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3. System Monitored Geologic Repository	4. Document Identifier 000-PSA-MGR0-01800-000-00A
5. Title Waste Form Throughputs for Preclosure Safety Analysis	
6. Group Preclosure Safety Analyses	
7. Document Status Designation ☐ Preliminary ☒ Committed ☐ Confirmed ☐ Cancelled/Superseded	
8. Notes/Comments	

Attachments	Total Number of Pages
Attachment A – Mathcad Calculations	8

RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. EGS (Print/Sign/Date)	16. Approved/Accepted (Print/Sign/Date)
00A	Initial Issue	36	A-8	P. Macheret P. Macheret 10/31/07	G. Waldman G. Waldman 10/31/07	M. Frank [signature] 10/31/07	M. Wisenburg [signature] 10/31/2007

DISCLAIMER

The calculations contained in this document were developed by Bechtel SAIC Company, LLC (BSC) and are intended solely for the use of BSC in its work for the Yucca Mountain Project.

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TABLES

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ACRONYMS AND ABBREVIATIONS

BSC	Bechtel SAIC Company
BWR	boiling water reactor
CRCF	Canister Receipt and Closure Facility
DHLW	Defense High-Level Waste
DIRS	Document Input Reference System
DOE	Department of Energy
DPC	dual-purpose canister
HLW	high-level waste
IHF	Initial Handling Facility
MCO	multi-canister overpack
MTHM	metric ton of heavy metal
PWR	pressurized water reactor
SNF	spent nuclear fuel
TAD	transport, aging, and disposal
WHF	Wet Handling Facility

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1. PURPOSE

Per 10 CFR 63.2 (Reference 2.2.1), an event sequence is a series of actions and/or occurrences within the natural and engineered components of a repository that could potentially lead to exposure of individuals to radiation; an event sequence includes one or more initiating events and associated combinations of repository system component failures, including those produced by the action or inaction of operating personnel. Event sequences are considered for the waste handling activities that take place before permanent closure of the repository.

In the preclosure safety analysis, event sequences are individualized according to several parameters. Namely, an event sequence is developed for the specific configuration a given waste form takes during an operational activity in a given operational area. In particular, the following general operational areas are considered:

- The subsurface facility
- The Initial Handling Facility (IHF)
- The Receipt Facility
- The Wet Handling Facility (WHF)
- The Canister Receipt and Closure Facility (CRCF) (3 separate buildings considered as a whole in this calculation)
- The intra-site operations and balance of plant.

An event sequence is also individualized to a particular waste form configuration, as follows:

- Waste package
- Naval canister, by itself or in a transportation cask
- High-level waste (HLW) canister, by itself or in a transportation cask
- Department of Energy (DOE) standardized canister, containing DOE-owned Spent Nuclear Fuel (SNF), by itself or in a transportation cask
- DOE multi-canister overpack (MCO), by itself or in a transportation cask
- Transport, aging, and disposal (TAD) canister, by itself, in a transportation cask, or in an aging overpack
- Dual-purpose canister (DPC), by itself, in a transportation cask, a horizontal shielded transfer cask, or an aging overpack
- Transportation cask containing bare SNF assemblies,
- SNF assembly (when handled directly).

Over the preclosure period, the expected (i.e., mean) number of occurrences of an event sequence associated with a given waste form configuration in a given operational area is proportional to the expected number of waste forms in that configuration and in that area. The purpose of this calculation is to provide the breakdown of these numbers, also designated as throughputs, for each general operational area and associated waste form configuration. The scope of the calculation is limited to providing the throughputs over the entire preclosure period; therefore, no breakdown per individual year is given. Also, these throughputs do not include low-level waste, and are only intended for use in the preclosure safety analysis.

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2.3 DESIGN CONSTRAINTS

None.

2.4 DESIGN OUTPUTS

This calculation provides inputs to the preclosure safety analysis.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

None.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1. Capacity of Transportation Casks Containing DOE standardized canisters with a Diameter of 24 Inches

Assumption: Transportation casks containing DOE standardized canisters with a diameter of 24 inches have a capacity of five canisters per cask.

Rationale: 24 inches is the diameter of HLW canisters (Reference 2.2.2, Section 11.2.2.7). Based on Reference 2.2.3 (Table C-1) rail-based transportation casks loaded with HLW canisters have a capacity of five canisters. Assuming the same capacity for transportation casks loaded with 24-inch diameter DOE standardized canisters is therefore acceptable.

3.2.2. Preferred Mode of Delivery of Transportation Cask Containing HLW Canisters

Assumption: HLW canisters are mostly delivered to the repository in rail-based transportation casks.

Rationale: HLW canisters could be delivered to the repository in truck-based or rail-based transportation casks. Based on Section 3.2.1.2 of Reference 2.2.2, truck-based transportation casks contain one HLW canister. A value of five HLW canisters per rail-based transportation cask, based on Table C-1 of Reference 2.2.3, is deemed representative and suitable for use in this calculation. Given the large number of HLW canisters, it is operationally more efficient to use rail-based transportation casks to deliver HLW canisters to the repository.

3.2.3. Staging of HLW Canisters inside Canister Receipt and Closure Facility

Assumption: In a CRCF, four of the five HLW canisters from a rail-based transportation cask are directly loaded into a waste package, the remaining fifth HLW canister is first staged before being loaded into a waste package.

Rationale: As indicated in Sections 3.2.2 and 6.1.3, the capacity of rail-based transportation casks loaded with HLW canisters is five canisters per cask, which is also the capacity of the 5-DHLW/DOE SNF co-disposal waste packages that are loaded with an 18-inch diameter DOE standardized canister in the central position. However, Section 6.1.3 also indicates that such waste packages have only a capacity of four HLW canisters if they are loaded with a 24-inch diameter DOE standardized canister. Finally, 2-MCO/2-DHLW co-disposal waste packages have a capacity of two HLW canisters per waste package (Section 6.1.3). As a consequence, it may not be possible to directly transfer all five HLW canisters from a transportation cask to a waste package in a CRCF; some of the HLW canisters may require staging first. More precisely, Table 3 shows that there are 3,300 5-DHLW/DOE SNF co-disposal waste packages, a much greater number than the 225 2-MCO/2-DHLW co-disposal waste packages. Also, based on Table 1, there are significantly more DOE standardized canisters with a diameter of 18 inches than canisters with a diameter of 24 inches. Therefore, it is anticipated that most HLW canisters could be directly transferred from a transportation cask to a waste package. Only a small fraction would require staging. To preserve flexibility in the conduct of operations by allowing a significant fraction of HLW canisters to be staged, it is assumed that four canisters per transportation cask undergo a direct transfer; the fifth one is staged. This corresponds to 20 percent of HLW canisters in the CRCFs undergoing staging, a significant fraction deemed to be conservative.

4. METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation is prepared in accordance with EG-PRO-3DP-G04B-00037 (Reference 2.1.1) and LS-PRO-0201 (Reference 2.1.2). The *Quality Management Directive* (Reference 2.1.4, Section 2.1.C.1.1.a.iii and 17.E) applies to this analysis and the final version is designated as QA: QA because it is part of the preclosure safety analysis.

4.2 USE OF SOFTWARE

Mathcad version 13.0 is used in this calculation. The use of this software is classified as Level 2 per procedure, IT-PRO-0011 (Reference 2.1.3, Attachment 12) and therefore the software does not need to be qualified. Mathcad is employed to conduct the calculations of probability distributions and is suitable for use in this document. The results of the Mathcad calculations are verified by visual inspection of the computer-generated results shown in Attachment A. Mathcad is installed on a Dell Optiplex 745 operated under Microsoft Windows XP Professional version 5.1.2600 Service Pack 2 Build 2600. All other calculations within the text were performed by hand.

4.3 THROUGHPUT CALCULATION METHODOLOGY

The purpose of this calculation is to provide throughputs for the waste form configurations and the general operational areas outlined in Section 1. Starting with projected waste streams, a conservative derivation of the throughputs for the various waste form configurations that will be handled is first carried out (Section 6.1). The conservatism in the derivation is introduced to ensure that the calculated values encompass the actual throughputs that will be recorded at the repository. Then, the throughputs are particularized to each relevant operational area (Section 6.2). The throughputs are developed such that they embed several scenarios that allow for some flexibility in the conduct of operations. For example, it is considered that all TAD canisters that are shipped to the repository could be delivered to the Receipt Facility, or, alternatively, to a CRCF. This approach is bounding and may consequently inflate the number of estimated handlings. In reality, a transportation cask loaded with a TAD canister will be delivered to a single facility, namely the Receipt Facility, or one of the CRCFs. Stated otherwise, the scenarios where shipped TAD canisters are all delivered to the Receipt Facility or all delivered to a CRCF are mutually exclusive. As a consequence, throughputs particularized to a given operational area are to be considered independently and should not be summed together. Summing them may cause double counting (for example a transportation cask loaded with a TAD canister is processed both in the Receipt Facility and in a CRCF).

There are inherent uncertainties in the number of waste form containers and SNF assemblies that will be shipped to or handled at the repository. These uncertainties are modeled with probability distributions. The probability distributions are evaluated with Monte Carlo simulations, which consist of pulling random samples from the subject distributions. Combining these samples as needed makes it possible to obtain probability distribution representations for a given waste form configuration. The throughputs are then derived as the expected value (i.e., mean) of the distribution. The choice of the mean to characterize the throughputs is based on the definition of the category of an event sequence. Based on 10 CFR 63.2 (Reference 2.2.1), Category 1 event sequences are those event sequences that are expected to occur one or more times before permanent closure of the repository; Category 2 event sequences are other event sequences that have at least one chance in 10,000 of occurring before permanent closure. Thus, calling N the expected number of occurrences of an event sequence before permanent closure, a value of N greater than or equal to 1 implies that the event sequence is Category 1; a value of N less than 1 indicates that the event sequence is Category 2, if its probability of occurrence before permanent closure, p, is greater than or equal to 10^{-4}. The relationship between N and p is modeled using a Poisson distribution; the probability that the event sequence occurs at least once before permanent closure is $p = 1 - \exp(-N)$ (Reference 2.2.14, p. A-13). With this formula, a value of p equal to 10^{-4} implies that N also has a value of 10^{-4}. N can thus be used as the sole metric to categorize an event sequence. An event sequence is Category 2 if N is greater than or equal to 10^{-4} but less than 1, and it is Category 1 if N is greater than or equal to 1. The value of N is directly proportional to the expected throughput for the waste form configuration and the operational area of the event sequence, hence justifying the use of means to characterize throughputs.

In conclusion, the throughputs developed for the preclosure safety analysis are based on expected values of conservatively derived distributions and enveloping waste handling scenarios. As a consequence, the throughputs are conservative values that are not anticipated to be exceeded.

5. LIST OF ATTACHMENTS

6. BODY OF CALCULATION

6.1 DERIVATION OF THROUGHPUTS PER WASTE FORM CONFIGURATION

Based on Section 2.2.1.1 of Reference 2.2.2, the repository is designed to accept 70,000 metric tons of heavy metal (MTHM) or the equivalent of SNF/HLW for disposal in the repository, allocated as follows:

- 63,000 MTHM of commercial SNF and HLW
- 4,667 MTHM of defense HLW
- 2,333 MTHM of DOE SNF and naval SNF.

Based on Reference 2.2.16 (Section 3.2), about 2 percent of the 2,333 MTHM of DOE SNF consists of SNF of commercial origin that may be delivered to the repository in an uncanistered form. This corresponds to $0.02 \times 2,333 = 47$ MTHM of DOE-owned SNF of commercial origin, an amount that is marginal compared to the 63,000 MTHM of commercial SNF (not DOE owned), and encompassed in the throughput for the waste form configurations associated with commercial SNF, which is conservatively evaluated in this calculation.

The partitioning of the MTHM numbers to a count of individual types of waste forms is performed in the following subsections.

6.1.1. Waste Form Configurations Associated with Naval Spent Nuclear Fuel

Based on Section 3.2.1.6 of Reference 2.2.2, the maximum number of naval canisters is 400. Given that there is one naval canister per transportation cask (Reference 2.2.2, Section 3.2.1.2) and per waste package (Reference 2.2.6 and Reference 2.2.7), the number of transportation casks and waste packages containing a naval canister is also 400. This number is bounding and no probability distribution around it was developed.

6.1.2. Waste Form Configurations Associated with Multi-Canister Overpacks and DOE Standardized Canisters

Reference 2.2.8 (p. F-4) provides an estimate of the count of MCOs and DOE standardized canisters to be delivered to the repository. This information is suitable for use in this calculation because it amounts to a DOE SNF inventory of around 2,400 MTHM (Reference 2.2.8, p. 39), which is a little greater than the 2,333 MTHM allocation shown at the beginning of Section 6.1, and is therefore conservative (i.e., it overestimates the actual amount of DOE SNF).

The canister count provided by Reference 2.2.8 is summarized in Table 1, where the number of DOE standardized canisters is further partitioned into four groups, corresponding to the possible nominal dimensions of such canisters, namely: 1) 18-inch diameter and 10-foot length, 2) 18-inch diameter and 15-foot length, 3) 24-inch diameter and 10-foot length, and 4) 24-inch diameter and 15-foot length. As explained in Reference 2.2.8 (p. 40), there are numerous uncertainties that could significantly affect the number of canisters, which justifies the provided canister count in the form of a point estimate within a range (i.e., a minimum value and maximum value).

Table 1. Count of MCOs and DOE Standardized Canisters

Canister Type	Canister Count		
	Minimum Value	Point Estimate	Maximum Value
MCO	300.4	419.0	600.9
18-inch × 10-foot DOE Standardized Canister	1,026.4	1,431.5	2,052.9
18-inch × 15-foot DOE Standardized Canister	1,035.2	1,443.8	2,070.4
24-inch × 10-foot DOE Standardized Canister	118.5	165.3	237.1
24-inch × 15-foot DOE Standardized Canister	19.4	27.0	38.7

SOURCE: Reference 2.2.8, p. F-4.

Reference 2.2.8 does not associate probability distributions with the ranges shown in Table 1, nor does it say if the point estimates represent means or medians, which prevents their use in a distribution determination. Therefore, only the minimum and maximum values are used as inputs to characterize the distribution associated with the count of each canister type. The distribution selected is the uniform distribution. This conforms to the distribution that would be employed based upon the maximum entropy method. As explained in Reference 2.2.9 (p. 102), this method provides a distribution which accounts for known constraints (here, the bounds of the distribution), but apart from that is as vague (i.e., noninformative) as possible to avoid injecting unwarranted information into the distribution. In the present case, the maximum-entropy distribution is a uniform distribution whose bounds are the minimum and maximum values (Reference 2.2.9, Table 2).

Using a uniform distribution, the mean number of canisters (which is also the median) is calculated as the arithmetic average of the minimum and maximum counts. Using the values of Table 1, the mean value is always found to be greater than the point estimate (for example, in the case of MCOs, the mean value is $0.5 \times [300.4 + 600.9] = 450.7$, and the point estimate 419.0). Given that a point estimate value typically is a representation of a mean or a median, this is an indication that the uniform distribution selected for representing MCO and DOE standardized canister counts is conservative, i.e., it overestimates the actual number of canisters.

MCOs and DOE standardized canisters are delivered to the repository within transportation casks. Based on Reference 2.2.3 (Table C-1), transportation casks loaded with MCOs have a capacity of four canisters per cask, and transportation casks loaded with 18-inch diameter DOE standardized canisters have a capacity of nine canisters per cask. This input is suitable for use in this calculation because it provides a representative capacity for these transportation casks. Finally, based on Assumption 3.2.1, transportation casks loaded with 24-inch diameter DOE standardized canisters have a capacity of five canisters per cask.

Considering that transportation casks are loaded with a unique type of canister, the probability distribution on the number of transportation casks loaded with MCOs is uniform, with bounds being one-fourth of the bounds given in Table 1 (since there are four MCOs per transportation cask). Similarly, the probability distributions on the number of transportation casks loaded with 18-inch diameter DOE standardized canisters are uniform, with bounds being one-ninth of the bounds given in Table 1 (since there are nine such canisters per transportation cask), and the probability distributions on the number of transportation casks loaded with 24-inch diameter

DOE standardized canisters are uniform, with bounds being one-fifth of the bounds given in Table 1 (since there are five such canisters per transportation cask).

MCOs and DOE standardized canisters are co-disposed with HLW canisters in waste packages. To calculate the distribution of the numbers of such waste packages, it is first necessary to evaluate the number of HLW canisters (Section 6.1.3).

6.1.3. Waste Form Configurations Associated with High-Level Waste Canisters

Reference 2.2.15 (Table 4-1) provides an estimate of the count of HLW canisters, given as 5,413 HLW "long" canisters and 3,921 HLW "short" canisters. This information is suitable for use in this calculation because it amounts to a total of 4,667 MTHM (Reference 2.2.15, p. 13), which conforms to the allocation shown at the beginning of Section 6.1. The conversion of the total number of canisters (5,413 + 3,921 = 9,334) to 4,667 MTHM is based on 0.5 MTHM per canister (Reference 2.2.15, p. 13).

To ensure that the throughputs of the waste form configurations associated with HLW canisters encompass the actual throughputs that will be recorded at the repository, a conservative probability distribution is assigned to the numbers above. The number of HLW canisters (from a given provenance) is considered to be uniformly distributed, with the lower bound equal to the nominal value, and the upper bound equal to 110 percent of that value (therefore, the mean of the distribution is equal to 105 percent of the nominal value). This 10 percent variability above the nominal HLW canister count is selected to account for the fact that the actual number of HLW canisters to be delivered to the repository, while still unknown at this time, is likely to be higher than the nominal count, given the large amount of HLW that might require disposal.

HLW canisters could be delivered to the repository either in truck-based or rail-based transportation casks. Based on Assumption 3.2.2, rail-based transportation casks will be the preferred mode of delivery of HLW canisters. Consequently, only rail-based transportation casks are considered in the rest of this section (truck-based transportation casks are considered only as an alternative mode of delivery of HLW canisters to the IHF: see Section 6.2.1). Based on Table C-1 of Reference 2.2.3, a value of five HLW canisters per rail-based transportation cask is deemed representative and therefore suitable for use in this calculation. Allowing a rail-based transportation cask to be loaded with only one type of HLW canister (i.e., according to its provenance), the probability distribution on the number of transportation casks is uniform, with bounds equal to one-fifth of the bounds of the distribution for that type of HLW canister (since there are five such canisters per rail-based transportation cask).

MCOs and DOE standardized canisters are co-disposed with HLW canisters in waste packages, as follows:

- The 5-DHLW/DOE SNF long co-disposal waste package (Reference 2.2.4) holds five HLW long canisters and an 18-inch × 15-foot DOE standardized canister in the center position, or, alternatively, four HLW long canisters and a 24-inch × 15-foot DOE standardized canister in a side position.

- The 5-DHLW/DOE SNF short co-disposal waste package (Reference 2.2.5) holds five HLW short canisters and an 18-inch × 10-foot DOE standardized canister in the center position, or, alternatively, four HLW long canisters and a 24-inch × 10-foot DOE standardized canister in a side position.

- The 2-MCO/2-DHLW waste package (Reference 2.2.10) holds two MCOs and two HLW long canisters.

The probability distribution for the number of co-disposal waste packages is evaluated based on the distributions of the canisters they hold and under the premise that, to the extent possible, a waste package will be loaded at full capacity. This leads to the following considerations:

- There are significantly less MCOs than HLW canisters. Therefore, the probability distribution on the number of 2-MCO/2-DHLW waste packages is controlled by the distribution on the number of MCOs. Specifically, the distribution of such waste packages is uniform, with bounds being 0.5 of the bounds of the distribution of the number of MCOs.

- There are significantly less DOE standardized canisters than HLW canisters. However, when accounting for the capacity of co-disposal waste packages, which can hold four to five times more HLW canisters than DOE standardized canisters, the probability distribution of the numbers of 5-DHLW/DOE SNF co-disposal waste packages is essentially controlled by the number of standardized canisters. This shows that a number of co-disposal waste packages would be loaded with one DOE standardized canister and no HLW canister.

6.1.4. Waste Form Configurations Associated with Commercial Spent Nuclear Fuel

Reference 2.2.11 (Table 5) provides an estimate of the count of commercial pressurized water reactor (PWR) and boiling water reactor (BWR) SNF assemblies that are anticipated to be delivered to the repository, along with the count of TAD canisters, DPCs, and transportation casks with bare SNF that are expected to transport them. This information is suitable for use in this calculation because it amounts to 63,000 MTHM of commercial SNF (Reference 2.2.11, p. 11), which conforms to the allocation shown at the beginning of Section 6.1. Furthermore, the commercial SNF assembly breakdown provided corresponds to a “10% bare commercial SNF” scenario, meaning that approximately 10 percent of the commercial SNF assemblies are delivered in containers other than TAD canisters (Reference 2.2.11, p. 19). This scenario conforms to the requirements of Reference 2.2.2 (Section 2.2.1.3). The count provided by Reference 2.2.11 is summarized in Table 2.

Table 2. Breakdown of “10% Bare Commercial SNF” Waste Stream

	Transportation Cask with Bare SNF		DPC with Bare SNF		TAD Canister	
	BWR	PWR	BWR	PWR	BWR	PWR
Casks/Canister	696	1,980	22	260	2,748	3,813
Assemblies	6,057	7,862	1,389	6,419	120,699	80,022

SOURCE: Reference 2.2.11, Table 5

The numbers from Table 2 are representative of a typical waste stream for commercial SNF. To allow for flexibility in the conduct of operations at the repository, key parameters are allowed to have a range of variation (modeled by probability distributions), based on the following considerations:

- The total number of BWR and PWR SNF assemblies is considered to be uniformly distributed around its nominal value, i.e., 6,057 + 1,389 + 120,699 = 128,145 for BWR SNF assemblies, and 7,862 + 6,419 + 80,022 = 94,303 for PWR SNF assemblies (Table 2), with the lower bound equal to 90 percent of the nominal value, and the upper bound equal to 110 percent of that value. This 10 percent variability around the nominal value is regarded as a reasonable representation of the uncertainty around the actual number of SNF assemblies that will be delivered to the repository. A precise knowledge of this uncertainty, however, is not important because this calculation focuses on mean throughputs, which are insensitive to the spread of the uncertainty distribution considered here. In addition, no conservatism is introduced in this distribution, contrary, for example, to the approach that was taken to model the probability distribution on the number of HLW canisters in Section 6.1.3. The reason for this difference in approach is that this distribution is used as a basis upon which subsequent conservatisms will be introduced to model the probability distributions of the numbers of DPCs, bare-SNF transportation casks, and TAD canisters shipped to the repository. It is therefore unnecessary to introduce conservatisms at this level.

- Based on Table 2, shipped BWR and PWR TAD canisters are respectively loaded with an average of 120,699/2,748 = 44 BWR SNF assemblies, and 80,022/3,813 = 21 PWR SNF assemblies (values rounded up to the next integer). This is the maximum capacity of such canisters (Reference 2.2.2, Section 11.2.2.1). It is anticipated that TAD canisters produced at the repository will also be loaded at full capacity.

- Based on Table 2, the fraction of BWR and PWR SNF assemblies respectively shipped to the repository in TAD canisters is 120,699/128,145 = 0.94 for BWR SNF assemblies, and 80,022/94,303 = 0.85 for PWR SNF assemblies. Following a conservative approach that will yield an average number of BWR and PWR SNF assemblies shipped in TAD canisters encompassing the number shown in Table 2, this fraction is considered to be uniform, with a lower bound equal to its nominal value, and an upper bound equal to 1. Therefore, an average of (94 + 100)/2 = 97 percent of BWR SNF assemblies and (85 + 100)/2 = 92.5 percent of PWR SNF assemblies are considered to be shipped in TAD canisters. This approach inflates the number of TAD canisters shipped to the repository. The throughput for shipped BWR and PWR TAD canisters is calculated as the product of the number of BWR or PWR SNF assemblies shipped in TAD canisters, multiplied by the applicable fraction above, and divided by 44 and 21, respectively. The number of shipped TAD canisters is then calculated as the sum of BWR and PWR TAD canisters. Because there is one TAD canister per transportation cask, the number of transportation casks containing a TAD canister is equal to the number of shipped TAD canisters.

- Based on Table 2, the fraction of BWR and PWR SNF assemblies respectively shipped to the repository in containers other than TAD canisters (i.e., DPCs or bare-SNF transportation casks) is (6,057 + 1,389)/128,145 = 0.06 for BWR SNF assemblies, and (7,862 +6,419)/94,303 = 0.15 for PWR fuel assemblies. Following a conservative approach that will yield an average number of SNF assemblies shipped in DPCs or bare-SNF transportation casks encompassing the actual number shown in Table 2, this fraction is considered to be uniform, with a lower bound equal to its nominal value, and an upper bound equal to 0.2. The 0.2 value is deemed a reasonable upper bound; a higher value may not be realistic as it would result in SNF assembly throughputs that a single WHF may not be able to process. For simplicity, the 0.2 upper bound is applied irrespective of the type of SNF assemblies (BWR or PWR). Therefore, an average of (6 + 20)/2 = 13 percent of BWR SNF assemblies and (15 + 20)/2 = 17.5 percent of PWR SNF assemblies are considered to be shipped in DPCs or bare-SNF transportation casks. This approach inflates the number of SNF assemblies processed in the pool of the WHF and the number of TAD canisters subsequently produced at the repository. The number of BWR and PWR SNF assemblies processed in the pool of the WHF is calculated as the product of the total number of BWR or PWR fuel assemblies, multiplied by the applicable fraction above. The number of produced BWR or PWR TAD canisters is the number of BWR or PWR fuel assemblies processed in the pool of the WHF, divided by 44 and 21, respectively. The number of TAD canisters produced at the repository is then calculated as the sum of produced BWR and PWR TAD canisters.

- The two previous bullets correspond to two different scenarios of delivery of commercial SNF to the repository. These scenarios have different objectives: one inflates the number of TAD canisters shipped to the repository, the other inflates the number of SNF assemblies processed and TAD canisters produced at the repository. Although in reality only one of these scenarios will be realized, both are considered simultaneously in this calculation to preserve flexibility in the conduct of operations. The total number of TAD canisters is calculated as the sum of the number of TAD canisters shipped to or produced at the repository. Given the conservatisms introduced in the evaluation of these numbers, the total TAD canister count amounts to more than 63,000 MTHM of commercial SNF. Because the capacity of a waste package is one TAD canister (Reference 2.2.12), the number of waste packages loaded with a TAD canister is also equal to the total number of TAD canisters.

- Based on Table 2, the average capacity of a transportation cask with bare BWR or PWR SNF assemblies is 6,057/696 = 9 BWR SNF assemblies and 7,862/1,980 = 4 PWR SNF assemblies; similarly, the average capacity of a BWR and PWR DPC is 1,389/22 = 64 BWR SNF assemblies and 6,419/260 = 25 PWR SNF assemblies (values are rounded up to the next integer). These average capacities are consistent with the capacities of individual transportation casks given in Reference 2.2.3 (Table C-1).

- Among the BWR and PWR SNF assemblies that are delivered to the repository in containers other than TAD canisters, the fraction that is in DPCs is 1,389/(6,057 + 1,389) = 0.19 for BWR SNF assemblies, and 6,419/(7,862 +6,419) = 0.45 for PWR fuel assemblies (Table 2). Variability for this fraction is modeled with a uniform distribution, with the lower bound equal to 90 percent of the nominal value, and the upper bound equal to 110 percent of that value. This 10 percent variability around the nominal value is regarded as a reasonable representation of the uncertainty around the actual fraction of SNF assemblies that will be delivered to the repository in DPCs. A precise knowledge of this uncertainty, however, is not important because this calculation focuses on mean throughputs, which are insensitive to the spread of the uncertainty distribution considered here. The number of DPCs is calculated as the product of the number of BWR or PWR fuel assemblies processed in the pool of the WHF, multiplied by the above applicable fraction (for PWR or BWR), and divided by 64 and 25, respectively. Given the conservatism in the estimated number of these SNF assemblies, the number of DPCs is also conservative. Because there is one DPC per transportation cask, the number of transportation casks loaded with a DPC is equal to the number of DPCs.

- Among the BWR and PWR SNF assemblies that are delivered to the repository in containers other than TAD canisters, the fraction that is in bare-SNF transportation casks is 6,057/(6,057 + 1,389) = 0.81 for BWR SNF assemblies, and, for PWR fuel assemblies: 7,862/(7,862 +6,419) = 0.55 (Table 2). Variability for this fraction is modeled with a uniform distribution, with the lower bound equal to 90 percent of the nominal value, and the upper bound equal to 110 percent of that value. This 10 percent variability around the nominal value is regarded as a reasonable representation of the uncertainty around the actual fraction of SNF assemblies that will be delivered to the repository in bare-SNF transportation casks. A precise knowledge of this uncertainty, however, is not important because this calculation focuses on mean throughputs, which are insensitive to the spread of the uncertainty distribution considered here. The number of bare-SNF transportation casks is calculated as the product of the number of BWR or PWR fuel assemblies processed in the pool of the WHF, multiplied by the above applicable fraction, and divided by 9 and 4, respectively. Given the conservatism in the estimated number of these SNF assemblies, the number of bare-SNF transportation casks is also conservative.

6.1.5. Summary of Results for Throughputs per Waste Form Configuration

A summary of the throughputs for different waste form configurations is presented in Table 3. The results are given as an expected (i.e., mean) value, along with an estimated standard deviation, as applicable. The calculations are based on the information presented in the previous sections (Section 6.1.1 to 6.1.4), and performed using Monte Carlo simulations in Mathcad (Section 4.2), which are reported in Attachment A. The mean and standard deviation shown are the sample mean and sample standard deviation of the simulations. The numbers are shown rounded to the nearest integer.

Given the conservatisms introduced in the derivation of the throughputs, the mean values are believed to encompass the actual throughput that will be recorded at the repository. For example, introduced conservatisms are apparent in the number of SNF assemblies that are not delivered in TAD canisters, given as 33,104 in Table 3, which is a value greater than the 6,057 + 7,862 + 1,389 + 6,419 = 21,727 SNF assemblies shown in Table 2.

Table 3. Throughputs for Different Waste Form Configurations

Waste Form Configuration	Expected (mean) Number	Standard Deviation
Naval canister[a]	400	N/A
Transportation cask loaded with naval canister[a]	400	N/A
Waste Package loaded with naval canister[a]	400	N/A
MCO	451	87
Transportation cask loaded with MCOs (4 MCOs per cask)	113	22
DOE standardized canister (total number, irrespective of size)	3,300	422
Transportation cask loaded with DOE standardized canisters (5 to 9 canisters per cask)	385	47
HLW canister (total number, irrespective of size)	9,801	193
Rail-based transportation cask loaded with HLW canisters (5 canisters per cask)[b]	1,960	39
Waste package loaded with HLW canisters and MCOs (2 HLW canisters and 2 MCOs per waste package)	225	43
Waste package loaded with HLW canisters and DOE standardized canister (4 to 5 HLW canisters and 1 DOE standardized canister per waste package)[c]	3,300	422
SNF assembly (not delivered in TAD canisters)	33,104	5,587
Transportation cask loaded with bare SNF assemblies (9 BWR or 4 PWR SNF assemblies per cask)	3,775	556
DPC (64 BWR or 25 PWR SNF assemblies per DPC)	346	41
Transportation cask loaded with DPC	346	41
TAD canister shipped to the repository (44 BWR or 21 PWR SNF assemblies per canister)	6,978	354
Transportation cask loaded with TAD canister	6,978	354
TAD canister produced at the repository (44 BWR or 21 PWR SNF assemblies per canister)	1,165	144

SOURCE: Attachment A

NOTES: [a]Value is bounding (Section 6.1.1); it is a point estimate, with no associated standard deviation.
[b]Number is based on total inventory of HLW canisters, irrespective of those that may be shipped in truck-based transportation casks.
[c]Number is based on total inventory of HLW canisters and DOE standardized canisters, irrespective of the waste packages produced in IHF, loaded with HLW canisters only.

As outlined in Section 4.3, the expected number of occurrences of a given event sequence over the preclosure period, i.e., the mean, is appropriate for determining the categorization of the event sequence. This expected number is directly proportional to the expected throughput for the waste form configuration and the operational area of the event sequence. Therefore, only the mean throughputs need to be considered for the categorization of an event sequence. Thus, the standard deviations shown in Table 3 are given for information only.

6.2 DERIVATION OF THROUGHPUTS PER GENERAL OPERATIONAL AREA

The information on throughputs per waste form configuration developed previously is now particularized to the general operational areas (defined in Section 1) to which these waste form configurations are applicable.

Throughputs are calculated according to waste form handling scenarios that are considered independently from each other to preserve flexibility in the conduct of operations. A consequence of this approach is that some scenarios may be mutually exclusive. Therefore, the individual throughput numbers developed in this section are particular to a given waste form configuration in a given operational area and should not be combined with other throughput numbers.

6.2.1. Waste Form Configurations Associated with the Internal Handling Facility

As summarized on Figure 1 of Reference 2.2.13, the IHF is the only facility that processes naval canisters, which are transferred from transportation casks to waste packages. Thus, based on the information of Table 3, there are 400 naval canisters and the same number of transportation casks and waste packages loaded with naval canisters that are handled in the IHF. This number is bounding and no probability distribution was developed around it (Section 6.1.1). Its designation as an “expected number” in Table 3 should be viewed as the expected value of a degenerate distribution with a single point.

The IHF has also the capability to process HLW canisters (Reference 2.2.13, Figure 1), received in truck-based or rail-based transportation casks and transferred to co-disposal waste packages, although such waste packages would not contain DOE standardized canisters or MCOs. As noted in Section 6.1.3, the capacity of co-disposal waste packages and the quantity of HLW canisters, MCOs, and DOE standardized canisters are such that the number of co-disposal waste packages is essentially controlled by the number of standardized canisters and MCOs. Therefore, it is beneficial to minimize the number of co-disposal waste packages that would be loaded with HLW canisters only. Accordingly, it is anticipated that only a small quantity of such waste packages would be produced in the IHF. Nevertheless, to preserve flexibility in the conduct of operations, it is considered that as many as 1,000 HLW canisters could be processed in the IHF. It is also considered that 500 of such canisters would be delivered in truck-based transportation casks, whose capacity is one HLW canister per cask (Reference 2.2.2, Section 3.2.1.2). The rest would be shipped in rail-based transportation casks, whose capacity is five HLW canisters per cask (Section 6.1.3), resulting in 500/5 = 100 of such transportation casks delivered to the IHF. A total of 600 transportation casks (rail- or truck-based) containing one or more HLW canister(s) is thus estimated. Also, a total of 1,000/5 = 200 waste packages loaded with HLW canisters would be produced at the IHF, given a capacity of five HLW canisters per waste package (Reference 2.2.4 and Reference 2.2.5). All these numbers are single-point estimates, believed to encompass the actual throughput that will be recorded in the IHF. They are treated as expected values of degenerate distributions with a single point.

6.2.2. Waste Form Configurations Associated with the Receipt Facility

The Receipt Facility has the capability to transfer TAD canisters and DPCs from a transportation cask to an aging overpack (Reference 2.2.13, Figure 1). To preserve flexibility in the conduct of operations, it is considered that all TAD canisters and DPCs could transit through this facility. Based on Table 3, this amounts to 6,978 TAD canisters and 346 DPCs. This is also the quantity of transportation casks and aging overpacks that would contain these canisters.

The Receipt Facility has also the capability to process horizontal DPCs, which are transferred, while inside their transportation cask, to a site-specific horizontal positioning transfer trailer (Reference 2.2.13, Section 3.1.8). To preserve flexibility in the conduct of operations, no presumption is made as to the fraction of horizontal DPCs to be received at the repository. Therefore, as many as 346 vertical or horizontal DPCs could transit through the Receipt Facility.

6.2.3. Waste Form Configurations Associated with the Wet Handling Facility

The WHF processes the SNF assemblies that are shipped to the repository in containers other than TAD canisters (i.e., in DPCs or bare-SNF transportation casks); these containers are received at the WHF in transportation casks, aging overpacks, or horizontal shielded transfer casks, and their SNF assemblies are transferred to TAD canisters, which are then loaded in aging overpacks for transfer to a CRCF or to an aging pad (Reference 2.2.13, Figure 1).

Based on Table 3, a mean number of 3,775 bare-SNF transportation casks and 346 DPCs are processed in the WHF. To preserve flexibility in the conduct of operations, it is further considered that the DPCs could be delivered either inside their transportation casks, or could equally have transited first through the aging facility, in which case they would be delivered in aging overpacks (for vertical DPCs), or horizontal shielded transfer casks (for horizontal DPCs) (Section 6.2.6). This results in 346 transportation casks, aging overpacks, or horizontal shielded transfer casks loaded with DPCs.

Also, based on Table 3, a mean number of 33,104 SNF assemblies are to be processed in the WHF. It is conservatively considered that each SNF assembly could first be staged in a rack in the pool before being transferred to a TAD canister, resulting in two transfers: one from a bare-SNF transportation cask or DPC to a staging rack, and one from a staging rack to a TAD canister. Therefore, the total number of fuel assemblies transferred is 33,104 × 2 = 66,208. Based on Table 3, 1,165 TAD canisters are produced as a result. These canisters are then loaded in the same number of aging overpacks.

6.2.4. Waste Form Configurations Associated with the Canister Receipt and Closure Facility

As many as three CRCFs could be constructed (Reference 2.2.2, Section 4.1.1). The throughputs developed in this calculation consider these three units as a whole, i.e., no breakdown per individual facility is performed.

The CRCF receives transportation casks loaded with HLW canisters, MCOs, or DOE standardized canisters, and transfers them to co-disposal waste packages; the CRCF also transfers TAD canisters from transportation casks or aging overpacks to waste packages; finally, the CRCF has the capability to transfer TAD canisters and vertical DPCs from transportation casks to aging overpacks (Reference 2.2.13, Figure 1).

Table 3 shows that 113 transportation casks loaded with MCOs and 385 with DOE standardized canisters are expected to be delivered to the CRCF. In addition, the total inventory of HLW canisters amounts to a total of 1,960 rail-based transportation casks (as indicated in Section 6.1.3, truck-based transportation casks loaded with HLW canisters deliver their content to the IHF only, and therefore are not examined further here). To preserve flexibility in the conduct of operations, it is considered that the entire inventory of HLW canisters could be processed at the CRCF, irrespective of those canisters that may be processed in the IHF.

An average of 451 MCOs are transferred to 2-MCO/2-DHLW co-disposal waste packages, which contain two MCOs per waste package (Reference 2.2.10). This translates into a mean number of 225 such waste packages (Table 3). MCOs are directly transferred from a transportation cask to a waste package; they are not staged.

Because transportation casks loaded with DOE standardized canisters have a capacity between five and nine canisters per cask (Section 6.1.2), while the co-disposal waste packages in which they are loaded hold at most one such canister (Reference 2.2.4 and Reference 2.2.5), some fraction of the 3,300 DOE standardized canisters (Table 3) will have to be staged in the CRCF, pending availability of a co-disposal waste package with an empty spot. Accordingly, one DOE standardized canister per transportation cask, i.e., 385 in total, based on Table 3, is directly transferred from a transportation cask into a waste package; the rest of the DOE standardized canisters, i.e., 3,300 - 385 = 2,915 canisters undergo staging, and therefore are transferred twice in the CRCF: once to staging, and once from staging. Therefore, a total of 2,915 × 2 + 385 = 6,215 DOE standardized canisters are transferred in the CRCF.

While the capacity of rail-based transportation casks carrying HLW canisters, five canisters per cask, is also the capacity of the 5-DHLW/DOE SNF co-disposal waste packages that are loaded with an 18-inch diameter DOE standardized canister in the central position, such waste packages have only a capacity of four HLW canisters if they are loaded with a 24-inch diameter DOE standardized canister; also, 2-MCO/2-DHLW co-disposal waste packages have a capacity of two HLW canisters per waste package (Section 6.1.3). Therefore, staging in the CRCF is anticipated for HLW canisters. Based on Assumption 3.2.3, four HLW canisters per transportation cask undergo a direct transfer; the fifth one is staged. Based on Table 3, 1,960 transportation casks are loaded with HLW canisters. Thus, accounting for four HLW canisters per cask directly transferred to a waste package, and one HLW canister per cask transferred to and from staging before being loaded in a waste package, the total number of HLW canisters transferred in the CRCF is 1,960 × 4 + 1,960 × 2 = 11,760.

Table 3 also shows that 6,978 transportation casks loaded with TAD canisters could be shipped to the CRCF. To preserve flexibility in the conduct of operations, it is considered that these TAD canisters could equally have transited first through the aging facility or the Receipt Facility, in which case they would be delivered to the CRCF in aging overpacks. Accounting also for the 1,165 TAD canisters produced in the WHF (Section 6.2.3) and delivered to the CRCF in aging overpacks too, a total of 6,978 + 1,165 = 8,143 aging overpacks loaded with a TAD canister could be delivered to the CRCF. At the end of their processing, they are loaded in 8,143 waste packages. A TAD canister received in a transportation cask at the CRCF may not be immediately transferred into a waste package, but instead loaded into an aging overpack and sent to the aging facility. Thus, a given TAD canister may be processed more than once in the CRCF. To preserve flexibility in the conduct of operations, it is considered that the 6,978 TAD canisters shipped to the repository could be transferred to an aging overpack in the CRCF and sent to the aging facility before being transferred again in the CRCF, this time from the aging overpack to a waste package. Accounting also for the 1,165 TAD canisters produced in the WHF (Section 6.2.3), this amounts to a total of 2 × 6,978 + 1,165 = 15,121 TAD canisters that are transferred in the CRCF.

The total number of waste packages produced at the CRCF is the sum of the 8,143 waste packages containing a TAD canister, the 225 2-MCO/2-DHLW co-disposal waste packages, and the 3,300 5-DHLW/DOE SNF co-disposal waste packages, yielding 11,668 waste packages.

Finally, DPCs could also transit through the CRCF. To preserve flexibility in the conduct of operations, it is considered that all 346 DPCs delivered to the repository (Table 3) could be transferred from their transportation cask to an aging overpack in the CRCF.

6.2.5. Waste Form Configurations Associated with the Subsurface Facility

The subsurface facility receives all waste packages to be emplaced in the repository. This is the sum of the 11,668 waste packages produced at the CRCF, and the 400 waste packages containing a naval canister produced at the IHF, yielding 12,068 waste packages.

The co-disposal waste packages loaded with HLW canisters that may be produced in the IHF are not included in this count, because, as noted in Section 6.2.1, only a small quantity of such waste packages would be produced in the IHF. Section 6.2.4 also indicates that co-disposal waste packages produced at the CRCF account for the entire inventory of HLW canisters. Moreover, because of the conservatisms introduced in the counts of canisters, a total number of 12,068 waste packages is conservative. Finally, this number does not account for room/capacity constraints in the emplacement drifts, which could restrict the number of waste packages to a lesser value.

6.2.6. Waste Form Configurations Associated with Intra-Site Operations and Balance of Plant

The intra-site operations and balance of plant oversees the movements of the waste form configurations that transit to or from a facility of the repository.

Based on Table 3, a mean number of 400, 385, and 113 transportation casks respectively loaded with naval canisters, DOE standardized canisters, and MCOs are delivered to the repository. Also, the total inventory of HLW canisters could be delivered in 1,960 rail-based transportation casks (each loaded with five HLW canisters). Based on Section 6.2.1, 500 truck-based transportation casks, each loaded with one HLW canister, could be used as an alternative mode of delivery of HLW canisters to the IHF. Therefore, the number of transportation casks loaded with one or more HLW canisters is calculated as the sum of 500 truck-based transportation casks and 1,960 rail-based transportation casks, to which 100 casks must be subtracted (to account for the 500 HLW canisters from the total inventory that will be delivered in truck-based casks), yielding a total of 500 + 1,860 = 2,360 transportation casks.

Based on Table 3, transportation casks carrying SNF assemblies are delivered to the repository in the following quantities: 6,978 are loaded with a TAD canister, 346 are loaded with a DPC, and 3,775 are loaded with bare SNF assemblies. To preserve flexibility in the conduct of operations, it is considered that all TAD canisters and DPCs could be sent to aging. Therefore, there would be a minimum of 6,978 aging overpacks loaded with a TAD canister. Adding to this the 1,165 TAD canisters produced at the WHF (Section 6.2.3), this amounts to a total of 6,978 + 1,165 = 8,143 TAD canisters transported inside an aging overpack.

Vertical DPCs are transported to and from aging inside aging overpacks (Reference 2.2.13, Section 3.1.7), while horizontal DPCs are transported to aging inside transportation casks, and retrieved from aging inside horizontal shielded transfer casks (Reference 2.2.13, Section 3.1.8). To preserve flexibility in the conduct of operations, no presumption is made as to the fraction of

DPCs that are horizontal or vertical. Therefore, there are as many as 346 aging overpacks (for vertical DPCs) or horizontal shielded transfer casks (for horizontal DPCs) that are loaded with a DPC and transported on the site to and/or from aging.

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7. RESULTS AND CONCLUSIONS

In this calculation, throughputs for the different waste form configurations and general operational areas defined in Section 1 were developed to support the preclosure safety analysis. Starting with projected waste streams, a conservative derivation of the throughputs for the various waste form configurations was first carried out (Section 6.1). The conservatism in the derivation was introduced to ensure that the numbers found would encompass the actual throughputs that will be recorded at the repository. Then, the throughputs were particularized to each relevant operational area (Section 6.2). To allow for some flexibility in the conduct of operations, multiple and bounding waste handling scenarios were embedded in the throughput numbers. The results are shown in Table 4. The numbers shown are rounded to the nearest integer. Because an entry in Table 4 may embed a waste handling scenario that is incompatible with the waste handling scenario of another entry, throughputs from different entries should not be summed together, but be considered independently.

The throughputs presented in Table 4 are conservative values that are not anticipated to be exceeded.

Table 4. Throughputs per Waste Form Configuration and General Operational Area

General Operational Area and Relevant Waste Form Configuration	Throughput over Preclosure Period[a, b]
Initial Handling Facility	
Transportation casks containing a naval canister	400
Transportation casks containing HLW canisters (100 rail-based transportation casks contain 5 HLW canisters and 500 truck-based transportation casks contain 1 HLW canister)	600
Naval canisters	400[d]
HLW canisters	1,000[d]
Waste packages containing a naval canister	400
Waste packages containing HLW canisters (5 HLW canisters per waste package)	200
Receipt Facility	
Transportation casks containing a TAD canister	6,978
Transportation casks containing a dual-purpose canister	346
TAD canisters (44 BWR or 21 PWR SNF assemblies per canister)	6,978[d]
Dual-purpose canisters (64 BWR or 25 PWR SNF assemblies per canister)	346[d]
Aging overpack containing a TAD canister	6,978
Aging overpack containing a dual-purpose canister	346
Wet Handling Facility	
Transportation casks containing bare SNF assemblies (9 BWR or 4 PWR SNF assemblies per cask)	3,775
Transportation casks or horizontal shielded transfer casks containing a dual-purpose canister	346
Aging overpacks containing a dual-purpose canister	346
Dual-purpose canisters (64 BWR or 25 PWR SNF assemblies per canister)	346[d]
Spent nuclear fuel assemblies transferred in the pool of the Wet Handling Facility (from a bare-fuel transportation cask or dual-purpose canister to a staging rack, and from a staging rack to a TAD canister)	66,208[e]
TAD canisters produced at repository (44 BWR or 21 PWR SNF assemblies per canister)	1,165
Aging overpacks containing a TAD canister	1,165
Canister Receipt and Closure Facility[c]	
Rail-Based Transportation casks containing HLW canisters (5 canisters per cask)	1,960
Transportation casks containing DOE standardized canisters (5 to 9 canisters per cask)	385
Transportation casks containing MCOs (4 canisters per cask)	113
Transportation casks containing a dual-purpose canister	346

General Operational Area and Relevant Waste Form Configuration	Throughput over Preclosure Period[a, b]
Transportation casks containing a TAD canister	6,978
Aging overpacks containing a TAD canister	8,143
HLW canisters (transferred from a transportation cask to staging, from staging to a waste package, or from a transportation cask to a waste package)	11,760[d]
DOE standardized canisters (transferred from a transportation cask to staging, from staging to a waste package, or from a transportation cask to a waste package)	6,215[d]
MCOs (transferred from a transportation cask to a waste package)	451[d]
Dual-purpose canisters	346[d]
TAD canisters (transferred from a transportation cask to an aging overpack, from an aging overpack to a waste package, or from a transportation cask to a waste package)	15,121[d]
Aging overpacks containing a dual-purpose canister	346
Waste packages containing 1 DOE standardized canister and 4 to 5 HLW canisters	3,300
Waste packages containing 2 HLW canisters and 2 MCOs	225
Waste packages loaded with a TAD canister	8,143
Waste packages (all types produced at canister receipt and closure facilities)	11,668
Subsurface Facility	
Waste packages (all types)	12,068
Intra-Site and Aging Facility	
Transportation casks containing HLW canisters (1,860 rail-based transportation casks contain 5 HLW canisters and 500 truck-based transportation casks contain 1 HLW canister)	2,360
Transportation casks containing DOE standardized canisters (5 to 9 canisters per transportation cask)	385
Transportation casks containing MCOs (4 canisters per transportation cask)	113
Transportation casks containing a naval canister	400
Transportation casks containing bare SNF assemblies (9 BWR or 4 PWR SNF assemblies per cask)	3,775
Transportation casks containing a TAD canister	6,978
Transportation casks containing a dual-purpose canister	346
Aging overpacks containing a vertical dual-purpose canister	346
Transportation casks or horizontal shielded transfer casks containing a horizontal dual-purpose canister (sent to or coming from aging)	346
Aging overpacks containing a TAD canister	8,143

SOURCE: Section 6

NOTES: [a]The throughput breakdown in this table embeds several bounding scenarios for waste handling facilities. Therefore, it is not appropriate to sum the throughputs for a waste form over several entries, because the resulting number could combine handling scenarios that are mutually exclusive. Entries should be considered independently.

[b]The throughputs shown are means of probability distributions that were conservatively estimated. Therefore, they are expected to encompass the actual throughputs that will be recorded at the repository.

[c]Throughputs are for as many as three Canister Receipt and Closure Facilities considered as a whole.

[d]Number shown is number of transfers by a canister transfer machine inside the facility considered.

[e]Number shown is number of transfers.

ATTACHMENT A - MATHCAD CALCULATIONS

In this attachment, Monte Carlo simulations performed on Mathcad are documented. The calculations consist of assigning probability distributions to different waste form configurations, based on the information given in Section 6.1 (and associated subsections) and modeling these distributions by vectors of sample values. The distributions are then combined, as needed, to develop the probability distribution of other waste form configurations. The mean and standard deviation of the resulting distributions are then calculated as the sample mean and sample standard deviation. The results are shown rounded to the nearest integer and feed Table 3.

Definition of general parameters:

Number of samples in a simulation:

This high number ensures that the sample mean and sample standard deviation values are close to the true mean and standard deviation of the distributions.

Define index for vectors, ranging from 1 to x:

Seed for the Monte Carlo simulations (this ensure reproducibility of the results): =

Calculations associated with Section 6.1.1:

Number of naval canisters to be considered in the calculations (this is also the number of transportation casks and waste packages loaded with a naval canister):

No distribution around this number is developed.

Calculations associated with Section 6.1.2:

Distribution of MCOs:

= =

Distribution of transportation casks containing MCOs (4 MCOs per cask):

= =

Distribution of 18 inch x 10 foot DOE standardized canisters:

Distribution of 18 inch x 15 foot DOE standardized canisters:

Distribution of 24 inch x 10 foot DOE standardized canisters:

Distribution of 24 inch x 15 foot DOE standardized canisters:

Distribution of DOE standardized canisters (all types):

= =

Distribution of transportation casks loaded with 18 inch x 10 foot DOE standardized canisters (9 canisters per cask):

Distribution of transportation casks loaded with 18 inch x 15 foot DOE standardized canisters (9 canisters per cask):

Distribution of transportation casks loaded with 24 inch x 10 foot DOE standardized canisters (5 canisters per cask):

Distribution of transportation casks loaded with 24 inch x 15 foot DOE standardized canisters (5 canisters per cask):

Distribution of transportation casks loaded with DOE standardized canisters (all types):

= =

Calculations associated with Section 6.1.3:

Distribution of HLW long canisters:

Distribution of HLW short canisters:

Distribution of HLW canisters (all types):

= =

Distribution of transportation casks loaded with HLW long canisters (5 canisters per cask):

Distribution of transportation casks loaded with HLW short canisters (5 canisters per cask):

Distribution of transportation casks loaded with HLW canisters (all types):

= =

Distribution of 2-MCO/2-DHLW waste packages (2 MCOs and 2 HLW long canisters):
As explained in Section 6.1.3, the number of such waste packages is controlled by the number of MCOs, leading to the following distribution:

= =

The number of HLW long canisters remaining (i.e., not loaded in 2-MCO/2-DHLW waste packages) is:

These remaining HLW canisters will be loaded in 5-DHLW/DOE SNF long co-disposal waste packages.

Distribution of 5-DHLW/DOE SNF long co-disposal waste packages: to maximize payload, these waste packages are loaded to full capacity to the extent possible, as follows: 1) one 24 inch x 15 foot DOE standardized canister in a side position and 4 HLW long canisters, 2) one 18 inch x 15 foot DOE standardized canister in the central position and 5 HLW long canisters, and 3) 5 HLW long canisters when all 15 foot DOE standardized canisters have been loaded. Therefore, the number of 5-DHLW/DOE SNF long co-disposal waste packages is the sum of the number of 15-ft DOE standardized canisters and the quantity of waste packages remaining after all these DOE standardized canisters have been loaded (waste packages loaded with 5 HLW long canisters).

Distribution of 5-DHLW/DOE SNF short co-disposal waste packages: derivation is similar to that of 5-DHLW/DOE SNF long co-disposal waste package.

Distribution of 5-DHLW/DOE SNF co-disposal waste packages (long or short)

= =

Calculations associated with Section 6.1.4:

Nominal total number of BWR fuel assemblies shipped to repository:

=

Nominal total number of PWR fuel assemblies shipped to repository:

=

Distribution of BWR fuel assemblies (total inventory):

Distribution of PWR fuel assemblies (total inventory):

Distribution of fraction of BWR fuel assemblies shipped in TAD canisters:

$$ad := runif\left(x, \frac{\quad}{btot}, 1\right)$$

Distribution of fraction of PWR fuel assemblies shipped in TAD canisters:

$$fpfatad := runif\left(x, \frac{80022}{ptot}, 1\right)$$

Distribution of BWR TAD canisters shipped to repository (44 BWR SNF assemblies per TAD canister):

$$shbtad_i := bfa_i \cdot fbfatad_i \cdot \frac{1}{44}$$

Distribution of PWR TAD canisters shipped to repository (21 PWR SNF assemblies per TAD canister):

$$shptad_i := pfa_i \cdot fpfatad_i \cdot \frac{1}{21}$$

Distribution of TAD canisters shipped to repository (this is also the number of transportation casks loaded with a TAD canister):

$$shtad := shbtad + shptad$$

$$mean(shtad) = 6978 \qquad Stdev(shtad) = 354$$

Distribution of fraction of BWR fuel assemblies shipped in containers other than TAD canisters (i.e., DPCs or bare-SNF transportation casks):

$$fbfantad := runif\left(x, \frac{6057 + 1389}{btot}, 0.2\right)$$

Distribution of fraction of PWR fuel assemblies shipped in containers other than TAD canisters (i.e., DPCs or bare-SNF transportation casks):

$$fpfantad := runif\left(x, \frac{7862 + 6419}{ptot}, 0.2\right)$$

Distribution of BWR fuel assemblies that are shipped in containers other than TAD canisters, and are consequently processed in the pool of the WHF:

$$wbfa_i := bfa_i \cdot fbfantad_i$$

Distribution of PWR fuel assemblies that are shipped in containers other than TAD canisters, and are consequently processed in the pool of the WHF:

$$_{i} := pfa_i \cdot fpfantad_i$$

Distribution of fuel assemblies (all types) that are shipped in containers other than TAD canisters, and are consequently processed in the pool of the WHF:

$$wfa := wbfa + wpfa$$

$$mean(wfa) = 33104 \qquad Stdev(wfa) = 5587$$

Distribution of BWR TAD canisters produced at repository (44 BWR SNF assemblies per TAD canister):

$$wbtad_i := wbfa_i \cdot \frac{1}{44}$$

Distribution of PWR TAD canisters produced at repository (21 PWR SNF assemblies per TAD canister):

$$wptad_i := wpfa_i \cdot \frac{1}{21}$$

Distribution of TAD canisters (BWR and PWR) produced at repository:

$$wtad := wbtad + wptad$$

$$mean(wtad) = 1165 \qquad Stdev(wtad) = 144$$

Distribution of TAD canisters, shipped to or produced at repository (this is also the number of waste packages loaded with a TAD canister):

$$tad := shtad + wtad$$

$$mean(tad) = 8143 \qquad Stdev(tad) = 418$$

Distribution of fraction of BWR fuel assemblies shipped in bare-SNF transportation casks:

$$fbfatc := runif\left(x, 0.9 \cdot \frac{6057}{1389 + 6057}, 1.1 \cdot \frac{6057}{1389 + 6057}\right)$$

Distribution of fraction of PWR fuel assemblies shipped in bare-SNF transportation casks:

$$fpfatc := runif\left(x, 0.9 \cdot \frac{7862}{7862 + 6419}, 1.1 \cdot \frac{7862}{7862 + 6419}\right)$$

Distribution of bare-SNF transportation casks loaded with BWR SNF assemblies (9 BWR SNF assemblies per cask):

$$atc_i := wbfa_i \cdot fbfatc_i \cdot \frac{}{9}$$

Distribution of bare-SNF transportation casks loaded with PWR SNF assemblies (4 PWR SNF assemblies per cask):

$$pfatc_i := wpfa_i \cdot fpfatc_i \cdot \frac{1}{4}$$

Distribution of bare-SNF transportation casks (all types):

$$fatc := bfatc + pfatc$$

$$mean(fatc) = 3775 \qquad Stdev(fatc) = 556$$

Distribution of fraction of BWR fuel assemblies shipped in DPCs:

$$fbfadpc := 1 - fbfatc$$

Distribution of fraction of PWR fuel assemblies shipped in DPCs:

$$fpfadpc := 1 - fpfatc$$

Distribution of DPCs loaded with BWR SNF assemblies (64 BWR SNF assemblies per cask):

$$bfadpc_i := wbfa_i \cdot fbfadpc_i \cdot \frac{1}{64}$$

Distribution of DPCs loaded with PWR SNF assemblies (25 PWR SNF assemblies per cask):

$$pfadpc_i := wpfa_i \cdot fpfadpc_i \cdot \frac{1}{25}$$

Distribution of DPCs (all types) (this is also the number of transportation casks loaded with a DPC):

$$dpc := bfadpc + pfadpc$$

$$mean(dpc) = 346 \qquad Stdev(dpc) = 41$$

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