNATIVES

This section identifies, develops, and screens applicable technologies and process options to assemble removal action alternatives. It provides a description and initial evaluation of each assembled alternative. Section 5.0 completes the alternative evaluation and recommendation with a comparison of each alternative.

4.1 IDENTIFICATION OF REMOVAL ACTION ALTERNATIVES

Unlike organic contaminants (and similar to metals), radionuclides cannot be destroyed or degraded. Therefore, remediation technologies applicable to radionuclides involve separation, concentration/volume reduction, and/or immobilization [Federal Remediation Technologies Roundtable (FRTR), 2010]. The most commonly used treatment technology for radionuclides in soil, sediment, and sludge is solidification/stabilization. However, these technologies would not meet the RAO, as the thorium would be left onsite and site use restrictions would be required.

The two removal action alternatives developed for the NTCRA at Site 1 are as follows:

- Alternative 1 – No Action
- Alternative 2 – Excavation and Offsite Disposal

The areal extent of the TRA shown on Figure 3-1 is approximately 1,075 square ft (ft^2) (less than 0.02 acre). Considering construction excavation techniques and the depth of known contamination at 2.5 ft, it is assumed conservatively that soil from ground surface to 3 ft bgs will be addressed by the NTCRA. This totals 3,225 cubic ft (ft^3) or 120 cubic yards (yd^3).

4.1.1 Alternative 1 – No Action

The no-action alternative implies that no removal work will be completed at this site. The site will be left as it currently exists leaving the soil contamination at levels posing potential risk to human health. This alternative provides a baseline for comparing other alternatives. Because no removal activities will be implemented, long-term human health risks for the site essentially will be the same as those identified in the SSP Report (Tetra Tech, 2009).

4.1.2 Alternative 2 – Excavation and Offsite Disposal

This alternative will include the removal of approximately 120 cubic yards of soil over an area of 1,075 ft^2 to a depth of 3 ft bgs (Figure 3-1). The proposed excavation limits are mostly defined by soil with

thorium-232 activity concentrations at individual sample locations that exceed the DCGL of 3 piC/g (see Section 2.2.5). The alternative will include post-excavation verification samples on the side-walls and bottom of each excavation area. It is possible to collect pre-excavation confirmation/verification samples pending Team approval. Samples will be analyzed for thorium-232 by alpha spectroscopy. If results show additional excavation is necessary, additional soil will be removed.

Site preparation activities would include mobilization and setup of facilities, installation of erosion and sediment controls, clearing of work areas (including demolition of any asphalt covering the excavation areas), installation of appropriate drainage controls to the degree necessary to support construction, preparation of radiological decontamination equipment and materials, and preparation for airborne radioactivity dust suppression. No specific site clearing will be required considering current site conditions (TRA is fully accessible).

Materials that have radioactivity above release criteria will be disposed at an NRC-licensed facility. Due to the relatively low levels of activity expected during excavation activities, minimal decontamination of heavy equipment will be required to provide for unconditional release. It is not expected that significant amounts of liquid decontamination waste would be generated. Any waste associated with excavation or decontamination activities will be processed and disposed of with the excavated soils.

Excavated areas will be backfilled with clean fill to grade and seeded with native grasses (restoration details will be determined during preparation of the RAWP). After implementation of Alternative 2, no monitoring or permanent controls will be necessary after the removal action is completed, other than verification of the re-establishment of vegetation in the area after one growing season. Following re-establishment of vegetation, site reviews will not be required as the contaminated media will be disposed offsite. Cost assumptions are provided in Appendix C. The cost estimation assumes full excavation from 0 to 3 ft bgs in the TRA. However, note that cost savings may be realized by not disposing the top 18 inches of soil at the site (which are not impacted by thorium-232). These soils could be used as backfill, which will decrease the need for importing clean fill and decrease the amount of low-level radioactive waste to be transported and disposed of at a permitted facility.

4.2 EVALUATION OF REMOVAL ACTION ALTERNATIVES

Table 4-1 presents the summary of the evaluation of Alternatives 1 and 2.

The effectiveness of a technology refers to its capability of removing the specific items in the volumes required, the degree to which the technology achieves the RAO, and the reliability and performance of the technology over time, including protection of human health and the environment, compliance with ARARs

to the extent practicable, long-term effectiveness and permanence, reduction in the toxicity, mobility or volume, and short-term effectiveness.

The ease of implementation of a technology refers to the availability of commercial services to support it, the constructability of the technology under specific site conditions, and the acceptability of the technology to all parties involved (e.g., regulators, public, owner), including technical feasibility, administrative feasibility, availability of services, support agency acceptance, and community acceptance.

For the detailed cost analysis of the alternatives, the expenditures required to complete each measure were estimated in terms of capital costs to complete initial construction activities. There are no future costs associated with the removal alternatives. The costs estimated are provided to an accuracy of +50% and –30%. The alternative cost estimates are in 2010 dollars and based on quotations from potential vendors and subcontractors, engineering estimates, recent and continual project experience on similar Navy projects, and published values by R.S. Means. Refer to Appendix C for all cost estimate details pertaining to Alternative 2 (there is no cost associated with Alternative 1).

TABLE 4-1

EVALUATION OF NON-TIME-CRITICAL REMOVAL ACTION ALTERNATIVES FOR SOIL
SITE 1 - THORIUM SPILL EE/CA
NSF-IH, INDIAN HEAD, MARYLAND

Alternative	Description	Effectiveness	Ease of Implementation	Cost			
				Capital Cost	*Post-Removal Site Control (PRSC)*		Total Cost of Alternative *(2010 Dollars)*
					O&M and/or Periodic Future Costs	Present Value (2010) Future Costs	
Alternative 1							
No Action	No removal work performed. Site left "as is".	This alternative would not be effective. Would not meet the RAO, comply with ARARs, reduce volume or mobility of contamination, or provide any short- or long-term protectiveness.	This alternative would be easy to implement since there is nothing to implement.	$0	$0	$0	**$0**
Alternative 2							
Excavation and Offsite Disposal	Excavation and offsite disposal of the thorium-232-impacted soils. Restoration back to grade and re-vegetation. No future actions would be required.	Will meet the RAO and comply with ARARs. Short-term effectiveness is impacted inherently by construction activities. Provides the greatest long-term effectiveness and permanence at the site by removing the contaminated soil and placing it in an NRC-permitted disposal facility. Requires no future actions to be protective. Unrestricted Use and Unlimited Exposure (UU/UE) is achieved following implementation of this alternative. Does not reduce the toxicity or volume of contamination.	Moderately Easy to implement, multiple general and specialized contractors could readily perform the excavation, hauling, backfilling operations with no specialized engineering constraints. Only one contractor/equipment mobilization would be necessary. Proper management of contaminated soils that are excavated and disposed will be required. Also requires heavy equipment/truck traffic through base and immediate vicinity.	**$340,000**	$0	$0	**$340,000** *-30% = $238,000* *+50% = $510,000*

Notes and Abbreviations
ARAR - Applicable or Relevant and Appropriate Requirement RAO - Removal Action Objective LUCs - Land Use Controls O&M - operation and maintenance

5.0 COMPARATIVE ANALYSIS OF REMOVAL ALTERNATIVES

This section provides a comparative analysis of the two alternatives presented in Section 4.0 to assist the decision-making process by which a removal action will be selected. In Section 4.0, these alternatives were evaluated according to their effectiveness (including protection of human health and the environment, compliance with ARARs to the extent practicable, short- and long-term effectiveness, and reduction in toxicity, mobility, or volume), ease of implementation (including technical and administrative feasibility, availability of services, support agency acceptance, and community acceptance), and cost. In this section, the alternatives are directly compared for each of the three criteria.

Levels of effectiveness were assessed based upon the number of "effectiveness criteria" that would be satisfied by each alternative. The "effectiveness criteria," from the EPA (1993) are identified as:

- Protection of human health
- Protection of workers during implementation
- Protection of environment
- Compliance with ARARs
- Level of treatment and containment expected
- Residual effect concerns

Levels of implementability were assessed based upon the number of "implementability criteria" satisfied by each alternative. Evaluation of implementability essentially assesses the technical and administrative feasibility of completing each task. The "implementability criteria" from the EPA (1993) are as follows:

- Technical Feasibility Elements
  - Construction and operational considerations
  - Demonstrated performance/useful life
  - Adaptable to environment conditions
  - Contributes to remedial performance
  - Can be implemented in 1 year
  - Availability of equipment, personnel, and services
  - Availability of outside laboratory testing capacity and offsite treatment and disposal capacity
- Administrative Feasibility Elements
  - Permits required
  - Easements or rights-of-way required
  - Impact on adjoining property
  - Ability to impose institutional controls

5.1 REMOVAL ALTERNATIVE COMPARISON

Referring to Table 4-1 and the summary table below, the comparison of the alternatives is discussed in this subsection.

NTCRA Alternative	Effectiveness	Ease of Implementation	Cost
1 - No Action	Not Effective	Easy	No Cost
2 - Excavation and Offsite Disposal	Most Effective	Moderately Easy	Moderate

5.1.1 Effectiveness

Alternative 1 (No Action) is not effective as it will not meet the RAO and will not comply with ARARs. Alternative 2 (Excavation) will meet the RAO by eliminating (via excavation and offsite disposal) potential unacceptable risk associated with residential exposure to thorium-impacted soil at the site and allowing for UU/UE. Alternative 2 will comply with ARARs.

Alternative 2's short-term effectiveness is impacted by potential worker safety issues during standard construction practices and exposure to low-level radioactivity during the removal action. Similarly, NSF IH personnel and the community may be impacted by the activity. Alternative 2 provides the greatest long-term effectiveness and permanence by physically removing the impacted soil from the site; however, offsite disposal does not reduce toxicity or volume of the contamination. Alternative 2 will not require future actions to remain protective.

5.1.2 Implementation

Alternative 1 (No Action) does not involve any removal activities, making it the easiest alternative to "implement." Alternative 2 (Excavation) is considered moderately easy to implement since this construction technology is common industry practice.

5.1.3 Cost

There is no cost associated with Alternative 1 (No Action) ($0). The estimated cost of Alternative 2 (Excavation) is $340,000, which is all capital costs (no future costs). No Post-Removal Site Control will be required after the implementation of Alternative 2 (NFA).

6.0 RECOMMENDED ALTERNATIVE

This EE/CA was performed in accordance with current EPA guidance documents for a NTCRA under the CERCLA framework. The goal of this EE/CA for Site 1, to identify the RAO and evaluate removal alternatives to meet the RAO, was met. The identified RAO is to reduce or eliminate the potential risk to human health associated with thorium-232-impacted soil (see Section 3.2.2). After an initial desktop screening of technologies, two alternatives were identified, evaluated, and compared based on effectiveness, implementability, and cost.

The comparative analysis included evaluating the effectiveness, implementability, and cost of each alternative. The evaluation of effectiveness included reviewing the protectiveness of the alternative; compliance with ARARs to the extent practicable; long-term effectiveness and permanence; reduction in toxicity, mobility, or volume; short-term effectiveness; and its ability to meet the RAOs. The evaluation of implementability included looking at the technical feasibility, availability, and administrative feasibility of the alternatives. The evaluation of cost included a review of capital and potential future costs.

Based on the comparative analysis of the alternatives completed in Section 5.0, the recommended action is Alternative 2 – Excavation and Offsite Disposal. This alternative meets the objective of the NTCRA and provides the best balance in meeting the evaluation criteria.

REFERENCES

CFR (Code of Federal Regulations). Codification of the general and permanent rules published in the Federal Register by the executive departments and agencies of the U.S. Federal Government. http://www.gpoaccess.gov/cfr/index.html.

EPA (U.S. Environmental Protection Agency), 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.

EPA, 1992. CERCLA/SUPERFUND Orientation Manual. Office of Solid Waste and Emergency Response, Techn0ology Innovation Office. EPA-542-R-92-005. October.

EPA, 1993. Guidance on Conducting Non-Time Critical Removal Actions Under CERCLA. EPA/540-R-93-057. August.

EPA, 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. With the U.S. Army Corps of Engineers. OSWER 9355.0-75. EPA 540-R-00-002. July.

Navy, 2000. Federal Facility Agreement Under CERCLA Section 120, Administrative Document No.

III-FCA-CERC-018. Signed by Navy and U.S. EPA. December 9.

Hart (Fred C. Hart Associates, Inc.), 1983. Initial Assessment Study of Naval Ordnance Station, Indian Head, Maryland.

Jorgensen, Shawn, 2002. Memorandum: Installation Restoration Site 1 – Thorium Spill, Memorandum

No. 5090, Serial Number 044SJ/07. March 29.

Navy, 2006. Department of the Navy Environmental Restoration Program (NERP) Manual. August.

NRC (Nuclear Regulatory Commission), 2000. Environmental Protection Agency, Department of Energy, Department of Defense, and Nuclear Regulatory Commission. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), Revision 1. EPA 402-R-97-016, Rev. 1. August.

Tetra Tech, 2005. Work Plan for Site Screening Process Report at Site – 1 Thorium Spill, Naval Support Facility, Indian Head, Maryland. October.

Tetra Tech, 2009. Site Screening Process Report at Site – 1 Thorium Spill, Naval Support Facility, Indian Head, Maryland. May.

USAEC (United States Atomic Energy Commission), 1974. Regulatory Guide 1.86, Termination of Operating Licenses for Nuclear Reactors. Directorate of Regulatory Standards. June. http://www.gov/reading-rm/doc-collections/reg-guides/power-reactors/active/01-086/01-086.pdf.

USC (United States Code). Codification by subject matter of the general and permanent laws of the U.S. Federal Government published by the Office of the Law Revision Counsel of the U.S. House of Representatives. http://www.gpoaccess.gov/uscode/index.html.

APPENDIX A

ANALYTICAL DATA
AND
RESRAD MODELING RUN

TABLE D - 1

ANALYTICAL DATA
THORIUM - 232 CONCENTRATIONS
SITE 1 - THORIUM SPILL
NSF-IH, INDIAN HEAD, MARYLAND

Reference Area Samples	Thorium - 232 Concentration pCi/g	Year Sampled
R01SB001	1.17	2005
R01SB002	1.17	2005
R01SB003	0.99	2005
R01SB004	3.10	2005
R01SB005	1.25	2005
R01SB006	1.02	2005
R01SB007	1.08	2005
R01SB008	1.25	2005
R01SB009	0.99	2005
R01SB010	1.06	2005
R01SB011	1.02	2005
R01SB012	1.23	2005
R01SB013	0.94	2005
R01SB014	1.24	2005
R01SB015	1.24	2005
R01SB016	1.10	2005
R01SB017	1.28	2005
R01SB018	1.18	2005
R01SB019	0.99	2005
R01SB020	1.32	2005
R01SB021	1.23	2005
R01SB022	1.18	2005
R01SB023	1.28	2005
R01SB024	1.05	2005
R01SB025	1.14	2005
R01SB026	1.28	2005
R01SB027	1.30	2005

Site 1 Samples	Thorium - 232 Concentration pCi/g	Year Sampled
S01SB001	0.52	2005
S01SB002	0.62	2005
S01SB003	0.64	2005
S01SB004	0.57	2005
S01SB005	0.59	2005
S01SB006	0.60	2005
S01SB007	0.50	2005
S01SB008	0.66	2005
S01SB009	0.60	2005
S01SB010	0.58	2005
S01SB011	4.57	2005
S01SB012	0.60	2005
S01SB013	0.68	2005
S01SB014	16.50	2005
S01SB015	0.53	2005
S01SB016	0.47	2005
S01SB017	0.51	2005
S01SB018	0.58	2005
S01SB019	0.42	2005
S01SB020	0.64	2005
S01SB021	0.66	2005
S01SB022	0.58	2005
S01SB023	14.30	2005
S01SB024	0.62	2005
S01SB025	0.62	2005
S01SB026	0.52	2005
S01SB027	0.52	2005
S01SB028	0.42	2007
S01SB029	0.70	2007
S01SB030	0.68	2007
S01SB031	3.53	2007
S01SB032	28.40	2007
S01SB033	1.79	2007
S01SB034	0.61	2007
S01SB035	0.66	2007
S01SB036	0.96	2007
S01SB037	1.06	2007
S01SB038	0.68	2007
S01SB039	3.67	2007
S01SB040	4.24	2007
S01SB041	0.72	2007

TABLE D - 2

ANALYTICAL DATA
NATURALLY OCCURRING RADIOLOGICAL MATERIAL (NORM) PARAMETERS
SITE 1 - THORIUM SPILL
NSF-IH, INDIAN HEAD, MARYLAND

Sample Name	S01SB0140101	S01SB0200102	S01SB0210102
Sample Location	S01SB014	S01SB020	S01SB021
Date Sampled	20051201	20070117	20070117
Matrix	Soil	Soil	Soil
Top of Sampled Interval Below Ground Surface (feet)	2	1.5	1.5
Bottom of Sampled Interval Below Ground Surface (feet)	2.5	2	2
Radiological Parameters (pCi/G)			
ACTINIUM-228	11.5	12	12.5
BISMUTH-212	8.1	8.7	9.3
BISMUTH-214	0.51	0.96	0.6
LEAD-212	12.3	13.1	13.8
LEAD-214	0.46	0.84	0.57
POTASSIUM-40	6.9	8.4	6.3
RADIUM-224	13.6		
RADIUM-226	0.51	0.96	0.6
RADIUM-228	11.5		
THALLIUM-208	3.91	4.84	4.9
THORIUM-234	2.2 U	1.5 U	1.2 U

U - Not detected.

SSP Report
Appendix G

WILCOXON RANK SUM ANALYSIS

WILCOXON RANK SUM ANALYSIS

SITE 1 - THORIUM SPILL
NSF-IH, INDIAN HEAD, MARYLAND

Sample Source		Thorium - 232 Concentration pCi/g	Adjusted Concentration pCi/g	Rank	Adjusted Rank for Reference Area Samples	Adjusted Rank for Site Samples	t
S01SB019	SITE	0.42	0.42	1		1.5	
S01SB028	SITE	0.42	0.42	2		1.5	2
S01SB016	SITE	0.47	0.47	3		3	
S01SB007	SITE	0.5	0.5	4		4	
S01SB017	SITE	0.51	0.51	5		5	
S01SB001	SITE	0.52	0.52	6		7	
S01SB026	SITE	0.52	0.52	7		7	3
S01SB027	SITE	0.52	0.52	8		7	
S01SB015	SITE	0.53	0.53	9		9	
S01SB004	SITE	0.57	0.57	10		10	
S01SB010	SITE	0.58	0.58	11		12	
S01SB018	SITE	0.58	0.58	12		12	3
S01SB022	SITE	0.58	0.58	13		12	
S01SB005	SITE	0.59	0.59	14		14	
S01SB006	SITE	0.6	0.6	15		16	
S01SB009	SITE	0.6	0.6	16		16	3
S01SB012	SITE	0.6	0.6	17		16	
S01SB034	SITE	0.61	0.61	18		18	
S01SB002	SITE	0.62	0.62	19		20	
S01SB024	SITE	0.62	0.62	20		20	3
S01SB025	SITE	0.62	0.62	21		20	
S01SB003	SITE	0.64	0.64	22		22.5	
S01SB020	SITE	0.64	0.64	23		22.5	2
S01SB008	SITE	0.66	0.66	24		25.5	
S01SB021	SITE	0.66	0.66	25		25.5	3
S01SB035	SITE	0.66	0.66	26		25.5	
S01SB013	SITE	0.68	0.68	27		28	
S01SB030	SITE	0.68	0.68	28		28	3
S01SB038	SITE	0.68	0.68	29		28	
S01SB029	SITE	0.7	0.7	30		30	
S01SB041	SITE	0.72	0.72	31		31	
S01SB036	SITE	0.96	0.96	32		32	
S01SB033	SITE	1.79	1.79	33		33	
R01SB013	REF	0.94	1.94	34	34		
R01SB003	REF	0.99	1.99	35	36		
R01SB009	REF	0.99	1.99	36	36		3
R01SB019	REF	0.99	1.99	37	36		
R01SB006	REF	1.02	2.02	38	38.5		
R01SB011	REF	1.02	2.02	39	38.5		2
R01SB024	REF	1.05	2.05	40	40		
R01SB010	REF	1.06	2.06	41	41.5		
S01SB037	SITE	1.06	2.06	42		41.5	2
R01SB007	REF	1.08	2.08	43	43		
R01SB016	REF	1.1	2.1	44	44		
R01SB025	REF	1.14	2.14	45	45		
R01SB001	REF	1.17	2.17	46	46.5		
R01SB002	REF	1.17	2.17	47	46.5		2
R01SB018	REF	1.18	2.18	48	48.5		
R01SB022	REF	1.18	2.18	49	48.5		2
R01SB012	REF	1.23	2.23	50	50.5		
R01SB021	REF	1.23	2.23	51	50.5		2
R01SB014	REF	1.24	2.24	52	52.5		
R01SB015	REF	1.24	2.24	53	52.5		2
R01SB005	REF	1.25	2.25	54	54.5		
R01SB008	REF	1.25	2.25	55	54.5		2
R01SB017	REF	1.28	2.28	56	57		
R01SB023	REF	1.28	2.28	57	57		3
R01SB026	REF	1.28	2.28	58	57		
R01SB027	REF	1.3	2.3	59	59		
R01SB020	REF	1.32	2.32	60	60		
S01SB031	SITE	3.53	3.53	61		61	
S01SB039	SITE	3.67	3.67	62		62	
R01SB004	REF	3.1	4.1	63	63		
S01SB040	SITE	4.24	4.24	64		64	
S01SB011	SITE	4.57	4.57	65		65	
S01SB023	SITE	14.3	14.3	66		66	
S01SB014	SITE	16.5	16.5	67		67	
S01SB032	SITE	28.4	28.4	68		68	
				RANK SUM>>	1290.5	1057	

First Round and Second Round Sampling

WILCOXON RANK SUM ANALYSIS

SITE 1 - THORIUM SPILL
NSF-IH, INDIAN HEAD, MARYLAND

$$\text{VALUE} = m(n+m+1)\frac{1}{2} + z\sqrt{\frac{nm}{12}\left[(n+m+1) - \sum_{j=1}^{g}\frac{t_j(t_j^2-1)}{(n+m)(n+m-1)}\right]}$$

Where: g = the number of data groups of tied measurements.
t_j = the number of tied measurements in the jth group.
z = the (1-α) percentile of a standard norman distribution = 1.645 for α = 0.05

n = # of site samples = 41
m = # of background samples = 27
N = # of total samples n + m = 68

$$m(n+m+1)\frac{1}{2} = 918$$

$$z = 1.645$$

$$\frac{nm}{12} = 90$$

$$n+m+1 = 68.00$$

$$\sum_{j=1}^{g}\frac{t_j(t_j^2-1)}{(n+m)(n+m-1)}] = 0.05481$$

$$918 + 1.645\sqrt{(90)[(68) - 0.0548]} = 1046.64$$

CRITICAL VALUE = 1046.64

REFERENCE AREA RANK SUM = 1291.5 > CRITICAL VALUE = 1046.64

THE NULL HYPOTHESIS IS REJECTED.

t	$\frac{t_j(t_j^2-1)}{(n+m)(n+m-1}$
2	0.00134
3	0.00535
3	0.00535
3	0.00535
3	0.00535
2	0.00134
3	0.00535
3	0.00535
3	0.00535
2	0.00134
2	0.00134
2	0.00134
2	0.00134
2	0.00134
2	0.00134
2	0.00134
3	0.00535
∑=	0.05481

SSP Report
Appendix H.3

RESRAD MODELING RUN

DCGL = 3 pCi/g

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Dose Conversion Factor (and Related) Parameter Summary
File: FGR 13 MORBIDITY

Menu	Parameter	Current Value	Base Case*	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ra-228+D	5.078E-03	4.770E-03	DCF2(1)
B-1	Th-228+D	3.454E-01	3.420E-01	DCF2(2)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(3)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ra-228+D	1.442E-03	1.440E-03	DCF3(1)
D-1	Th-228+D	8.086E-04	3.960E-04	DCF3(2)
D-1	Th-232	2.730E-03	2.730E-03	DCF3(3)
D-34	Food transfer factors:			
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(1,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(1,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(1,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(2,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(2,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(2,3)
D-34				
D-34	Th-232 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(3,1)
D-34	Th-232 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(3,2)
D-34	Th-232 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(3,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(1,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(1,2)
D-5				
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(2,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(2,2)
D-5				
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(3,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(3,2)

*Base Case means Default.Lib w/o Associate Nuclide contributions.

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	7.525E+02	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.500E-01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Th-232	3.000E+00	0.000E+00	---	S1(3)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(3)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.500E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.500E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	3.704E-05	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	3.165E-02	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	3.704E-05	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	1.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	7.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	5.100E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.376E+00	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
C14	DCF correction factor for gaseous forms of C14	not used	0.000E+00	---	CO2F
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS
TITL	Maximum number of integration points for dose	17	---	---	LYMAX

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
TITL	Maximum number of integration points for risk	257.	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	752.49 square meters	Th-232	3.000E+00
Thickness:	0.15 meters		
Cover Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	1.182E+00	2.710E+00	5.949E+00	1.391E+01	1.738E+01	1.040E+01	0.000E+00	0.000E+00
M(t):	4.730E-02	1.084E-01	2.380E-01	5.563E-01	6.950E-01	4.159E-01	0.000E+00	0.000E+00

Maximum TDOSE(t): 1.748E+01 mrem/yr at t = 25.44 ± 0.05 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.544E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	1.571E+01	0.8989	2.314E-01	0.0132	0.000E+00	0.0000	1.307E+00	0.0748	0.000E+00	0.0000	0.000E+00	0.0000	2.282E-01	0.013
Total	1.571E+01	0.8989	2.314E-01	0.0132	0.000E+00	0.0000	1.307E+00	0.0748	0.000E+00	0.0000	0.000E+00	0.0000	2.282E-01	0.013

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.544E+01 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.748E+01	1.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.748E+01	1.000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	5.775E-01	0.4884	2.402E-01	0.2032	0.000E+00	0.0000	1.912E-01	0.1617	0.000E+00	0.0000	0.000E+00	0.0000	1.735E-01	0.146
Total	5.775E-01	0.4884	2.402E-01	0.2032	0.000E+00	0.0000	1.912E-01	0.1617	0.000E+00	0.0000	0.000E+00	0.0000	1.735E-01	0.146

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.182E+00	1.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.182E+00	1.000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	1.901E+00	0.7015	2.403E-01	0.0887	0.000E+00	0.0000	3.857E-01	0.1423	0.000E+00	0.0000	0.000E+00	0.0000	1.831E-01	0.067
Total	1.901E+00	0.7015	2.403E-01	0.0887	0.000E+00	0.0000	3.857E-01	0.1423	0.000E+00	0.0000	0.000E+00	0.0000	1.831E-01	0.067

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.710E+00	1.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.710E+00	1.000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	4.814E+00	0.8093	2.428E-01	0.0408	0.000E+00	0.0000	6.914E-01	0.1162	0.000E+00	0.0000	0.000E+00	0.0000	2.006E-01	0.033
Total	4.814E+00	0.8093	2.428E-01	0.0408	0.000E+00	0.0000	6.914E-01	0.1162	0.000E+00	0.0000	0.000E+00	0.0000	2.006E-01	0.033

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.949E+00	1.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.949E+00	1.000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	1.222E+01	0.8784	2.491E-01	0.0179	0.000E+00	0.0000	1.208E+00	0.0868	0.000E+00	0.0000	0.000E+00	0.0000	2.337E-01	0.016
Total	1.222E+01	0.8784	2.491E-01	0.0179	0.000E+00	0.0000	1.208E+00	0.0868	0.000E+00	0.0000	0.000E+00	0.0000	2.337E-01	0.016

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.391E+01	1.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.391E+01	1.000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	1.566E+01	0.9013	2.234E-01	0.0129	0.000E+00	0.0000	1.271E+00	0.0731	0.000E+00	0.0000	0.000E+00	0.0000	2.209E-01	0.012
Total	1.566E+01	0.9013	2.234E-01	0.0129	0.000E+00	0.0000	1.271E+00	0.0731	0.000E+00	0.0000	0.000E+00	0.0000	2.209E-01	0.012

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.738E+01	1.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.738E+01	1.000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	9.684E+00	0.9313	9.253E-02	0.0089	0.000E+00	0.0000	5.301E-01	0.0510	0.000E+00	0.0000	0.000E+00	0.0000	9.170E-02	0.008
Total	9.684E+00	0.9313	9.253E-02	0.0089	0.000E+00	0.0000	5.301E-01	0.0510	0.000E+00	0.0000	0.000E+00	0.0000	9.170E-02	0.008

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.040E+01	1.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.040E+01	1.000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Thread Fraction	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	1.662E-01	1.650E-01	1.628E-01	1.550E-01	1.327E-01	5.496E-02	0.000E+00	0.000E+00
Th-232	Ra-228+D	1.000E+00	1.985E-01	5.601E-01	1.131E+00	2.138E+00	2.452E+00	1.451E+00	0.000E+00	1.586E-31
Th-232	Th-228+D	1.000E+00	2.953E-02	1.783E-01	6.890E-01	2.343E+00	3.207E+00	1.960E+00	0.000E+00	2.389E-34
Th-232	∑DSR(j)		3.942E-01	9.035E-01	1.983E+00	4.636E+00	5.792E+00	3.466E+00	0.000E+00	1.589E-31

The DSR includes contributions from associated (half-life ≤ 180 days) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.500E+01 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	6.343E+01	2.767E+01	1.261E+01	5.393E+00	4.316E+00	7.212E+00	*1.097E+05	*1.097E+05

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 25.44 ± 0.05 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Th-232	3.000E+00	25.44 ± 0.05	5.826E+00	4.291E+00	5.826E+00	4.291E+00

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	4.985E-01	4.951E-01	4.884E-01	4.650E-01	3.982E-01	1.649E-01	0.000E+00	0.000E+00
Ra-228	Th-232	1.000E+00	5.954E-01	1.680E+00	3.394E+00	6.413E+00	7.356E+00	4.353E+00	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	8.859E-02	5.350E-01	2.067E+00	7.029E+00	9.622E+00	5.881E+00	0.000E+00	0.000E+00

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	3.000E+00	3.000E+00	3.000E+00	2.999E+00	2.997E+00	2.989E+00	2.967E+00	2.891E+00
Ra-228	Th-232	1.000E+00	0.000E+00	3.355E-01	8.709E-01	1.857E+00	2.349E+00	2.368E+00	2.350E+00	2.290E+00
Th-228	Th-232	1.000E+00	0.000E+00	5.534E-02	3.612E-01	1.527E+00	2.332E+00	2.368E+00	2.350E+00	2.290E+00

THF(i) is the thread fraction of the parent nuclide.

RESCALC.EXE,execution time = 1.10 seconds

APPENDIX B

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

TABLE B-1

CHEMICAL-SPECIFIC ARARs AND TBCs
SITE 1 – THORIUM SPILL EE/CA
NSF-IH, INDIAN HEAD, MARYLAND

Act/Authority	Criteria/Issues	Citation	Brief Description	Status	Consideration in the EE/CA
Federal					
Navy's RASO Residential Radioactivity (RESRAD) Computer Software	Radiation	RESRAD	DCGLs are derived using RESRAD modeling.	TBC	The DCGL of 3 pCi/g, which corresponds to a carcinogenic risk of approximately 10^{-5}, was derived using RESRAD (Tetra Tech, 2009).
NRC	Radiation	10 CFR Part 20.1101 and 20.1301	NRC guidance to implement as low as reasonably achievable constraints on air emissions of radioactive material to the environment	Applicable	Applicable during soil excavation activities.
NRC	Radiation	10 CFR Part 20.1402	Radiological criteria for unrestricted use at closing NRC licensed facilities.	Relevant and Appropriate	A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in Total Effective Dose Exposure (TEDE) to an average member of the critical group that does not exceed 25 mrem/year, including that from groundwater sources of drinking water, and that the residual radioactivity has been reduced to as low as reasonably achievable (ALARA).
NRC	Radiation	10 CFR Part 20.1801	Licensee shall secure from unauthorized removal or access licensed materials stored in controlled or unrestricted Areas	Relevant and Appropriate	During removal action, recovered materials will be appropriately controlled.

TABLE B-1

CHEMICAL-SPECIFIC ARARs AND TBCs
SITE 1 – THORIUM SPILL EE/CA
NSF-IH, INDIAN HEAD, MARYLAND

Act/Authority	Criteria/Issues	Citation	Brief Description	Status	Consideration in the EE/CA
NRC	Radiation	10 CFR Part 20.1802	Licensee shall control and maintain constant surveillance of licensed material in a controlled or unrestricted area and not in storage.	Relevant and Appropriate	During removal action, recovered materials will be appropriately controlled.
State					
Regulations for the Control of Ionizing Radiation	Radiation	COMAR 26.12.01.01	Provides for protection of public health and safety from exposure to radiological sources	Applicable	Relevant portions of COMAR 26.12.01.01 *"Supplements"* are applicable during llrw soil excavation and transport.

Notes, Acronyms, and Abbreviations

ARARs	Applicable or Relevant and Appropriate Requirements.
CFR	Code of Federal Regulations.
COMAR	Code of Maryland Regulations.
llrw	Low-level radioactive waste
NRC	Nuclear Regulatory Commission
pCi/g	picoCuries per gram
TBC	To be considered.

TABLE B-2

LOCATION-SPECIFIC ARARs
SITE 1 – THORIUM SPILL EE/CA
NSF-IH, INDIAN HEAD, MARYLAND
PAGE 1 OF 1

Act/Authority	Criteria/Issues	Citation	Brief Description	Status	Consideration in the EE/CA
No location-specific ARARs are applicable or relevant and appropriate to the removal action at Site 1. There are no archeological and historical areas, endangered species, or wetlands at Site 1.					

Notes, Acronyms, and Abbreviations
ARARs Applicable or Relevant and Appropriate Requirements.

TABLE B-3

ACTION-SPECIFIC ARARs AND TBCs
SITE 1 – THORIUM SPILL EE/CA
NSF-IH, INDIAN HEAD, MARYLAND

Act/Authority	Criteria/Issues	Citation	Brief Description	Status	Consideration in the EE/CA
Federal					
Transportation of Licensed Material	Radiation	49 CFR Parts 107, 171-180, 390-397	DOT criteria for packaging and transportation of licensed material	Applicable	Applicable for transportation of demolition debris to NRC-regulated facility.
Occupational Safety and Health Act		29 USC 651-678	Governs worker health and safety during implementation of remedial actions.	Applicable	Applicable to any investigative or remedial action at the site.
State					
Regulations for the Control of Ionizing Radiation	Radiation	COMAR 26.12.01.01	Provides for protection of public health and safety from exposure to radiological sources	Applicable	Relevant portions of COMAR 26.12.01.01 *"Supplements"* are applicable during llrw soil excavation and transport.
Stormwater Management	Design and Construction	COMAR 26.09.02	Requires measures to control stormwater runoff during removal alternatives or development of land.	Applicable	Applicable for land disturbance activity at Site 1 (only 1,075 square feet). Appropriate control measures will be incorporated into the removal action.
Erosion and Sediment Control	Land Disturbance	COMAR 26.09.01	Requires measures to control stormwater runoff during removal alternatives or development of land.	Applicable	Applicable for land disturbance activity at Site 1 (only 1,075 square feet). Appropriate control measures will be incorporated into the removal action.
Ambient Air Quality Control (Environment Article, Title 2)	Ambient Air Quality Standards	COMAR 26.11.04	Establishes ambient standards for particulate matter, sulfur oxides, carbon monoxide, ozone, nitrogen oxides, lead, and fluoride.	Potentially Applicable	Particulate matter will be minimized during the removal action using standard construction practices.

TABLE B-3

ACTION-SPECIFIC ARARs AND TBCs
SITE 1 – THORIUM SPILL EE/CA
NSF-IH, INDIAN HEAD, MARYLAND
PAGE 2 OF 2

Act/Authority	Criteria/Issues	Citation	Brief Description	Status	Consideration in the EE/CA
General Emission Standards, Prohibitions, and Restrictions	Emissions	COMAR 26.11.06	Establishes emission standards for visible emissions, particulate matter, carbon monoxide, sulfur compounds, VOCs, and fluoride and control of NSPS sources.	Potentially Applicable	Particulate matter will be minimized during the removal action using standard construction practices.
Noise Standards	Noise Generation	COMAR 26.02.03.02	Limits set on the levels of noise must be met; these limits are protective of the health welfare, and property of the people in Maryland. The maximum permitted levels for construction activities may not exceed 90 dBA during the day and 75 dBA during the night.	Applicable	Maximum allowable noise levels will not be exceeded during the removal action.

Notes, Acronyms, and Abbreviations

Previous investigations determined site soils are non-hazardous but are handled as llrw.

ARARs Applicable or Relevant and Appropriate Requirements.
CFR Code of Federal Regulations.
COMAR Code of Maryland Regulations.
llrw Low-level radioactive waste
NRC Nuclear Regulatory Commission

APPENDIX C

COST ESTIMATES

TABLE C-1
COST ESTIMATE - ALTERNATIVE 2 - EXCAVATION AND DISPOSAL
SITE 1 - THORIUM SPILL EE/CA
NSF-IH, INDIAN HEAD, MARYLAND

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
1 PROJECT PLANNING											
1.1 Prepare Constructions/Specifications	80	hours			$25.00		$0	$0	$2,000	$0	$2,000
2 MOBILIZATION/DEMOBILIZATION AND FIELD SUPPORT											
2.1 Office Trailer	1	mo		$202.50			$0	$203	$0	$0	$203
2.2 Storage Trailer (1)	1	mo		$105.00			$0	$105	$0	$0	$105
2.3 Vehicles	1	week				$700.00	$0	$0	$0	$700	$700
2.4 Equipment Mobilization/Demobilization	2	ea			$73.50	$175.00	$0	$0	$147	$350	$497
3 DECONTAMINATION											
3.1 Temporary Equipment Decon Pad	1	ls		$2,000.00	$3,325.00	$350.00	$0	$2,000	$3,325	$350	$5,675
3.2 Radiation Decontamination Services	1	mo	$25,000.00			$0.00	$25,000	$0	$0	$0	$25,000
3.3 Pre/Post Decontamination Survey	4	ea		$375.00			$0	$1,500	$0	$0	$1,500
4 BUILDING DEMOLITION											
4.1 Miscellaneous Equipment/Tools	1	week				$500.00	$0	$0	$0	$500	$500
4.2 Excavator, Crawler Mounted, 1 1/2 cy	1	week				$3,000.00	$0	$0	$0	$3,000	$3,000
4.3 Front End Loader, 80 HP	1	week				$1,600.00	$0	$0	$0	$1,600	$1,600
4.4 [reserved]											
4.5 Radiation/safety Monitoring Instruments & Supplies	1	week				$2,500.00	$0	$0	$0	$2,500	$2,500
5 DISPOSAL & TRANSPORTATION											
5.1 Waste Acceptance Criteria Certification Testing	1	ea	$5,000.00				$5,000	$0	$0	$0	$5,000
5.2 [reserved]											
5.3 Transportation (per container)	4	ea	$7,100.00				$28,400	$0	$0	$0	$28,400
5.4 Roll Off Rental	30	days	$10.00				$300	$0	$0	$0	$300
5.5 Container Liner	4	ea		$35.00			$0	$140	$0	$0	$140
5.6 Waste Burial	3,225	cu. ft.	$32.00				$103,200	$0	$0	$0	$103,200
6.0 LABOR											
6.1 Project Manager/CHP	60	hours			$35.00		$0	$0	$2,100	$2,100	$4,200
6.2 Radiation Technicians (2)	120	hours			$20.00		$0	$0	$2,400	$2,400	$4,800
6.3 Laborers (3)	180	hours			$15.00		$0	$0	$2,700	$2,700	$5,400
6.4 Equipment Operators (2)	120	hours			$25.00		$0	$0	$3,000	$3,000	$6,000
7 MISCELLANEOUS											
7.1 Post Construction Documents	40	hr			$25.00		$0	$0	$1,000	$0	$1,000
Subtotal							$161,900	$3,948	$16,672	$19,200	$201,720
Overhead on Labor Cost @ 30%									$5,002		$5,002
G & A on Labor Cost @ 10%									$1,667		$1,667
G & A on Material Cost @ 10%								$395			$395
G & A on Subcontract Cost @ 10%							$16,190				$16,190
G & A on Equipment Cost @ 10%										$1,920	$1,920
Total Direct Cost							$178,090	$4,342	$23,341	$21,120	$226,893
Indirects on Total Direct Cost @ 35%			(Total Direct Cost minus Transportation and Disposal Costs)								$33,353

TABLE C-1
COST ESTIMATE - ALTERNATIVE 2 - EXCAVATION AND DISPOSAL
SITE 1 - THORIUM SPILL EE/CA
NSF-IH, INDIAN HEAD, MARYLAND

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
Profit on Total Direct Cost @ 10%											$22,689
Subtotal											$282,935
Total Field Cost											$282,935
Contingency on Total Field Costs @ 20%											$56,587
TOTAL COST											**$339,522**