TASK 1.1: TECHNICAL MEMORANDUM – COMPARISON OF PREVIOUS INVENTORIES

Revision 1

WEST VALLEY DEMONSTRATION PROJECT AND WESTERN NEW YORK NUCLEAR SERVICE CENTER

Prepared for:

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New York State Energy Research and Development Authority

Prepared By:

WVDP EXHUMATION WORKING GROUP
Enviro Compliance Solutions, Inc. (ECS)

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Task 1.1: Technical Memorandum – Comparison of Previous Inventories
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WEST VALLEY DEMONSTRATION PROJECT AND WESTERN NEW YORK NUCLEAR SERVICE CENTER

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Task 1.1: Technical Memorandum – Comparison of Previous Inventories
Revision Draft B
TABLE OF CONTENTS

Page

Contents

Figures

Tables

Acronyms & Abbreviations

AEC	Atomic Energy Commission
Ag	silver
Am	americium
Ba	barium
BPM	byproduct material
BWR	boiling-water reactor
C	carbon
CFR	*Code of Federal Regulations*
Ci	curie
Ci/m^3	curies per cubic meter
Cm	curium
Co	cobalt
Cs	cesium
D&D	Decontamination and Decommissioning
DEIS	Draft Environmental Impact Statement (DOE/EIS-0226)
DOE	United States Department of Energy
ECS	Enviro Compliance Solutions, Inc.
EIS	environmental impact statement
EPA	United States Environmental Protection Agency
Eu	europium
EXWG	West Valley Exhumation Working Group
Fe	iron
FEIS	Final Environmental Impact Statement (DOE/EIS-0226)
ft^3	cubic feet
g	gram
H	hydrogen
HLW	high-level waste
I	iodine
K&M,D,E	Kelleher & Michael (1973), Duckworth (1981), and Envirosphere (1986)
keV	kilo-electronvolt
kg	kilogram
lbs	pounds
LWR	light-water reactor
µCi/mL	microcuries per milliliter
m^3	cubic meters
MC	Monte Carlo
MFP	mixed mission products
Mix & Misc.	mixture and miscellaneous
Mn	manganese
MWD/MTU	megawatt days per metric ton of uranium
MUF	material unaccounted for
Nb	niobium
NDA	NRC-Licensed Disposal Area
NFS	Nuclear Fuel Services
Ni	nickel

Np	neptunium
NPR	New Production Reactor
NRC	United States Nuclear Regulatory Commission
NYSDEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research and Development Authority
ORNL	Oak Ridge National Laboratory
PNL	Pacific Northwest Laboratory
PNNL	Pacific Northwest National Laboratory
ppm	parts per million
Pu	plutonium
PWR	pressurized water reactor
Ra	radium
rem/hr	rem per hour
Ru	ruthenium
SAI	Science Applications, Inc.
SBW	sodium-bearing waste
SDA	State-Licensed Disposal Area
SM	source material
SNAP	Systems for Nuclear Auxiliary Power
SNM	special nuclear material
Sr	strontium
$SrCO_3$	strontium carbonate
$SrO\text{-}TiO_2$	strontium titanate
SRS	Supernatant Removal System
Tc	technetium
Th	thorium
U	uranium
UCL	upper confidence level
URS	URS Corporation
USAEC	U.S. Atomic Energy Commission
VAST	vitrification analytical sample tracking
WMA	Waste Management Area
WNYNSC	Western New York Nuclear Service Center
WTF	Waste Tank Farm
WVDP	West Valley Demonstration Project
WVNS	West Valley Nuclear Services Company, Inc.
Y	yttrium
Zn	zinc
Zr	zirconium

Executive Summary

Enviro Compliance Solutions, Inc. (ECS) and the West Valley Exhumation Working Group (EXWG) are performing exhumation-related studies as part of the Phase 1 Studies at the West Valley Demonstration Project (WVDP) and Western New York Nuclear Service Center (WNYNSC). The purpose of the collective Phase 1 exhumation studies is (1) to enable improved forecasts of future exhumation alternatives at the WVDP and WNYNSC, (2) to evaluate and potentially reduce the associated uncertainty, and (3) to assist the agencies in reaching consensus on those waste exhumation alternatives eventually selected for final analysis.

A. Purpose of Task 1.1

In planning the Phase I exhumation studies, the U.S. Department of Energy (DOE) and New York State Energy Research and Development Authority (NYSERDA) indicated a need for the Exhumation Work Group (EXWG) to address yet-to-be-defined selective (partial) exhumation scenarios. Recognizing that the reliability of the current waste inventory is of central importance to the development and evaluation of any selective exhumation scenario, the EXWG has also focused its initial studies on the following objectives: (1) evaluating and updating the inventory; (2) projecting the inventory estimates into the future; (3) conducting additional characterization to determine whether the inventory can be confirmed with field measurements; and (4) providing information about specific locations, radionuclide activities, and volumes of materials that may be exhumed under various selective exhumation scenarios. The same information would also help refine the full exhumation alternative.

Current and former EXWG members were the primary developers of the most current waste inventories for the State-Licensed Disposal Area (SDA), U.S. Nuclear Regulatory Commission (NRC)-Licensed Disposal Area (NDA), and Waste Tank Farm (WTF), as reported in the following documents:

- "Estimated Radionuclide Inventory for the NRC-Licensed Disposal Area at the West Valley Demonstration Project" (URS Corporation, 2000)
- "SDA Radiological Characterization Report" (URS Corporation, 2002)
- "West Valley Demonstration Project, Residual Radionuclide Inventory Estimate for the Waste Tank Farm, Supplemental Report" (WVNS & Gemini Consulting Company, 2005)

These inventories are considered to be the most recent and robust waste inventories yet developed for the corresponding waste units and, thus, were selected for use in the proposed Phase I studies. However, numerous other attempts to quantify the waste inventories of the SDA, NDA, and WTF have been completed over the last 40-plus years. Although many of these inventories were based on the same source (i.e., the disposal records), differences in the inventories are known to exist. The purpose of Task 1.1, as reported herein, is to evaluate these differences and to determine how best to use the above-referenced inventories as the basis of the proposed Phase I studies.

B. Summary of Results

1. State Licensed Disposal Area

The SDA inventory estimates presented in the following eight documents were reviewed:

1. Kelleher and Michael, 1973
2. O'Connell and Holcomb, 1974
3. EPA, 1977
4. Duckworth, 1981
5. Prudic, 1986
6. Envirosphere, 1986
7. WVNS, 1995a
8. URS, 2002

Two of the above eight estimates [O'Connell and Holcomb (1974) and EPA (1977)] simply repeated the estimates that were made by Kelleher and Michael (1973), and added no new information or data to the estimates. Two others [Duckworth (1981) and Envirosphere (1986)] built upon the Kelleher and Michael (1973) estimates by providing information and data on disposals that occurred after 1972 (i.e., for Trenches 12, 13, and 14). In most respects, these five documents can be thought of as variations of a single SDA inventory estimate, and that is what was done in the SDA volume and activity comparisons.

Although Prudic (1986) presents some information on the volume of waste that was disposed in Trenches 8 through 14, that report is mostly interested in the groundwater hydrology and subsurface migration of radionuclides from the SDA. To this end, Prudic (1986) presents data on the radionuclide concentrations at various locations within and near the SDA but does not provide any information on the activity of the waste that was disposed within the SDA trenches. Although it does provide some useful information regarding the construction of the SDA disposal trenches and the procedures followed for the placement and covering of the waste, Prudic (1986) is not useful in obtaining an SDA activity estimate and was not included in the SDA activity comparison.

WVNS (1995a) and URS (2002) were SDA inventory estimates that were developed in support of the 1996 DEIS and 2008 Revised DEIS. These two estimates are the most detailed of the SDA inventory estimates, in that they each provide a volume and activity estimate for each 50-foot segment of each trench. As explained in its introduction, one of the purposes for producing the URS (2002) SDA estimate was to correct deficiencies that had been identified with the WVNS (1995a) estimate. For example, URS (2002) states the following about the WVNS (1995a) study: in "*many cases, the wastes assigned to a single shipment number were from more than one generator; however, only one waste profile was assigned to each shipment (each database record).*" To help accomplish the project goal, URS (2002) included 33 waste profiles, whereas WVNS (1995a) used only 16 waste profiles.

Four SDA waste volume estimates were compared: the combined Kelleher and Michael (1973), Duckworth (1981), and Envirosphere (1986) (K&M,D,E) estimates; Prudic (1986);

WVNS (1995); and URS (2002). There is only a 3.5% difference between the largest SDA volume estimate [i.e., 2,370,000 ft^3, Prudic (1986)] and the smallest [2,290,000 ft^3, WVNS (1995)]. However, an inter-trench comparison of the WVNS (1995) and URS (2002) volumes revealed differences in the placement of the waste within the SDA. Some of these differences can be explained by the fact that one estimate put the waste in one trench segment and the other estimate put the same waste in a neighboring trench segment. Other differences are not so easily explained, e.g., the over 25,000 ft^3 greater volume for Trench 5, Segment 50-99, estimated by URS (2002).

Three SDA waste activity estimates were compared: the combined Kelleher and Michael (1973), Duckworth (1981), and Envirosphere (1986) (K&M,D,E) estimates; WVNS (1995); and URS (2002). Quite a few differences were identified between the three estimates, as well as an attempt to identify a reason for them. Perhaps the largest difference is in the URS (2002) Sr-90 activity estimate, which is about two orders of magnitude lower than the other two estimates. Although URS (2002), Section 2.3.6.5, discusses the Sr-90 waste that was sent to the SDA from the Martin Marietta, Quehanna, Pennsylvania, facility, it does not seem to have included that waste in its activity estimate.

Nonetheless, based on the overall comparison results, as well as the additional waste profiles that were used, it is believed that URS (2002) provides the best estimate of the SDA inventory for use in the Phase I studies, with the exception of the Sr-90 activity. Before URS (2002) is used in these studies, it is recommended that its Sr-90 activity estimate be revised to specifically include the 1966–1967 waste shipments from the Martin Marietta, Quehanna, Pennsylvania, facility. This conclusion is consistent with Garrick et al. (2009, page 4-4), which identified URS (2002) as the "*most comprehensive and detailed*" effort to "*identify and characterize the inventories of wastes that are buried in the 14 SDA trenches*."

2. NRC-Licensed Disposal Area

The NDA inventory estimates presented in the following documents were reviewed:

1. Kelleher and Michael, 1973
2. Duckworth, 1981
3. Nicholson and Hurt, 1985
4. Ryan, 1992
5. WVNS, 1995b (and DOE and NYSERDA, 1996)
6. SAI, 1983, and PNL, 1992
7. URS, 2000

The NDA inventory estimates can be broken into two groups: those that were made prior to the PNL (1992) ORIGEN2 runs and those that were made after. The estimates that were made prior to PNL (1992) were usually based on disposal records and, therefore, were limited to those radionuclides included in the records. As was the case for the SDA, the Duckworth (1981) estimate extends the Kelleher and Michael (1973) estimate beyond 1972; therefore, these two estimates are considered the same (unless otherwise indicated).

Nicholson and Hurt (1985) was part of an NRC research project to study the characteristics of the NDA. The inventory estimate was only one part of Nicholson and

Hurt (1985), which also contained information and data on the NDA site geology, geomorphic conditions, and groundwater transport. Regarding the NDA inventory estimate, Nicholson and Hurt (1985) made adjustments to the Duckworth (1981) estimate based on the results of ORIGEN-2 computer calculations for "generic" NPR and LWR fuel.

WVNS contracted with PNL to develop the Ryan (1992) NDA inventory estimates. Three documents appear as the basis for the Ryan (1992) estimates: Duckworth (1981); PNL (1992); and DOE (1979). For the most part, Ryan (1992) does not provide a radionuclide breakdown of his NDA activity estimate but rather groups his estimates into activation products, fission products, and actinides. Ryan (1992) does break down the activity estimates by waste category, with hulls and hardware being by far the largest contributor at about 94% of the total activity.

Although it was made after PNL (1992), and states that document was used in its development, WVNS (1995b) offers no information on specific radionuclide activities in the NDA other than to identify the nine largest contributors: Cs-137, Ba-137m, Co-60, Eu-154, Ni-63, Pu-238, Pu-241, Sr-90, and Y-90. Another shortcoming of WVNS (1995b), as identified in Section III, is the fact that the same activity is estimated for waste containers of different sizes, containing different types of waste, and with widely ranging dose rates. WVNS (1995b), Appendix B, provides a useful disposal hole-by-hole inventory of where the waste associated with each disposal record was buried.

Because DOE and NYSERDA (1996), Table C-9, attributes its NDA radionuclide breakdown to WVNS (1995b), it has been included in the WVNS (1995b) evaluation. However, no evidence could be found that would establish a connection between WVNS (1995b) and DOE and NYSERDA (1996), notwithstanding a footnote to Table C-9 attributing the data to WVNS (1995b). On the contrary, what evidence there is seems to indicate that there is no connection between WVNS (1995b) and DOE and NYSERDA (1996), Table C-9. For example, when the DOE and NYSERDA (1996), Table C-9, activities are decay-corrected to January 1, 1993, the total DOE and NYSERDA (1996) activity of 230,000 Ci is less than half of the total WVNS (1995b) activity of 679,000 Ci. Also, some of the nine radionuclides that WVNS (1995b) identifies as major contributors to the total activity are either not included in DOE and NYSERDA (1996), Table C-9 (e.g., Ni-63), or are present in only small amounts (e.g., Eu-154, Pu-238).

Although technically they are not NDA inventory estimates, SAI (1983) and PNL (1992) have been included in this review of NDA activity estimates. SAI (1983) uses NFS nuclear materials management reports for each campaign to document the mass of uranium and plutonium entering and leaving the reprocessing plant, including the amount transferred to the NDA with the hulls. Likewise, PNL (1992) uses the ORIGEN2 computer program to estimate the specific activation products, fission products, and transuranics contained within each of the spent fuel reprocessing campaigns conducted by NFS. Together, these two reports were used to estimate the activity that was sent from the onsite reprocessing plant to the NDA.

At least partly because of the difficulty in connecting the DOE and NYSERDA (1996), Table C-9, NDA activities to the WVNS (1995b) estimate, DOE and NYSERDA requested that a new inventory (URS, 2000) be prepared. In developing its NDA activity estimates, URS (2000) relied heavily on SAI (1981) and PNL (1992). Thus, it is not surprising that the URS (2000) NDA activity estimates agree with the activities provided in PNL (1992).

Using data from URS (2000) support files an estimated of the NDA disposal volume was made as a function of time. Good agreement was found between this URS (2000) based time-varying volume estimate and the NDA volume estimates made in Kelleher & Michael (1973), Nicholson and Hurt (1985), Duckworth (1981), and WVNS (1995b).

It is concluded that the NDA activity comparison supports the continued use of the URS (2000) inventory estimate. Specific concerns have been previously expressed regarding the NDA plutonium inventory. The investigations performed for this study conclude that the plutonium activities provided in DOE and NYSERDA (1996), Table C-9, are an error, and that, there is substantial agreement between the other NDA plutonium activity and/or mass estimates. A 2008 Revised DEIS commenter similarly stated: "*My educated guess is that the 2600-curie figure* [from DOE and NYSERDA (1996), Table C-9] *for Pu-239 is an error*." (DOE and NYSERDA, 2010, Volume 3, Commenter No. 110: Raymond C. Vaughan, PhD)

3. Waste Tank Farm

For the WTF, the activity estimates from only two documents were compared: WVNS (2002) and WVNS (2005). Both of these documents were prepared in support of the EIS (DOE/EIS-0226). After WVNS (2002) was prepared and comments were received back from the reviewing agencies, including requests for additional clarification regarding specific technical issues, the determination was made to prepare a supplemental report that addressed the comments and requests. That supplemental report is WVNS (2005).

WVNS (2002) and WVNS (2005) Tank 8D-1 and Tank 8D-2 activity estimates were compared, and, with three exceptions, it was found that there is good agreement between the two WTF estimates. The three exceptions are: (1) the I-129 activity in both tanks, (2) the Tank 8D-1 plutonium activities, and (3) the Cs-137 activity in Tank 8D-2.

The difference in the I-129 activity estimates is due primarily to the WVNS (2005) use of sampling results that were not available to WVNS (2002). The Tank 8D-1 plutonium activity difference is due to a different (more realistic) method for calculating the Tank 8D-1 fixed inventory used by WVNS (2005), as described in Section IV.C.2. Finally, as described in Section IV.C.3, the Cs-137 Tank 8D-2 activity difference is due to the selection of highly conservative values of fixed Cs-137 activity in WVNS (2005) based on the results of a Monte Carlo simulation.

Based on this discussion and the Section IV.C comparisons, it is recommended that WVNS (2005) be used as the source of the Tank 8D-1 and Tank 8D-2 activities. CH2MHILL · B&W West Valley (2012) should be used for the Tank 8D-4 activity.

I. Introduction and Background

Enviro Compliance Solutions, Inc. (ECS) and the West Valley Exhumation Working Group (EXWG) are performing exhumation-related studies as part of the Phase 1 Studies at the West Valley Demonstration Project (WVDP) and Western New York Nuclear Service Center (WNYNSC). The purpose of the collective Phase 1 exhumation studies is (1) to enable improved forecasts of future exhumation alternatives at the WVDP and WNYNSC, (2) to evaluate and potentially reduce the associated uncertainty, and (3) to assist the agencies in reaching consensus on those waste exhumation alternatives eventually selected for final analysis.

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B. Report Organization

This technical memorandum is organized into three main sections: Section II: State-Licensed Disposal Area; Section III: NRC-Licensed Disposal Area; and Section IV: Waste Tank Farm. Section V summarizes the SDA, NDA, and WTF inventory comparisons, and Section VI provides a list of references.

Within each of the three main sections, a brief description of the area being studied is first presented, followed by a description of the area's current waste inventory estimate as used in the "Final Environmental Impact Statement for Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center," DOE/EIS-0226 (hereafter referred to as the "FEIS"; DOE & NYSERDA, 2010). In the FEIS the WTF, NDA, and SDA are sometimes referred to as Waste Management Area (WMA) 3, WMA 7, and WMA 8. This is followed by a description of the various waste inventory estimates that have previously been made for each of the three areas. These descriptions are presented mostly in the form of tables and figures showing the results of the estimates and do not usually delve into the details of how the estimates were calculated. They are primarily included so that the reader will not have to search through the source documents to verify the information provided in the later comparison discussions. In some cases, the information is presented in a manner that differs from the source document presentation in order to facilitate comparisons.

Each main section contains one or two final subsections that compare the current and previous inventory estimates. For the SDA and NDA, there are two comparison subsections, one that compares the volume estimates and a second that compares the activity estimates. Since volume is not a driver for the WTF, only the activity estimates are compared in its final subsection.

II. State-Licensed Disposal Area

From 1963 to 1975, low-level radioactive wastes were received at the SDA for burial from six types of sources: nuclear power plants; institutional and educational facilities and hospitals; Federal government facilities; Industrial, pharmaceutical manufacturing, and industrial research facilities; Nuclear Fuel Services operations; and waste disposal and decontamination companies. The wastes were disposed in their original shipping containers, including 18.9-liter (5-gallon) steel drums, 114-liter (30-gallon) steel drums, 208-liter (55-gallon) steel drums, wooden crates, cardboard boxes, fiber drums, and plastic bags.

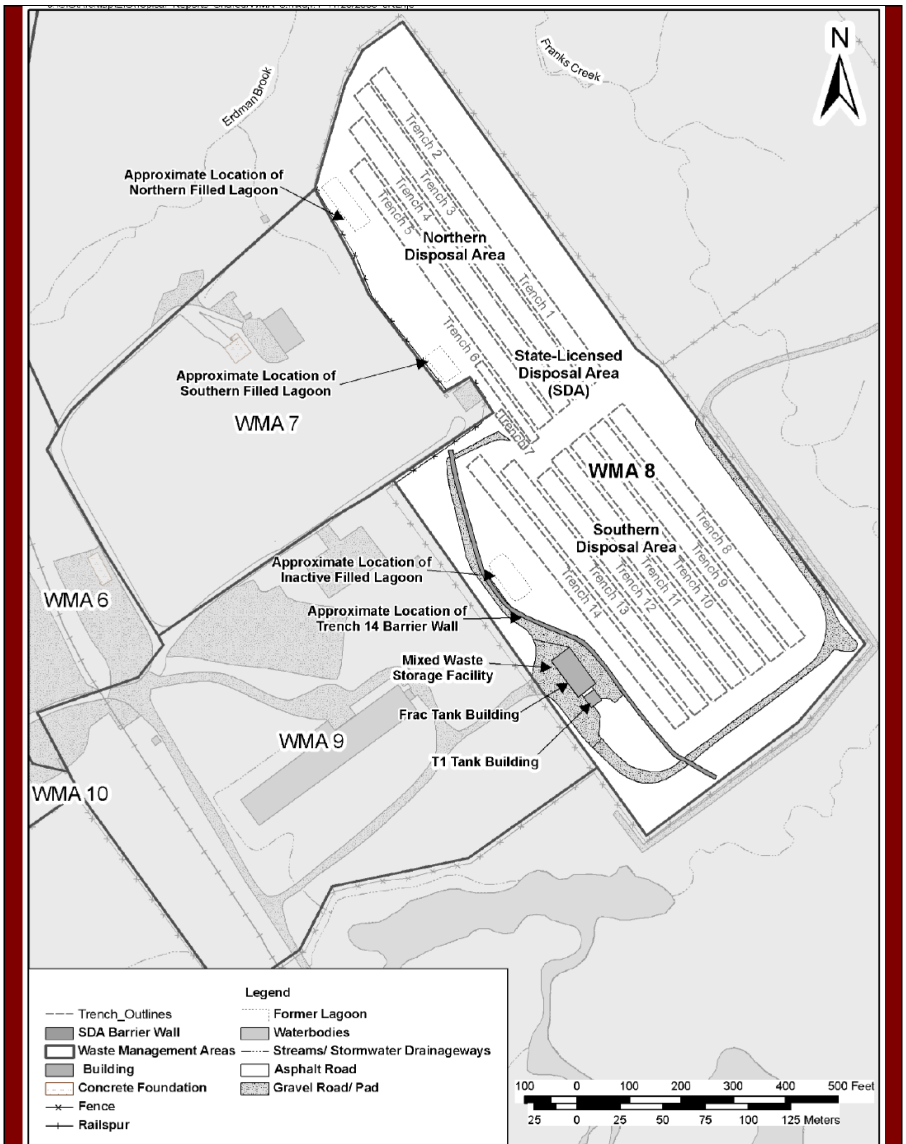

Figure II-1: WMA 8 — State Licensed Disposal Area

The SDA is approximately 6.1 hectares (15 acres) in size and can be divided into North and South Disposal Areas; see Figure II-1. The North Disposal Area includes Trenches 1 through 7. Trenches 1 through 5 were about 10.7 meters (35 feet) across and were excavated to a depth of about 6.1

meters (20 feet). These trenches were used to dispose of solid wastes having contact surface readings of 200 millirad per hour or less. The wastes were disposed in the same packages that were used to contain and transport them. Trench 6 is a series of 19 special-purpose holes that were used to dispose of wastes having contact surface readings of more than 200 millirad per hour. These holes were 0.6 to 1.8 meters (2 to 6 feet) wide, 1.2 to 3.6 meters (4 to 12 feet) long, and 2.4 to 3.6 meters (8 to 12 feet) deep. The wastes disposed in these holes consisted primarily of irradiated reactor parts. Trench 7 consists of a concrete slab with wastes placed on top of the slab and concrete poured over the wastes to encase them. The wastes were similar to those placed in Trenches 1 through 5.

Figure II-2 and Figure II-3 show two open SDA trenches. Notice that waste was disposed in 55-gallon metal drums and in large wooden boxes in these photos.

Figure II-2: WMA 8 — State Licensed Disposal Area – Open Trench Photo One

Figure II-3: WMA 8 — State Licensed Disposal Area – Open Trench Photo Two

A. Final Environmental Impact Statement Inventory Estimate

During preparation of the FEIS, DOE/NYSERDA asked URS Corporation (URS) to revise the SDA inventory estimate. The inventory presented in the URS (2002) report was prepared in response to that request. A summary of the SDA inventory estimate that was presented in URS 2002 is given in Table II-1. Notice that two methods of calculating activity are given: fixed and variable. The fixed method assigns the waste profile concentration to each disposal record assigned to the profile. Using this method, the activity for each record is proportional to its volume.

The variable method ensures that the total activity of all wastes assigned to a profile equals the product of the volume of waste and the radionuclide concentrations that define the profile, but allows the concentration of individual disposal records to vary in proportion to the activity reported in the record. In other words, the variable method allows for some shipments to have higher or lower concentrations than the waste profile concentration, as long as the total for the waste stream matches the waste profile. URS (2002) recommended that the "results based on the fixed concentration method should not be used in analyses of radiological impacts involving SDA wastes." Therefore, all comparisons performed in Task 1.1 utilize the activity estimates based on the variable method. However, it is instructive to observe how sensitive the Table II-1 activities are to this single assumption; if two activity estimates calculated by a single analyst vary as shown in Table II-1 due to a single assumption variation, then one can imagine the potential variation that could occur when multiple analysts, making multiple different assumptions, estimate the SDA activity.

Table II-1: URS 2002, Summary

Trench	Volume (App. B) (ft^3)	Activity (Table 3-8) (Ci)	
		Fixed	Variable
1	52,400	1,269	520
2	117,681	2,237	1,717
3	201,557	4,448	2,957
4	298,405	10,245	21,624
5	258,675	21,314	9,777
6	468	2,975	23,113
7	2,490	84	213
8	252,227	24,324	12,834
9	173,542	11,302	14,391
10	184,169	18,696	19,696
11	184,467	14,813	15,045
12	197,504	6,365	4,117
13	209,220	4,851	1,981
14	229,665	5,101	1,629
Total	2,362,471	128,024	129,615

Figure II-4 is a breakdown of the URS 2002, Appendix B waste volume estimates by 50-foot trench segment. The darker the blue in Figure II-4, the greater the volume of waste disposed in that trench segment. Neither the Trench 6 special holes nor the short Trench 7 are shown in Figure II-4.

URS 2002 SDA Waste Volume Distribution (ft^3)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	3,385	3,261	14,054	16,050	10,239	0	879	4,533	--	--	--	--	--	--	52,400
Trench 2	25,360	8,404	13,653	12,864	14,877	21,027	21,207	288	--	--	--	--	--	--	117,681
Trench 3	15,666	14,806	10,289	11,281	12,188	15,938	15,825	16,080	16,124	15,960	14,997	13,936	15,438	13,031	201,557
Trench 4	31,237	16,224	18,027	18,869	19,083	18,004	19,249	18,704	19,983	20,867	25,742	25,650	30,458	16,307	298,405
Trench 5	25,259	27,362	26,051	26,986	27,045	27,384	20,688	27,345	24,831	5,025	14,974	5,725	0	--	258,675
Trench 8	28,360	24,687	21,060	25,266	26,461	27,297	22,044	25,541	17,342	20,401	13,767	0	--	--	252,227
Trench 9	9,391	23,570	26,253	11,967	16,049	22,515	12,762	15,400	12,018	11,979	8,552	3,086	--	--	173,542
Trench 10	14,801	17,384	19,514	15,275	24,526	9,711	13,792	9,444	19,195	18,743	15,452	6,333	--	--	184,169
Trench 11	18,601	11,964	22,206	19,861	26,604	15,862	9,371	12,010	15,521	11,994	16,518	3,955	--	--	184,467
Trench 12	19,255	19,257	18,628	16,027	18,724	17,259	24,409	16,825	16,943	19,477	10,152	550	--	--	197,504
Trench 13	13,101	15,462	21,468	25,047	12,872	22,388	18,924	16,868	17,728	19,281	18,502	5,498	2,081	--	209,220
Trench 14	14,757	23,958	24,439	24,068	23,817	21,149	23,072	15,971	16,130	17,330	18,989	4,833	1,152	0	229,665

Figure II-4: URS, 2002; SDA Waste Volume Distribution

Two of the radionuclides that are major contributors to the estimated SDA inventory are cesium-137 (Cs-137) and cobalt-60 (Co-60). For these reasons, Figure II-5 and Figure II-6 present the breakdown of the URS (2002) estimated Cs-137 and Co-60 activity by 50-foot trench segments, respectively. The Trench 6 special holes and the short Trench 7 activities are shown in both Figure II-5 and Figure II-6.

State Licensed Disposal Area URS 2002 Cs-137 Disposal Distribution (Ci)

Distance (ft)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	0.85	10.3	137	47.7	30.9	--	3.4	12.5	--	--	--	--	--	--	243
Trench 2	585	27.3	20.1	14.3	12.5	32	102	6.95	--	--	--	--	--	--	800
Trench 3	153	98.6	20.7	49.5	70.7	73.8	55.3	8.57	8.58	8.51	35.4	173	169	34.7	959
Trench 4	1,410	1,160	366	1,130	1,840	481	590	435	228	169	219	0	0	99.2	8,127
Trench 5	791	0.101	2.18	1.35	8.43	1.78	47.4	166	163	1.41	2.23	0.00602	--	--	1,185
Trench 7	101	--	--	--	--	--	--	--	--	--	--	--	--	--	101
Trench 8	44.2	81.1	27	4.03	5.05	9.05	33.3	13.4	43.3	4.12	67.5	--	--	--	332
Trench 9	50.5	218	17.5	268	185	317	294	250	18.6	272	5.79	0.167	--	--	1,897
Trench 10	1.31	2.04	0.936	23.4	2.96	7.56	2.19	2.91	7.24	3.92	4.23	4.16	--	--	63
Trench 11	10.2	110	22.4	5	35.6	2.33	2.34	3.78	149	7.23	7.73	0.349	--	--	356
Trench 12	29.2	20.9	11.2	11.3	22.9	46.9	11.3	4.22	5.93	10.2	4.11	0.00353	--	--	178
Trench 13	6.71	8.1	18.8	8.43	7.65	23.2	5.77	38.5	1.97	4.12	4.8	0.38	0.358	--	129
Trench 14	7.67	11	11.5	92.4	1.74	4.04	19.8	10.3	3.36	9.94	56.1	30.5	0.0696	--	258
	SPH-01	SPH-02	SPH-03	SPH-04	SPH-05	SPH-06	SPH-07	SPH-08	SPH-09	SPH-10					
Trench 6	0.0268	0.0000629	0.0000353	0.000559	0.0803	0.0803	0.0602	0.0879	0.0879	0.0516					
	SPH-11	SPH-12	SPH-13	SPH-14	SPH-15	SPH-16	SPH-17	SPH-18	SPH-19						
	0.0697	0.132	0.12	7.17E-06	2.87E-06	0.0516	0.0516	0.0315	0.0516						1.0

Figure II-5: URS, 2002; SDA Cs-137 January 1, 2000, Distribution

Figure II-5 shows that most of the Cs-137 activity is located primarily within a handful of Trench 4 segments.

State Licensed Disposal Area URS 2002 Co-60 January 1, 2000 Distribution (Ci)

Distance (ft)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	0.0122	0.329	1.63	0.277	0.146	--	0.016	0.204	--	--	--	--	--	--	2.6
Trench 2	15.8	0.669	0.444	0.219	0.21	0.579	1	0.0327	--	--	--	--	--	--	19
Trench 3	4.3	2.18	0.552	0.669	1.73	2	2	0.3	0.3	0.3	1.06	4.24	3.54	1.19	24
Trench 4	9.1	6.48	2.39	40.4	33.4	12.2	5	7.79	7.05	31.2	120	0	0	3.31	278
Trench 5	122	0.00261	0	0.021	0.304	0.0503	2.76	10.2	262	0.0684	0.0889	1.19	--	--	399
Trench 7	0.832	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8
Trench 8	0.594	0.79	0.395	0.157	0.0598	0.429	10	0.676	20.2	0.0951	0.629	--	--	--	34
Trench 9	2.85	1.99	3.2	2.87	1.93	3.34	4.1	2.95	0.939	3.22	0.215	0.00202	--	--	28
Trench 10	0.0445	13.4	0.0558	0.296	0.121	0.568	0.113	0.0903	0.141	0.218	0.214	0.178	--	--	15
Trench 11	0.619	7.79	1.12	0.213	1.84	0.071	0.0991	0.195	7.68	0.32	0.39	0.0343	--	--	20
Trench 12	32.3	103	5.3	0.521	1.67	1.65	8.44	0.304	0.206	0.515	0.325	0.000366	--	--	154
Trench 13	0.262	0.611	0.663	0.599	0.502	2.03	28.4	1.18	1.05	0.29	0.279	0.0288	0.021	--	36
Trench 14	2.01	0.696	9.19	4.77	0.113	0.284	1.35	0.688	0.241	0.759	1.17	1	0.00103	--	22
	SPH-01	SPH-02	SPH-03	SPH-04	SPH-05	SPH-06	SPH-07	SPH-08	SPH-09	SPH-10					
Trench 6	85.1	0.2	0.112	1.78	354	354	265	387	387	227					
	SPH-11	SPH-12	SPH-13	SPH-14	SPH-15	SPH-16	SPH-17	SPH-18	SPH-19						
	307	581	529	0.03	0.0126	227	227	139	227						4,298

Figure II-6: URS, 2002; SDA Co-60 January 1, 2000, Distribution

Figure II-6 shows that most Co-60 activity is contained within the Trench 6 special holes.

Additionally, barium-137m (Ba-137m) is a significant gamma emitter [662 kilo-electronvolts (keV)], and would be of concern in any SDA waste exhumation design. Even though the Ba-137m gamma emission is the concern, Ba-137m by itself has a very short half-life (i.e., 2.55 minutes) and would rapidly decay to an insignificant level. However, because it is in equilibrium with its parent, Cs-137, it remains present at 94.6% of the Cs-137 activity. Although this study does not explicitly discuss Ba-137m, any discussion of Cs-137 should also be applied to Ba-137m.

Another radionuclide that is expected to be important for the exhumation of the SDA is strontium-90 (Sr-90). For Sr-90, URS (2002) reports that the radionuclide concentrations assigned to this profile were based on the volume-weighted averages of as-generated evaporator bottoms from decommissioning a reference boiling-water reactor (BWR) and pressurized-water reactor (PWR) and scaled to the concentration calculated from database records. Under this scenario, and based on the period when this waste was received (i.e., beginning in May 1966), a large amount of Sr-90 would be expected to be present in Trench 4. This is not the case, however, as shown in Figure II-7. The reason for this discrepancy is that using the reference BWR and PWR evaporator bottoms radionuclide concentration does not align with the processing that was being performed at the Quehanna facility, which was Sr-90 in the form of strontium titanate received from Hanford. This concern is discussed in more detail in Section II.D (“SDA Activity Estimate Comparisons”).

State Licensed Disposal Area URS 2002 Sr-90 Disposal Distribution (Ci)															
	Distance (ft)														
	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	0.00909	0.0887	0.998	0.39	0.265	--	0.0288	0.0673	--	--	--	--	--	--	1.8
Trench 2	1.44	0.158	0.0766	0.0805	0.0653	0.173	2.02	0.0588	--	--	--	--	--	--	4.1
Trench 3	0.459	0.878	0.0792	0.452	0.262	0.248	0.121	0.0146	0.0147	0.0145	0.159	0.697	0.984	0.37	4.8
Trench 4	11.6	10.1	3.15	4.03	12.4	2.99	4.86	2.86	1.04	0.312	1.64	0	0	0.347	55
Trench 5	3.34	0.0018	0.0678	0.0435	0.046	0.912	0.156	0.275	0.369	0.00367	0.0885	0.00548	--	--	5.3
Trench 7	0.807	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8
Trench 8	0.399	0.724	1.01	0.0744	0.1	1.71	0.174	0.106	0.121	0.0601	0.604	--	--	--	5.1
Trench 9	0.109	1.89	0.19	2.29	1.61	2.8	2.51	2.15	0.12	2.26	0.052	0.00304	--	--	16
Trench 10	0.0499	0.144	0.218	0.484	0.428	6.59	1.9	0.388	1.44	0.449	0.153	1.32	--	--	14
Trench 11	0.456	0.285	0.971	0.487	1.13	0.147	0.495	0.104	1.44	2.06	0.308	0.209	--	--	8.1
Trench 12	5.62	0.743	1.29	3.62	0.224	0.56	3.81	0.15	3.33	3.94	0.0678	0.00358	--	--	23
Trench 13	3.1	0.086	0.83	0.414	0.0837	0.133	11.5	0.387	0.372	0.567	0.973	0.0716	0.027	--	19
Trench 14	12.6	0.805	0.728	1.4	0.077	0.25	0.619	0.114	0.147	0.15	0.696	0.214	0.000597	--	18
Trench 6	SPH-01	SPH-02	SPH-03	SPH-04	SPH-05	SPH-06	SPH-07	SPH-08	SPH-09	SPH-10					
	0.008	0.0000188	1.05E-05	1.67E-04	0.0241	0.0241	0.0181	0.0264	0.0264	0.0155					
	SPH-11	SPH-12	SPH-13	SPH-14	SPH-15	SPH-16	SPH-17	SPH-18	SPH-19						
	0.0209	0.0396	0.036	2.15E-06	8.6E-07	0.0155	0.0155	0.00946	0.0155						0.3

Figure II-7: URS, 2002; SDA Sr-90 January 1, 2000, Distribution

B. Historical Inventory Estimates

In this section, the following seven previous estimates of the inventory of radionuclides disposed in the SDA are described:

1. Kelleher and Michael, 1973
2. O’Connell and Holcomb, 1974
3. U.S. Environmental Protection Agency (EPA), 1977
4. Duckworth, 1981
5. Prudic, 1986
6. Envirosphere, 1986
7. West Valley Nuclear Services Company, Inc. (WVNS), 1995a

1. Kelleher and Michael, 1973

At the request of the EPA, the New York State Department of Environmental Conservation (NYSDEC), Bureau of Radiological Control made an initial estimate of the inventory of radioactive materials buried in the West Valley site, including both the SDA and NDA. The report by Kelleher and Michael (1973) is the result of that request. The following passage from the “Introduction” section of the Kelleher and Michael (1973, page 1) report provides background on why the inventory estimates were made, who made them, and how they were made.

> *The inventory will be used … to determine volumes, types of radioactive wastes, and the originators of the wastes so that better predictions can be made as to future requirements for low level burial sites. In addition, an assessment can be made of the potential for future problems from long lived radioactive materials buried at the site. The inventory was made of over 1,700,000 cubic feet of wastes buried at the commercial site from October 1964 through December 1972. An inventory was also made of over 87,000 cubic feet of wastes from the Nuclear Fuel Services reprocessing plant, licensed by the USAEC buried in an adjacent area, from 1966–1972.*

> *Shipping records were provided by Nuclear Fuel Services (NFS), the operator of the site. The volumes of wastes, type of facility shipping the wastes, and the important radionuclides were obtained from the shipping records. No attempt was made to change the shipping information except in a few instances where the shipper was contacted for verification before making changes. The only confirmation that could be made of the records supplied by the shipper was on volume because the shipper is charged by volume.*

Kelleher and Michael (1973) state that the radionuclides were recorded in units most frequently used by the shipper, as follows:

- BPM (byproduct material) – hydrogen-3 (H-3), carbon-14 (C-14), H-3 and C-14, Co-60, Cs-137, iodine-131 (I-131) and I-125, radium-226 (Ra-226), americium-241 (Am-241) – curies (Ci)
- MFP (mixed mission products) — Ci
- Mix & Misc. (mixture and miscellaneous) – includes all of the isotopes not mentioned previously – Ci
- plutonium-238 (Pu-238) – Ci and grams (g)
- uranium-235 (U-235), U-233, Pu-239 – g
- U-238, U-natural (U-nat), thorium-232 (Th-232) – pounds (lbs)

A summary of the results of the Kelleher and Michael (1973) SDA inventory estimate is presented in Table II-2.

Table II-2: Kelleher and Michael, 1973; Summary

Trench	Volume (Table I) (ft^3)	Activity (Table II) (Ci)	
		BPM	Pu-238
1	55,275	4,117	—
2	114,246	2,215	—
3	198,675	17,061	—
4	274,416	67,117	—
5	278,401	90,432	2,400
6	75	10,245	—
7	2,465	1,568	—
8	252,435	34,757	3,914
9	173,722	27,323	6,835
10	182,462	39,887	15,006
11	182,769	46,704	6,827
Total	**1,714,941**	**341,426**	**34,982**

A breakdown of the activity by radionuclide is shown in Table II-3 for the BPM, MFP, Mix & Misc., and Pu-238 groupings.

Table II-3: Kelleher and Michael, 1973, Table II; Byproduct Material Radionuclides

Trench	Byproduct Material (Ci)								MFP (Ci)	Mix & Misc. (Ci)	Pu-238 (Ci)
	H-3	C-14	H-3 & C-14	Co-60	Cs-137	I-125 / I-131	Ra-226	Am-241			
1	17	1	0	34	—	—	—	—	566	3,499	—
2	8		620	139	—	—	0.2	—	915	533	—
3	667	5	5,498	4,017	—	98	0.5	—	2,808	3,968	0.1
4	2,768	8	11,758	171	3	180	1.67	—	15,088	37,139	—
5	10,772	3	10,325	46,469	0.1	46	0.6	—	67	22,749	2,400
6	—	—	—	10,208	—	—	—	—	—	37	—

Table II-3: Kelleher and Michael, 1973, Table II; Byproduct Material Radionuclides

Trench	Byproduct Material (Ci)								MFP (Ci)	Mix & Misc. (Ci)	Pu-238 (Ci)
	H-3	C-14	H-3 & C-14	Co-60	Cs-137	I-125 / I-131	Ra-226	Am-241			
7	—	—	—	254	—	—	—	—	—	1,314	—
8	15,771	35	3,221	13,188	1	31	1.625	1.5	191	2,316	3,914
9	7,843	15	12,767	139	9	12	0.014	5	330	6,203	6,835
10	31,711	33	2,954	1,827	3	71	0.003	4	292	2,992	15,006
11	36,139	342	5,090	264	3	6	1	7	586	4,266	6,827
Total	**105,696**	**442**	**52,233**	**76,710**	**19.1**	**444**	**5.612**	**17.5**	**20,843**	**85,016**	**34,982**

With regard to Sr-90, Kelleher and Michael (1973, page 5) make the following comment:

> *With the exception of trench 4 only trace quantities of ^{90}Sr were found in the trenches. For this reason, a separate column for ^{90}Sr was not included in* [Table II-3]. *It should be noted that there are approximately 15,763 curies of ^{90}Sr in trench 4 shipped by an industry which is believed to result from the discontinuance of the space battery program in 1966–1967.*

Kelleher and Michael (1973) also estimate the mass of special nuclear material (SNM) and source material (SM) deposited in the SDA. Those estimates are shown in Table II-4.

Table II-4: Kelleher and Michael, 1973, Table II; Special Nuclear Material and Source Material Quantities

Trench	Special Nuclear Material (g)					Source Material (lbs)		
	Pu-238	Pu-239	U-235	U-233	Total	Th-232	U-238 & U-nat	Total
1	—	—	2,858	—	2,858	630	109	739
2	—	9	650	—	659	—	553	553
3	<0.1	100	1,794	—	1,894	180	44,403	44,583
4	—	476	7,857	—	8,333	—	140,825	140,825
5	138	298	3,143	—	3,579	5,203	19,721	24,924
6	—	—	—	—	—	—	—	—
7	—	—	294	—	—	—	—	—
8	224	453	12,397	—	13,074	7,460	313,766	321,226
9	393	94	3,804	255	4,546	510	43,267	43,777
10	862	63	2,214	—	3,139	268	101,346	101,614
11	392	1	5,758	—	6,151	1,037	79,055	80,092
Total	**2,009**	**1,494**	**40,769**	**255**	**44,233**	**15,288**	**743,045**	**758,333**

2. O'Connell and Holcomb, 1974

The EPA contracted with the six states having commercial burial facilities for low-level radioactive wastes to obtain inventories of the types and quantities of waste buried at these six sites. The SDA was one of these six sites. O'Connell and Holcomb (1974) present the information received back from the six states in a series of tables. Table II-5 summarizes the information presented in O'Connell and Holcomb (1974) for the SDA.

Table II-5: O'Connell and Holcomb, 1974; Summary

Year	Volume (ft^3)	BPM Activity (Ci)	SNM (g)	SM (lbs)
1963	18,425	1,372	952	16,716
1964	225,597	11,355	3,273	22,197
1965	166,564	21,515	2,433	48,987

Table II-5: O'Connell and Holcomb, 1974; Summary				
Year	**Volume (ft³)**	**BPM Activity (Ci)**	**SNM (g)**	**SM (lbs)**
1966	165,872	41,066	4,999	84,492
1967	174,657	51,230	3,446	44,699
1968	159,084	51,675	2,045	14,244
1969	150,948	23,264	7,301	176,401
1970	179,960	36,291	8,273	69,931
1971	224,687	42,458	4,816	113,438
1972	249,117	61,208	7,821	159,930
Subtotal	**1,714,911**	**341,434**	**45,359**	**751,035**
1973	250,000	40,000	4,000	100,000
Total	**1,964,911**	**381,434**	**49,359**	**851,035**

Comparing the information given in Table II-5 to the information provided in Table II-2, Table II-3, and Table II-4 shows that O'Connell and Holcomb (1974) are using the Kelleher and Michael (1973) estimates (at least through 1972), although Kelleher and Michael (1973) is not identified as a reference. For example, the Table II-5 volume and BPM and Source Material activities match the Table II-2 and Table II-3 values (within round-off). At 45,359 grams the O'Connell and Holcomb (1974) SNM estimate is larger than can be justified by round-off than the Kelleher and Michael (1973) SNM estimate of 44,233 grams. O'Connell and Holcomb (1974) state that they manipulated the SNM values, i.e., "Plutonium-238 [was] added to the [SNM] figures supplied by New York State," perhaps an error was made during this process. Nonetheless, the difference between the two estimates is only about 2.6%, well within the uncertainty of these types of calculations. Therefore, there is no need to provide a separate review of O'Connell and Holcomb (1974).

3. EPA, 1977

In 1977, EPA published a summary report on the SDA covering the years 1963 through 1975. EPA (1977) included a discussion on the volume and activity of the waste disposed in the SDA, which was extracted from Kelleher and Michael (1973). In fact, EPA (1977) Tables 1, 2, and 3 are attributed to and contain the same information as Kelleher and Michael (1973) Tables I, II, and V. Thus, there is no need to provide a separate review of EPA (1977).

4. Duckworth, 1981

In response to a number of requests for information related to the solid radioactive waste burial operations, James Duckworth (1981) put together a compilation of the West Valley burial operations from 1963 through 1975. Duckworth (1981, page 1) states that Information on operations prior to 1972 was obtained from Kelleher and Michael (1973):

> *Information prior to 1972 that could not be confirmed without detailed review of the microfilmed receiving bills of lading was taken from the Kelleher report* [Kelleher and Michael, 1973]*. The individual receiving records after 1972 were reviewed on a spot basis. A detailed or itemized review was not done because the information on the receiving records is too general in nature and would not greatly improve the accuracy of the data.*

Therefore, the manpower necessary for a complete detailed review was not justified at this time.

Table II-6 is a summary of the periods when each SDA trench was operating and the volume and activity of the waste that was buried, as reported in Duckworth (1981).

Table II-6: Duckworth, 1981; Summary

Trench	Operating Period		Volume (ft^3)	Activity (Ci)
	Begin	End		
1	11/1963	5/1964	55,300	4,100
2	5/1964	10/1964	114,200	2,200
3	7/1964	11/1965	198,700	17,100
4	10/1965	6/1967	274,400	67,100
5	5/1967	3/1969	278,400	92,800
6	7/1970	11/1973	500	339,600
7	11/1965	3/1966	2,500	1,600
8	11/1969	11/1970	252,400	38,700
9	10/1970	7/1971	175,800	34,200
10	6/1971	5/1972	185,800	54,900
11	5/1972	1/1973	182,800	53,500
12	12/1972	10/1973	196,700	11,200
13	10/1973	6/1974	207,800	7,400
14	6/1974	3/1975	229,800	12,300

For Trenches 1 through 11, because of the pre-1973 operating periods, the Duckworth (1981) volume and activity estimates (Table II-6), are identical to the Kelleher and Michael (1973) estimates (Table II-2), except that in Duckworth (1981) the estimates have been rounded to the nearest hundred.

Similar to Kelleher and Michael (1973), Duckworth (1981) presents the activities of the major radionuclides at the time of their disposal. Unlike Kelleher and Michael (1973), Duckworth (1981) also presents the major radionuclide activity remaining in the SDA as of January 1, 1981. These "as disposed" and "remaining" activities from Duckworth (1981) are shown in Table II-7.

Table II-7: Duckworth, 1981, Table V; Major Radionuclides

Nuclide	Radioactivity (Ci)	
	As Disposed	Remaining
H-3	171,400	99,100
C-14	1,700	1,695
Co-60	316,500	127,000
Cs-137	9,100	7,400
Sr-90	24,800	20,100
Ra-226/ Am-241	500	500
Ru-106	2,300	6
Misc.	175,100	60,000
Zr-95	—	—
Pu-238	35,000	32,500
U, Pu & Th	300	300
Total	**736,700**	**348,600**

5. Prudic, 1986

Prudic (1986) is a summary of the U.S. Geological Survey study at the SDA from 1975 through 1980 and has a fourfold purpose. First, it describes the general geohydrologic setting in the vicinity of the burial site, including climate, stream flow, geology, groundwater movement, and groundwater quality. Second, it describes the history of the site, including the types of waste buried and the method of burying the wastes. Third, it describes in detail the groundwater hydrology and geology at the burial site, including the periodic rise of water within some of the trenches. Fourth, it evaluates the potential for subsurface migration of radionuclides from the trenches to land surface.

Prudic (1986) provides an informative discussion on the construction and operation of the trenches, as well as some data on the radionuclide concentration of water within and beneath the trenches. However, because it was not needed for the report's purposes, Prudic (1986) provides no information on the activity of waste disposed within the SDA. Prudic (1986, page 10) does state that the SDA "*operated from November 1963 until May 1975, during which time more than 67,000 m^3* [2, 366,000 ft^3] *of waste was buried in a series of trenches excavated in fine-grained till*." Also, for the seven south trenches (i.e., Trenches 8 through 14), Prudic (1986) provides a breakdown of that volume estimate by the type of waste container that was used (e.g., metal drum, wooden box, etc.). This waste volume data from Prudic (1986) is shown in Table II-8.

Table II-8: Prudic, 1986, Table 3; Volume of Waste Containers in Trenches 8 Through 14

Trench	Waste Volume (ft^3)							
	Metal Drums	Wood Boxes	Paper Boxes	Loose Dirt, Gravel	Concrete Casks	Metal Tanks	Misc. & Other	Total volume
Trench 8	115,797	38,175	60,459	13,526	4,202	5,792	15,538	**253,000**
Trench 9	89,805	25,356	27,157	8,158	5,686	1,377	13,314	**171,000**
Trench 10	87,121	31,395	35,880	16,280	1,130	2,966	8,935	**184,000**
Trench 11	107,145	33,620	14,938	14,797	2,366	5,827	4,344	**183,000**
Trench 12	120,070	32,066	10,383	6,180	5,933	9,394	12,254	**196,000**
Trench 13	137,480	36,374	8,476	1,766	16,139	1,624	6,639	**208,000**
Trench 14	143,272	37,469	5,156	3,567	15,609	14,408	7,910	**227,000**
Total	**801,000**	**234,000**	**162,000**	**64,000**	**51,000**	**41,000**	**69,000**	**1,423,000**
Percentage	56.3%	16.5%	11.4%	4.5%	3.6%	2.9%	4.8%	**100.0%**

6. Envirosphere, 1986

In the 1980s, NYSERDA and DOE sponsored a project to develop a long-term management plan for the SDA. The plan was directed to upgrade the disposal area such that passive custodial care and monitoring activities would be sufficient to protect public health and safety and the environment. The initial task of that project was to characterize the SDA, including the volume and radioactivity of the disposed waste. The SDA's waste volume and activity, as estimated from the SDA characterization study, are provided in Table 2-2 of the Envirosphere (1986) report, a portion of which has been reproduced below as Table II-9.

Table II-9: Envirosphere, 1986, Table 2-2; Summary

Trench	Operating Period		Volume (ft^3)	Activity (Ci)
	Begin	End		
1	11/1963	5/1964	55,300	4,100

Table II-9: Envirosphere, 1986, Table 2-2; Summary				
Trench	Operating Period		Volume (ft^3)	Activity (Ci)
	Begin	End		
2	5/1964	10/1964	114,200	2,200
3	7/1964	11/1965	198,700	17,100
4	10/1965	6/1967	274,400	67,100
5	5/1967	3/1969	278,400	92,800
6	7/1970	11/1973	500	339,600
7	11/1965	3/1966	2,500	1,600
8	11/1969	11/1970	252,400	38,700
9	10/1970	7/1971	175,800	34,200
10	6/1971	5/1972	185,800	54,900
11	5/1972	1/1973	182,800	53,500
12	12/1972	10/1973	196,700	11,200
13	10/1973	6/1974	207,800	7,400
14	6/1974	3/1975	229,800	12,300

Envirosphere (1986) states that its Table 2-2 source is Duckworth (1981), Table IV, and a comparison of Table II-9 to Table II-6 shows that they are identical. Additionally, except for the fact that Envirosphere (1986) includes the Ra-226/Am-241 activity within the "Others" category, the Duckworth (1981) radionuclide activity breakdown given in Table II-7 above is identical to the Envirosphere (1986) radionuclide breakdown reproduced in Table II-10 below.

Table II-10: Envirosphere, 1986, Table 2-5; Major Radionuclides		
Nuclide	Radioactivity (Ci)	
	As Disposed (1963–75)	January 1981
H-3	171,400	99,100
C-14	1,700	1,700
Co-60	316,500	127,000
Cs-137	9,100	7,400
Sr-90	24,800	20,100
Ra-226	10	10
Ru-106	2,300	6
Pu-238	35,000	32,500
Pu-239	300	300
U-235		
U-238		
Others	175,600	60,500
Total	736,700	348,600

7. West Valley Nuclear Services Company, Inc., 1995a

The purpose of the WVNS (1995a) report was to provide physical, chemical, and radiological information about the SDA to support the 1996 Draft Environmental Impact Statement (DEIS) (DOE/EIS-0226D; DOE & NYSERDA, 1996). The two primary elements of the WVNS (1995a) report were: (1) the Nuclear Fuel Services electronic database, containing information from both the NFS "Radioactive Waste Receiving Records" and the "Radioactive Waste Shipment Records" sent to NFS by the generators and waste brokers; and (2) a Pacific Northwest Laboratory (PNL) waste profile report that organized the various waste generators into six primary industry groups and 16 secondary groups, and assigned a radionuclide inventory profile to each group.

Table II-11 presents a trench-by-trench summary of the WVNS (1995a) results.

Table II-11: WVNS, 1995a; Summary

Trench	Volume (Table 3.1) (m^3)	Activity (Table 3.2) (Ci)
1	1,479	18,300
2	3,276	65,300
3	5,673	41,000
4	7,839	87,000
5	6,143	18,400
6	13	67,500
7	71	35
8	7,112	14,400
9	4,923	10,700
10	5,204	25,600
11	5,178	20,400
12	5,653	20,700
13	5,937	18,200
14	6,400	22,100

Figure II-8 shows the breakdown of the WVNS (1995a) waste volume estimate by 50-foot trench segment. The darker the red in Figure II-8, the greater the volume of waste disposed in that trench segment. Neither the Trench 6 special holes nor the short Trench 7 are shown in Figure II-8.

WVNS 1995 SDA Waste Volume Distribution (ft^3)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	3,002	3,461	13,596	16,527	10,206	0	883	4,520	--	--	--	--	--	--	52,195
Trench 2	21,542	8,935	25,638	883	26,910	9,429	22,389	0	--	--	--	--	--	--	115,726
Trench 3	13,773	13,702	11,513	11,301	12,113	15,927	15,927	48,134	0	0	14,585	14,550	14,867	13,914	200,305
Trench 4	20,235	19,141	19,458	20,271	19,070	20,129	20,059	18,576	20,023	20,871	26,309	44,320	0	8,440	276,902
Trench 5	18,116	1,942	24,862	26,874	15,433	27,334	27,122	25,709	25,497	5,050	14,302	4,767	0	--	217,009
Trench 8	15,892	25,638	21,012	28,958	27,228	26,133	25,850	27,192	17,445	22,142	13,773	0	--	--	251,264
Trench 9	7,734	25,215	26,733	11,760	15,821	22,531	12,749	15,397	12,042	11,972	8,546	3,355	--	--	173,854
Trench 10	13,985	17,587	19,105	14,620	22,178	11,336	14,550	11,301	19,352	17,940	16,280	5,474	--	--	183,707
Trench 11	20,765	9,252	24,579	17,657	26,133	15,397	8,440	12,572	14,585	14,196	16,103	2,790	--	--	182,471
Trench 12	21,224	21,648	15,750	17,622	16,386	21,224	22,213	19,494	17,587	16,103	9,853	1,872	--	--	200,976
Trench 13	15,927	11,442	20,694	24,932	13,243	22,813	20,023	14,938	21,365	16,386	19,706	3,885	4,344	--	209,698
Trench 14	16,739	20,200	25,144	21,966	23,308	21,118	25,179	18,893	13,137	15,397	18,964	4,838	1,165	0	226,049

Figure II-8: WVNS, 1995a; SDA Waste Volume Distribution

WVNS (1995a, page 9, footnote 1) states:

> *There are some accounts that indicate the measurements were made from the southern end of trenches 1 through 7. While these conflicting accounts may need to be resolved in the future, they do not influence the economic or technical feasibility of the closure options being considered and will not be resolved in this study.*

If it is determined that is the case, then the non-zero values for Trenches 1 through 5 in Figure II-8 would be reversed. For partial exhumation, it is very important that this be resolved, so that the waste to be exhumed can be properly located. However, for full exhumation or for leaving the waste in place, this is of lesser importance.

Table II-12 is a radionuclide breakdown of the activity given in Table II-11. Based on activity, nickel-63 (Ni-63) is the most abundant radionuclide estimated to be in the SDA, followed by Pu-241, Cs-137, Co-60, Sr-90, and so forth.

Table II-12: WVNS, 1995a; Major Radionuclides

Nuclide	Activity (Ci)
Ni-63	1.23E+05
Pu-241	4.88E+04
Cs-137	4.73E+04
Co-60	4.10E+04
Sr-90	3.62E+04
Pu-238	3.49E+04
Eu-154	1.20E+04
H-3	2.27E+03
Ni-59	5.70E+02
C-14	2.87E+02
Pu-239	1.82E+02
Ra-226	8.73E-01
U-238	7.99E-01
U-235	4.12E-01
Ru-106	1.65E-09

Figure II-9 and Figure II-10 present the breakdown of the WVNS (1995a) estimated Cs-137 and Co-60 activity by 50-foot trench segments, respectively. The Trench 6 special holes and the short Trench 7 activities are shown in both Figure II-9 and Figure II-10.

State Licensed Disposal Area WNVS 1995 Cs-137 January 1, 1993 Distribution (Ci)

Distance (ft)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	49	94.6	216	695	791	--	5.25	354	--	--	--	--	--	--	2,205
Trench 2	375	261	170	5.21	349	37.9	1,150	--	--	--	--	--	--	--	2,348
Trench 3	300	84	119	193	392	955	871	98.3	98.3	98.3	350	597	710	293	5,159
Trench 4	168	157	274	236	167	177	133	200	135	187	250	3,385	3,385	59.9	8,914
Trench 5	90	24.8	1,260	263	147	248	236	231	238	53.8	85.8	38.2	--	--	2,916
Trench 7	3.44	--	--	--	--	--	--	--	--	--	--	--	--	--	3
Trench 8	169	276	133	161	157	260	238	278	168	231	112	--	--	--	2,183
Trench 9	63.5	251	216	75.5	107	157	85.5	158	82.7	108	34.2	48.6	--	--	1,387
Trench 10	125	113	164	98.6	215	70.1	458	92.8	476	363	316	139	--	--	2,631
Trench 11	400	81.3	467	311	386	120	82.7	135	273	240	417	11.6	--	--	2,925
Trench 12	406	82.6	475	316	392	122	84	137	277	244	424	11.8	--	--	2,971
Trench 13	352	146	435	323	225	367	180	243	397	338	349	162	111	--	3,628
Trench 14	553	347	455	352	308	431	435	339	242	239	685	20.5	8.81	--	4,415
	SPH-01	SPH-02	SPH-03	SPH-04	SPH-05	SPH-06	SPH-07	SPH-08	SPH-09	SPH-10					
Trench 6	160	0.094	0.053	3.3	520	650	490	560	560	350					
	SPH-11	SPH-12	SPH-13	SPH-14	SPH-15	SPH-16	SPH-17	SPH-18	SPH-19						
	460	840	760	0.07	0.023	46	46	70	46						5,562

Figure II-9: WVNS, 1995a; SDA Cs-137 January 1, 1993, Distribution

Figure II-9 shows that the trench segments with the largest WVNS (1995a) estimated Cs-137 activity occur in Trench 4, and that Trenches 2 and 5 also have segments that each contain over 1,000 Ci of Cs-137. When compared to Figure II-5, the distribution of Cs-137 in the Trench 4 segments appears to support the claim that the WVNS (1995a) values shown in Figure II-9 are reversed in direction (i.e., from south to north).

The Co-60 activity shown in Figure II-10 closely follows the Figure II-9 Cs-137 activity, except that nine of the 19 Trench 6 special holes each contain over 1,000 Ci of Co-60.

State Licensed Disposal Area WNVS 1995 Co-60 January 1, 1993 Distribution (Ci)

Distance (ft)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	44.2	92.1	117	762	896	--	0.458	402	--	--	--	--	--	--	2,314
Trench 2	347	276	13.9	0.474	253	2.69	1,350	--	--	--	--	--	--	--	2,243
Trench 3	333	8.17	80.7	200	477	1,150	1,040	9.6	9.6	9.6	367	679	885	218	5,467
Trench 4	38.9	12.8	215	10.5	11.3	9.76	8.72	5.5	19.5	16	52.3	4,955	4,955	12	10,322
Trench 5	18.6	0.613	1,990	86.2	16.9	30.9	13	9.19	63.5	2.43	4.7	0.987	--	--	2,237
Trench 7	10.6	--	--	--	--	--	--	--	--	--	--	--	--	--	11
Trench 8	4.63	15.5	7.55	43.3	10.3	11.9	14	12.9	9.43	117	8.82	--	--	--	255
Trench 9	4.85	17.9	15.7	6.37	9.74	17.5	11.2	11.4	9.23	11.4	6.37	0.887	--	--	123
Trench 10	10.8	14.7	15.2	7.4	11.1	6.81	2.84	9.73	4.42	3.23	1.84	0.776	--	--	89
Trench 11	11.9	10.3	15.9	14.1	117	4.94	0.767	6.09	8.62	7.56	9.21	0.0324	--	--	206
Trench 12	13	11.3	17.4	15.4	128	5.4	0.839	6.66	9.43	8.26	10.1	0.0354	--	--	226
Trench 13	11.4	12.1	24.7	21.3	12.1	35.5	28.6	16.9	16.1	96.6	21.6	3.15	5.18	--	305
Trench 14	6.69	26.9	20.3	28.6	36.8	27.7	32.1	23.7	14.3	23.8	10.8	14	2.45	--	268
	SPH-01	SPH-02	SPH-03	SPH-04	SPH-05	SPH-06	SPH-07	SPH-08	SPH-09	SPH-10					
Trench 6	480	0.29	0.16	10	1,600	2,000	1,500	1,700	1,700	1,100					
	SPH-11	SPH-12	SPH-13	SPH-14	SPH-15	SPH-16	SPH-17	SPH-18	SPH-19						
	1,400	2,600	2,400	0.22	0.072	140	140	220	140						17,131

Figure II-10: WVNS, 1995a; SDA Co-60 January 1, 1993, Distribution

Figure II-11 indicates that almost a quarter of the Sr-90 activity was disposed in Trench 4, Segment 500 (i.e., 22.8%). This is consistent with the beginning of waste shipments from the Martin-Marietta, Quehanna, Pennsylvania, facility, even though WVNS (1995a) does not explicitly discuss the Quehanna facility. However, according to URS (2002), the Quehanna facility waste shipments continued for about a year, so it would be expected that this Sr-90 activity would have been spread over more than one 50-foot segment of Trench 4 (i.e., Table II-9 indicates that the last Trench 4 segment was closed in June 1967, about the time the Quehanna facility waste shipments were ending). This concern is discussed in more detail in Section II.D.4.

State Licensed Disposal Area WNVS 1995 Sr-90 Disposal Distribution (Ci)

Distance (ft)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	3.79	5.42	113	15.9	23.9	--	1.61	4.04	--	--	--	--	--	--	168
Trench 2	30.8	12.3	73.9	1.59	47.3	22.6	18.4	--	--	--	--	--	--	--	207
Trench 3	15.6	25.7	57.5	12.3	9.78	63.7	55.8	30.1	30.1	30.1	36.3	62.4	8.38	128	566
Trench 4	83.6	114	80.9	244	134	131	111	154	95.3	148	8,260	1.5	1.5	33.4	9,592
Trench 5	37.7	19.5	171	175	108	183	178	191	146	37.5	59.6	29.8	--	--	1,336
Trench 7	0.00153														0.0
Trench 8	184	244	92	99.6	125	224	185	234	144	139	71	--	--	--	1,742
Trench 9	45	204	193	77.7	64.8	89.3	64.9	133	69.6	60.6	10.7	40.7	--	--	1,053
Trench 10	103	63.4	138	66.9	161	43.1	656	54.9	619	501	339	180	--	--	2,925
Trench 11	494	56.7	582	367	503	150	125	175	381	318	611	10.4	--	--	3,773
Trench 12	503	57.7	592	373	511	152	127	178	387	323	622	10.6	--	--	3,836
Trench 13	482	191	608	450	310	472	173	337	562	429	470	255	148	--	4,887
Trench 14	855	459	653	468	338	588	591	449	321	288	1,080	2.48	2.73	--	6,095
	SPH-01	SPH-02	SPH-03	SPH-04	SPH-05	SPH-06	SPH-07	SPH-08	SPH-09	SPH-10					
Trench 6	0.07	4.2E-05	2.4E-05	0.0015	0.23	0.29	0.22	0.25	0.25	0.16					
	SPH-11	SPH-12	SPH-13	SPH-14	SPH-15	SPH-16	SPH-17	SPH-18	SPH-19						
	0.21	0.37	0.34	3.10E-05	1.0E-05	0.021	0.021	0.031	0.021						2.5

Figure II-11: WVNS, 1995a; SDA Sr-90 January 1, 1993, Distribution

C. SDA Volume Estimate Comparisons

This section focuses on the waste volume estimates from each of the SDA inventory estimate documents and how they compare to the values reported by URS (2002), while the following section (Section D) focuses on the activity estimates.

For all intents and purposes, the SDA radionuclide inventory estimates given in Kelleher and Michael (1973), Duckworth (1981), and Envirosphere (1986) are identical for Trenches 1 through 11, whereas Duckworth (1981) and Envirosphere (1986) are identical for Trenches 12 through 14. Thus, for comparison purposes, the three inventories will be treated as one (hereafter referred to as the "K&M,D,E inventories"), with Kelleher and Michael (1973) the primary source for Trenches 1 through 11 and Duckworth (1981) the primary source for Trenches 12 through 14.

Table II-13 compares the waste volume estimates from the various source documents and shows that there is quite good agreement between each of the estimates at both the trench level and in total, with only about a 3.5% difference between the smallest and largest estimate.

Table II-13: SDA Waste Volume Comparison

Trench	Waste Volume (ft^3)			
	K&M,D,E*	Prudic, 1986	WVNS, 1995a	URS, 2002
1	55,275	—	52,230	52,400
2	114,246	—	115,691	117,681
3	198,675	—	200,340	201,557
4	274,416	—	276,832	298,405
5	278,401	—	216,938	258,675
6	500	—	459	468
7	2,465	—	2,507	2,490
8	252,435	253,000	251,158	252,227
9	173,722	171,000	173,854	173,542
10	182,462	184,000	183,778	184,169
11	182,769	183,000	182,859	184,467
12	196,700	196,000	199,634	197,504
13	207,800	208,000	209,663	209,220
14	229,800	227,000	226,014	229,665
Total	**2,350,000**	**2,370,000**	**2,290,000**	**2,360,000**

* K&M,D,E = Kelleher and Michael, 1973; Duckworth, 1981; and Envirosphere, 1986.

The Table II-13 waste volume estimates are shown as a function of available disposal trench volume in Figure II-12.

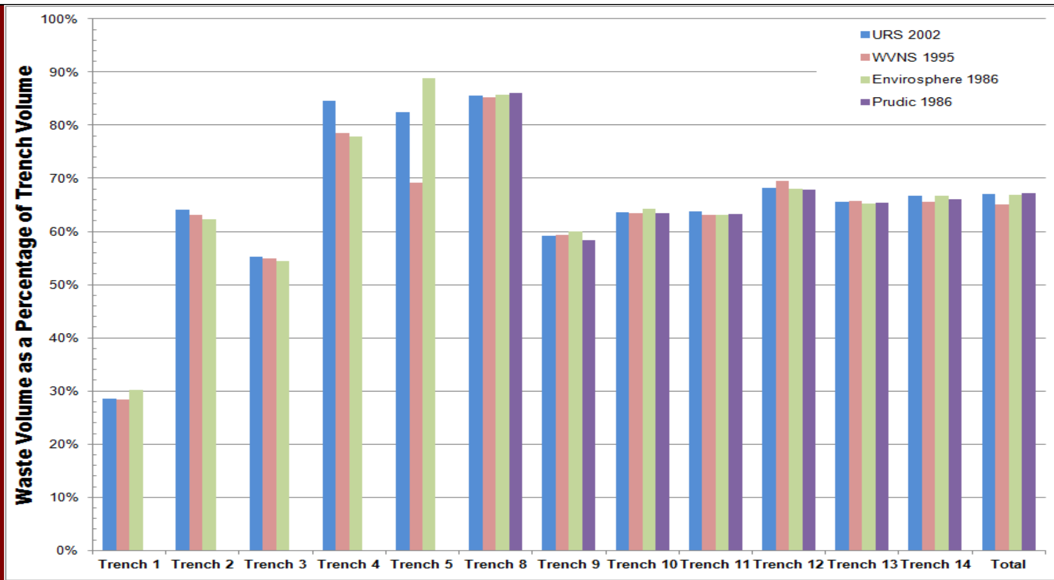

Figure II-12: Estimated Waste Volume as a Percentage of Available Trench Volume

To classify the type of facility that originated the waste, both WVNS (1995a) and URS (2002) used the same six waste generator types: Fuel Cycle, Industrial, Institutional, Isotope Production, Power Reactor, and Special Purpose Reactor. Table II-14 shows the percentage of waste in each waste generator type. The Table II-14 WVNS (1995a) percentages were obtained from WVNS (1995a), Figure 3.1, while the URS (2002) percentages were calculated using the volumes from URS (2002), Table 3-3. There is good agreement for the Industrial, Special Purpose Reactor, and Institutional categories. It appears that some waste that URS (2002) categorized as Fuel Cycle, WVNS (1995a) categorized as Power Reactor. Finally, WVNS (1995a) has four times as much waste in the Isotope Production category than does URS (2002), but in either case the overall amount in this category is small.

Table II-14: WVNS, 1995a, and URS, 2002, Volume by Waste Generator Category

Waste Generator Category	WVNS, 1995a, Figure 3.1	URS, 2002, Table 3-3
Fuel Cycle	19.2%	26.8%
Industrial	6.1%	6.6%
Institutional	14.1%	16.8%
Isotope Production	6.1%	1.5%
Power Reactor	24.2%	17.4%
Special Purpose Reactor	30.3%	30.9%

1. Inter-Trench Distribution

The distributions of waste volume within the SDA estimated by WVNS (1995a) and URS (2002) are shown in Figure II-8 and Figure II-4, respectively. Figure II-13 shows the difference between the WVNS (1995a) and URS (2002) estimated waste volumes by trench segment. Red entries indicate that the WVNS (1995a) values exceeded the URS (2002) values, with blue indicating that the URS (2002) value was larger. The deeper the shade of red or blue indicates the larger the waste volume discrepancy. Because of the small amount of waste they contain, Trenches 6 and 7 are not included in Figure II-13. A similar figure could not be generated for the K&M,D,E inventories because the necessary detailed information is not provided in those reports.

SDA Waste Volume Distribution: (URS, 2002) - (WVNS, 1995) (ft^3)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	383	-200	458	-478	33	0	-4	12	0	0	0	0	0	0	205
Trench 2	3,818	-530	-11,985	11,981	-12,033	11,598	-1,183	288	0	0	0	0	0	0	1,955
Trench 3	1,893	1,104	-1,224	-20	75	11	-102	-32,054	16,124	15,960	412	-614	570	-883	1,253
Trench 4	11,002	-2,917	-1,431	-1,402	14	-2,125	-810	129	-41	-4	-567	-18,670	30,458	7,866	21,502
Trench 5	7,143	25,419	1,190	111	11,613	51	-6,434	1,636	-666	-25	672	958	0	0	41,667
Trench 8	12,468	-951	48	-3,692	-767	1,164	-3,806	-1,651	-103	-1,741	-5	0	0	0	963
Trench 9	1,657	-1,645	-481	208	228	-16	13	3	-24	7	6	-269	0	0	-312
Trench 10	817	-202	409	654	2,348	-1,625	-758	-1,857	-157	803	-828	859	0	0	462
Trench 11	-2,164	2,711	-2,373	2,203	471	464	931	-562	937	-2,202	414	1,165	0	0	1,996
Trench 12	-1,970	-2,391	2,878	-1,595	2,338	-3,965	2,196	-2,669	-644	3,373	299	-1,322	0	0	-3,471
Trench 13	-2,826	4,020	773	115	-371	-425	-1,099	1,930	-3,637	2,895	-1,203	1,613	-2,263	0	-478
Trench 14	-1,983	3,758	-705	2,102	510	31	-2,108	-2,922	2,993	1,933	25	-5	-13	0	3,616

Figure II-13: (URS, 2002) – (WVNS, 1995a) SDA Waste Volume Distribution

As shown in Figure II-13, there are many segments where the estimated disposal volumes are in near agreement, and others where the volume estimates are offset by one 50-foot segment (e.g., the third through sixth segments of Trench 2). For Trench 3 segments 350-399, 400-449, and 450-499, WVNS (1005a) place all the volume in the first segment, whereas URS (2002) divided the volume over all three segments; if the three segments are looked at together, then there is good agreement. This information could prove useful in locating the waste by indicating that it was disposed near the border between the two segments. The segment with the largest discrepancy is Trench 5, Segment 50-99. Figure II-8 shows that WVNS (1995a) only estimated 1,942 cubic feet (ft^3) for this segment while, for the surrounding segments, substantially more waste was estimated, which may indicate that the WVNS (1995a) volume estimate for this segment is in error.

D. SDA Activity Estimate Comparisons

This section focuses on a comparison of the waste activity estimates from each of the SDA inventory estimate documents. For the same reasons as presented for the volume estimate comparisons, the Kelleher and Michael (1973), Duckworth (1981), and Envirosphere (1986) reports will be treated as one (the "K&M,D,E" reports), with Kelleher and Michael (1973) the primary source for Trenches 1 through 11 and Duckworth (1981) the primary source for Trenches 12 through 14.

Kelleher and Michael (1973) made no attempt to identify the specific radionuclides within the MFP and Mix & Misc. categories. In contrast, Duckworth (1981) apportions the MFP activity between Sr-90 (45%), Cs-137 (45%), and ruthenium-103 (Ru-103) (10%), and says that the Misc. category includes about 21,000 Ci of manganese-54 (Mn-54), about 21,000 Ci of silver-110 (Ag-110), and about 56,000 Ci of europium-154 (Eu-154). The Duckworth (1981) Table V radionuclide waste activity values were reproduced in Table 2-5 of Envirosphere (1986), which provides the source for the values shown in the "K&M,D,E" column in Table II-15 below.

Both WVNS (1995a) and URS (2002) used the waste profile method to estimate the SDA activity for radionuclides other than those that were recorded by the shippers. The waste profile method uses "characteristic" radionuclide mixes for various waste generators (e.g., Fuel Cycle, Industrial, Institutional, Isotope Production, Power Reactor, and Special Purpose Reactor) and adjusts the shipper-specified activity accordingly. For example, if a manifest specified that a waste shipment contained Cs-137 and was from a Power Reactor, then the Power Reactor waste profile was used to estimate the other radionuclides that were contained within the shipment (i.e., $A_x = A_{Cs-137} \frac{WP_x}{WP_{Cs-137}}$).

Although both WVNS (1995a) and URS (2002) have waste profiles for the six waste generators identified above, WVNS (1995a) has 16 subcategories of generators and calculated SDA activity estimates for 52 radionuclides, while URS (2002) has 33 subcategories and calculated SDA activity estimates for 60 radionuclides.

Table II-15 presents a summary of the waste activity estimates from the various sources for the 12 radionuclides that appear in the K&M,D,E; WVNS (1995a); and URS (2002) reports. The "As Reported" columns provide the activities as they were given in the source documents, while the activities in the "Common Date" columns have been corrected to allow for the comparisons to be made relative to a common date.

Table II-15: Summary SDA Waste Activity Comparison

Nuclide	Waste Activity (Ci)					
	As Reported			Common Date: 1/1/2000		
	K&M, D,E*	WVNS, 1995a	URS, 2000	K&M, D,E*	WVNS, 1995a	URS, 2002
H-3	171,400	2,270	41,300	33,968	1,530	41,300
C-14	1,700	287	306	1,696	287	306
Co-60	316,500	41,100	5,330	10,386	16,339	5,330
Cs-137	9,100	47,300	14,600	4,771	40,237	14,600
Ba-137m	8,600	44,699	13,797	4,508	38,024	13,797
Sr-90	24,800	36,200	175	12,579	30,459	175
Ra-226	10	1	27	10	1	27
Ru-106	2,300	0	0	0	0	0
Pu-238	35,000	34,900	26,500	27,885	32,985	26,500
Pu-239		182	184	145		184
U-235	300	0	4	3	300	4
U-238		1	192	152		192
Others	175,600	223,060	27,155	25,689	162,693	27,155
Total	**745,000**	**430,000**	**130,000**	**122,000**	**323,000**	**130,000**

* K&M,D,E = Kelleher and Michael, 1973; Duckworth, 1981; and Envirosphere, 1986.

The following sections provide some discussion and additional comparisons for specific radionuclides listed in Table II-15.

1. Hydrogen-3 (Tritium)

Kelleher and Michael (1973, page 6) state that the "*large amounts of tritium in targets account for much of the tritium*." Using data from URS (2002) it can be shown that isotope production facilities account for about 92% of the 41,300 Ci of H-3 reported in URS (2002). Thus, URS (2002) supports the Kelleher and Michael (1973) statement. Prudic (1986, page 75) also states that "*the tritium content* [of the SDA] *could be as high as 40,000 curies*"; however, this statement was not made independently but rather is based on the Kelleher and Michael (1973) estimate.

WVNS (1995a) reports only 2,270 Ci of H-3 in all of the SDA. The reason for such a low estimate is believed to be due to the waste profile WVNS (1995a) used for isotope production facilities. Unlike URS (2002), which included five isotope production waste profiles (including both large and small tritium facilities), WVNS (1995a) used a single waste profile for all isotope production facilities, and the H-3 activity fraction in that profile was less than 0.5%. For comparison, in the URS (2002) large and small tritium facility waste profiles, the H-3 activity fractions are both 100%. The use of a single isotope production waste profile, with an unreasonably small H-3 fraction, is the reason that the WVNS (1995a) H-3 estimate is so much smaller than the other SDA H-3 estimates.

The Ecology and Environment, Inc. (E&E) 1994b report, Table 3-1, reports that about 10.9 million gallons of leachate have been pumped from the SDA trenches, and E&E (1994b), Table 5-2, reports that the trench leachate tritium concentration ranged from 0.03 to 1.99 µCi/ml. Combining the data from these two tables results in a calculated estimate of the tritium pumped from the SDA trenches that is greater than the WVNS

(1995a) estimate. Therefore, for all of these reasons, the WVNS (1995a) SDA tritium activity estimate is not considered to be credible.

2. Carbon-14

The WVNS (1995a) and URS (2002) total C-14 activity estimates are in good agreement, but the Duckworth (1981) C-14 estimate is about a factor of 5⅔ larger than the URS (2002) values. Kelleher and Michael (1973) report 442 Ci of C-14, plus an unspecified amount of C-14 mixed with H-3. Regarding the H-3 and C-14 mixed activity, Kelleher and Michael (1973) state that the "*^{14}C appears to originate at medical and education institutions but is shipped by waste disposal firms. The mixture of ^{3}H and ^{14}C was listed separately because the mixture frequently appeared in the shipping records.* ***There was no way to determine the percentages of each isotope present*** [emphasis added]." Similarly, Duckworth (1981) states that "*in the cases of research waste the curies were listed as combined tritium and Carbon-14 with no separation of types,* ***so there the specific amounts were estimated*** [emphasis added]." Specifically, of the 52,233 Ci that Kelleher and Michael (1973) reported in the H-3 and C-14 Mixed category, Duckworth (1981) assigned about 692 Ci to C-14 (with the remainder assigned to H-3). No basis was given for these assignments.

3. Cobalt-60

Table II-15 shows about a factor of three difference between the WVNS (1995a) and URS (2002) Co-60 estimates, with the K&M,D,E Co-60 values falling between them.

Figure II-14 is a trench segment comparison of the WVNS (1995a) and URS (2002) Co-60 estimates and presents the difference between the URS (2002) and WVNS (1995a) activity values. It shows that much of the WVNS (1995a) higher estimate is due to two Trench 4 segments that are each almost 2,000 Ci greater than the corresponding URS (2002) estimates. Figure II-14 also shows that, for many of the trench segments, the WVNS (1995a) Co-60 estimates are consistently slightly larger than the URS (2002) estimates, with the difference being greatest in the Trench 6 special holes. Only in a handful of cases are the URS (2002) Co-60 estimates larger than the WVNS (1995a) estimates (e.g., Trench 6, Special Holes 16, 17, and 19, and individual segments in Trenches 4, 5, and 12). The following subsections discuss and provide probable explanations for these differences, first for Trench 6 and then for the other trenches.

State Licensed Disposal Area (URS 2002) - (WVNS 1995) Co-60 January 1, 2000 Distribution (Ci)

Distance (ft)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	-17.6	-36.4	-45.0	-303	-357	--	-0.2	-160	--	--	--	--	--	--	-919
Trench 2	-122	-109	-5.1	0.0	-101	-0.5	-537	--	--	--	--	--	--	--	-875
Trench 3	-128	-1.1	-31.6	-79.0	-188	-456	-412	-3.5	-3.5	-3.5	-145	-266	-349	-85.6	-2,153
Trench 4	-6.4	1.4	-83.2	36.2	28.9	8.3	1.5	5.6	-0.7	24.8	99	-1,974	-1,974	-1.5	-3,833
Trench 5	115	-0.2	-793	-34.3	-6.4	-12.3	-2.4	6.5	237	-0.9	-1.8	0.8	--	--	-492
Trench 7	-3.4	--	--	--	--	--	--	--	--	--	--	--	--	--	-3.4
Trench 8	-1.3	-5.4	-2.6	-17.1	-4.0	-4.3	4.4	-4.5	16.4	-46.5	-2.9	--	--	--	-68
Trench 9	0.9	-5.1	-3.1	0.3	-1.9	-3.6	-0.4	-1.6	-2.7	-1.3	-2.3	-0.4	--	--	-21
Trench 10	-4.3	7.5	-6.0	-2.7	-4.3	-2.1	-1.0	-3.8	-1.6	-1.1	-0.5	-0.1	--	--	-20
Trench 11	-4.1	3.7	-5.2	-5.4	-44.8	-1.9	-0.2	-2.2	4.2	-2.7	-3.3	0.0	--	--	-62
Trench 12	27.1	98.5	-1.6	-5.6	-49.3	-0.5	8.1	-2.3	-3.6	-2.8	-3.7	0.0	--	--	64
Trench 13	-4.3	-4.2	-9.2	-7.9	-4.3	-12.1	17.0	-5.6	-5.4	-38.2	-8.3	-1.2	-2.0	--	-86
Trench 14	-0.7	-10.0	1.1	-6.6	-14.5	-10.7	-11.4	-8.8	-5.5	-8.7	-3.1	-4.6	-1.0	--	-85
Trench 6	SPH-01	SPH-02	SPH-03	SPH-04	SPH-05	SPH-06	SPH-07	SPH-08	SPH-09	SPH-10					
	-106	0.1	0.0	-2.2	-283	-443	-332	-290	-290	-211					
	SPH-11	SPH-12	SPH-13	SPH-14	SPH-15	SPH-16	SPH-17	SPH-18	SPH-19						
	-251	-455	-427	-0.1	0.0	171	171	51.4	171						-2,525

Figure II-14: (URS, 2002) – (WVNS, 1995a) SDA Co-60 January 1, 2000, Distribution

K&M,D,E does not provide a trench segment breakdown of its activity estimates, so a comparison similar to Figure II-14 cannot be made for its Co-60 estimate, although Duckworth (1981) does provide a Trench 6 special hole Co-60 breakdown that will be included in the next comparison.

Trench 6

Table II-16 shows the Duckworth (1981), WVNS (1995a), and URS (2002) Co-60 activity estimates for the 19 Trench 6 special holes. As can be seen, with less than 5% difference, there is good agreement between the Duckworth (1981) and WVNS (1995a) estimates, but the URS (2002) estimate is only 60% of the Duckworth (1981) estimate.

Table II-16: Trench 6 Co-60 Comparisons

Special Hole	Estimated Co-60 Activity (Ci)						
	Duckworth, 1981		WVNS, 1995a	URS, 2002	Common Date: 1/1/2000		
	Date	Activity	1/1/1993	1/1/2000	Duck-worth	WVNS, 1995a	URS, 2002
SH-1	7/2/70	10,000	480	85.1	205.0	190.9	85.1
SH-2	7/20/70	6.0	0.3	0.2	0.1	0.1	0.2
SH-3	7/27/70	3.4	0.2	0.1	0.1	0.1	0.1
SH-4	10/3/70	209	10	1.8	4.4	4.0	1.8
SH-5	2/1/73	22,400	1,600	354.0	645.7	636.2	354.0
SH-6	2/1/73	28,000	2,000	354.0	807.1	795.3	354.0
SH-7	2/1/73	21,000	1,500	265.0	605.3	596.5	265.0
SH-8	3/7/73	24,000	1,700	387.0	700.3	676.0	387.0
SH-9	3/19/73	24,000	1,700	387.0	703.4	676.0	387.0
SH-10	3/12/73	15,000	1,100	227.0	438.5	437.4	227.0
SH-11	3/15/73	20,000	1,400	307.0	585.3	556.7	307.0
SH-12	10/1/73	36,000	2,600	581.0	1,132.4	1,033.9	581.0
SH-13	10/1/73	32,800	2,400	529.0	1,031.7	954.4	529.0
SH-14	11/2/73	3.0	0.2	0.03	0.10	0.09	0.03
SH-15	11/9/73	1.0	0.1	0.01	0.03	0.03	0.01
SH-16	11/10/73	2,000	140	227.0	63.8	55.7	227.0
SH-17	11/26/73	2,000	140	227.0	64.2	55.7	227.0
SH-18	11/27/73	3,000	220	139.0	96.3	87.5	139.0
SH-19	11/30/73	2,000	140	227.0	64.3	55.7	227.0
Total	**—**	**241,600**	**17,100**	**4,300**	**7,100**	**6,800**	**4,300**

Curiously, when the Trench 6 special hole total activity estimates are compared, the opposite occurs, as shown in Table II-17. That is, there is good agreement between Duckworth (1981) and URS (2002), but less agreement between WVNS (1995a) and the other two estimates.

Table II-17: Initial Trench 6 Total Activity

Special Hole	Disposal Date	Duck-worth, 1981	WVNS, 1995a	URS, 2002
SH-1	7/2/1970	10,000	20,464	9,845
SH-2	7/20/1970	23	12	23
SH-3	7/27/1970	13	7	13
SH-4	10/3/1970	209	412	199
SH-5	2/1/1973	28,000	48,508	29,121
SH-6	2/1/1973	28,000	60,634	29,121

Table II-17: Initial Trench 6 Total Activity				
Special Hole	Disposal Date	Duck-worth, 1981	WVNS, 1995a	URS, 2002
SH-7	2/1/1973	21,000	45,476	21,800
SH-8	3/7/1973	30,000	50,911	31,448
SH-9	3/19/1973	30,000	50,691	31,312
SH-10	3/12/1973	17,600	32,883	18,413
SH-11	3/15/1973	23,790	41,806	24,875
SH-12	10/1/1973	45,000	72,235	43,799
SH-13	10/1/1973	41,000	66,678	39,879
SH-14	11/2/1973	3	6	2
SH-15	11/9/1973	1	2	1
SH-16	11/10/1973	18,000	19,834	16,867
SH-17	11/26/1973	18,000	19,812	16,770
SH-18	11/27/1973	11,000	13,988	10,265
SH-19	11/30/1973	18,000	19,806	16,746
Total	—	**339,600**	**564,200**	**341,200**

Table II-18 shows that WVNS (1995a) and URS (2002) each took a different approach to matching the Duckworth (1981) Trench 6 activities. WVNS (1995a) attempted to match the Duckworth (1981) Co-60 and Eu-154 activities, and, when the other radionuclides from the WVNS (1995a) waste stream profile were included, the total Trench 6 WVNS (1995a) activity was larger than the total reported by Duckworth (1981). URS (2002), on the other hand, attempted to match the Duckworth (1981) total activity; consequently, when the URS (2002) waste stream profile was applied, the URS (2002) Co-60 activity was smaller than the Co-60 reported by Duckworth (1981), and Eu-154 disappeared altogether.

Table II-18: Trench 6 Initial Major Radionuclide Activities			
Nuclide	Duckworth, 1981	WVNS, 1995a	URS, 2002
Co-60	241,600	231,200	143,600
Mn-54	20,900	18,000	10,400
Ag-110m	20,900	—	—
Eu-154	56,000	56,000	—
Fe-55	—	162,700	155,200
Ni-63	—	30,000	18,700
Co-58	—	37,700	—
H-3	—	1,400	12,100
Others	—	27,200	1,200
Total	**339,600**	**564,200**	**341,200**

Other Trenches

Table II-19 presents the estimated Co-60 activities for the 13 trenches other than Trench 6.

Table II-19: Non-Trench 6 Co-60 Comparisons						
Burial Location	Estimated Co-60 Activity (Ci)					
	Duck-worth	WVNS, 1995a	URS, 2002	Common Date: 1/1/2000		
				Duck-worth	WVNS, 1995a	URS, 2002
	Various	1/1/1993	1/1/2000			
Trench 1	34	2,310	2.6	0.3	918.6	2.6
Trench 2	139	2,240	19.0	1.3	890.7	19.0
Trench 3	4,017	5,470	24.2	44.5	2,175.2	24.2
Trench 4	171	10,300	279.0	2.3	4,095.9	279.0
Trench 5	46,469	2,230	400.0	798.7	886.8	400.0
Trench 7	254	11	0.8	2.9	4.4	0.8
Trench 8	13,469	255	34.0	288.5	101.4	34.0
Trench 9	139	123	27.6	3.2	48.9	27.6
Trench 10	1,827	89	15.5	47.7	35.3	15.5
Trench 11	264	207	20.4	7.5	82.3	20.4
Trench 12	8,094	226	154.0	306.7	89.9	154.0
Trench 13		305	35.9		121.3	35.9
Trench 14		288	22.3		114.5	22.3
Total	74,900	24,100	1,000	1,500	9,600	1,000

Kelleher and Michael (1973, page 5) state that the "*amount of ^{60}Co buried in trench 5 is due to large sealed sources from one shipper buried in that trench*." This does seem to be reflected in both the WVNS (1995a) and URS (2002) estimates. However, WVNS (1995a) shows large amounts of Co-60 in Trenches 1 through 4, even larger than in Trench 5. Neither Duckworth (1981) nor URS (2002) show similar Co-60 estimates for these trenches. In order to result in the 1993 Co-60 estimates reported in WVNS (1995a), it would be necessary for the "As Disposed" Co-60 activities to be on the order of 100,000 to 300,000 Ci for Trenches 1 through 4, each. Because Co-60 is a strong gamma emitter, it seems that these levels of activities would not have been missed by Kelleher and Michael (1973) and URS (2002), and they would likely have been commented upon if present (as was the lower Trench 5 Co-60 activity).

4. Strontium-90

Table II-15 shows that the URS (2002) Sr-90 inventory estimate is about two orders of magnitude smaller than either of the earlier estimates. This is likely due to the manner in which URS (2002) handled the waste received from Martin-Marietta's Quehanna, Pennsylvania, facility in 1966 and 1967, which is believed to be the largest source of Sr-90 in the SDA.

At Quehanna, Pennsylvania, Martin-Marietta was engaged in the manufacture of SNAP (Systems for Nuclear Auxiliary Power) thermoelectric generators, using Sr-90 as the heat source. Purified Sr-90, as a strontium carbonate ($SrCO_3$) slurry, was shipped to the Quehanna, Pennsylvania, facility from the Hanford site in Richland, Washington. At the Quehanna facility, the Sr-90 was converted to strontium titanate ($SrO\text{-}TiO_2$) for use as a SNAP 7B thermoelectric generator.

As far as possible, all wastes were converted to solid form and suitably packaged for shipment and ultimate disposal by land burial (Martin, 1964). As reported in URS (2002):

> *Most of this waste was described as "neutralized solids" with Sr-90 as the principal isotope, and was shipped in 55-gal drums. The waste shipped to*

the SDA does not appear to contain general demolition rubble or plant components. The license for this reactor was terminated in December 1966. The waste was received over a 12-month period beginning in May 1966.

URS (2002) explains that "*The radionuclide concentrations assigned to this profile are based on the volume-weighted averages of as-generated evaporator bottoms from decommissioning a reference BWR and PWR…and scaled to the concentration calculated from database records.*" However, using the reference BWR and PWR evaporator bottoms radionuclide concentration does not align with the processing that was being performed at the Quehanna facility, which was Sr-90 in the form of SrO-TiO_2. Based on the period when this waste was received (i.e., beginning in May 1966), a large amount of Sr-90 would be expected to be present in Trench 4 but is not represented by the URS (2002) values in Table II-15. That is, by assigning a waste profile in which Sr-90 makes up only about 0.03% of the total activity, which results in almost negligible Sr-90 from this source, the URS (2002) values are likely highly underestimated as opposed to the 15,763 Ci of Sr-90 provided by Kelleher and Michael (1973).

Kelleher and Michael (1973) state that this Sr-90 waste was also disposed in Trench 4. Trench 4 was open from October 1965 to June 1967, and URS (2002) indicates that this waste was received over a 12-month period beginning in May 1966. Therefore, the timing is consistent. Additionally, WVNS (1995a) estimated a total of about 9,600 Ci of Sr-90 in Trench 4, which is consistent with a 1966 source of about 15,500 Ci.

Figure II-15 compares the URS (2002) and WVNS (1995a) Sr-90 activity distribution within the SDA. It clearly shows the WVNS (1995) Quehanna facility waste in Trench 4 that is missing from URS (2002). As stated in Section II.B.7, according to URS (2002) the Quehanna facility waste shipments continued for about a year, so it would be expected that this Sr-90 activity would have been spread over more than one 50-foot segment of Trench 4 (i.e., Table II-9 indicates that the last Trench 4 segment was closed in June 1967, about the time the Quehanna facility waste shipments were ending). Therefore, it would not be surprising if the Sr-90 that WVNS (1995a) shows as all being in Segment 500-549, is actually spread out over the last four Trench 4 segments.

State Licensed Disposal Area (URS 2002) - (WVNS 1995) Sr-90 January 1, 2000 Distribution (Ci)

Distance (ft)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	-3.18	-4.47	-94.1	-12.99	-19.8	--	-1.33	-3.33	--	--	--	--	--	--	-139
Trench 2	-24.5	-10.2	-62.1	-1.26	-39.7	-18.8	-13.5	--	--	--	--	--	--	--	-170
Trench 3	-12.7	-20.7	-48.3	-9.90	-7.97	-53.4	-46.8	-25.3	-25.3	-25.3	-30.4	-51.8	-6.07	-107	-471
Trench 4	-58.7	-85.8	-64.9	-201	-100	-107	-88.5	-127	-79.1	-124	-6950	-1.27	-1.27	-27.8	-8,016
Trench 5	-28.4	-16.4	-144	-147	-90.8	-153	-150	-160	-122	-31.5	-50.1	-25.1	--	--	-1,119
Trench 7	0.81	--	--	--	--	--	--	--	--	--	--	--	--	--	1
Trench 8	-154	-205	-76.4	-83.7	-105	-187	-155	-197	-121	-117	-59.1	--	--	--	-1,460
Trench 9	-37.8	-170	-162	-63.1	-52.9	-72.3	-52.1	-110	-58.4	-48.7	-8.95	-34.2	--	--	-870
Trench 10	-86.6	-53.2	-116	-55.8	-135	-29.7	-550	-45.8	-519	-421	-285	-150	--	--	-2,448
Trench 11	-415	-47.4	-489	-308	-422	-126	-105	-147	-319	-266	-514	-8.54	--	--	-3,167
Trench 12	-418	-48	-497	-310	-430	-127	-103	-150	-322	-268	-523	-8.92	--	--	-3,205
Trench 13	-402	-161	-511	-378	-261	-397	-134	-283	-473	-360	-394	-214	-125	--	-4,093
Trench 14	-707	-385	-549	-392	-284	-495	-497	-378	-270	-242	-908	-1.87	-2.30	--	-5,111
Trench 6	SPH-01	SPH-02	SPH-03	SPH-04	SPH-05	SPH-06	SPH-07	SPH-08	SPH-09	SPH-10					
	-0.05	0.00	0.00	0.00	-0.17	-0.22	-0.17	-0.18	-0.18	-0.12					
	SPH-11	SPH-12	SPH-13	SPH-14	SPH-15	SPH-16	SPH-17	SPH-18	SPH-19						
	-0.16	-0.27	-0.25	0.00	0.00	0.00	0.00	-0.02	0.00						-2.0

Figure II-15: (URS, 2002) – (WVNS, 1995a) SDA Sr-90 January 1, 2000, Distribution

Between June 1976 and August 1979 leachate samples were collected from the SDA trenches and analyzed for chemical and radiological constituents, including Sr-90. The results of those analyses are presented in Prudic (1980), which concluded that the "concentrations of radioactive species were roughly the same in all trenches from which samples were collected, except that ^{90}Sr in trench 4 was at least 10 times higher than in the other trenches." Similar results were reported in RCRA Facility Investigation (RFI, E&E 1994b), Table J-1 for samples collected in June 1987 and 1989/1990. All of these Sr-90 trench leachate concentrations are shown in Figure II-16. This is another indicator that a large quantity of Sr-90 was buried in Trench 4, consistent with WVNS (1995a) but missing from URS (2000).

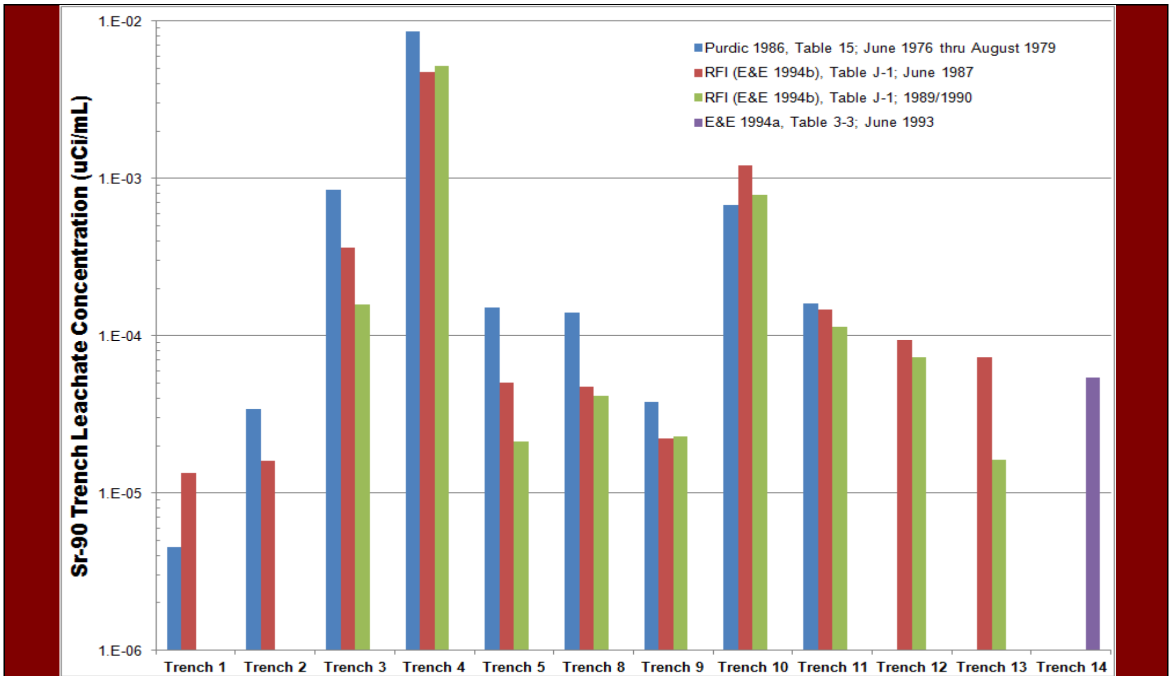

Figure II-16: Sr-90 Trench Leachate Concentration

Note: Prudic 1986, Table 15 did not report any Sr-90 concentrations for Trenches 12, 13, or 14, while RFI (E&E 1994b), Table J-1 did not report a 1987 Sr-90 concentration for Trench 14 or any 1989/1990 Sr-90 concentrations for Trenches 1, 2, or 14, and E&E 1994a only presented concentrations for Trench 14.

Figure II-15 also shows that the WVNS (1995a) Sr-90 activity in all of the other trench segments is greater than the URS (2002) estimated Sr-90 activity. The likely reason for this result is that for other SDA sources of Sr-90, Duckworth (1981) apportions the MFP activity between Sr-90 (45%), Cs-137 (45%), and Ru-103 (10%). Apportioning such a large percentage to Sr-90 does not seem to be consistent with what was observed by Kelleher and Michael (1973) (see page 10 above), or with nuclear power plant operations that would be generating the MFP waste. Specifically, the NRC published the volume of solid radioactive waste shipped by each licensed nuclear power plant in 1993, as well as the major radionuclides contained within the waste (NRC, 1995). Figure II-17 is a cumulative distribution plot of the NRC's 1993 data and shows that the 50th percentile Sr-90 to Cs-137 ratio in solid waste is about 0.01, or about two orders of magnitude less than the ratio used by Duckworth (1981).

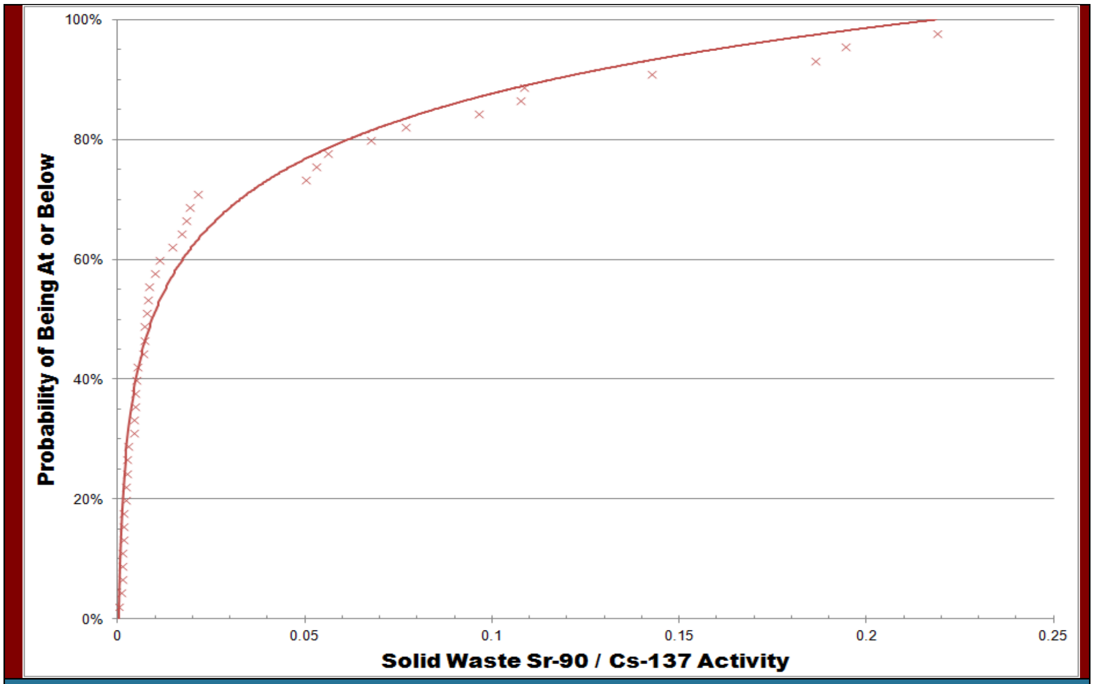

Figure II-17: Nuclear Power Plant Solid Waste Sr-90/Cs-137 Activity

Most SDA Sr-90 and Cs-137 would have been generated by nuclear power reactors. As stated elsewhere in this report, both WVNS (1995a) and URS (2002) use waste profiles to estimate the activities of radionuclides not explicitly identified on the waste shipment manifests, including Sr-90. Table II-20 presents the Sr-90 and Cs-137 concentrations assumed by WVNS (1995a) and URS (2002) for PWR and BWR power reactors. It shows that the URS (2002) and WVNS (1995a) BWR ratios are consistent with Figure II-17, but that the WVNS (1995a) PWR ratio is about a factor of 50 larger than the Figure II-17 50th percentile ratio. This large PWR Sr-90-to-Cs-137 ratio used by WVNS (1995a) is likely the reason why Figure II-15 shows the WVNS (1995a) Sr-90 values outside of Trench 4 to be consistently larger than the URS (2002) estimates.

Table II-20: SDA Sr-90/Cs-137 Concentration Ratios

Source Document	Nuclide	Power Reactor Concentration (Ci/m^3)	
		BWR	PWR
WVNS 1995a	Cs-137	0.18	0.32
	Sr-90	0.0014	0.13
URS 2002	Cs-137	0.530	0.142
	Sr-90	9.44E-04	1.25E-03
Concentration Ratio	**Source Document**	**Ratio**	
		BWR	**PWR**
Sr-90/Cs-137	WVNS 1995a	0.008	0.406
	URS 2002	0.002	0.009

5. Cesium-137 (and Barium-137m)

Because the activity of the Cs-137 short-lived daughter product, Ba-137m, is in equilibrium with the Cs-137 activity, the discussion presented in this section applies equally to the Ba-137m activity as it does to the Cs-137 activity, even though Ba-137m is not explicitly mentioned.

Table II-15 shows that the SDA Cs-137 activity estimates range from a low of 4,771 Ci from K&M,D,E to 14,600 Ci from URS (2002) to a high of 40,237 Ci from WVNS (1995a).

Figure II-18 is a trench segment comparison of the WVNS (1995a) and URS (2002) Cs-137 estimates. It shows that much of the WVNS (1995a) higher estimate is due to two Trench 4 segments that are each almost 2,800 Ci greater than the corresponding URS (2002) estimates. Figure II-18 further shows that, for many of the trench segments, the WVNS (1995a) Cs-137 estimates are consistently slightly larger than the URS (2002) estimates. Only in a handful of cases (mostly in Trench 4) are the URS (2002) Cs-137 estimates larger than the WVNS (1995a) estimates.

State Licensed Disposal Area (URS 2002) - (WVNS 1995) Cs-137 January 1, 2000 Distribution (Ci)

Distance (ft)

	0-49	50-99	100-149	150-199	200-249	250-299	300-349	350-399	400-449	450-499	500-549	550-599	600-649	650-699	Total
Trench 1	-40.8	-70.2	-46.7	-544	-642	--	-1.07	-289	--	--	--	--	--	--	-1,633
Trench 2	266	-195	-125	9.87	-284	-0.24	-876	--	--	--	--	--	--	--	-1,197
Trench 3	-102	27.1	-80.5	-115	-263	-739	-686	-75.1	-75.1	-75.1	-262	-335	-435	-215	-3,429
Trench 4	1,270	1,030	133	929	1,700	330	477	265	113	9.93	6.33	-2,880	-2,880	48.2	544
Trench 5	714	-21	-1,070	-222	-117	-209	-153	-30.5	-39.5	-44.4	-70.8	-32.5	--	--	-1,295
Trench 7	98.1	--	--	--	--	--	--	--	--	--	--	--	--	--	98
Trench 8	-99.6	-154	-86.1	-133	-129	-212	-169	-223	-99.6	-192	-27.8	--	--	--	-1,525
Trench 9	-3.52	4.48	-166	204	94	183	221	116	-51.8	180	-23.3	-41.2	--	--	717
Trench 10	-105	-94.1	-139	-60.5	-180	-52.1	-387	-76	-398	-305	-265	-114	--	--	-2,175
Trench 11	-330	40.8	-375	-260	-293	-99.8	-68	-111	-83.2	-197	-347	-9.52	--	--	-2,132
Trench 12	-316	-49.4	-393	-258	-311	-56.9	-60.2	-112	-230	-197	-357	-10	--	--	-2,350
Trench 13	-293	-116	-351	-266	-184	-289	-147	-168	-336	-283	-292	-137	-94.1	--	-2,957
Trench 14	-463	-284	-376	-207	-260	-363	-350	-278	-203	-193	-527	13.1	-7.42	--	-3,498
	SPH-01	SPH-02	SPH-03	SPH-04	SPH-05	SPH-06	SPH-07	SPH-08	SPH-09	SPH-10					
Trench 6	-136	-0.080	-0.045	-2.81	-442	-553	-417	-476	-476	-298					
	SPH-11	SPH-12	SPH-13	SPH-14	SPH-15	SPH-16	SPH-17	SPH-18	SPH-19						
	-391	-714	-646	-0.060	-0.020	-39.1	-39.1	-59.5	-39.1						-4,730

Figure II-18: (URS, 2002) – (WVNS, 1995a) SDA Cs-137 January 1, 2000, Distribution

K&M,D,E does not provide a trench segment breakdown of its activity estimates, so a comparison similar Figure II-18 cannot be made for its Cs-137 estimate.

WVNS (1995a) and URS (2002) both use waste profiles to estimate their inventories; Table II-21 shows and compares the Cs-137 profile used by each. Table II-21 indicates that many of the WVNS (1995a) and URS (2002) Cs-137 profiles are similar, with one major exception: the Fuel Cycle profile. Approximately 15% of the waste volume in the SDA originated in the onsite NFS reprocessing plant (WVNS 1995a, page 16), which is considered part of the Fuel Cycle. Therefore, the Fuel Cycle Cs-137 profile is likely responsible for the discrepancy between the WVNS (1995a) and URS (2002) Cs-137 activity estimates.

Table II-21: SDA Cs-137 Waste Profiles

Main Waste Category	Waste Subcategory	Cs-137 (Ci/m^3)		Ratio
		WVNS, 1995a	URS, 2002	
Fuel Cycle	Reprocessing	1	0.00168	595.2
Industrial	LSA Trash	0.00142	0.00152	0.93
	Biomedical	—	0.00361	—
Institutional	Bioresearch	0.00361	0.00361	1.0
	Medical	0.00481	0.00481	1.0
	Non-bioresearch	0.00545	0.00648	0.84
Isotope Production	Reactor Targets	3.73	1.54	2.4
	Reactor Trash	—	0.00027	—

Table II-21: SDA Cs-137 Waste Profiles

Main Waste Category	Waste Subcategory	Cs-137 (Ci/m^3)		Ratio
		WVNS, 1995a	URS, 2002	
Power Reactor	BWR	0.18	0.53	0.34
	PWR	0.41	0.142	2.89
	Internals	—	0.0106	—
	D&D	10	—	—
Special Purpose Reactor	D&D	10	9.35	1.07
	Naval	0.41	1.46	0.28
	Experimental	0.41	0.53	0.77
	Small Research	0.41	0.53	0.77
	Internals	—	0.0459	—

As described above for Sr-90, Duckworth (1981) apportions the MFP activity between Sr-90 (45%), Cs-137 (45%), and Ru-103 (10%). This likely overestimated the Duckworth (1981) Sr-90 activity and underestimated the Cs-137 activity.

6. Radium-226

The comparative Ra-226 activities are shown in Table II-15. Kelleher and Michael (1973, Table II) report a total of 5.6 Ci of Ra-226, with most of it being in Trenches 4, 8, and 11. Because Trenches 12, 13, and 14 were filled after 1973, any Ra-226 present in those three trenches is not included in the Kelleher and Michael (1973) estimate. Duckworth (1981, Table V) does not give a separate estimate for Ra-226 but rather gives a single value for Ra-226 and Am-241 of 500 Ci. Concerning Ra-226, Envirosphere (1986, page 2-15) states the following.

> *"It seems that Ra-226 is present in all trenches. The total Ra-226 activity disposed cannot be readily determined, since, in addition to sealed sources, radium needles, and foils, large amounts of bulk wastes (ores and contaminated soils) were also disposed in the trenches. For these types of waste shipments, the Ra-226 activity was typically not reported. It is estimated that there are at least six Curies of Ra-226 and at most 10 Curies."*

Thus, based on the information from Envirosphere (1986), a value of 10 Ci is shown for all SDA trenches for the "K&M,D,E" column of Table II-15.

Almost all (i.e., 87%) of the 0.9 Ci of Ra-226 estimated by WVNS (1995a) is located in Trench 14, Section 350. None of the waste profiles used by WVNS (1995a, Appendix A) include Ra-226. WVNS (1995a, page 5) describes the methodology used for estimating the Ra-226 activity:

> *"A unit-volume radionuclide inventory for the "Radium" secondary group (including Ra-226) was originally intended; however, published data regarding the characteristics of this waste stream were not found. As a result, all of the records that were originally assigned to the "Radium" secondary group were either re-assigned to another secondary group (…) or were characterized by the radium activity levels contained in the "Memo" field."*

URS (2002) indicates that most of its Ra-226 is found in Trench 4 (42%) and Trench 14 (14%), and the remainder spread between Trenches 8, 11, 12, and 13. This breakdown is consistent with both Kelleher and Michael (1973) and WVNS (1995).

7. Ruthenium-106 and Plutonium-238

Table II-15 shows that there is good agreement between the various inventory estimates for Pu-238. As for Ru-106, although Envirosphere (1986) reported 2,300 Ci disposed in the SDA, Ru-106 had decayed to zero in all three inventory estimates by January 1, 2000. Therefore, no additional comparisons will be undertaken for these two radionuclides.

III. Nuclear Regulatory Commission Licensed Disposal Area

The NDA was operated by NFS, under license from the Atomic Energy Commission (AEC; now NRC), for disposal of solid radioactive waste generated from onsite fuel reprocessing operations. Beginning in 1966, solid radioactive waste materials from the nearby Main Plant Process Building exceeding 200 milliroentgen per hour, and other materials for which disposal in the SDA was not permitted, were buried in holes and trenches in the NDA and backfilled with earth. For this study, the NDA is divisible into three distinct areas: (1) the NFS deep holes; (2) the NFS special holes; and (3) the WVDP disposal trenches. These areas are shown in Figure III-1.

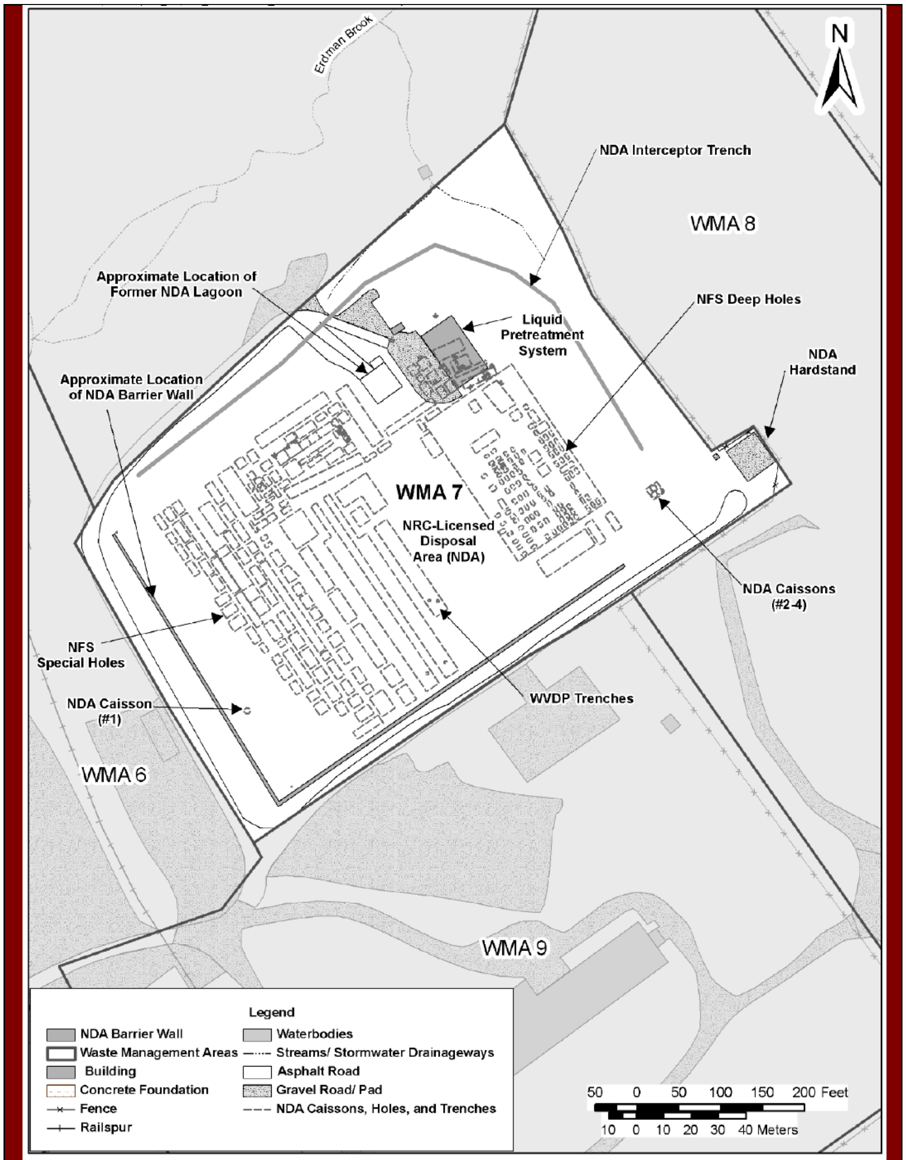

Figure III-1: WMA 7 — NRC-Licensed Disposal Area

Approximately 100 NFS deep holes are located in the eastern portion of the NDA, containing leached cladding from reprocessed fuel, also known as hulls. Many of these holes are 2.7 feet by 6.5 feet by 50 to 70 feet deep. Generally, the hulls are in 30-gallon steel drums and are stacked three abreast in deep narrow holes. Hole 48 contains three 30-gallon drums with irradiated, unreprocessed New Production Reactor (NPR) fuel with damaged cladding.

Approximately 230 NFS special holes are located in the northern and western portions of the NFS burial area. The special holes are typically about 20 feet deep but have various lengths and widths. Miscellaneous wastes, other than leached hulls or related spent fuel debris, are in several types of containers, including steel drums, wooden crates, and cardboard boxes.

Between 1982 and 1986, the WVDP disposed of waste resulting from decontamination activities in 12 trenches within the NDA.

A. Final Environmental Impact Statement Inventory Estimate

The rationale for producing the URS (2000) NDA waste inventory estimate is best described in its "Executive Summary":

> *The need for revision* [of the NDA waste inventory estimate] *came to light during the review period for the Draft Environmental Impact Statement for the Completion of the West Valley Demonstration Project and Closure or Long-Term Management of Facilities at the Western New York Nuclear Service Center (DOE* [& NYSERDA]*, 1996). The West Valley DEIS includes Table C-9, Projected Radionuclide Activities of Nuclear Fuel Services, Inc. and the West Valley Demonstration Project Wastes Buried in the NRC-Licensed Disposal Area on January 1, 2000, and indicates that the table was derived from Characterization Report for the NRC Licensed Disposal Area (WVNS, 1995*[b]*). The details of the derivation were not available. A preliminary review of the NDA characterization report revealed that documentation of its methods and assumptions was insufficient to allow inventory calculations to be repeated or verified.*

Table III-1 presents a summary of the NDA waste inventory estimate taken from URS (2000), Table 2-1. In Table III-1, the waste is divided into Category 1, or waste that consists of fuel assembly components, and Category 2, or other wastes generated from the on-site reprocessing plant, which is the only other waste disposed in the NDA. Under the Category 1 waste, Table III-1 lists the 26 reprocessing campaigns that were performed before the onsite plant was shut down.

Table III-1: URS, 2000, Table 2-1; Summary

Category 1 Waste	Volume	Activity (Ci)	
Campaign	(ft^3)	At Disposal	Jan. 1, 2000
1	92	1,312	17
2	120	1,916	24
3	245	35,712	681
4	726	292,568	9,456
5	902	1,766,147	37,419
6	229	31,644	872
7	148	31,068	856
8	285	50,419	1,389
9	345	47,665	1,394
10	463	67,911	1,987

Table III-1: URS, 2000, Table 2-1; Summary			
Category 1 Waste Campaign	Volume (ft^3)	Activity (Ci)	
		At Disposal	Jan. 1, 2000
11	184	506,995	13,447
12a	401	280,725	14,046
13	329	1,057,281	26,473
14b	277	0.06	0.06
15	249	116,984	4,586
16	305	657,405	18,360
17	276	451,326	12,959
18	285	15,095	589
19	196	365,332	12,431
20	280	365,422	11,839
21	156	18,952	600
22	133	35,312	1,017
23	269	464,572	19,522
24	140	507,448	14,571
25	184	18,463	1,252
26	363	66,649	3,366
Subtotal	7,582	7,254,322	209,154
Category 2 Waste	Volume (ft^3)	Activity (Ci)	
		At Disposal	Jan. 1, 2000
"Head End" Waste	12,913	13,975	743
"Waste Side" Waste	338,459	293,747	87,219
"Product Side" Waste	1,953	4,863	1,248
SDA Type Waste	17	3	0
Subtotal	353,342	312,589	89,210
Grand Total	**360,924**	**7,566,910**	**298,364**

Table III-1 identifies Category 2 wastes as being one of four waste types. Table III-2 shows the source of each Category 2 waste type, as well as its radionuclide profile.

Table III-2: Category 2 Waste Source and Radionuclide Profiles		
Waste Type	Source of Waste	Radionuclide Profile
"Head End"	Prior to the dissolvers	Spent fuel profile
"Waste Side"	After the extraction columns	Mostly fission products
"Product Side"	After the extraction columns	Mostly uranium and plutonium
SDA Type	Waste intended for the SDA but inadvertently buried in the NDA	See SDA waste profiles

In Table III-1, notice that, although Category 1 waste accounts for only about 2% of the NDA waste volume, it represents 70% of its activity (Jan. 1, 2000).

Figure III-2 shows the URS (2000) determined volume of NDA waste versus its disposal date. As shown, the NDA began operation in 1966 and ceased operation in 1986, at which time a total of 360,924 ft^3 of waste had been disposed in the NDA. Figure III-2 was developed using both data that are presented in URS (2000) and data included within the files that support URS (2000).

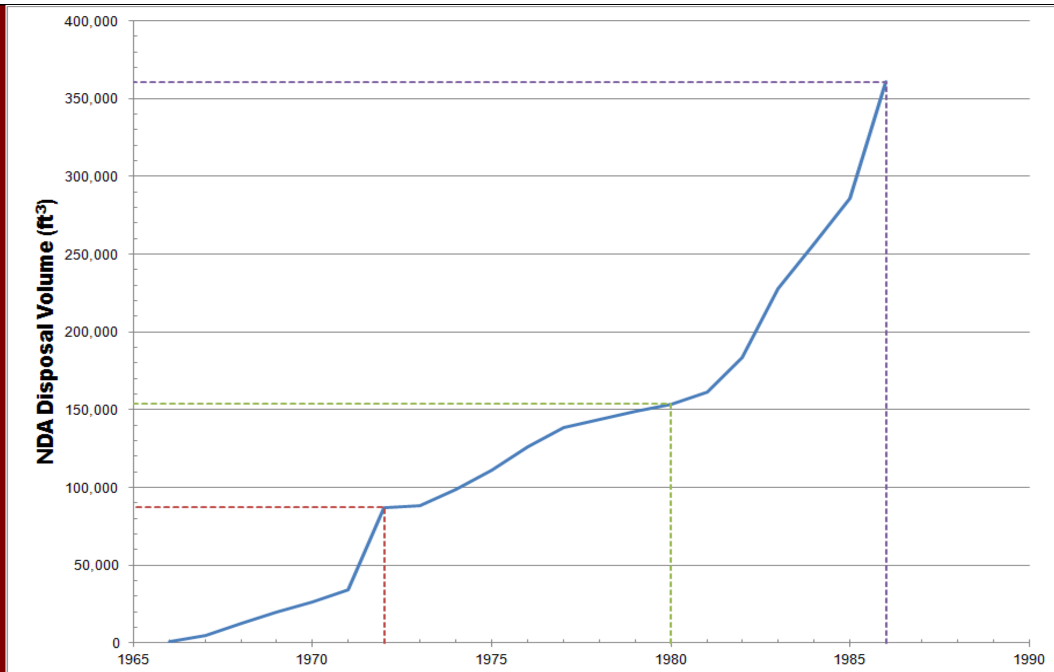

Figure III-2: URS, 2000; Waste Volume as a Function of Disposal Date

Table III-3 presents the January 1, 2000, activity estimates for those radionuclides that are major contributors to the total NDA activity.

Table III-3: URS, 2000; Major Radionuclides

Nuclide	Activity (1/1/2000) (Ci)	Percentage
Ni-63	116,407	39.1%
Cs-137	36,819	12.4%
Ba-137m	34,831	11.7%
Co-60	29,723	10.0%
Y-90	28,814	9.7%
Sr-90	28,806	9.7%
Pu-241	15,372	5.2%
Fe-55	1,823	0.61%
Am-241	1,783	0.60%
Ni-59	1,110	0.37%
Pu-239	579	0.19%
C-14	517	0.17%
Pu-240	399	0.13%
Pu-238	379	0.13%
H-3	64.9	0.02%
Nb-94	14.5	0.005%
Zr-93	13.2	0.004%
U-233	11.3	0.004%
Tc-99	10.2	0.003%

Three of the top major contributors are activation products: Ni-63, Co-60, and iron-55 (Fe-55). Two are fission products (and their daughters): Cs-137 (Ba-137m) and Sr-90 [yttrium-90 (Y-90)]. Two are transuranics: Pu-241 and Am-241. Beyond these radionuclides, each individual radionuclide's contribution is less than 0.5%.

Table III-4 reproduces the information on volume and activity by waste type from URS (2000), Table 5-5. In Table III-4, "Fuel" refers to the Deep Hole 48 irradiated, unreprocessed NPR fuel and "Hardware" refer to the remaining Category 1 waste, while all of the other Table III-4 waste types are Category 2.

Table III-4: URS, 2000, Table 2-2; NDA Plutonium Breakdown

Waste Type	Volume (ft^3)			Activity (Ci)		
	NFS	WVDP	Total	NFS	WVDP	Total
Fuel	12	0	12	12,316	0	12,316
Hardware	7,570	0	7,570	196,838	0	196,838
Ion Exchange	10,289	14,509	24,798	9,400	1,167	10,567
Degraded Solvent	3,995	0	3,995	3,210	0	3,210
Air Filters	10,783	111	10,894	1,975	0.07	1,975
Failed Equipment	16,877	9,878	26,755	24,987	15	25,002
Compacted Trash	261	1,404	1,665	855	0.1	855
Non-Compacted Trash	442	14,071	14,513	283	1.55	285
Soil	41,183	79,238	120,421	576	9.9	586
General Waste	23,015	51,912	74,927	7,191	10.1	7,201
Combination	42,287	1,458	43,745	39,511	0.183	39,511
Special	5,700	0	5,700	7.75	0	8
Debris	31	25,898	25,929	5.67	4.86	11
Total	**162,445**	**198,479**	**360,923**	**297,155**	**1,209**	**298,362**

Table III-5 is similar to Table III-4, except that it focuses on the plutonium that was disposed within the NDA. Table III-5 has been included because some of the comments received on the 2008 Revised DEIS [DOE/EIS-0226-D (Revised); DOE & NYSERDA, 2008] were focused on the plutonium inventory estimates.

Table III-5: URS, 2000, Table 2-2; NDA Pu-239 and Pu-240 Breakdown

Waste Type	Activity (Ci)		Mass (kg)	
	Pu-239	Pu-240	Pu-239	Pu-240
Fuel	73.7	39.6	1.2	0.17
Hardware	169	120	2.8	0.53
Ion Exchange	40.5	28.8	0.66	0.13
Degraded Solvent	11.1	7.9	0.18	0.035
Air Filters	6.56	4.66	0.11	0.021
Failed Equipment	86.7	61.6	1.4	0.27
Compacted Trash	27.7	19.7	0.45	0.087
Non-Compacted Trash	3.61	2.56	0.059	0.011
Dirt	1.97	1.4	0.032	0.0062
Combined	132	93.6	2.2	0.41
Special	0.0167	0.0119	0.00027	0.000052
General	26.3	18.7	0.43	0.082
Debris	0.0354	0.0252	0.00058	0.00011
Total	**579**	**399**	**9.5**	**1.8**

Figure III-3 shows the activity breakdown (January 1, 2000) within the 50 deep and special holes that have the largest estimated activities. Figure III-3 was developed using both data presented in URS (2000) and data included within the files that support URS (2000).

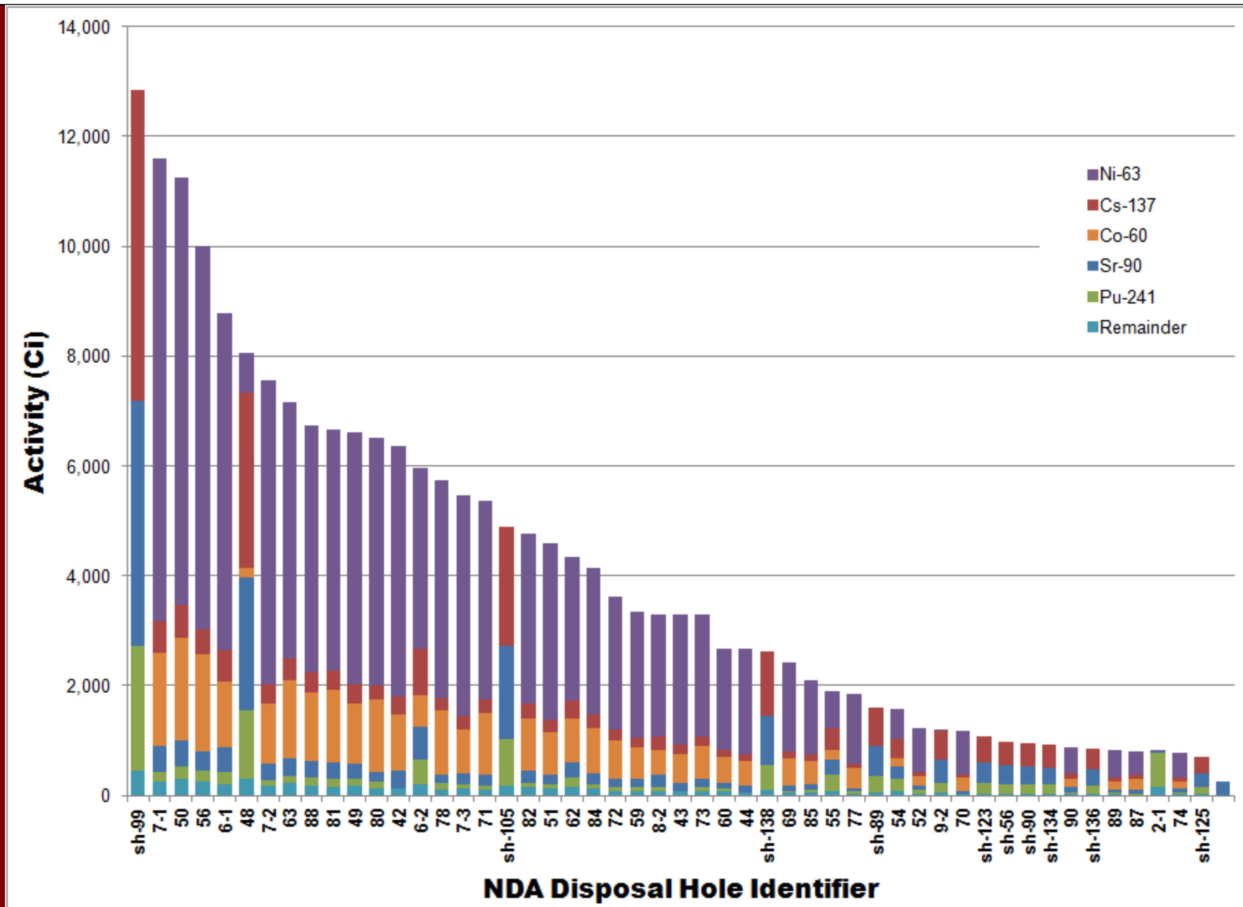

Figure III-3: URS, 2000; NDA Five Largest Radionuclide Distributions

Figure III-3 shows that most of the activity within the deep holes is due to Ni-63, except for Hole 48, which contains the irradiated, unreprocessed NPR fuel. Because Co-60 has a relatively short half-life, its contribution to the Figure III-3 activities will decrease quickly with time. For example, almost 16 years have passed since the date of the URS (2000) estimates, and the Co-60 activities have decreased to about 12% of the values shown in Figure III-3.

Special Hole sh-99 has the largest activity estimate, with Cs-137 being responsible for a substantial portion of that activity. Other special holes that have a sizable Cs-137 contribution include sh-105, sh-138, sh-89, and sh-123.

B. Historical Inventory Estimates

In this section, the following five previous estimates of the inventory of radionuclides disposed in the SDA are described:

1. Kelleher and Michael, 1973
2. Duckworth, 1981
3. Nicholson and Hurt, 1985
4. Ryan, 1992
5. WVNS, 1995b

In addition to these five NDA historical inventory estimates, the NDA inventory given in the 1996 DEIS, Table C-9 (DOE & NYSERDA, 1996), is included because (1) WVNS (1995b) is given as the source of the Table C-9 activities, and (2) comments received on the 1996 DEIS expressed concern with the Table C-9 activities, especially with the plutonium estimates.

A 1983 study by Science Applications, Inc. (SAI, 1983) and a 1992 study by the Pacific Northwest Laboratory (PNL, 1992) will be discussed. These two studies present information on the activity contained within the fuel as it was received at West Valley for reprocessing, and on the distribution of that activity after reprocessing. PNL (1992) is a series of ORIGEN2 model runs that calculate the radionuclide activity that was brought on site for each of the 27 onsite reprocessing campaigns. SAI (1983) is a compilation of the material balance sheets, which tracked uranium and plutonium that was brought on site, that left the site as product, that went to Tank 8D-2 or 8D-4, that went to the NDA with the hulls, and that was unmeasured losses. In combination, these two reports provide a good estimate of the activity that went into the NDA.

1. Kelleher and Michael, 1973

Kelleher and Michael (1973) was prepared for the NYSDEC Bureau of Radiological Control in response to a request from the EPA for an estimate of the inventory of radioactive materials buried in the West Valley site, including both the SDA and NDA. See Section II.B.1 for more details.

Regarding the NDA, Kelleher and Michael (1973) state that:

> *all of the activity buried in the Atomic Energy Commission's licensed burial area was identified by four main categories: 1) mixed fission products, 2) ^{95}Zr, 3) ^{60}Co, and 4) mixed nuclides. The mixed nuclides category is approximately 99 percent a mixture of ^{60}Co, ^{58}Co, and ^{95}Zr.*

Table III-6 presents a summary of the Kelleher and Michael (1973) estimate of the volume and activity of waste deposited within the NDA between 1966 and 1972.

Table III-6: Kelleher and Michael, 1973, Table III; Summary

Year	No. of Holes	Volume (ft^3)	NDA Activity (Ci)				
			MFP	Zr-95	Co-60	Mixed	Total
1972	44	51,965	49,502	—	684	—	50,186
1971	27	8,125	98,705	223,075	51,883	0.050	373,663
1970	21	6,767	31	—	71,340	—	71,371
1969	20	7,821	10	—	25,852	0.018	25,862
1968	17	7,146	25	46	2,598	—	2,669
1967	17	4,718	525	33	21,052	113	21,723
1966	5	1,236	24	2	0.109	508	534
Total	**151**	**87,778**	**148,822**	**223,156**	**173,409**	**621**	**546,008**

Kelleher and Michael (1973) also document that irradiated, unreprocessed NPR fuel with damaged cladding was disposed of in the NDA:

> *On April 23, 1969 several ruptured fuel elements were encased in concrete and buried at the 50' level in hole number 48. There was a total of 457,000 grams of SNM of which 3,330 grams were ^{235}U. Because these were low burnup fuel elements, there was only 819 grams of ^{239}Pu.*

2. Duckworth, 1981

In addition to providing an SDA inventory estimate, Duckworth (1981) provides an NDA inventory estimate that extends on the earlier estimate made by Kelleher and Michael (1973). Table III-7 presents a summary of the Duckworth (1981) NDA volume and total activity estimates.

Table III-7: Duckworth, 1981, Table II; Annual and Cumulative NDA Waste Inventory

Year	Annual		Cumulative	
	Volume (ft^3)	Activity (Ci)	Volume (ft^3)	Activity (Ci)
1966	1,240	644	1,240	644
1967	4,729	20,325	5,969	20,969
1968	7,148	2,705	13,117	23,674
1969	7,822	19,627	20,939	43,301
1970	6,779	53,013	27,718	96,314
1971	8,125	373,722	35,843	470,036
1972	51,965	51,841	87,808	521,877
1973	1,118	1,465	88,926	523,342
1974	10,160	1,054	99,086	524,396
1975	12,525	1,259	111,611	525,655
1976	15,133	1,149	126,744	526,804
1977	12,437	908	139,181	527,712
1978	5,047	668	144,228	528,380
1979	4,853	396	149,081	528,776
1980	4,976	295	154,057	529,071

A radionuclide breakdown of the Table III-7 Duckworth (1981) total activity estimate both at the time of disposal and remaining in 2000 is given in Table III-8.

Table III-8: Duckworth, 1981, Table V; NDA Major Radionuclides

Nuclide	Radioactivity (Ci)	
	Input	Remaining
Co-60	173,400	41,400
Cs-137	64,500	52,800
Sr-90	64,500	52,500
Ru-106	14,100	30
Misc.	600	80
Zr-95	211,000	—
U, Pu, & Th	300	300

Likewise, Table III-9 provides the Duckworth (1981) breakdown of the mass of SNM and SM that was estimated to be disposed within the NDA. The Table III-9 Fuel U-235 mass is for the fuel elements disposed of in Hole 48, and matches the values given above from Kelleher and Michael (1973), but that the Table III-9 fuel Pu-239/241 mass is smaller than the Pu-239 mass (819 grams) for Pu-239 given in the above quote from Kelleher and Michael (1973).

Table III-9: Duckworth, 1981, Table VI; NDA Special Nuclear Material and Source Material

Nuclide	Mass (kg)			
	Hulls	Fuel	Resins & Others	Total
Th	165	—	—	165
U-233	0.81	—	—	0.81
U-235	19.72	3.33	—	23.05
Total U	1,351	458	—	1,809
Pu-239/241	3.14	0.70	0.32	4.16
Total Pu	3.74	0.82	0.39	4.95

3. Nicholson and Hurt, 1985

In 1978, the NRC initiated a series of research projects to study the characteristics of the NDA, similar to the EPA's SDA project. One of the topics of study was the radioactive source term for the NDA. Nicholson and Hurt (1985) summarize the results of those studies, including the NDA radioactive source term, or waste inventory estimate.

Table III-10 reproduces the radionuclide-specific NDA activity estimate give in Nicholson and Hurt (1985), Table 5.

Table III-10: Nicholson and Hurt, 1985, Table 5; Major Radionuclides

Nuclide	Activity (Ci)
H-3	9,500
Co-60	64,000
Sr-90/Y-90	24,300
Cs-137/Ba-137m	24,400
Pu-241	13,300
Total	135,500

It's not clear from Nicholson and Hurt (1985) whether the values given for Sr-90/Y-90 and Cs-137/Ba-137m are the totals from both parent and daughter, or both parent and daughter are present at the activities given. Since Nicholson and Hurt (1985) only discuss Sr-90 and Cs-137, and make no mention of either Y-90 or Ba-137, it is assumed the latter is the case.

Regarding the distribution of the radionuclides within the NDA waste, Nicholson and Hurt (1985) state:

> *(1) the H-3 is bound to the hulls as a zirconium hydride, (2) the Co-60 is mostly contained in the stainless steel end fittings that are mainly distributed among the hull cans, and (3) the Sr-90, Cs-137, and Pu-241 are present mostly in bits of un-dissolved spent fuel in the leached hulls.*

The Nicholson and Hurt (1985) estimates of the amount of plutonium disposed with the leached hulls within the NDA are shown in Table III-11.

Table III-11: Nicholson and Hurt, 1985, Table 4; Leached Hulls Plutonium Radionuclides

Nuclide	Activity (Ci)			Mass (g)		
	NPR	LWR	Total	NPR	LWR	Total
Pu-238	10	284	294	0.6	17	17.6
Pu-239	69	102	171	1,132	1,664	2,796
Pu-240	27	135	162	120	598	718
Pu-241	942	13,550	14,492	9.4	135	144.4
Pu-242	–0	–0	–0	1.4	79	80.4
Total	**1,048**	**14,071**	**15,119**	**1,263**	**2,493**	**3,756**

As shown in Table III-11, Nicholson and Hurt (1985) differentiate between NPR hulls and light water reactor (LWR) hulls. They give SAI (1983) as a source for the values provided.

In addition to the leached hulls, plutonium could have entered the NDA with the NPR fuel and along with miscellaneous other plant wastes that were disposed there. Regarding these plutonium sources, Nicholson and Hurt (1985) state:

> *Considering all three constituents together—hulls, spent fuel, and miscellaneous—the information we have at present indicates that a conservative estimate of total long-lived plutonium inventory would be about 5.5 kg, with an uncertainty of about 2.0-2.5 kg.*

4. Ryan, 1992

Ryan (1992) was prepared by PNL with the intent that it "*provide data for use in the site closure Environmental Impact Statement*"(Bonner 1992). In arriving at his waste inventory estimates, Ryan (1992) used information from Kelleher and Michael (1973), Duckworth (1981), SAI (1983), and PNL (1992). In addition, for his non-fuel, hulls, or hardware inventory estimates, Ryan (1992) relied heavily on a DOE analysis of waste generation at a fuel storage basin connected with a generic reprocessing plant (DOE, 1979), with West Valley site adjustments. This approach differs from most of the other NDA estimates, which rely mainly on NDA disposal records.

Ryan (1992, page 42) provides the following summation of the NDA radionuclide inventory:

> [Table III-12] *summarizes the radionuclide content of the various categories of waste buried in the NDA at West Valley. The total fission product activity shown would, from decay considerations alone, be mostly Cs-^{137m}Ba and ^{90}Sr, but because of the nature of the way these wastes were produced they are biased somewhat more toward Cs-^{137m}Ba than the ratio in the fuel. The total actinide activity contains slightly more Pu than the fuel ratio. Even without this excess Pu the actinide activity would be due principally to ^{241}Pu. There is also some excess of ^{241}Am over the fuel ratio because of ^{241}Pu decay over more than 20 years.*
>
> *The total activity of all radionuclides in the NDA is estimated at 268,760 Ci as of 01-01-93. Only 2.1% of this is estimated to be in the wastes other than fuel, hulls, and hardware. About 4.4% of the total fission product activity and about 20% of the actinide activity in the wastes buried in the NDA are estimated to be in the waste categories other than fuel, hulls and hardware.*

It is estimated that 21% of the total Pu buried In the NDA is in the wastes other than fuel, hulls, and hardware.

Table III-12: Ryan, 1992, Table 2; Plutonium Radionuclides				
Waste Type	Activity (1/1/1993) (Ci)			Mass Total Pu (g)
	Fission Products	Actinides	Activation Products	
Fuel	8,443	2,260	0.74	913
Hulls	54,440	8,100	161,000	3,360
Hardware	0	0	30,000	0
Ion Exchangers and Sludges	946	557	12.6	297
Degraded Extractant	004	1,240	0	587
Filters	1,340	200	0	82
Failed and Discarded Equipment	254	248	0	116
Compactable Trash	175	26	0	10
Non-Compactable Trash	175	26	0	10
Dirt	15	0	0	0
Total	**65,790**	**11,659**	**191,310**	**5,375**

5. WVNS, 1995b (and DOE & NYSERDA, 1996)

The purpose of the WVNS (1995b) report was to provide physical, radiological, and chemical information about the NDA. It was intended that key data elements from WVNS (1995b) be used to support planning for the WVDP completion and closure and/or long-term management of the WNYNSC, i.e., preparation of the DEIS (DOE & NYSERDA, 1996).

In its summary, WVNS (1995b) states:

As of January 1, 1993, the total estimated activity of all waste placed in the NDA from all sources was approximately 679,000 curies; 54% is attributed to category 1 wastes (leached hulls and irradiated fuel components).

There is an estimated 344,800 cubic feet of waste buried in the NDA, 53% of which has been classified according to NRC criteria as Class A, less than 1% as Class B, 23% Class C, and the remaining 23% as Greater than Class C. The total volume of mixed wastes in the NDA is estimated at 17,250 ft^3.

While more than 100 radionuclides are included in this study, 99% of the estimated activity was from nine radionuclides: Cs-137, *Ba-137m, Co-60, Eu-154, Ni-63, Pu-238, Pu-241, Sr-90, and Y-90.*

WVNS (1995b) does not provide a radionuclide breakdown of its estimated activity; however, it does provide an estimated activity breakdown of the NFS burials by waste type, shown here in Table III-13.

Table III-13: WVNS, 1995b, Table 3.2; Summary of NFS Burials		
Waste Type	**Volume (ft^3)**	**Activity (Ci)**
Fuel	12	3,744
Hulls	6,250	294,362
Hardware	393	13,935
Ion Exchangers and Sludges	3,025	10,596
Degraded Extractant	380	40
Filters	11,860	84,636
Failed and Discarded Equipment	11,519	49,488
Compactable Trash	1,563	234
Non-Compactable Trash	497	236
Dirt	39,779	128
Combined	2,135	8,333
Special	5,700	93
General	17,338	207,469
Total	**100,451**	**673,294**

WVNS 1995b, Section 2.2.3 describes how the NDA activity estimates were made utilizing waste generator information from the NDA Database and waste profile information from PNL 1994. Unfortunately, this approach does not account for different waste volumes or different measured dose rate associated with individual waste records. As an indication of this problem, Table III-14 presents the Deep Hole 84 disposal characteristics as reported in WVNS (1995b), Appendix B.

Table III-14: WVNS, 1995b, Appendix B; Hole 84 Characterization				
Date	**Waste Category***	**Volume (ft^3)**	**Dose (rem/hr)**	**Activity (Ci)**
9/7/1971	general	58.8	0.35	1,095
9/7/1971	hull	4.01	3,880	1,095
9/7/1971	hull	4.01	3,880	1,095
9/7/1971	hull	4.01	3,880	1,095
9/2/1971	general	40.1	0.89	1,095
9/3/1971	general	22.05	0.35	1,095
9/3/1971	general	16.04	2.95	1,095
9/7/1971	general	4.01	5.90	1,095
9/7/1971	general	7.35	8.85	1,095
9/7/1971	general	12.5	5.90	1,095
9/9/1971	hull	4.01	3,880	1,095
9/9/1971	hull	4.01	3,880	1,095
9/9/1971	hull	4.01	3,880	1,095
9/10/1971	general	58.8	0.59	1,095
9/10/1971	hull	4.01	3,880	1,095
9/10/1971	hull	4.01	3,880	1,095
9/10/1971	ana general	4.01	11,800	1,095
9/13/1971	general	4.01	0.30	1,095
9/13/1971	general	7.35	0.30	1,095

Table III-14: WVNS, 1995b, Appendix B; Hole 84 Characterization				
Date	Waste Category*	Volume (ft^3)	Dose (rem/hr)	Activity (Ci)
9/13/1971	general	7.35	0.30	1,095
9/13/1971	pmc general	4.01	29.50	1,095
9/13/1971	pmc general	4.01	29.50	1,095
9/13/1971	pmc general	4.01	1,180	1,095
9/14/1971	pmc general	4.01	129.80	1,095
9/14/1971	pmc general	4.01	1,475	1,095
9/14/1971	pmc general	4.01	2,655	1,095
9/8/1971	general	22.05	1.18	1,095
9/8/1971	hev filter	29.75	147.50	488.37
9/15/1971	dog filter	12.5	106.20	367.13
9/20/1971	o2 general	7.35	0.15	1,095
9/20/1971	o2 general	7.35	0.15	1,095
9/20/1971	o2 general	7.35	0.15	1,095
9/20/1971	o2 general	7.35	0.18	1,095
9/20/1971	mrr general	14.7	0.30	1,095

* ana = analytical aisle; pmc = process mechanical cell; hev = head end ventilation; dog = dissolver off-gas; o2 = o2 building; mrr = manipulator repair room.

As Table III-14 shows, the eight hull entries are consistent with a volume of 4.01 ft^3 (30 gallons), a dose rate of 3,880 rem per hour (rem/hr), and an activity estimate of 1,095 Ci. Unfortunately, the 24 general waste entries had volumes ranging from 4.01 to 58.8 ft^3, and had doses ranging from 0.15 to 11,800 rem/hr, but all had an estimated activity of 1,095 Ci. There is no way to explain this data.

DOE & NYSERDA, 1996

Regarding the WVNS (1995b) NDA radionuclide inventory estimate, URS (2000, page 1-1) states:

> *This report included detailed information about waste disposed in the NDA by Nuclear Fuel Services, Inc. (NFS) and summary information about wastes disposed in the NDA by the West Valley Demonstration Project (WVDP). The report was based on two databases that included records of NFS waste disposal but did not incorporate WVDP burial records.*
>
> *Following publication of the West Valley DEIS, it was found that the link between Characterization Report for the NRC Licensed Disposal Area, WVDP-EIS-021 (WVNS, 1995*[b]*) and the NDA radionuclide inventory shown in Table C-9, Volume 2 of the DEIS (DOE* [& NYSERDA]*, 1996) was not well-documented.*

A portion of DOE and NYSERDA (1996), Table C-9, has been reproduced as Table III-15. The 1996 DEIS (DOE & NYSERDA, 1996), Table C-9, attributes the reported radionuclide breakdown to WVNS (1995b). However, as stated above, WVNS (1995b) does not present the activities associated with specific radionuclides. As a result, the true source of the data presented in Table III-14 is uncertain.

Table III-15: DOE & NYSERDA 1996, Table C-9; Activation and Fission Product Breakdown

Waste Type	NDA Activity (1/1/2000) (Ci)			
	Cs-137	Co-60	Sr-90	Pu-241
Fuel	8,000	3	600	300
Hardware	20,000	30,000	10,000	6,000
Ion Exchangers and Sludges	1,000	2	900	4,000
Degraded Extractant	1	0	1	20
Filters	4,000	7	4,000	4,000
Failed and Discarded Equipment	9,000	20	8,000	5,000
Compactable Trash	40	0	40	20
Non-Compactable Trash	40	0	40	20
Dirt	20	0	20	10
Combined	2,000	3	2,000	700
Special	20	0	20	8
General	3,000	5	3,000	1,000
Total	**47,100**	**30,000**	**28,600**	**21,100**

Table III-16 attempts to compare the radionuclide-specific information from WVNS (1995b) to the DOE and NYSERDA (1996), Table C-9, data.

Table III-16: WVNS (1995b) and DOE & NYSERDA (1996) NDA Activity Comparison

Nuclide	NDA Activity (Ci)		
	WVNS, 1995b	DOE, 1996*	
	1/1/1993	1/1/1993	1/1/2000
Cs-137	672,210	55,251	47,000
Ba-137m		52,267	44,500
Co-60		75,317	30,000
Eu-154		347	200
Ni-63		—	—
Pu-238		7,500	7,500
Pu-241		29,414	21,000
Sr-90		34,258	29,000
Y-90		34,258	29,000
H-3	6,790	14,812	10,000
Others		19,800	19,800
Total	**679,000**	**323,000**	**238,000**

* DOE & NYSERDA (1996) did not provide Ba-137m or Y-90 activity estimates. The estimates shown were calculated for this study by assuming equilibrium with their parent radionuclides: Cs-137 and Sr-90.

Several observations bring into question the premise that the DOE and NYSERDA (1996) values are attributed to the WVNS (1995b) radionuclide values. First, as stated above, other than to indicate that nine radionuclides were responsible for 90% of the total NDA activity, WVNS (1995b) does not provide any radionuclide-specific activity estimates. Second, WVNS (1995b) identifies Ba-137m, Y-90, Eu-154, and Ni-63 as four of the nine significant radionuclides. However, DOE and NYSERDA (1996) estimate that Eu-154 contributes only 0.1% to the NDA's total activity and provides no NDA activity estimates for Ba-137m, Y-90, or Ni-63.[1] Third, the DOE and NYSERDA (1996) H-3 and "Others" activities are about five times larger than the corresponding WVNS (1995b) estimate. Finally, even when the DOE and NYSERDA (1996) activity is decay corrected back to January 1, 1993, to be consistent with WVNS (1995b), the DOE and NYSERDA (1996) estimate is less than half of the WVNS (1995b) estimate.

Because the comments received on DOE and NYSERDA (1996) focused on plutonium, Table III-17 summarizes the DOE and NYSERDA (1996), Table C-9, plutonium data. The activities presented in Table III-17 are from the DEIS (DOE & NYSERDA, 1996), Table C-9, while the masses were calculated for this study.

Table III-17: DOE & NYSERDA. 1996; NDA Pu-239 and Pu-240 Breakdown

Waste Type	Activity (Ci)		Mass (kg)	
	Pu-239	Pu-240	Pu-239	Pu-240
Fuel	10	8	0.16	0.035
Hardware	300	200	4.9	0.88
Ion Exchangers and Sludges	100	100	1.6	0.44
Degraded Extractant	0.9	0.7	0.015	0.0031
Filters	2,000	1,000	33	4.4
Failed and Discarded Equipment	200	200	3.3	0.88
Compactable Trash	0.7	0.6	0.011	0.0026
Non-Compactable Trash	0.7	0.5	0.011	0.0022
Dirt	0.4	0.3	0.0065	0.0013
Combined	30	20	0.49	0.088
Special	0.3	0.2	0.0049	0.00088
General	50	40	0.82	0.18
Total	**2,690**	**1,570**	**44**	**6.9**

6. SAI, 1983 and PNL, 1992

The AEC (now NRC) required that NFS keep close track of the uranium and plutonium that flowed through the West Valley reprocessing plant. NFS initiated standard operating procedures to meet the AEC requirements. One of the standard operating procedure requirements was for NFS to develop nuclear materials management reports for each campaign that documented the quantity of uranium and plutonium shipped to the site (input), the quantity shipped from the site (product), the amount transferred as

[1] Of course whenever Sr-90 and/or Cs-137 are present Y-90 and/or Ba-137m will also be present.

liquid waste to Tanks 8D-2 or 8D-4, the amount transferred to the NDA with the hulls, the ending inventory, and any material unaccounted for (MUF).

SAI (1983) consolidates the information from all of the NFS nuclear materials management reports, which has been reproduced in Table III-18.

Table III-18: SAI, 1983; Uranium and Plutonium Material Balance

Cam-	Input		Product		Liquid Waste		Hulls		Ending Inventory		MUF	
paign	U (kg)	Pu (g)	U (kg)	Pu (g)	U (kg)	Pu (g)	U (kg)	Pu (g)	U (kg)	Pu (g)	U (kg)	Pu (g)
1	19,716	1,739	19,252	1,199	36	28	52	3	246	194	130	315
2	28,814	2,297	28,714	2,455	24	24	14	1	149	129	159	-118
3	46,681	50,881	46,322	50,235	136	191	108	118	8	356	256	110
4	50,017	191,016	49,567	182,269	200	5,465	56	183	8	3,082	194	373
5	49,759	285,067	49,448	278,616	316	3,763	50	285	16	1,464	-63	4,021
6	26,618	52,625	26,052	50,438	193	1,717	27	52	239	2,414	123	-532
7	26,116	47,376	26,031	46,898	65	505	46	83	73	1,977	140	327
8	42,396	75,441	42,221	76,952	204	1,123	121	216	133	455	-210	-1,328
9	38,837	79,116	38,440	78,039	143	799	118	240	236	1,072	33	-579
10	55,330	115,692	53,991	114,387	315	2,564	268	561	113	406	879	-1,154
11	1,049	2,698	1,039	237	8	1,832	11	21	97	383	7	631
12	48,882	102,526	48,475	98,564	55	2,325	63	132	361	389	25	1,499
13	19,571	176,039	19,251	171,627	78	1,013	40	346	367	983	196	2,459
14	30,295	0	30,022	0	82	1,198	7	0	374	983	177	-1,198
15	21,544	104,640	21,392	102,260	31	509	28	136	396	976	71	1,742
16	15,563	107,579	15,346	104,249	99	1,405	23	161	393	1,574	98	1,166
17	9,280	95,599	9,184	91,478	46	1,244	25	250	399	3,121	19	1,080
18	9,591	7,053	9,599	7,036	46	757	14	11	380	2,173	-49	197
18A	0	0	0	0	58	735	0	0	396	2,217	-74	-779
19	18,410	72,792	18,267	72,741	112	443	28	109	363	1,604	36	112
20	7,575	68,082	7,500	62,982	35	559	3	26	367	1,876	33	4,243
21	15,841	25,442	15,472	25,551	22	789	159	269	471	2,509	84	-1,800
22	4,140	4,939	4,255	6,459	16	259	4	5	385	1,845	-49	-1,120
23	20,796	87,167	20,637	85,951	31	579	41	172	503	1,595	-31	715
24	9,472	95,744	9,404	91,032	54	1,378	30	303	482	3,623	5	1,003
25	3,517	11,616	3,311	11,770	30	458	5	18	479	2,068	174	925
26	5,815	27,894	5,945	28,388	57	521	9	42	367	980	-84	31
27	9,929	95,463	3,267	95,241	46	996	0	0	6,185	711	798	-505
27A	0	0	0		55	1,646	0	0	6,185	711	-55	-1,646

The MUF is calculated by: (Input) – (Product + Liquid Waste + Hulls + Ending Inventory) (AEC 1940, page 64) As Table III-18 shows, the "MUF" column is negative for some campaigns. This indicates that for that campaign more material was generated as Product, Liquid Waste, and Hulls than was provided as Input. The additional material was obtained from the previous campaign's Ending Inventory. Although not shown in Table III-18, the running total of the "MUF" column is always positive.

For this study, the "Hulls", "Ending Inventory", and "MUF" columns are of most interest. The "Hulls" column shows that about 0.2% of the uranium and plutonium that entered the site remained with the hulls, and thus was disposed in the NDA deep holes. Several of the NDA inventory estimates have made use of this fact, including URS (2000) and Ryan (1992).

The “Ending Inventory” and “MUF” columns can be used to place an upper limit on the non-hull activity that was sent to the NDA. However, a portion of the “Ending Inventory” and “MUF” mass likely remained within cells of the Main Plant Process Building, e.g., the General Purpose Cell, the Process Mechanical Cell, the Chemical Process Cell (CPC), the Extraction Cells (XC1, XC2, XC3), etc.

PNL (1992; included in WVNS, 1992, as Attachment A) provides the physical and radionuclide characterization of the reactor fuel that was reprocessed at West Valley. This fuel characterization provided the basis for determining the source term associated with the spent fuel hulls, the fuel assembly structural materials, and the fuel material that was retained with the spent fuel hulls following reprocessing placed in the NDA.

PNL (1992) used ORIGEN2 to calculate the activation product, fission product, and transuranic nuclide activities in each of the 26 West Valley spent fuel reprocessing campaigns. The ORIGEN computer code was written in the late 1960s and released in 1973 by the Oak Ridge National Laboratory (ORNL) for calculating the buildup and decay of nuclides in nuclear materials. A revision, ORIGEN2, was released in 1980. ORIGEN2 is widely used throughout the world for predicting the characteristics of spent reactor fuel and high-level waste (HLW). Because of similarities between some of the campaigns, only 22 ORIGEN2 runs were needed to characterize all 26 campaigns. The ORIGEN2 results for Campaigns 9, 10, and 12[2] are summarized in Table III-19. (Note that the 27th West Valley reprocessing campaign was of Southwest Experimental Fast Oxide Reactor plutonium nitrate solution, rather than spent fuel.)

Table III-19: PNL, 1992; ORIGEN2 Results for Campaigns 9, 10, & 12

Nuclide	Activity (Ci) – 2/13/1969	
	All	42 Assemblies
Activation Products		
Mn-54	4.88E+02	2.40E+00
Fe-55	8.66E+03	4.26E+01
Fe-59	2.52E+00	1.24E-02
Co-58	6.97E+01	3.43E-01
Co-60	2.51E+03	1.23E+01
Ni-59	7.27E-01	3.58E-03
Ni-63	9.04E+01	4.45E-01
Zn-65	4.82E-02	2.37E-04
Fission Products		
H-3	6.46E+03	3.18E+01
Sr-90	1.02E+06	5.00E+03
Tc-99	1.80E+02	8.84E-01
I-129	3.89E-01	1.91E-03
Cs-137	1.28E+06	6.29E+03

[2] Because they were all Mark I design from the N-Reactor with similar enrichments and burnups, PNL (1992) modeled the Campaigns 9, 10, and 12 fuels in a single ORIGEN2 run.

Eu-154	2.33E+04	1.15E+02
Transuranics		
Pu-238	4.82E+03	2.37E+01
Pu-239	1.50E+04	7.38E+01
Pu-240	8.06E+03	3.97E+01
Pu-241	1.08E+06	5.29E+03

As stated previously, irradiated, unreprocessed NPR fuel was disposed in the NDA in Deep Hole 48. That fuel was from Campaign 12, and Table III-19 shows the activity associated with the 42 disposed assemblies. PNL (1992), Table 3, documents that there were 2,318, 3,302, and 2,917 assemblies in Campaigns 9, 10, and 12, respectively, or 8,537 total assemblies. The Hole 48 fuel activity is calculated as the total activity for Campaigns 9, 10, and 12, multiplied by the ratio of 42 over 8,537.

Table III-20 combines the results from PNL (1992) with SAI (1983) to arrive at an estimate of the activity in the NDA deep holes [also called Category 1 waste by WVNS (1995b) and URS (2000)]. In Table III-20, the fuel activity is from Table III-19, the hardware activity is the sum of the PNL (1992) results, and the hulls activity is the sum of the PNL (1992) results times 0.2% carryover, as documented in SAI (1983).

Table III-20: PNL, 1992, and SAI, 1983; NDA Deep Hole Activity

Nuclide	Activity (Ci) – As Deposited			Activity (Ci) – 1/1/2000		
	Fuel	Hulls	Hardware	Fuel	Hulls	Hardware
Activation Products*						
Mn-54	2.40E+00	2.31E+05	2.76E+04	3.27E-11	5.66E-06	1.08E-06
Fe-55	4.26E+01	3.83E+06	5.12E+05	1.54E-02	1.52E+03	2.42E+02
Fe-59	1.24E-02	1.18E+01	7.66E-01	6.98E-79	1.09E-71	1.59E-71
Co-58	3.43E-01	1.55E+03	2.65E+02	3.79E-49	8.82E-43	2.79E-43
Co-60	1.23E+01	1.35E+06	2.34E+05	2.12E-01	2.48E+04	4.55E+03
Ni-59	3.58E-03	9.41E+02	1.67E+02	3.58E-03	9.41E+02	1.67E+02
Ni-63	4.45E-01	1.22E+05	2.13E+04	3.56E-01	9.80E+04	1.72E+04
Zn-65	2.37E-04	6.49E-01	9.88E-02	2.84E-18	5.34E-14	4.98E-15
Fission Products*						
H-3	3.18E+01	1.12E+02	2.09E-03	5.62E+00	2.00E+01	3.81E-04
Sr-90	5.00E+03	1.95E+04	1.31E-02	2.40E+03	9.41E+03	6.28E-03
Tc-99	8.84E-01	3.41E+00	4.98E-04	8.84E-01	3.41E+00	4.98E-04
I-129	1.91E-03	7.13E-03	1.03E-14	1.91E-03	7.13E-03	1.03E-14
Cs-137	6.29E+03	2.40E+04	0.00E+00	3.08E+03	1.18E+04	0.00E+00
Eu-154	1.15E+02	7.62E+02	0.00E+00	1.01E+01	6.95E+01	0.00E+00
Transuranics						
Pu-238	2.37E+01	1.51E+02	0.00E+00	1.86E+01	1.19E+02	0.00E+00
Pu-239	7.38E+01	1.69E+02	0.00E+00	7.37E+01	1.69E+02	0.00E+00
Pu-240	3.97E+01	1.21E+02	0.00E+00	3.95E+01	1.20E+02	0.00E+00
Pu-241	5.29E+03	1.95E+04	0.00E+00	1.20E+03	4.45E+03	0.00E+00
	Mass (kg) - As Deposited			Mass (kg) - 1/1/2000		
Pu-238	1.39E-03	8.84E-03	0.00E+00	1.09E-03	6.95E-03	0.00E+00
Pu-239	1.19E+00	2.73E+00	0.00E+00	1.19E+00	2.73E+00	0.00E+00
Pu-240	1.74E-01	5.30E-01	0.00E+00	1.74E-01	5.28E-01	0.00E+00
Pu-241	5.14E-02	1.90E-01	0.00E+00	1.16E-02	4.32E-02	0.00E+00

* Some radionuclides are both an activation product and a fission product; ORIGEN2 accounts for this. When this occurs in this table, the radionuclide is shown were it is most prevalent.

C. NDA Volume Estimate Comparisons

In addition to URS (2000), four of the historic inventories provided estimates of the volume of waste disposed of in the NDA. Unfortunately, the NDA volume estimates are at three different dates in the operation of the NDA, so it is not possible to directly compare them. For purposes of this study, estimates of the waste disposal volumes at each of the three dates were derived from the URS (2000) support files. Table III-21 shows the various NDA disposal volume estimates and compares them to the URS (2000) volume estimate.

Table III-21: NDA Estimated Disposal Volume

Date	Disposal Volume Source	Disposal Volume (ft^3)	URS, 2000 Volume (ft^3)
1972	Kelleher & Michael, 1973	87,778	87,207
1980	Nicholson & Hurt, 1985	151,853	153,658
	Duckworth, 1981	154,057	
1986	WVNS, 1995b	344,800	360,924

Table III-21 shows that URS (2000) is in good agreement with the four other estimates of NDA waste volume.

D. NDA Activity Estimate Comparisons

Table III-22 presents a summary of the various NDA inventory activity estimates. The left side of Table III-22 presents the activities as they were provided by each source, while on the right side the activities have all been decay adjusted to a common date for easier comparison. As was the case for the SDA, in Table III-22, Duckworth (1981) should be considered as a surrogate for Kelleher and Michael (1973). WVNS (1995b) is absent from Table III-22 because it does not provide a radionuclide breakdown of its activity estimate, as previously discussed.

Table III-22: Summary NDA Waste Activity Comparison

Nuclide	NDA Activity Estimate (Ci)							
	Duckworth, 1981	Nicholson & Hurt, 1985	DOE & NYSERDA, 1996	URS, 2000 (NFS only)	Common Date: 1/1/2000			
	As Disposed	1/1/1985	1/1/2000	1/1/2000	Duckworth, 1981	Nicholson & Hurt, 1985	DOE & NYSERDA, 1996	URS, 2000 (NFS only)
H-3	—	9,500	10,001	64	—	4,094	10,001	64
C-14	—	—	1,200	517	—	—	1,200	517
Co-60	173,400	64,000	30,040	29,700	3,403	8,903	30,040	29,700
Ni-63	—	—	—	116,000	—	—	—	116,000
Sr-90	64,500	24,300	28,621	28,600	33,400	17,004	28,621	28,600
Zr-95	211,000	—	—	--	0	—	—	--
Ru-106	14,100	—	—	0.00	0	—	—	0.00
Cs-137	64,500	24,400	47,121	36,500	34,039	17,253	47,121	36,500
Pu-241	—	13,300	21,078	15,200	—	6,461	21,078	15,200

Table III-22: Summary NDA Waste Activity Comparison

Nuclide	NDA Activity Estimate (Ci)							
	Duckworth, 1981	Nicholson & Hurt, 1985	DOE & NYSERDA, 1996	URS, 2000 (NFS only)	Common Date: 1/1/2000			
	As Disposed	1/1/1985	1/1/2000	1/1/2000	Duckworth, 1981	Nicholson & Hurt, 1985	DOE & NYSERDA, 1996	URS, 2000 (NFS only)
Th-232	300	—	0.00	0.01	300	—	0.00	0.01
Pu-238		—	2,693	575		—	2,693	575
U-238		—	4.7	1.5		—	4.7	1.5
Misc.	600	—	11,241	6,842	600	—	11,241	6,842
Total	**528,400**	**135,500**	**152,000**	**234,000**	**71,700**	**53,700**	**152,000**	**234,000**

The activation products, Co-60 and Ni-63, show the largest variation between the various NDA activity estimates. Both activation products in general, and Co-60 specifically, are discussed in more detail below.

Because neither Kelleher and Michael (1973) nor Ryan (1992) provide NDA activity estimates on a per radionuclide basis, Table III-23 compares the estimates for the three types of radionuclides from these two documents— activation products, fission products, and actinides—to the estimates from the four Table III-22 documents.

Table III-23: Summary NDA Nuclide Type Activity Comparison

Nuclide Type	NDA Activity Estimate (Ci)					
	Kelleher & Michael, 1973	Duckworth, 1981	Nicholson & Hurt, 1985	Ryan, 1993	DOE & NYSERDA, 1996	URS, 2000
Activation Products	396,565	384,400	64,000	191,310	31,241	146,217
Fission Products*	149,443	143,100	58,200	65,790	85,742	65,665
Actinides	—	300	13,300	11,659	28,612	15,980
Total	**546,000**	**528,400**	**136,000**	**268,800**	**152,000**	**235,000**

* Does not include Ba-137m or Y-90.

Because the three types are composed of multiple radionuclides, it is not possible to decay correct the Table III-23 activity estimates to a common date. Therefore, it is difficult to draw any conclusions.

In the following sections, more detailed comparisons of the NDA activity estimates are presented, including Deep Hole 84, Hole 48, spent fuel, plutonium, Co-60, and activation products. The PNL (1992) ORIGEN2-calculated spent fuel activities are included in those comparisons, as well as the various NDA activity estimates. Table III-22 shows that the Sr-90 and Cs-137 activity estimates range over factors of 2.0 and 2.7, respectively. While not ideal, these ranges are not as significantly different as the items that are discussed below.

1. Deep Hole 84

For each NDA disposal hole, WVNS (1995b), Appendix B, provides information for each individual burial record, including date of burial, volume (ft^3), container type (e.g., steel drum, wooden box), the waste category, the estimated activity (Ci), and the estimated dose (roentgen per hour), plus a comment. Each NDA disposal hole contains a number of individual disposal records; e.g., Hole 84 contains 34 individual burials occurring over 10 days, see Table III-14 (page 43). Although not included in URS (2000), similar (but not as extensive) data have been included as part of the URS (2000) support files, including disposal dates, number of disposal records, volume (ft^3), and activity (Ci).

These two data sources can be used to perform a hole-by-hole comparison between URS (2000) and WVNS (1995b), as was done for Hole 84. Table III-24 shows the results of the Hole 84 comparison. There is quite a bit of agreement, e.g., the disposal dates, the number of records, and the volume of waste (as expected based on the Section III.C comparisons).

Table III-24: NDA Hole 84 Comparison – WVNS, 1995b, to URS, 2000

Disposal Date	Records		Volume (ft^3)		Estimated Activity (Ci)			
	WVNS, 1995b	URS, 2000	WVNS, 1995b	URS, 2000	WVNS, 1995b	URS, 2000		
						At Disposal	1/1/1993	1/1/2000
9/2/1971	1	1	40.1	40.1	1,095.0	6.8	3.8	3.3
9/3/1971	2	2	38.09	38.09	2,190.0	10.0	5.6	4.8
9/7/1971	7	7	94.69	94.69	7,665.0	8,627.9	1,325.7	1,005.7
9/8/1971	2	2	51.8	51.8	1,583.4	71.7	18.9	15.3
9/9/1971	3	3	12.03	12.03	3,285.0	14,071.1	2,147.9	1,627.3
9/10/1971	4	4	70.83	70.83	4,380.0	14,852.4	2,269.6	1,719.8
9/13/1971	6	6	30.74	30.74	6,570.0	324.0	50.8	38.7
9/14/1971	3	3	12.03	12.03	3,285.0	1,116.8	173.0	131.3
9/15/1971	1	1	12.5	12.5	367.1	106.1	59.6	50.9
9/20/1971	5	5	44.1	44.1	5,475.0	1.1	0.6	0.5
Total	**34**	**34**	**406.91**	**406.91**	**35,895.5**	**39,188.0**	**6,055.4**	**4,597.7**

At first glance, it appears that the WVNS (1995b) and URS (2000) activity estimates for Hole 84 are within about 10% of each other (i.e., 35,900 Ci versus 39,200 Ci). However, when one looks at the daily breakdown of the activity, it is seen that there is not much agreement between the two estimates, as Figure III-4 illustrates.

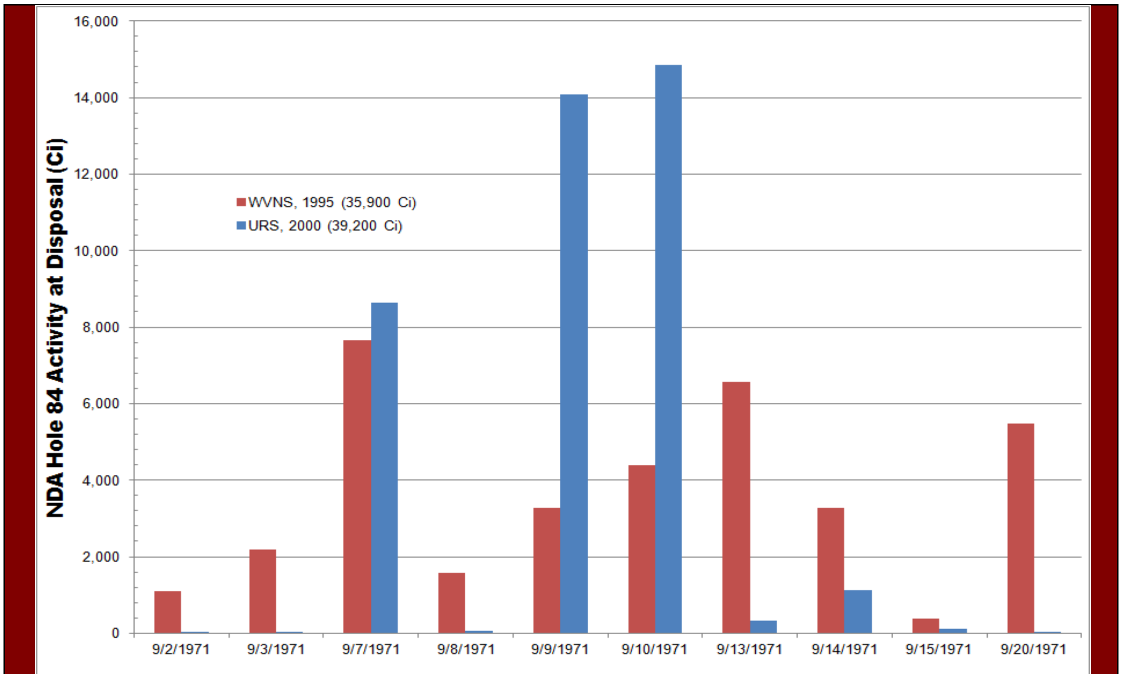

Figure III-4: NDA Hole 84 WVNS (1995b) to URS (2000) Activity at Disposal Comparison

WVNS (1995b), Appendix B, indicates that hulls were disposed on September 7, 9, and 10, 1971. Hulls are expected to be the most highly radioactive waste disposed in the NDA, other than the spent fuel in Hole 48. Figure III-4 shows that URS (2000) agrees with both of these points, with activity "spikes" on September 7, 9, and 10, 1971. For WVNS (1995b), Figure III-4 shows an activity "spike" on September 7, but not so much on September 9 or 10. In fact, WVNS (1995b) shows more activity on September 20, 1971, when general waste from the O2 Building and the Manipulator Repair Room (both expected to be low-activity areas) was buried, than for the hulls on September 9 or 10, 1971.

Granted, this is only one, randomly selected disposal hole out of the 102 deep holes and 133 special holes that are in the NDA, but the fact that this one example demonstrates little correlation between the waste being disposed and the associated activity estimate leads one to question the WVNS (1995b) overall results. On the other hand, Figure III-4 shows that the URS (2000) Hole 84 activity estimate is consistent with what is expected; i.e., most activity is from hull disposal.

2. Hole 48 — Spent Fuel

As described previously, on April 29, 1969, 42 assemblies of irradiated, unreprocessed NPR fuel with damaged cladding were disposed in three 30-gallon drums in NDA Hole 48. This NPR fuel was part of Campaign 12 and has been characterized by PNL (1992); see Table III-19. As Table III-25 shows, DOE and NYSERDA (1996) and URS (2000) also provide a radionuclide breakdown of the Hole 48 deposited spent fuel.

Table III-25: Hole 48 Deposited Fuel Activity

Nuclide	PNL, 1992	DOE & NYSERDA, 1996	URS, 2000
Activation Products			
Mn-54	3.27E-11	—	3.33E-11
Fe-55	1.54E-02	—	1.54E-02
Co-60	2.13E-01	3.00E+00	2.13E-01
Ni-59	3.58E-03	—	3.58E-03
Ni-63	3.56E-01	—	3.59E-01
Zn-65	2.84E-18	—	0.00E+00
Fission Products			
H-3	5.62E+00	1.00E+00	5.56E+00
Sr-90	2.40E+03	6.00E+02	2.37E+03
Tc-99	8.84E-01	2.00E-01	8.84E-01
I-129	1.91E-03	5.00E-04	1.91E-03
Cs-137	3.08E+03	8.00E+03	3.10E+03
Eu-154	1.01E+01	4.00E+00	1.01E+01
Transuranics			
Pu-238	1.86E+01	7.00E+00	1.88E+01
Pu-239	7.37E+01	1.00E+01	7.37E+01
Pu-240	3.95E+01	8.00E+00	3.96E+01
Pu-241	1.20E+03	3.00E+02	1.20E+03
U-235	1.13E-02	3.00E-03	1.14E-02

The URS (2000) characterization of the Hole 48 spent fuel is virtually identical to that provided by PNL (1992), while the DOE and NYSERDA (1996) characterization differs in significant ways. Most obvious are the missing activation products, which are discussed in detail below. In addition, the DOE and NYSERDA (1996) Co-60 and Cs-137 activities are larger than in PNL (1992), while the DOE and NYSERDA (1996) activities for all of the other reported radionuclides are lower than in PNL (1992). No rationale for this behavior has been found.

None of the other NDA inventory estimates present a full radionuclide inventory for the Hole 48 deposited fuel. However, Kelleher and Michael (1973) and Duckworth (1981) present the estimated Pu-239 and U-235 inventories. Nicholson and Hurt (1985) refer to an estimate of 0.82 kilograms (kg) for "long-lived plutonium," or 50.8 Ci. These values are compared to the PNL (1992) and other inventories in Table III-26.

Table III-26: Hole 48 Deposited Fuel – Pu-238 and U-235 Activity

Source	Activity (Ci)	
	Pu-239	U-235
Kelleher & Michael, 1973	5.08E+01	7.13E-03
Duckworth, 1981	4.34E+01	7.19E-03
Nicholson & Hurt, 1985	5.08E+01	—
PNL, 1992	7.37E+01	1.13E-02
DOE & NYSERDA, 1996	1.00E+01	3.00E-03
URS, 2000	7.37E+01	1.14E-02

The URS (2000) and PNL (1992) Pu-239 and U-235 estimates are virtually identical, while the Kelleher and Michael (1973), Duckworth (1981), and Nicholson and Hurt (1985) estimates are within a factor of two of the PNL (1992) estimate. The DOE and NYSERDA (1996) Pu-239 and U-235 estimates are lower than the PNL (1992) estimates for 42 Campaign 12 fuel assemblies by factors of approximately seven and four, respectively.

3. Plutonium

In comments received on both the 1996 DEIS and the 2008 Revised DEIS, concern was expressed regarding the NDA plutonium activity estimate, as illustrated by these excerpts from the 2010 FEIS and Synapse (2008):

> *111. One of the greatest source-term discrepancies is the quantity of Pu-239 buried in the NDA. Before the Draft EIS was issued, the most thorough analysis of the plutonium source term in the NDA was by Nicholson & Hurt, Information on the Confinement Capability of the Facility Disposal Area at West Valley, NY, NUREG-1164, September 1985, esp. pages 14-17. Nicholson & Hurt conclude that "a conservative estimate of total long-lived plutonium inventory [i.e., total Pu-239, Pu-240, and Pu-242 in the NDA] would be about 5.5 kg, with an uncertainty of about 2.0-2.5 kg." …. The Draft EIS indicates that the NDA contains a much greater inventory of Pu-239. On page C-42 (Table C-9), the Draft EIS indicates that the NDA contains 2600 curies of Pu-239, mostly on filters buried in the NDA. If the figure of 2600 curies is correct, it means that the quantity of Pu-239 buried in the NDA is 42 kilograms, or more than seven times the quantity estimated by Nicholson & Hurt. This is an incredibly large discrepancy for a material as dangerous, as fissionable, and as closely controlled as Pu-239.* [DOE & NYSERDA, 2010, Volume 3, Commenter No. 110: Raymond C. Vaughan, PhD]

> *The 1996 DEIS report estimates the activity in the NDA from a 1994 characterization report by the West Valley Nuclear Services, while the 2005 DEIS report estimates the activity in the NDA from a report by URS in 2000.[…] The estimates from the two reports differ somewhat; for example, the plutonium-239 activity in the 1996 DEIS report is 2,006 Ci, while it is 579 Ci in the 2005 DEIS report. Overall the activity reported in the 1996 DEIS report was 36,550 Ci greater (151,300 Ci) than that reported in the 2005 DEIS report (114,700 Ci).* [Synapse, 2008, Appendix B, page 36]

Table III-27 presents a summary of the Pu-239 and total plutonium estimates that have been made in the documents being compared in this study.

Table III-27: NDA Pu-239 and Total Plutonium Estimates

Document	Mass in NDA (kg)			
	Fuel	Hulls	Other	Total
Pu-239				
Kelleher & Michael, 1973	0.82	—	—	0.82
Duckworth, 1981	0.70	3.14	0.32	4.16
Nicholson & Hurt, 1985	0.70	2.80	0.30	3.80
PNL, 1992	1.19	2.73	—	3.92
DOE & NYSERDA, 1996	0.16	4.89	38.86	43.91
URS, 2000	1.19	2.72	5.41	9.32
Total Plutonium				
Duckworth, 1981	0.82	3.74	0.39	4.95
SAI, 1983	—	3.74	<10.90	<14.64
Nicholson & Hurt, 1985	0.82	3.60	1.08	5.50
PNL, 1992	1.42	3.48	—	4.90
DOE & NYSERDA, 1996	0.20	5.77	44.86	50.83
URS, 2000	1.38	3.32	6.62	11.32

In their Table VI, Kelleher and Michael (1973) give an estimate of the Pu-239 within the Hole 48 irradiated, unreprocessed NPR fuel but provide no other information concerning NDA plutonium. For fuel, Duckworth (1981) reinterpreted the Kelleher and Michael (1973) estimate to be for total plutonium, rather than specific to Pu-239, and in his Table VI, added estimates for the plutonium associated with hulls and resins and others. Nicholson and Hurt (1985) accepted the Duckworth (1981) plutonium in fuel and calculated plutonium estimates associated with hulls and the NDA total.

Using NFS nuclear materials management reports, SAI (1983) estimated the total plutonium mass transferred to the NDA with the hulls, as well as the amount of total plutonium that was “Unaccounted For” during the 27 reprocessing campaigns. This “Unaccounted For” amount is shown in Table III-27 under the “Other” column, as it provides an upper limit on the total plutonium that could have been transferred to the NDA with the miscellaneous NDA waste streams (e.g., resins, filters, spent equipment). In reality, the SAI (1983) “Other” column estimate includes not only plutonium associated with the miscellaneous NDA waste streams, but also the Hole 48 irradiated, unreprocessed NPR fuel and any plutonium that remained in the Main Plant Process Building (e.g., General Purpose Cell, Process Mechanical Cell, Chemical Process Cell, Extraction Cells XC1, XC2, XC3). Hence, the less-than indicator has been used with the SAI (1983) “Other” column total plutonium estimate in Table III-27. Finally, SAI (1983) provides no Pu-239-specific information, or any other specific radionuclides.

The PNL (1992) fuel plutonium estimates are directly from the ORIGEN2 output (adjusted only to account for the number of Campaign 12 fuel assemblies that were buried), and the hulls estimates are based in the SAI (1983) average plutonium hull carry over of 0.2% times the ORIGEN2 output for all 26 campaigns.

For all three waste streams shown in Table III-27 (“Fuel,” “Hulls,” and “Other”), there are concerns with the DOE and NYSERDA (1996) plutonium estimates. First, the amount of plutonium estimated to be with the Hole 48 fuel is low, when compared to all of the other estimates. On the other hand, the DOE and NYSERDA (1996) hulls estimate appears to be high. However, the most concern is with the DOE and NYSERDA (1996) “Other” column plutonium estimate, which is substantially greater than all of the NFS nuclear materials management reports’ “Unaccounted For” plutonium (which includes not only NDA other waste streams but also residual plutonium within the Main Plant Process Building).

The URS (2000) fuel and hulls plutonium estimates are consistent with the plutonium estimates from all of the other documents, except DOE and NYSERDA (1996). Although the URS (2000) total plutonium estimate is larger than most of the other document estimates, it is 3.32 kg less than the SAI (1983) upper limit estimate, which would be the residual plutonium throughout the Main Plant Process Building.

4. Cobalt-60

As both Table III-22 and Table III-28 show, the pre-PNL (1992) Co-60 estimates are about an order of magnitude lower that the post-PNL (1992) Co-60 estimates.

Table III-28: Summary of NDA Co-60 Activity Estimates

Source	Activity (Ci)	
	As Disposed	1/1/2000
Kelleher & Michael, 1973	1.73E+05	3.40E+03
Duckworth, 1981		
Nicholson & Hurt, 1985	4.60E+05	8.90E+03
PNL, 1992	1.58E+06	2.93E+04
DOE & NYSERDA, 1996	—	3.00E+04
URS, 2000	—	2.97E+04

Examination of Table III-6 shows that, for 1972, the Kelleher and Michael (1973) estimate shows a large volume of waste disposed in the NDA, but very little Co-60. For example, between 1967 and 1971, the NDA received about 5 Ci of Co-60 per cubic foot of waste, according to Kelleher and Michael (1973), Table III, but for 1972 the NDA received only about 0.013 Ci of Co-60 per cubic foot of waste. There may be an explanation for this, but neither Kelleher and Michael (1973) nor Duckworth (1981)—nor anyone else—has presented one.

Nicholson and Hurt (1985) also question the Kelleher and Michael (1973)/Duckworth (1981) NDA Co-60 estimate. As an alternative, Nicholson and Hurt (1985) describe an ORIGEN2 calculation for an average stainless steel LWR fuel assembly with a 13,000 megawatt days per metric ton of uranium (MWD/MTU) burnup. Because Nicholson and Hurt (1985) do not reference a source for their ORIGEN2 calculation, it is likely that they performed the calculation themselves. As Table III-28 shows, the Nicholson and Hurt (1985) ORIGEN2 calculation resulted in an NDA Co-60 estimate that is about 2.6 times larger than the Kelleher and Michael (1973) estimate.

Rather than perform the ORIGEN2 calculation for an average stainless steel LWR fuel assembly with a 13,000 MWD/MTU burnup, PNL (1992) performed ORIGEN2 calculations tailored to all 26 spent fuel reprocessing campaigns. In doing so, PNL (1992) included not only stainless steel fuel assemblies, but also the inconel components (e.g., springs, grid spacers). Including the inconel components is important because, although the mass of inconel is usually small compared to the mass of stainless steel, inconel contains a higher percentage of both nickel and cobalt, both of with can be activated to Co-60; see Table III-29. Thus, a PNL (1992) Co-60 activity estimate that is about three times larger than the Nicholson and Hurt (1985) Co-60 estimate is reasonable.

Table III-29: Fuel Assembly Material Cobalt and Nickel Composition

Material	Cobalt	Nickel
Inconel-718	4,700 ppm	52.0%
Inconel-750	6,500 ppm	72.2%
Stainless Steel 304	800 ppm	8.92%
Zircaloy-2	10 ppm	500 ppm
Zircaloy-4	10 ppm	20 ppm

Source: ORNL (1992), page 2.7-2.

Table III-28 shows that both the DOE and NYSERDA (1996) and URS (2000) Co-60 activity estimates are essentially identical to the PNL (1992) estimate.

5. Nickel-63 (and Other Activation Products)

As Table III-30 shows, PNL (1992) and URS (2000) both include Ni-59 and Ni-63, as well as several other activation products. Furthermore, the URS (2000) NDA disposal estimates are in good agreement with the PNL (1992) spent fuel estimates, as would be expected because all the activation products were located in the hulls and hardware. Table III-30 also shows that DOE and NYSERDA (1996), Table C-9, does not include Ni-59, Ni-63, or any other activation products beside Co-60 in its NDA inventory.

Table III-30: Activation Product Estimates

Nuclide	Activity (1/1/2000) (Ci)		
	PNL, 1992	DOE & NYSERDA, 1996	URS, 2000
Mn-54	6.74E-06	—	8.13E-06
Fe-55	1.76E+03	—	1.82E+03
Co-60	2.93E+04	3.00E+04	2.97E+04
Ni-59	1.11E+03	—	1.11E+03
Ni-63	1.15E+05	—	1.16E+05
Zn-65	5.84E-14	—	6.21E-14

Ryan (1992) provides an estimate of 191,000 Ci (January 1, 1993) for the total activation products in the hulls and hardware but does not give a radionuclide breakdown. When the PNL (1992) total activation product inventory is decay corrected to January 1, 1993, it results in an inventory of 206,000 Ci.

In addition to Co-60, Ni-63 is also included in Title 10 of the *Code of Federal Regulations* (10 CFR) 61.55, Table 2, and Ni-59 is included in 10 CFR 61.55, Table 1. If the 10 CFR Part 61 waste classification is to be used, then these two activation products should be included in any waste inventory estimate. Figure III-5 shows the importance of including

Ni-59 and Ni-63 in the NDA activity estimates. On January 1, 2000, it had been 35 to 40 years since the fuel was irradiated, Figure III-5 indicates that at that time NI-63 would have had a higher activity than Co-60, which is shown to be the case for the URS (2000) NDA estimates in Figure III-3. With reference to Figure III-5, the dominance of Ni-63 would continue to increase each year since 2000.

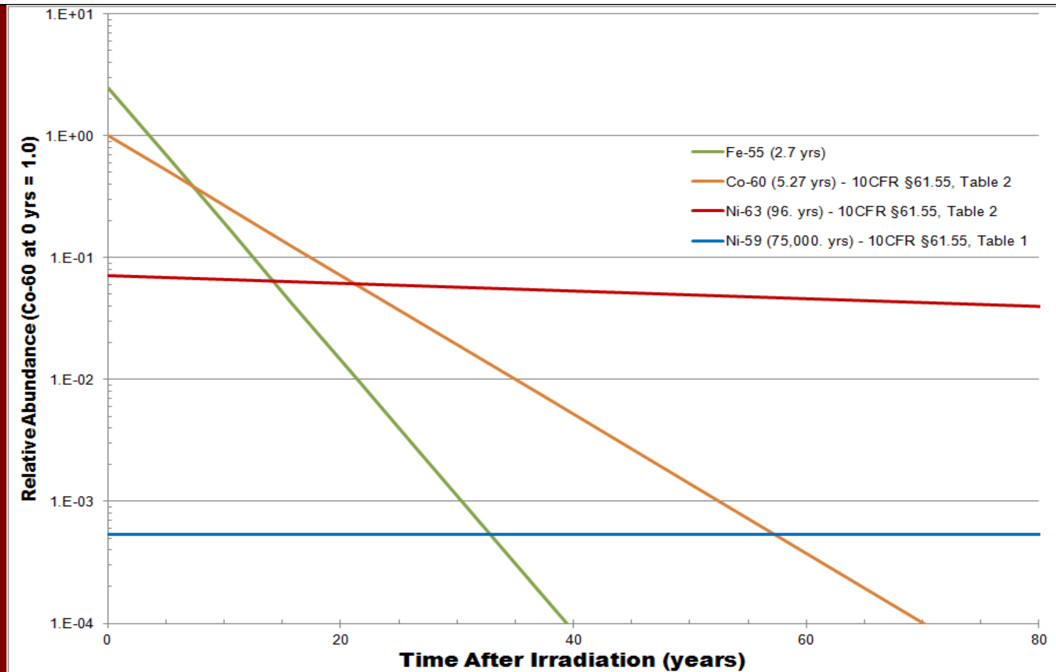

Figure III-5: Relative Abundance of Activation Products

Other than URS (2000), none of the NDA inventory estimates provide information on Ni-59, Ni-63, or any other activation products beside Co-60. WVNS (1995b) does list Ni-63 as one of the nine radionuclides that are major contributors to its NDA activity estimate, but as mentioned elsewhere, WVNS (1995b) does not provide a radionuclide breakdown of its NDA activity estimate.

IV. Waste Tank Farm

The WTF area is shown in Figure IV-1. For this study, the primary components of the WTF are the four underground HLW storage tanks: 8D-1, 8D-2, 8D-3, and 8D-4. During reprocessing, HLW from the plant was sent to Tanks 8D-2 and 8D-4. Tank 8D-4 held the acidic THOREX waste produced during Campaign 11, while the PUREX waste from all of the other campaigns was held in Tank 8D-2. WVDP Tank 8D-1 was used to house ion exchange columns that were part of the Supernatant Treatment System, and the spent resins were dumped to the bottom of Tank 8D-1. Tank 8D-3 was mostly kept as a spare to Tank 8D-4.

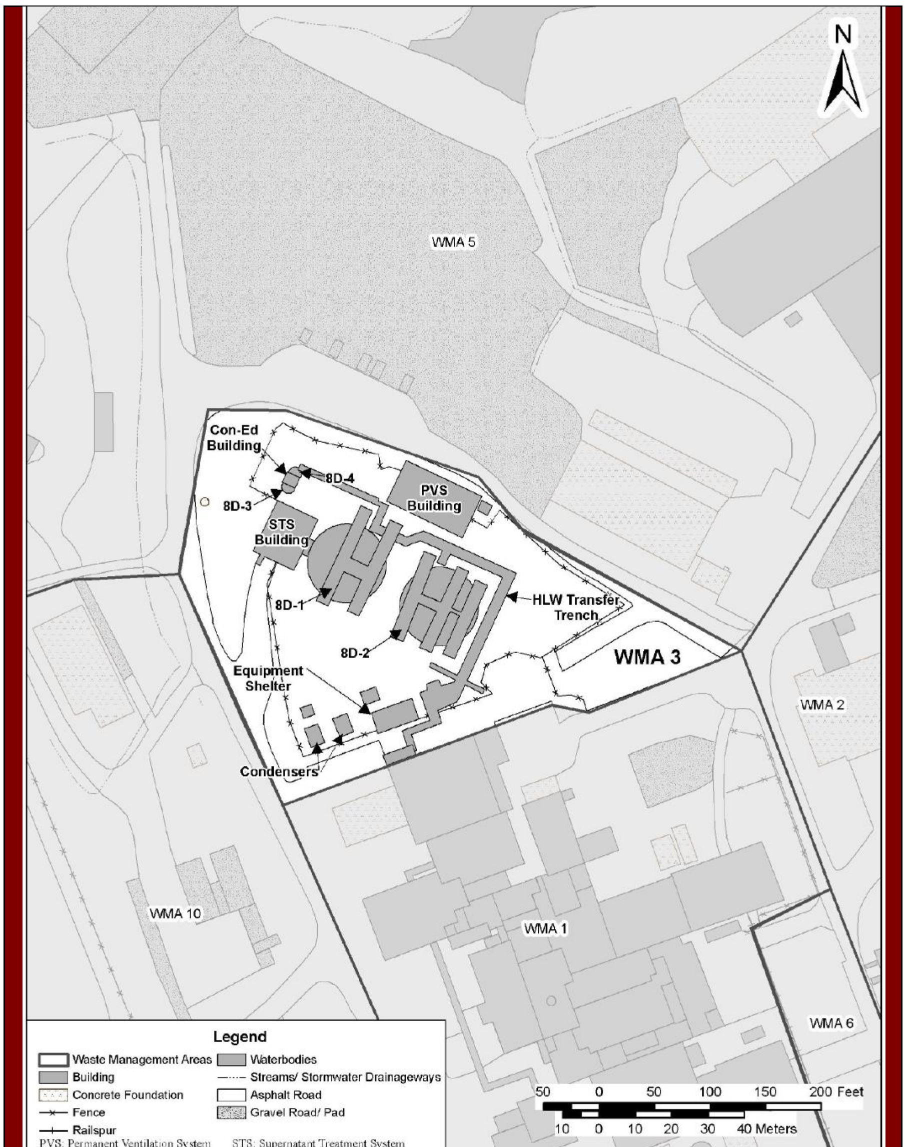

Figure IV-1: WMA 3 — Waste Tank Farm

As shown in Figure IV-2, much of the HLW that had been stored in the tanks was removed and vitrified in the five-year period from 1996 to 2001. In particular, about 98% and greater than 99.9% of the Cs-137 and Sr-90 activity, respectively, have been removed.

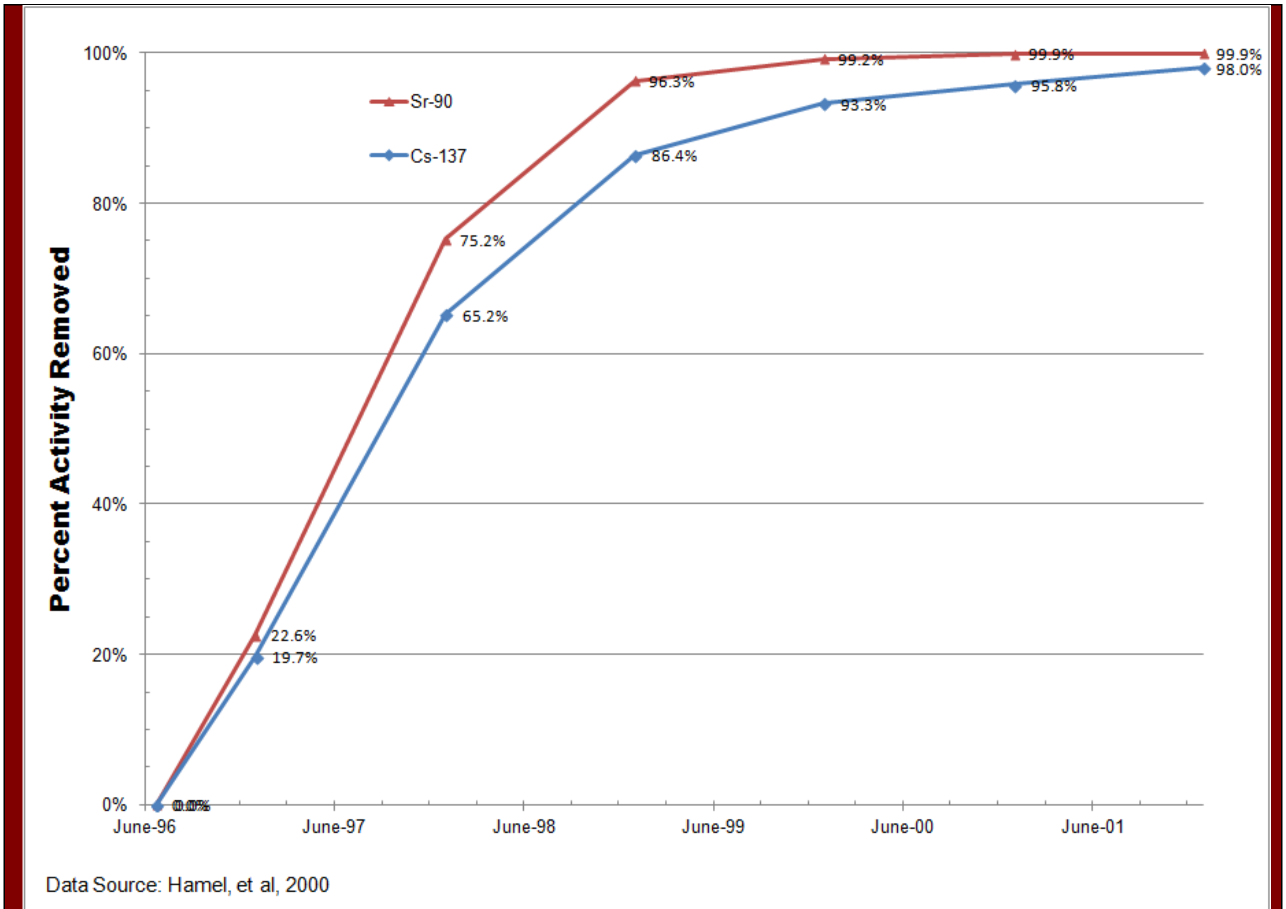

Figure IV-2: WTF Activity Removal During WVDP Vitrification

Because the WVDP vitrification process removed much of the activity from the WTF tanks, only those WTF inventory estimates that were made after the 2002 completion of vitrification will be reviewed as part of this study. The one exception to this is the pre-vitrification characterization performed by Rykken (WVNS, 1986), which has been briefly included in Section IV.B.1 to provide background perspective, but not for comparison.

The activity estimates for Tank 8D-3 are very small compared to the estimates in the other tanks. Additionally, the liquid level in Tank 8D-3 was reduced by about 500 gallons in 2011 and 1,400 gallons in 2012. In 2013, the Tank 8D-3 liquid level was further reduced to below the level indicator. Finally, because Tank 8D-3 is located in the same vault as Tank 8D-4, which has a much larger residual activity estimate, any decisions to remediate Tank 8D-3 would almost assuredly be based on the Tank 8D-4 remediation decisions. For these reasons, no attempt has been made at this time to investigate the differences between the WVNS (2002) and WVNS (2005) Tank 8D-3 residual activity estimates.

Similar to Tank 8D-3, from 2011 through 2014, the liquid level in Tank 8D-4 was also reduced by about 500, 1,400, 250, and 120 gallons, respectively, leaving approximately 4,680 gallons in Tank 8D-4 at the end of 2014. In 2012, sampling was performed of the liquid, sludge, and internal walls to characterize the radiological and hazardous contents of Tank 8D-4 (CH2M HILL · BWXT West Valley, LLC, 2013, page EXE-3). A Tank 8D-4 characterization report based upon the results of this sampling program was issued on August 30, 2012 (CH2MHILL · B&W West Valley, 2012). Because the Tank 8D-4 residual activity estimate has been recalculated, no attempt has been made at this time to investigate the differences between the WVNS (2002) and WVNS (2005) Tank 8D-4 residual activity estimates.

While CH2MHILL · B&W West Valley (2012) provides the results of the most recent sampling of Tank 8D-4, it does not provide an estimate of the total Tank 8D-4 residual activity. Table IV-1 presents an estimate of the Tank 8D-4 activity using CH2MHILL · B&W West Valley (2012) data, developed as part of this study.

Table IV-1: CH2MHILL • B&W West Valley, 2012; Tank 8D-4 Estimated Activity

Nuclide	Residual Activity (Ci)			
	Liquid	Sludge	Fixed	Total
C-14	2.7E-03	6.6E-03	3.8E-06	9.3E-03
Sr-90	4.7E-01	2.1E+03	4.7E-02	2.1E+03
Tc-99	1.0E+00	1.1E-01	1.4E-03	1.1E+00
I-129	1.3E-04	1.4E-02	4.7E-08	1.4E-02
Cs-137	5.3E+02	1.3E+04	4.4E+00	1.3E+04
U-232	5.4E-03	9.3E-03	2.0E-06	1.5E-02
U-233/234	3.7E-03	8.6E-03	5.6E-06	1.2E-02
U-235	9.1E-05	8.2E-05	2.0E-06	1.8E-04
U-238	2.6E-04	5.7E-04	5.4E-06	8.3E-04
Np-237	3.9E-04	1.5E-02	1.8E-06	1.5E-02
Pu-238	1.0E-01	2.2E+01	4.7E-03	2.2E+01
Pu-239/240	2.1E-02	6.6E+00	9.6E-04	6.6E+00
Am-241	8.4E-04	5.5E+01	3.8E-03	5.5E+01
Cm-243/244	1.1E-04	5.3E+00	2.2E-04	5.3E+00

In Table IV-1, the liquid activity is based on the average of the three liquid sample results from Table E of CH2MHILL · B&W West Valley (2012),[3] and a liquid volume of 4,400 gallons from Section 3.2.1. The sludge activity is based on the average of the two sludge sample results from Table H, a sludge volume of 1,100 gallons from Section 3.3.1, and the average of the two sludge densities from Table G. The fixed activity is based on the upper and lower coupon surface activities and the surface area from Appendix L. It was assumed that the lower coupon activity applied to the surface area below 107 inches, and the upper coupon activity to the surface area in the upper 106 inches of Tank 8D-4.

[3] Tables E, H, and G, Sections 3.2.1 and 3.3.1, and Appendix L referred to in this paragraph may be found in CH2MHILL · B&W West Valley (2012).

A. FEIS Inventory Estimate

A radionuclide inventory report was prepared for Tanks 8D-1 and 8D-2 in 2002 (WVNS, 2002), which is described in more detail in Section IV.B.2. The WVNS (2002) report was provided to NYSERDA, EPA, NYSDEC, and NRC for review and comment. Based on a range of factors addressed in the comments received back from the reviewing agencies, as well as requests for additional clarification regarding specific technical issues, the determination was made to prepare a Supplemental Report that addressed the comments and requests. That Supplemental Report is WVNS (2005) and represents the inventory used in the FEIS and selected for use in the Phase I studies.

Unlike the SDA and NDA inventories that relied on shipping manifests, generic waste profiles, and computer modeling for their activity estimates, there were a number of grab samples, radiation measurements, and burnishing samples from the WTF that were used to develop the activity estimates. Table IV-2 lists the vitrification analytical samples that were used to make the WVNS (2005) activity estimates.

Table IV-2: WVNS, 2005, Table 5; Vitrification Analytical Samples Used

VAST #	Date	Location	Comments
00-1048	5/30/2000	SBS Liquid*	Used for Tank 8D-4 mobile inventory
00-1534	8/4/2000	CFMT	Batch 72; Heel; Used for Tank 8D-2 inventory
00-2076	10/3/2000	CFMT	Batch 72; Last Transfer; Used for Tank 8D-2 inventory
00-2153	10/6/2000	SBS Liquid	Used for Tank 8D-4 mobile inventory
00-2155	10/12/2000	SBS Liquid	Used for Tank 8D-4 mobile inventory
01-0612	4/6/2001	CFMT	Batch 74; Heel; Used for Tank 8D-2 inventory
01-1199	6/15/2001	CFMT	Batch 74; Last Transfer; Used for Tank 8D-2 inventory
01-1281	6/18/2001	CFMT	Batch 75; Heel; Used for Tank 8D-2 inventory
01-2498	11/24/2001	CFMT	Batch 75; Last Transfer; Used for Tank 8D-2 inventory
03-0060	12/20/2002	Tank 8D-1	Unmobilized Liquid (Supernatant)
03-0061	12/20/2002	Tank 8D-1	Liquid (Supernatant)/Sludge Mixture
03-0262	2/4/2003	CFMT	Scaling factors
03-0329	3/2003	Tank 5D-15A1	Decontaminated Sodium Bearing Waste (SBW) concentrate
03-1026	7/7/2003	Tank 8D-3	Liquid from Tank 8D-3
03-1155	7/7/2003	CFMT	After chloride/fluoride waste was added

* SBS = Submerged Bed Scrubber; CFMT = Concentrator Feed Makeup Tank

WVNS (2005) analyzed three cases: Best Case Estimate, Conservative Case Estimate, and Worst Case Estimate. The Conservative Case Estimate is based on "realistic conservatism"—"realistic" in the sense of being anchored in the real world of physics and experience, and "conservatism" in the sense of preserving adequate safety margins. The Best Case Estimate (as in most realistic, not most optimistic) and Worst Case Estimate are presented to achieve the proper bounding of the conservative case. The conservative case activity estimates for Tank 8D-1 and Tank 8D-2 are shown in Table IV-3 and Table IV-4, respectively.

Table IV-3: WVNS, 2005, Table 61; Tank 8D-1 Estimated Activity — Conservative Case							
Nuclide	Residual Activity (Ci)						
	Liquid	Sludge	Zeolite	Fixed	STS IX	STS Equip	Total
C-14	2.6E-03	5.2E-03	—	1.2E-03	—	1.4E-02	2.0E-02
Sr-90	1.3E+01	5.8E+01	2.4E+02	1.8E+03	1.6E+02	7.1E+01	2.3E+03
Tc-99	7.5E-01	5.4E-01	—	2.1E-01	—	4.1E+00	5.4E+00
I-129	9.5E-04	6.8E-04	—	2.6E-04	—	5.2E-03	6.8E-03
Cs-137	5.2E+02	4.6E+02	1.5E+05	5.5E+03	1.0E+05	2.8E+03	2.6E+05
U-232	2.3E-02	1.7E-02	—	4.5E-01	—	1.3E-01	6.0E-01
U-233	1.0E-02	7.2E-03	—	2.0E-01	—	5.7E-02	2.6E-01
U-234	4.0E-03	2.8E-03	—	7.7E-02	—	2.2E-02	1.0E-01
U-235	1.2E-04	1.2E-04	—	2.6E-03	—	6.8E-04	3.4E-03
U-238	1.1E-03	1.1E-03	—	2.4E-02	—	6.1E-03	3.1E-02
Np-237	1.2E-03	1.4E-03	—	1.5E-02	—	6.4E-03	2.3E-02
Pu-238	2.6E-02	1.1E-01	3.2E-01	4.9E+00	2.1E-01	1.4E-01	5.6E+00
Pu-239	4.7E-03	3.1E-02	8.8E-02	1.3E+00	5.8E-02	2.5E-02	1.5E+00
Pu-240	3.3E-03	2.2E-02	6.3E-02	9.5E-01	4.1E-02	1.8E-02	1.1E+00
Pu-241	1.3E-01	6.5E-01	2.7E+00	3.8E+01	1.8E+00	7.3E-01	4.4E+01
Am-241	1.4E-03	1.3E-01	—	2.9E-01	—	7.8E-03	3.8E-01
Cm-243	4.1E-06	4.4E-04	—	8.4E-04	—	2.3E-05	1.1E-03
Cm-244	1.9E-04	2.0E-02	—	3.8E-02	—	1.0E-03	5.0E-02

For Tank 8D-1, the total activity values reported in Table IV-3 are the sums of the best case component activities plus two times the square root of the product of the square of each component's standard error. This results in slightly lower conservative case total estimates when compared to simply adding the six component activities. For example, for I-129, simply adding the six component activity estimates gives 7.1E-03 Ci, rather than the 6.8E-03 Ci reported in Table IV-3.

Table IV-4: WVNS, 2005, Table 61; Tank 8D-2 Estimated Activity — Conservative Case							
Nuclide	Residual Activity (Ci)						
	Batch 72	Zeolite	Fixed	Batch 74	Batch 75	Liquid	Total
C-14	9.8E-04	—	1.4E-03	4.8E-04	1.3E-03	4.7E-04	2.7E-03
Sr-90	9.7E+02	1.8E+02	4.3E+04	1.8E+03	8.2E+03	7.6E+00	3.4E+04
Tc-99	1.0E+00	—	1.6E+00	5.1E-01	1.4E+00	5.0E-01	2.9E+00
I-129	1.3E-03	—	2.0E-03	6.4E-04	1.8E-03	9.0E-04	3.8E-03
Cs-137	3.4E+04	1.2E+05	7.7E+04	3.1E+04	1.1E+05	5.2E+02	8.6E+04
U-232	1.9E-03	—	1.7E-01	1.3E-02	5.7E-02	1.7E-02	1.2E-01
U-233	8.9E-04	—	8.6E-02	6.1E-03	2.7E-02	8.1E-03	5.9E-02
U-234	3.2E-04	—	3.2E-02	2.2E-03	9.8E-03	3.1E-03	2.2E-02
U-235	9.4E-06	—	1.3E-03	6.4E-05	2.9E-04	8.5E-05	1.1E-03
U-238	8.4E-05	—	7.8E-03	5.7E-04	2.6E-03	7.6E-04	5.2E-03
Np-237	8.6E-03	—	5.8E-01	1.6E-02	6.5E-02	1.0E-03	5.0E-01
Pu-238	8.7E-01	2.4E-01	1.6E+02	2.5E+00	1.2E+01	1.7E-02	1.5E+02
Pu-239	2.4E-01	6.6E-02	4.0E+01	6.7E-01	2.9E+00	3.8E-03	3.6E+01
Pu-240	1.7E-01	4.7E-02	2.9E+01	4.8E-01	2.0E+00	2.7E-03	2.6E+01
Pu-241	7.6E+00	2.1E+00	8.6E+02	2.2E+01	1.0E+02	8.6E-02	7.4E+02
Am-241	6.9E+00	—	4.2E+02	8.8E+00	3.7E+01	1.1E-02	3.8E+02
Cm-243	2.7E-02	—	3.7E+00	3.6E-02	1.4E-01	2.8E-05	3.6E+00
Cm-244	1.2E+00	—	8.7E+01	1.6E+00	6.5E+00	1.3E-03	8.0E+01

As for Tank 8D-1, the Tank 8D-2 conservative case total activity is the sum of the best case component activities plus two times the square root of the product of the square of each component's standard error. Additionally, the best case total activity is calculated as follows:

$$I_{8D\text{-}2,i} = I_{M,i} + I_{F,i} + I_{Z,i} + I_{L,i} - \varepsilon_i \left(I_{74,i} + I_{75,i}\right)$$

where:

- $I_{8D\text{-}2,i}$ = final inventory of radionuclide i in Tank 8D-2 after all waste transfers into and out of the tank are complete (Ci),
- $I_{M,i}$ = mobile inventory of radionuclide i within Tank 8D-2 at the end of Batch 72 prior to wall washing (Ci),
- $I_{F,i}$ = inventory of radionuclide i within Tank 8D-2 fixed to the internal structures of the tank prior to wall washing (Ci),
- $I_{Z,i}$ = inventory of radionuclide i in the zeolite transferred from Tank 8D-1 into Tank 8D-2 following Batch 72 transfers (Ci),
- $I_{L,i}$ = liquid inventory of radionuclide i transferred from Tank 8D-1 into Tank 8D-2 following Batch 72 transfers (Ci),
- ε_i = melter efficiency for radionuclide i,
- $I_{74,i}$ = inventory of radionuclide i transferred to vitrification via Batch 74 (Ci), and
- $I_{75,i}$ = inventory of radionuclide i transferred to vitrification via Batch 75 (Ci).

Please see WVNS (2005), Section 6, for an explanation of the basis for this equation.

B. Historical Inventory Estimates

1. Pre-Vitrification Characterization – WVNS, 1986

One of the first efforts to characterize the WTF after the initiation of the WVDP was performed by Larry E. Rykken (WVNS, 1986, widely referred to as the "Rykken report"). Rykken utilized analytical (e.g., gamma spectrometry) and theoretical (e.g., the ORIGEN computer program, ORNL, 1980) approaches to radiologically characterize the PUREX supernatant (WVNS, 1986, Table 6) and sludge (WVNS, 1986, Table 22) in Tank 8D-2 and the THOREX (WVNS, 1986, Table 12) waste in Tank 8D-4. At that time, there was minimal onsite analytical capability, so most of the analysis was performed off site at the Westinghouse Laboratory in Madison, Pennsylvania, with additional analysis performed by Babcock and Wilcox Analytical Laboratories and the Battelle Pacific Northwest Laboratories.

Since most of the WTF HLW has been vitrified, Rykken's activity estimates are not useful for estimating the current WTF inventory. However, WVNS (2005) made use of some of the information provided in WVNS (1986), particularly when attempting to develop scaling factors for radionuclides that are difficult to directly measure.

2. Tanks 8D-1 & 8D-2 – WVNS, 2002

The WVNS (2002) report was to provide DOE with a final radionuclide inventory of the HLW Tanks 8D-1 and 8D-2 as of September 2002. The resultant inventory was intended to support the performance assessment for the decommissioning and/or long-term stewardship environmental impact statement (EIS; DOE/EIS-0226), as well as the waste incidental to reprocessing determination per the NRC's final decommissioning criteria for the WVDP.

A number of technologies were deployed by the authors of WVNS (2002) to quantify the source term in the tanks, including the following:

- Direct sampling of the mobilized waste in Tanks 8D-1 and 8D-2
- Visual mapping of solids remaining in Tanks 8D-1 and 8D-2
- General area gamma radiation probe measurements with dose-to-curie modeling in Tank 8D-1
- Solid state track recorder neutron dosimetry in Tanks 8D-1 and 8D-2
- Burnishing samples from Tank 8D-2
- Gamma camera inspection of Tank 8D-2
- Beta-gamma detector readings collected from the M-I, M-4, and M-7 risers in Tank 8D-2

Table IV-5 presents the WVNS (2002) Tank 8D-1 radionuclide activity estimate. WVNS (2002) kept the Supernatant Removal System (SRS) inventory separate from the other sources of radioactivity within Tank 8D-1, and this separation has been maintained in Table IV-5. Also note that the WVNS (2002) Tank 8D-1 inventory includes a 95% upper confidence level (UCL) estimate (i.e., mean plus two standard deviations) for the Tank 8D-1 activity, but not for the SRS inventory.

Table IV-5: WVNS, 2002, Tables 4-11 and 4-12; Tank 8D-1 Inventory Summary

Nuclide	Tank 8D-1 Activity (Ci)						SRS Activity (Ci)	
	Super-natant	Sludge	Zeolite	Fixed	Totals	95% UCL	SRS IX	SRS Equip.
C-14	6.2E-02	<5.0e-04	—	9.1E-03	7.1E-02	1.1E-01	—	1.5E-02
Ni-63	7.5E+00	1.3E+00	—	1.6E+00	1.0E+01	1.4E+01	—	2.6E+00
Co-60	9.0E-01	1.5E-01	—	1.9E-01	1.2E+00	1.7E+00	—	3.1E-01
Tc-99	1.1E+01	<5.0e-04	—	1.6E+00	1.2E+01	1.3E+01	—	2.6E+00
I-129	<5.0e-04	<5.0e-04	—	7.3E-06	7.3E-06	7.2E-05	—	1.2E-05
U-232	2.4E-01	2.9E-05	—	4.6e.05	2.4E-01	—	—	7.7E-05
U-233	3.4E-01	3.1E-05	—	4.8E-05	3.4E-01	—	—	8.1E-05
U-234	1.6E-01	1.1E-05	—	1.7E-05	1.6E-01	—	—	2.9E-05
U-235	3.6E-03	3.3E-07	—	5.le-07	3.6E-03	—	—	8.5E-07
Np-237	3.3E-02	<5.0e-04	—	5.3E-03	3.8E-02	4.2E-02	—	8.9E-03
U-238	3.0E-02	2.9E-06	—	4.5E-06	3.0E-02	—	—	7.6E-06
Pu-238	1.7E-01	3.4E-02	3.0E-01	5.3E-02	5.6E-01	5.9E+00	1.8E-01	8.9E-02
Pu-239	3.9E-02	7.9E-03	8.0E-02	1.4E-02	1.4E-01	—	4.8E-02	2.4E-02
Pu-240	2.9E-02	6.1E-03	6.1E-02	1.1E-02	1.1E-01	—	3.7E-02	1.9E-02
Pu-241	1.5E+00	3.0E-01	2.8E+00	4.6E-01	4.9E+00	5.2E+00	1.6E+00	7.7E-01
Pu-242	<5.0e-04	<5.0e-04	—	1.1E-05	1.1E-05	1.9E-05	—	1.8E-05
Am-241	1.1E-01	5.6E-02	—	5.5E-02	2.2E-01	2.5E-01	—	9.2E-02
Arn-243	2.0E-03	1.0E-03	—	1.1E-03	4.1E-03	4.6E-03	—	1.9E-03
Cm-242	1.0E-03	<5.0e-04	—	1.1E-04	1.1E-03	1.3E-03	—	1.8E-04

Cm-243	4.8E-04	5.5E-04	—	5.4E-04	1.6E-03	—	—	9.1E-04
Cm-244	1.3E-02	1.4E-02	—	1.4E-02	4.1E-02	—	—	2.4E-02
Cs-137	7.5E+03	8.8E+02	1.5E+05	4.5E+03	1.6E+05	1.9E+05	8.9E+04	7.5E+03
Sr-90	1.0E+03	1.6E+01	2.3E+02	1.5E+02	1.4E+03	1.5E+03	1.4E+02	2.6E+02

The WVNS (2002) Tank 8D-2 radionuclide activity estimates are presented in Table IV-6. Similar to Tank 8D-1, the Tank 8D-2 estimates include a 95% UCL estimate. In addition, Table IV-6 shows that WVNS (2002) calculated both a material balance and a fraction-based total Tank 8D-2 activity estimate. The following equation was used to calculate the material balance total:

Total = mobile + sludge/zeolite + fixed – Batch 74 – Batch 75

As Table IV-6 shows, when this equation was applied to some of the radionuclides, the result was a negative Tank 8D-2 activity. To resolve this unrealistic result, WVNS (2002) identified the radionuclides with the lowest Batch 74 and Batch 75 removal efficiency and used that removal efficiency for all radionuclides (WVNS, 2002, page 45).

Table IV-6: WVNS, 2002, Table 5-11; Tank 8D-2 Inventory Summary

Nuclide	Mobile Waste	Estimated activity (Ci)								
		Zeolite	Fixed Waste		Batch 74	Batch 75	Material Balance		Fraction-Based	
			Estimate	95% UCL			Total	95% UCL	Total	95% UCL
C-14	1.0E-03	—	2.2E-03	4.5E-03	3.0E-03	9.0E-03	-8.8E-03	-2.2E-03	1.8E-03	3.8E-03
Co-60	4.9E-01	—	1.1E+00	1.7E+00	2.8E-01	2.6E+00	-1.3E+00	-5.5E-01	8.9E-01	1.4E+00
Ni-63	4.1E+00	—	8.8E+00	1.4E+01	2.3E+00	2.2E+01	-1.1E+01	-4.3E+00	7.4E+00	1.2E+01
Sr-90	8.1E+02	1.8E+02	2.9E+04	4.7E+04	1.8E+03	8.6E+03	2.0E+04	3.8E+04	2.5E+04	4.0E+04
Tc-99	1.2E-01	—	3.8E-01	7.2E-01	5.7E-01	1.5E+00	-1.6E+00	-1.2E+00	3.2E-01	6.1E-01
I-129	0.0E+00	—	1.7E-06	3.8E-06	0.0E+00	0.0E+00	1.7E-06	3.8E-06	1.5E-06	3.2E-06
Cs-137	2.1E+04	1.1E+05	4.2E+03	1.1E+04	3.3E+04	1.1E+05	-8.6E+03	1.4E+02	3.6E+03	9.0E+03
U-232	0.0E+00	—	2.6E-02	2.6E-02	5.0E-03	2.2E-02	-1.0E-03	—	2.2E-02	2.2E-02
U-233	1.0E-03	—	3.5E-02	3.5E-02	7.0E-03	2.9E-02	-5.0E-04	—	2.9E-02	2.9E-02
U-234	0.0E+00	—	1.6E-02	1.6E-02	3.0E-03	1.4E-02	-6.0E-04	—	1.4E-02	1.4E-02
U-235	0.0E+00	—	3.7E-04	3.7E-04	1.0E-03	3.0E-03	-3.6E-03	—	3.1E-04	3.1E-04
U-238	0.0E+00	—	3.1E-03	3.1E-03	1.0E-03	3.0E-03	-9.1E-04	—	2.6E-03	2.6E-03
Pu-241	6.4E+00	2.0E+00	8.0E+02	1.3E+03	2.3E+01	1.1E+02	6.7E+02	1.2E+03	6.7E+02	1.1E+03
Cm-242	6.4E-02	—	1.2E+00	1.8E+00	8.3E-02	4.3E-01	7.1E-01	1.4E+00	9.8E-01	1.6E+00
Np-237	7.0E-03	—	2.5E-01	4.7E-01	1.9E-02	7.1E-02	1.7E-01	3.9E-01	2.1E-01	4.0E-01
Pu-238	7.3E-01	2.3E-01	9.2E+01	1.5E+02	2.7E+00	1.3E+01	7.8E+01	1.4E+02	7.8E+01	1.3E+02
Pu-239	1.9E-01	6.1E-02	2.2E+01	3.6E+01	7.0E-01	3.0E+00	1.9E+01	3.3E+01	1.9E+01	3.1E+01
Pu-240	1.5E-01	4.6E-02	1.7E+01	2.8E+01	5.4E-01	2.3E+00	1.4E+01	2.5E+01	1.4E+01	2.3E+01
Pu-242	0.0E+00	—	1.8E-02	3.1E-02	0.0E+00	0.0E+00	1.8E-02	3.0E-02	1.5E-02	2.6E-02
Am-241	5.4E+00	—	1.5E+02	2.3E+02	9.1E+00	3.8E+01	1.0E+02	1.9E+02	1.2E+02	1.9E+02
Am-243	9.8E-02	—	3.0E+00	4.5E+00	8.6E-02	4.6E-01	2.6E+00	4.1E+00	2.6E+00	3.8E+00
Cm-243	4.0E-02	—	7.4E-01	1.2E+00	6.4E-02	2.5E-01	4.6E-01	8.8E-01	6.3E-01	9.8E-01
Cm-244	1.0E+00	—	1.9E+01	3.0E+01	1.7E+00	6.6E+00	1.2E+01	2.3E+01	1.6E+01	2.6E+01

C. WTF Activity Estimate Comparisons

Table IV-7 and Table IV-8 compare the WVNS (2002) and WVNS (2005) Tank 8D-1 and 8D-2 estimated activities, respectively. The right column of both tables gives the ratio of the WVNS (2005) activity to the WVNS (2002) activity. Table IV-7 shows that for Tank 8D-1 there is good agreement between the two estimates, except for I-129 and to a lesser extent the plutonium isotopes. These differences are discussed in the sections below.

Table IV-7: Tank 8D-1 Activity Comparison

Nuclide	Total Activity (Ci)		Ratio
	WVNS, 2002	WVNS, 2005	
C-14	8.6E-02	2.00E-02	0.2
Sr-90	1.8E+03	2.30E+03	1.3
Tc-99	1.5E+01	5.40E+00	0.4
I-129	1.9E-05	6.80E-03	352.3
Cs-137	2.6E+05	2.50E+05	1.0
U-232	2.4E-01	6.00E-01	2.5
U-233	3.4E-01	2.60E-01	0.8
U-234	1.6E-01	1.00E-01	0.6
U-235	3.6E-03	3.40E-03	0.9
U-238	3.0E-02	3.10E-02	1.0
Np-237	4.7E-02	2.30E-02	0.5
Pu-238	8.3E-01	5.60E+00	6.8
Pu-239	2.1E-01	1.50E+00	7.1
Pu-240	1.7E-01	1.10E+00	6.6
Pu-241	7.3E+00	4.40E+01	6.1
Am-241	3.1E-01	3.80E-01	1.2
Cm-243	2.5E-03	1.10E-03	0.4
Cm-244	6.5E-02	5.00E-02	0.8

Table IV-8 shows that for Tank 8D-2 there is good agreement between the two estimates, except for I-129 and Cs-137. The I-129 and Cs-137 differences are discussed below in Section IV.C.1 and Section IV.C.3, respectively.

Table IV-8: Tank 8D-2 Activity Comparison

Nuclide	Total Activity (Ci)		Ratio
	WVNS, 2002	WVNS, 2005	
C-14	1.8E-03	2.70E-03	1.5
Sr-90	2.5E+04	3.40E+04	1.4
Tc-99	3.2E-01	2.90E+00	9.1
I-129	1.5E-06	3.80E-03	2,500.0
Cs-137	3.6E+03	8.60E+04	24.0
U-232	2.2E-02	1.20E-01	5.5
U-233	2.9E-02	5.90E-02	2.0
U-234	1.4E-02	2.20E-02	1.6
U-235	3.1E-04	1.10E-03	3.5
U-238	2.6E-03	5.20E-03	2.0
Np-237	2.1E-01	5.00E-01	2.4
Pu-238	7.8E+01	1.50E+02	1.9
Pu-239	1.9E+01	3.60E+01	1.9
Pu-240	1.4E+01	2.60E+01	1.9
Pu-241	6.7E+02	7.40E+02	1.1
Am-241	1.2E+02	3.80E+02	3.2
Cm-243	6.3E-01	3.60E+00	5.7

Table IV-8: Tank 8D-2 Activity Comparison			
Nuclide	Total Activity (Ci)		Ratio
	WVNS, 2002	WVNS, 2005	
Cm-244	1.6E+01	8.00E+01	5.0

1. Iodine-129

Due to its low beta and gamma energies, plus the fact that it is usually present in only small amounts, I-129 is difficult to measure. In both WVNS (2002) and WVNS (2005), scaling factors were used to estimate the I-129 WTF activity. Concerning its I-129 scaling factor, WVNS (2002, page 36) states:

> *Batch 10 scaling factors were used to calculate activities for radionuclides that could not be directly measured by the A&PC Laboratory for this project, e.g., C-14, Ni-63, I-129, and Pu-241. Batch 10 refers to samples collected from the first HLW Tank 8D-2 transfer to the CFMT in 1996. These samples were sent off-site to PNNL for complete chemical and radiochemical analysis.*

Batch 10 represents the first batch of the HLW campaign. The same scaling factors derived from Batch 10 data were used to assign an inventory to each of the HLW canisters for disposal.

Between 2002 and 2005, several additional sources of I-129 data became available for potential use in deriving a scaling factor, particularly VAST 03-0262, and VAST 03-0329. Concerning its I-129 scaling factor, WVNS (2005, page 58) states:

> *Since few analytical results for I-129 exist, scaling factors have been used to calculate I-129 activity estimates. These scaling factors have been developed by employing one of five potential sources as the basis for factor development. As identified in the list of scaling factors presented in Table 27, the sources considered include the scaling factors developed from:*
>
> 1) *Results reported for samples taken from Tank 8D-2: VAST 03-0262,*
> 2) *Results reported for samples of decontaminated sodium bearing waste (SBW) concentrate taken from Tank 15D-15A: VAST 03-0329,*
> 3) *Results reported for the sample of HLW taken from Batch 10: PNNL analysis…,*
> 4) *Rykken characterization data for Tank 8D-2 supernatant, and*
> 5) *Rykken characterization data for THOREX liquid.*
>
> *Each source considered was evaluated to determine the viability of using it as the basis for developing a scaling factor to estimate I-129 activity levels. Of the scaling factors considered, those developed from Rykken characterization data were eliminated from consideration because they were not based directly on sample results.* ***The scaling factor developed from the Batch 10 analysis*** **[as used in WVNS (2002)]** ***was also eliminated from consideration because it is approximately two orders of magnitude lower than the other factors developed for I-129.*** [emphasis added]

The referenced two order of magnitude difference in scaling factors explains most of the difference observed between the WVNS (2002) and WVNS (2005) I-129 activity estimates.

2. Plutonium

Although the WVNS (2002) and WVNS (2005) Tank 8D-1 plutonium isotope activity estimates differ by less than an order of magnitude, they show more difference than most of the other Tank 8D-1 radionuclide estimates; see Table IV-7. Examination and comparison of Table IV-3 for WVNS (2005) and Table IV-5 for WVNS (2002) shows that the difference between the plutonium estimates is due to the fixed activity estimates, as shown in Table IV-9.

Table IV-9: Tank 8D-1 Fixed Activity Estimates

Nuclide	WVNS, 2002	WVNS, 2005
Pu-238	0.053	4.90
Pu-239	0.014	1.30
Pu-240	0.011	0.95
Pu-241	0.46	38.00

To estimate the Tank 8D-1 plutonium fixed activity, WVNS (2002, Section 4.7.2) utilized a scaling factor based on the Batch 10 sample results. Using Batch 10 as the basis for the fixed activity implicitly assumes that all radionuclides plate out onto the tank surfaces at the same rate, so that the ratio between radionuclides that are fixed to the surface is the same as the mobile (or liquid) ratio.

Rather than use the Batch 10 scaling factor to estimate its Tank 8D-1 fixed activity, WVNS (2005) utilized mobile-to-fixed transfer factors. According to WVNS (2005), element-specific transfer factors were calculated from burnishing samples collected from the Tank 8D-2 surfaces. Using this transfer factor approach resulted in a Tank 8D-1 fixed-to-mobile plutonium activities ratio that is consistent with the sampled Tank 8D-2 fixed-to-mobile plutonium ratio and, therefore, is more credible than the scaling factor approach used in WVNS (2002).

3. Cesium-137

Table IV-8 shows that for Tank 8D-2, Cs-137 activity estimates differ by about a factor of 24 between WVNS (2002) and WVNS (2005). Table IV-10 is a breakdown and comparison of the WVNS (2002) and WVNS (2005) Cs-137 activity estimates and shows that the difference between the two estimates is primarily in the fixed activity.

Table IV-10: Tank 8D-2 Estimated Cs-137 Activity

Tank Area	WVNS, 2002		WVNS, 2005		
	Total	Upper Bound	Best Estimate	Conser-vative	Worst Case
Mobile Waste	21,000	—	32,000	34,000	39,000
Liquid	—	—	470	520	530
Zeolite	110,000	—	110,000	120,000	120,000
Fixed Waste	4,200	11,000	14,000	77,000	90,000
Batch 74	33,000	—	33,000	31,000	28,000

Batch 75	110,000	—	110,000	110,000	100,000
Total	**3,600**	**9,000**	**22,000**	**86,000**	**120,000**

Table IV-11 shows that, while the Cs-137 fixed activity estimates consistently differ, there is good agreement between the WVNS (2002) and WVNS (2005) Sr-90 fixed activity estimates.

Table IV-11: Tank 8D-2 Estimated Fixed Activity

Fixed Waste	WVNS 2002b		WVNS 2005		
	Total	Upper Bound	Best Estimate	Conser-vative	Worst Case
Sr-90	29,000	47,000	30,000	43,000	47,000
Cs-137	4,200	11,000	14,000	77,000	90,000

Both WVNS (2002) and WVNS (2005) utilized the same burnishing sample and beta-gamma detector results in their fixed activity estimates. WVNS (2002), Sections 5.3 and 5.4, describe the classical statistics methodology it used to calculate its fixed activity estimate. WVNS (2005), Section 6.3, describes its Monte Carlo methodology. Figure IV-3, which is a reproduction of WVNS (2005), Figure 21, shows the complementary cumulative distribution of the WVNS (2005) fixed inventory Monte Carlo results, while Table IV-12 is a tabulation of those results.

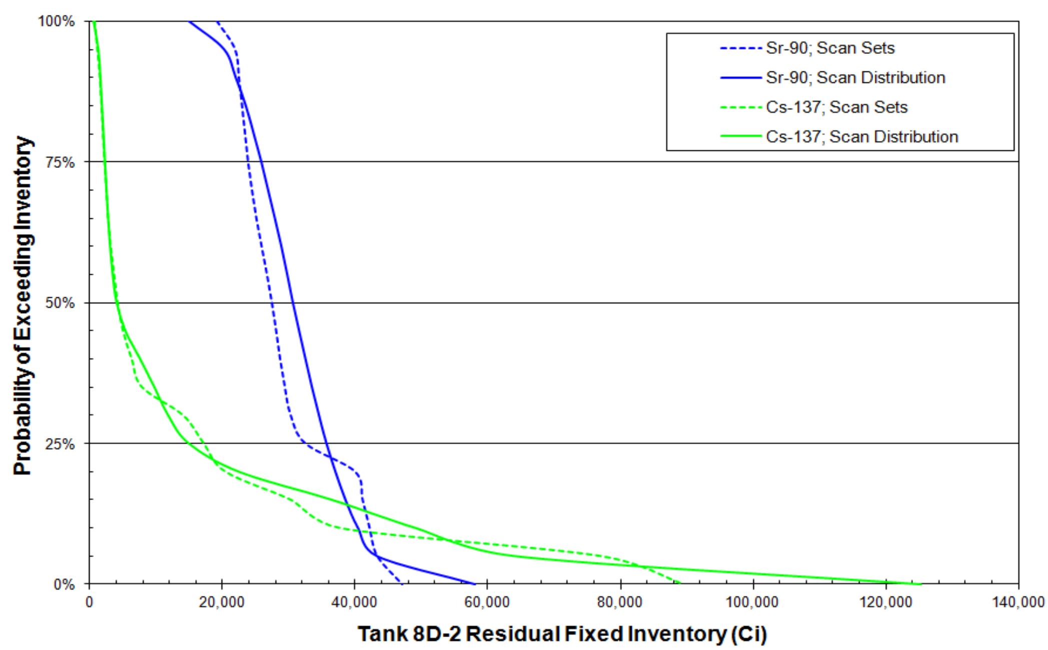

Figure IV-3: Complementary Cumulative Distribution of Sr-90 and Cs-137 Residual Fixed Inventory Estimates

Figure IV-3 shows that the WVNS (2005) fixed activity Monte Carlo results closely follow the scan results for both Sr-90 and Cs-137. However, there is much more variability in the Cs-137 results than in the Sr-90 results in the upper tail region of the curve. For example, the Sr-90 95th percentile is less than twice its 50th percentile (i.e., 43,300 Ci versus 27,400 Ci), whereas the Cs-137 95th percentile is more than an order of magnitude greater than its 50th percentile (i.e., 77,100 Ci versus 4,200 Ci), as shown in Table IV-12.

Table IV-12: WVNS, 2005 Sr-90 and Cs-137 Tank 8D-2 Fixed Activity		
Percentile	Fixed Activity (Ci)	
	Sr-90	Cs-137
Minimum	19,200	700
5%	21,900	1,100
10%	22,500	1,500
25%	23,900	2,200
50%	27,400	4,200
67.5%	29,800	11,000
70%	30,300	14,000
75%	32,500	17,200
90%	42,100	37,700
95%	43,300	77,100
Maximum	47,000	89,500

With reference to Table IV-10 and Table IV-11, the following observations can be made:

1. The total activities reported in WVNS (2002) for both Cs-137 and Sr-90 are close to the median (or 50th percentile) values generated from the WVNS (2005) Monte Carlo simulation.
2. The upper bound activities reported in WVNS (2002) are not consistently related to the Monte Carlo results, as the 47,000 Ci value reported for Sr-90 is equivalent to the maximum (100th percentile) Monte Carlo value, whereas the 11,000 Ci value for Cs-137 represents only the 67th percentile Monte Carlo value.
3. The values selected in WVNS (2005) are extremely conservative relative to the WVNS (2002) values and the Monte Carlo results. In particular, the 95th percentile values were selected as the conservative case values for both Sr-90 and Cs-137. Due to the curve shape within the upper tail section, this resulted in a very high value for Cs-137. In addition, even the best case values were set equal to the 70th percentile Monte Carlo values, well above the median values used in WVDP (2002). For both Sr-90 and Cs-137, the worst case values were the maximum (100th percentile) values from the Monte Carlo simulation.

Figure IV-4 [WVNS (2005), Figure 23, modified to include the median Cs-137 activity] shows that using the mean Cs-137 results tends to envelop the burnishing sample results, while the median results tend to fall within the burnishing sample results. To be conservative, WVNS (2005) used the mean Monte Carlo results.

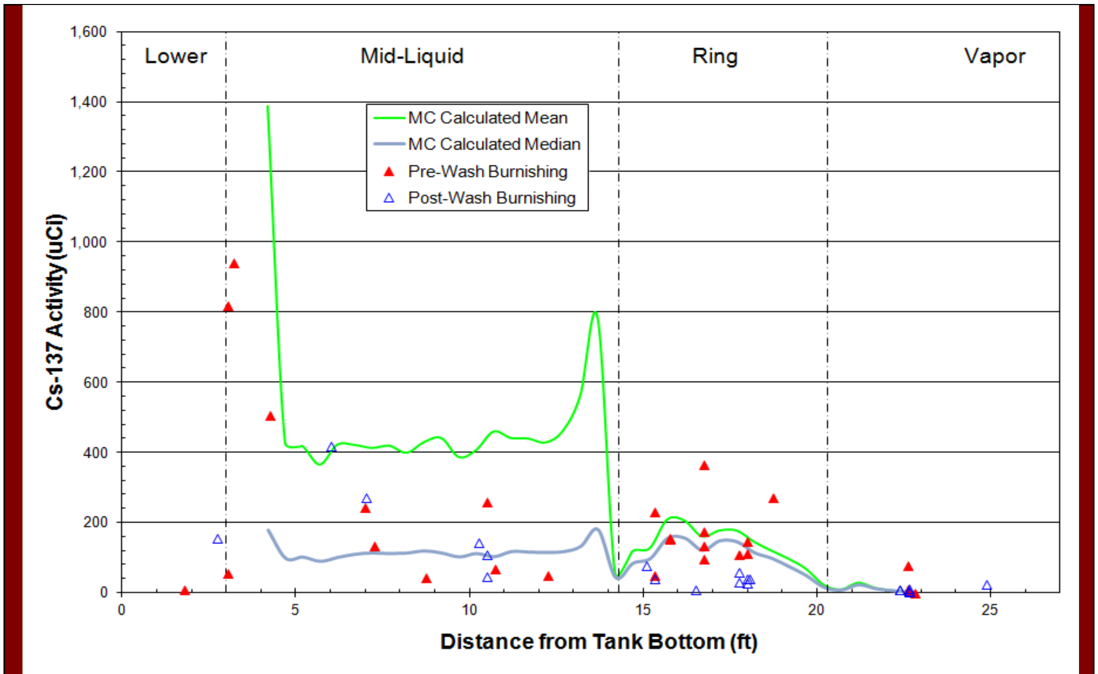

Figure IV-4: Comparison of Cs-137 Monte Carlo Results to Burnishing Samples

V. Summary of Results

A. State Licensed Disposal Area

The SDA inventory estimates presented in the following eight documents were reviewed:

1. Kelleher and Michael, 1973
2. O'Connell and Holcomb, 1974
3. EPA, 1977
4. Duckworth, 1981
5. Prudic, 1986
6. Envirosphere, 1986
7. WVNS, 1995a
8. URS, 2002

Two of the above eight estimates [O'Connell and Holcomb (1974) and EPA (1977)] simply repeated the estimates that were made by Kelleher and Michael (1973), and added no new information or data to the estimates. Two others [Duckworth (1981) and Envirosphere (1986)] built upon the Kelleher and Michael (1973) estimates by providing information and data on disposals that occurred after 1972 (i.e., for Trenches 12, 13, and 14). In most respects, these five documents can be thought of as variations of a single SDA inventory estimate, and that is what was done in the Section II.C and II.D SDA volume and activity comparisons.

Although Prudic (1986) presents some information on the volume of waste that was disposed in Trenches 8 through 14, that report is mostly interested in the groundwater hydrology and subsurface migration of radionuclides from the SDA. To this end, Prudic (1986) presents data on the radionuclide concentrations at various locations within and near the SDA but does not provide any information on the activity of the waste that was disposed within the SDA trenches. Although it does provide some useful information regarding the construction of the SDA disposal trenches and the procedures followed for the placement and covering of the waste, Prudic (1986) is not useful in obtaining an SDA activity estimate and was not included in the Section II.D SDA activity comparison.

WVNS (1995a) and URS (2002) were SDA inventory estimates that were developed in support of the 1996 DEIS and 2008 Revised DEIS. These two estimates are the most detailed of the SDA inventory estimates, in that they each provide a volume and activity estimate for each 50-foot segment of each trench. As explained in its introduction, one of the purposes for producing the URS (2002) SDA estimate was to correct deficiencies that had been identified with the WVNS (1995a) estimate. For example, URS (2002) states the following about the WVNS (1995a) study: in "*many cases, the wastes assigned to a single shipment number were from more than one generator; however, only one waste profile was assigned to each shipment (each database record).*" To help accomplish the project goal, URS (2002) included 33 waste profiles, whereas WVNS (1995a) used only 16 waste profiles.

Four SDA waste volume estimates were compared: the combined Kelleher and Michael (1973), Duckworth (1981), and Envirosphere (1986) (K&M,D,E) estimates; Prudic (1986);

WVNS (1995); and URS (2002). As Table II-13 shows, there is only a 3.5% difference between the largest SDA volume estimate [i.e., 2,370,000 ft^3, Prudic (1986)] and the smallest [2,290,000 ft^3, WVNS (1995)]. However, an inter-trench comparison of the WVNS (1995) and URS (2002) volumes revealed differences in the placement of the waste within the SDA, as shown in Figure II-13. Some of these differences can be explained by the fact that one estimate put the waste in one trench segment and the other estimate put the same waste in a neighboring trench segment. For example, see Trench 2, Segments 100-149 and 150-199, and Segments 200-249 and 250-299 in Figure II-13. Other differences are not so easily explained, e.g., the over 25,000 ft^3 greater volume for Trench 5, Segment 50-99, estimated by URS (2002).

Section II.D compared three SDA waste activity estimates: the combined Kelleher and Michael (1973), Duckworth (1981), and Envirosphere (1986) (K&M,D,E) estimates; WVNS (1995); and URS (2002). As documented in Table II-15, quite a few differences were identified between the three estimates. The Section II.D subsections describe these differences and attempt to identify a reason for them. Perhaps the largest difference is in the URS (2002) Sr-90 activity estimate, which is about two orders of magnitude lower than the other two estimates. Although URS (2002), Section 2.3.6.5, discusses the Sr-90 waste that was sent to the SDA from the Martin Marietta, Quehanna, Pennsylvania, facility, it does not seem to have included that waste in its activity estimate.

Nonetheless, based on the overall comparison results, as well as the additional waste profiles that were used, it is believed that URS (2002) provides the best estimate of the SDA inventory for use in the Phase I studies, with the exception of the Sr-90 activity. Before URS (2002) is used in these studies, it is recommended that its Sr-90 activity estimate be revised to specifically include the 1966–1967 waste shipments from the Martin Marietta, Quehanna, Pennsylvania, facility. This conclusion is consistent with Garrick et al. (2009, page 4-4), which identified URS (2002) as the "*most comprehensive and detailed*" effort to "*identify and characterize the inventories of wastes that are buried in the 14 SDA trenches*."

B. NRC-Licensed Disposal Area

The NDA inventory estimates presented in the following documents were reviewed:

1. Kelleher and Michael, 1973
2. Duckworth, 1981
3. Nicholson and Hurt, 1985
4. Ryan, 1992
5. WVNS, 1995b (and DOE and NYSERDA, 1996)
6. SAI, 1983, and PNL, 1992
7. URS, 2000

The NDA inventory estimates can be broken into two groups: those that were made prior to the PNL (1992) ORIGEN2 runs and those that were made after. The estimates that were made prior to PNL (1992) were usually based on disposal records and, therefore, were limited to those radionuclides included in the records. As was the case for the SDA, the Duckworth (1981) estimate extends the Kelleher and Michael (1973) estimate beyond 1972; therefore, these two estimates are considered the same (unless otherwise indicated).

Nicholson and Hurt (1985) was part of an NRC research project to study the characteristics of the NDA. The inventory estimate was only one part of Nicholson and Hurt (1985), which also contained information and data on the NDA site geology, geomorphic conditions, and groundwater transport. Regarding the NDA inventory estimate, Nicholson and Hurt (1985) made adjustments to the Duckworth (1981) estimate based on the results of ORIGEN computer calculations for "generic" NPR and LWR fuel.

WVNS contracted with PNL to develop the Ryan (1992) NDA inventory estimates. Three documents appear as the basis for the Ryan (1992) estimates: Duckworth (1981); PNL (1992); and DOE (1979). For the most part, Ryan (1992) does not provide a radionuclide breakdown of his NDA activity estimate but rather groups his estimates into activation products, fission products, and actinides. Ryan (1992) does break down the activity estimates by waste category, with hulls and hardware being by far the largest contributor at about 94% of the total activity.

Although it was made after PNL (1992), and states that document was used in its development, WVNS (1995b) offers no information on specific radionuclide activities in the NDA other than to identify the nine largest contributors: Cs-137, Ba-137m, Co-60, Eu-154, Ni-63, Pu-238, Pu-241, Sr-90, and Y-90. Another shortcoming of WVNS (1995b), as identified in Section III, is the fact that the same activity is estimated for waste containers of different sizes, containing different types of waste, and with widely ranging dose rates (see the Table III-14 discussion, page 43). WVNS (1995b), Appendix B, provides a useful disposal hole-by-hole inventory of where the waste associated with each disposal record was buried.

Because DOE and NYSERDA (1996), Table C-9, attributes its NDA radionuclide breakdown to WVNS (1995b), it has been included in the WVNS (1995b) evaluation. However, no evidence could be found that would establish a connection between WVNS (1995b) and DOE and NYSERDA (1996), notwithstanding a footnote to Table C-9 attributing the data to WVNS (1995b). On the contrary, what evidence there is seems to indicate that there is no connection between WVNS (1995b) and DOE and NYSERDA (1996), Table C-9. For example, when the DOE and NYSERDA (1996), Table C-9, activities are decay-corrected to January 1, 1993, the total DOE and NYSERDA (1996) activity of 230,000 Ci is less than half of the total WVNS (1995b) activity of 679,000 Ci. Also, some of the nine radionuclides that WVNS (1995b) identifies as major contributors to the total activity are either not included in DOE and NYSERDA (1996), Table C-9 (e.g., Ni-63), or are present in only small amounts (e.g., Eu-154, Pu-238).

Although technically they are not NDA inventory estimates, SAI (1983) and PNL (1992) have been included in this review of NDA activity estimates. SAI (1983) uses NFS nuclear materials management reports for each campaign to document the mass of uranium and plutonium entering and leaving the reprocessing plant, including the amount transferred to the NDA with the hulls. Likewise, PNL (1992) uses the ORIGEN2 computer program to estimate the specific activation products, fission products, and transuranics contained within each of the spent fuel reprocessing campaigns conducted by NFS. Together, these two reports were used to estimate the activity that was sent from the onsite reprocessing plant to the NDA.

At least partly because of the difficulty in connecting the DOE and NYSERDA (1996), Table C-9, NDA activities to the WVNS (1995b) estimate, DOE and NYSERDA requested that a new inventory (URS, 2000) be prepared. In developing its NDA activity estimates, URS (2000) relied heavily on SAI (1981) and PNL (1992). Thus, it is not surprising that the URS (2000) NDA activity estimates agree with the activities provided in PNL (1992); e.g., see Table III-25 and Table III-30.

Figure III-2 [which was developed for this report from URS (2000) support files] shows the URS (2000) estimated NDA disposal volume as a function of time. Table III-21 shows that there is good agreement between the URS (2000) time-varying volume estimate and the NDA volume estimates made in Kelleher & Michael (1973), Nicholson and Hurt (1985), Duckworth (1981), and WVNS (1995b).

It is concluded that the NDA activity comparison performed in Section III.D supports the continued use of the URS (2000) inventory estimate. As indicated in Section III.D.3, specific concerns have been previously expressed regarding the NDA plutonium inventory. The investigations performed for this study conclude that the plutonium activities provided in DOE and NYSERDA (1996), Table C-9, are an error, and that, as Table III-27 shows, there is substantial agreement between the other NDA plutonium activity and/or mass estimates. A 2008 Revised DEIS commenter similarly stated: "*My educated guess is that the 2600-curie figure* [from DOE and NYSERDA (1996), Table C-9] *for Pu-239 is an error*." (DOE and NYSERDA, 2010, Volume 3, Commenter No. 110: Raymond C. Vaughan, PhD)

C. Waste Tank Farm

For the WTF, the activity estimates from only two documents were compared: WVNS (2002) and WVNS (2005). Both of these documents were prepared in support of the EIS (DOE/EIS-0226). After WVNS (2002) was prepared and comments were received back from the reviewing agencies, including requests for additional clarification regarding specific technical issues, the determination was made to prepare a supplemental report that addressed the comments and requests. That supplemental report is WVNS (2005).

Table IV-7 and Table IV-8 compare the WVNS (2002) and WVNS (2005) Tank 8D-1 and Tank 8D-2 activity estimates, respectively. Those tables show that, with three exceptions, there is good agreement between the two WTF estimates. The three exceptions are: (1) the I-129 activity in both tanks, (2) the Tank 8D-1 plutonium activities, and (3) the Cs-137 activity in Tank 8D-2.

As described in Section IV.C.1, the difference in the I-129 activity estimates is due primarily to the WVNS (2005) use of sampling results that were not available to WVNS (2002). The Tank 8D-1 plutonium activity difference is due to a different (more realistic) method for calculating the Tank 8D-1 fixed inventory used by WVNS (2005), as described in Section IV.C.2. Finally, as described in Section IV.C.3, the Cs-137 Tank 8D-2 activity difference is due to the selection of highly conservative values of fixed Cs-137 activity in WVNS (2005) based on the results of a Monte Carlo simulation.

Based on this discussion and the Section IV.C comparisons, it is recommended that WVNS (2005) be used as the source of the Tank 8D-1 and Tank 8D-2 activities. As indicated in Section IV, CH2MHILL · B&W West Valley (2012) should be used for the Tank 8D-4 activity.

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