Preliminary Evaluation of Removing Used Nuclear Fuel from Shutdown Sites – 15568

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ABSTRACT

A preliminary evaluation of removing spent nuclear fuel (SNF) from 12 shutdown nuclear power reactor sites was conducted. At these shutdown sites the nuclear power reactors have been permanently shut down and the sites have been decommissioned or are undergoing decommissioning. The shutdown sites were Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, Zion, Crystal River, Kewaunee, and San Onofre. The evaluation was divided into four components: (1) characterization of the SNF and greater-than-Class C low-level radioactive waste (GTCC waste) inventory, (2) a description of the on-site infrastructure and conditions relevant to transportation of SNF and GTCC waste, (3) an evaluation of the near-site transportation infrastructure and experience relevant to shipping transportation casks containing SNF and GTCC waste, including identification of gaps in information, and (4) an evaluation of the actions necessary to prepare for and remove SNF and GTCC waste. Every site was found to have at least one off-site transportation mode option for removing its SNF and GTCC waste; some have multiple options. Experience removing large components during reactor decommissioning provided an important source of information used to identify the transportation mode options for the sites. Especially important in conducting the evaluation were site visits, through which information was obtained that would not have been available otherwise. Extensive photographs taken during the site visits proved to be particularly useful in documenting the current conditions at or near the sites. It is expected that additional site visits will be conducted to add to the information presented in the evaluation.

INTRODUCTION

In January 2013, the U.S. Department of Energy (DOE) issued the Administration's *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* [1]. Among the elements contained in this strategy is an initial focus on accepting spent nuclear fuel (SNF) from shutdown reactor sites. This focus is consistent with the recommendations of the Blue Ribbon Commission on America's Nuclear Future, which identified removal of stranded SNF at shutdown sites as a priority so that these sites may be completely decommissioned and put to other beneficial uses [2].

In order to prepare for the transportation of SNF with an initial focus on removing SNF from the shutdown sites, a preliminary evaluation of removing SNF from 12 shutdown sites was conducted. The shutdown sites were Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, Zion, Crystal River, Kewaunee, and San Onofre (see Fig. 1). These sites have no other operating nuclear power reactors at their sites and have also notified the U.S. Nuclear Regulatory Commission (NRC) that their reactors have permanently ceased power operations and that nuclear fuel has been permanently removed from their reactor vessels. Shutdown reactors at sites having other operating reactors were not included in this evaluation.

EVALUATION OF THE SHUTDOWN SITES

The evaluation of the shutdown sites was divided into four components:

- characterization of the SNF and greater-than-Class C low-level radioactive waste (GTCC waste) inventory
- a description of the on-site infrastructure and conditions relevant to transportation activities
- an evaluation of the near-site transportation infrastructure and experience relevant to shipping transportation casks containing SNF from the shutdown sites, including gaps in information
- an evaluation of the actions necessary to prepare for and remove SNF and GTCC waste from the shutdown sites.

Maheras et al. [3] summarizes the information used in the evaluation. The primary sources for the inventory of SNF and GTCC waste are the DOE RW-859 used nuclear fuel inventory database, industry sources such as *StoreFUEL* and *SpentFUEL*, and government sources such as the U.S. Nuclear Regulatory Commission (NRC). The primary sources for the information on the site conditions and near-site transportation infrastructure and experience include site visits to the Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, Zion, and Kewaunee sites; information provided by managers at the shutdown sites; Facility Interface Data Sheets compiled for DOE in 2005; Services Planning Documents prepared for DOE in 1993 and 1994; industry publications such as *Radwaste Solutions*; and Google Earth. State and Regional Group, Tribal, and Federal Railroad Administration representatives have participated in seven of the shutdown site visits.

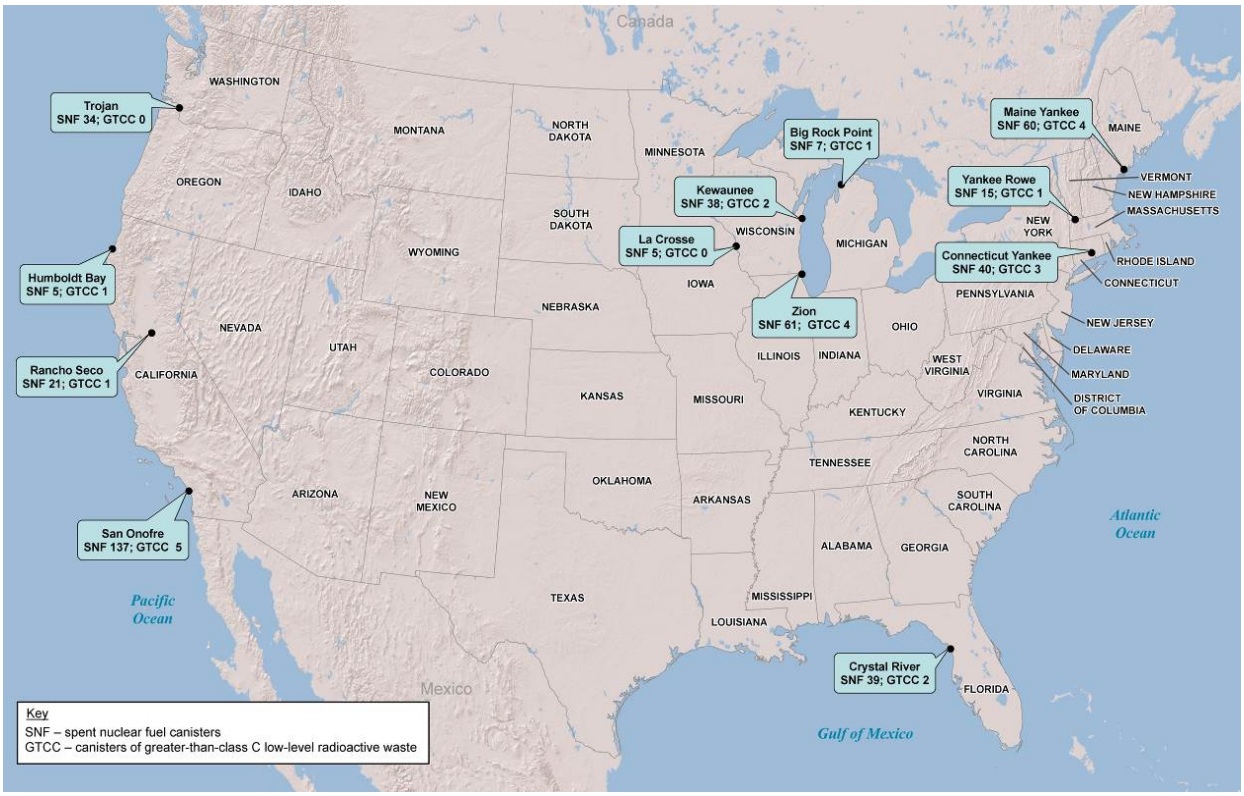

Fig. 1. Locations of shutdown sites.

RESULTS

Fig. 2 illustrates the number of canisters and type of storage canisters containing SNF and GTCC waste that are stored or are anticipated to be stored at each of the shutdown sites. The number of canisters stored at Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, and La Crosse represent actual canisters in storage. The number of SNF canisters at Zion, Crystal River, Kewaunee, and San Onofre represents an estimate of the number of canisters that will be stored at the conclusion of canister loading and the number of canisters at Zion, Crystal River, Kewaunee, and San Onofre containing GTCC waste represents an estimate of the number of canisters generated during decommissioning. There are predicted to be a total of 486 canisters in storage at the 12 sites (actual plus estimated). The number of canisters ranges from 5 at La Crosse to 142 at San Onofre.

Fig. 3 illustrates the number of SNF assemblies stored at each site. There are a total of 14,083 SNF assemblies present at the shutdown sites. These assemblies are composed of 12,919 pressurized water reactor assemblies and 1164 boiling water reactor assemblies. The number of assemblies ranges from 333 at La Crosse to 3855 at San Onofre. The majority (12,421) of the SNF assemblies are zirconium alloy-clad; but Yankee Rowe, Connecticut Yankee, La Crosse, and San Onofre-1 have a combined total of 1662 stainless steel-clad SNF assemblies in storage.

Fig. 4 illustrates the metric tons of heavy metal stored at each site. A total of 5519.3 metric tons heavy metal (MTHM) of used nuclear fuel at the shutdown sites consists of 5394.5 MTHM of pressurized water reactor SNF and 124.8 MTHM of boiling water reactor SNF.

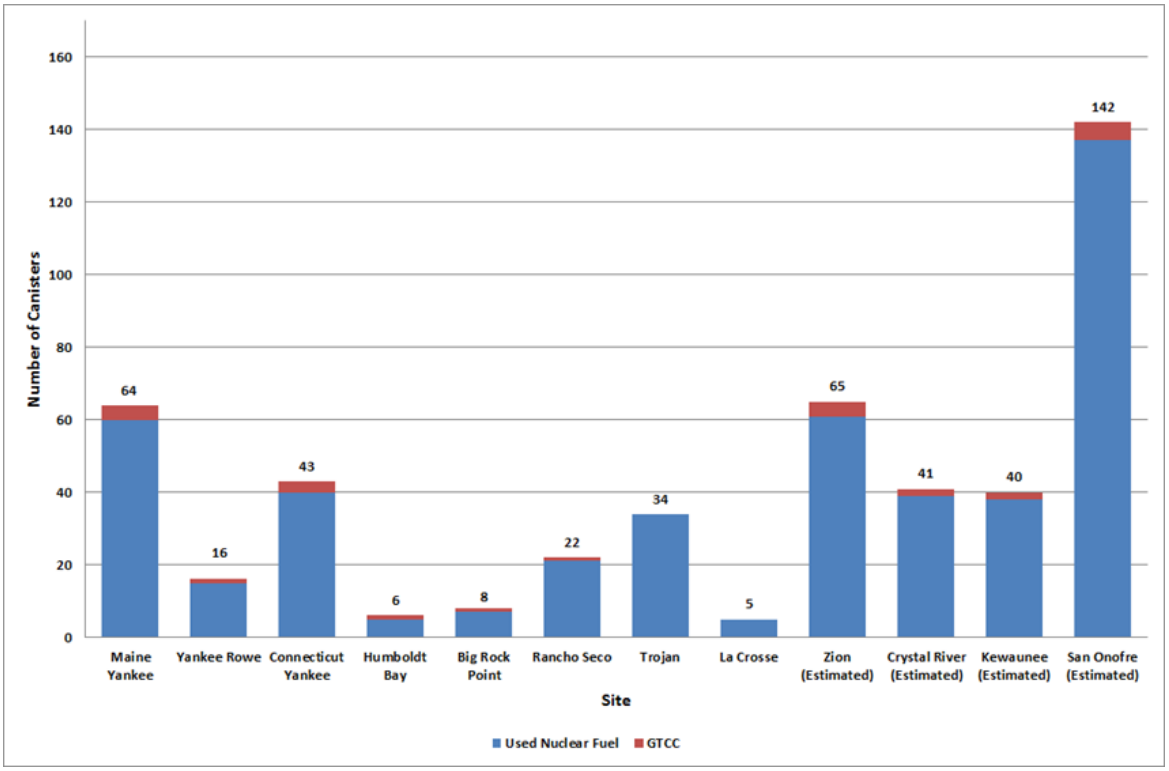

Fig. 2. Number of canisters at shutdown sites.

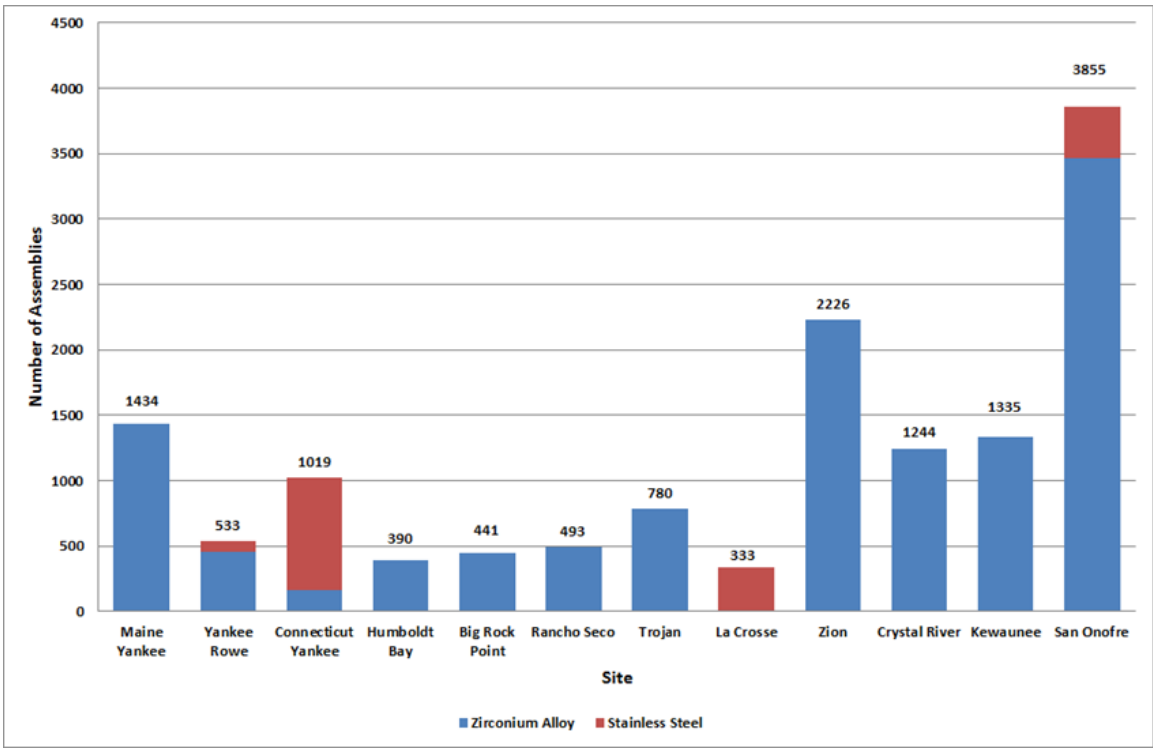

Fig. 3. Number of assemblies at shutdown sites.

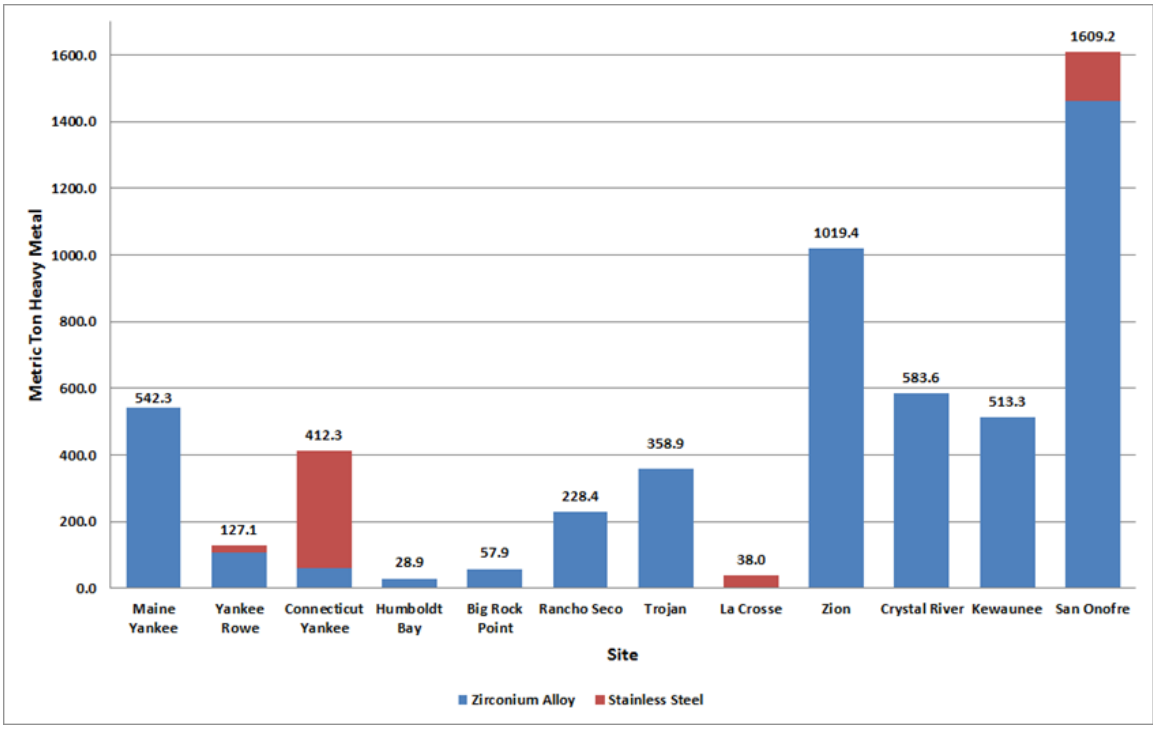

Fig. 4. Metric tons heavy metal at shutdown sites.

Table I lists the storage systems used at the shutdown sites and the corresponding transportation casks that are certified to ship the storage canisters containing SNF and GTCC waste at each of the sites. The 12 shutdown sites use designs from 4 different suppliers, including 9 different (horizontal and vertical) storage systems that would require 8 different transportation cask designs. Out of the eight transportation cask designs listed in Table I, only three types have been fabricated for use in the U.S.: the HI STAR HB, the MP187, and the HI-STAR 100. Impact limiters have not been fabricated for any of the transportation casks. The HI-STAR HB transportation casks can only be used to ship SNF from the Humboldt Bay site. The MP187 transportation cask can be used to ship SNF from the Rancho Seco and San Onofre sites. The HI-STAR 100 casks that have been fabricated are being used as storage casks at the Dresden and Hatch commercial nuclear power reactor sites. For these HI-STAR 100s to be used to ship SNF from the Trojan site, they would need to be unloaded, their contents placed in other storage overpacks, and the casks transported to the Trojan site. It would also be necessary to procure impact limiters and spacers for the HI-STAR 100 casks. Two NAC-STC transportation casks have been fabricated for use in China, but not for use in the United States. In addition, an MP197HB transportation cask is being fabricated in Japan. Fabrication is expected to be completed in 2015.

Several issues were identified during the characterization of the SNF and GTCC waste inventory at the shutdown sites. The most important of the issues was at the Rancho Seco site, where six damaged fuel assemblies were loaded into five fuel-with-control-component dry shielded canisters (FC-DSCs) instead of into failed fuel dry shielded canisters (FF-DSCs). Further evaluation would be needed to determine if the canisters containing this damaged fuel can be shipped in the MP187 transportation cask without repackaging.

The lists of approved contents in the certificates of compliance for the TS125, HI-STAR HB, and MP187 transportation casks do not include GTCC waste. For GTCC waste to be shipped from the Humboldt Bay, Rancho Seco, and San Onofre sites in these transportation casks, the certificates of compliance would need to be revised. The transportation certificate of compliance for the HI-STAR HB transportation cask would also need to be revised to allow transport of 44 SNF assemblies with initial enrichments of 2.08 weight percent, which is less than the minimum initial enrichment authorized by the NRC transportation certificate of compliance. Also, the certificates of compliance for the TS125 and MP187 transportation casks would need to be updated from a -85 to a -96 designation before the casks or impact limiters could be fabricated. In addition, the SNF that would be stored in 32PTH2 canisters at San Onofre would not be transportable without a revision to the list of approved contents in the certificate of compliance for the MP197HB transportation cask.

Two of the sites, Maine Yankee and Zion, have high burnup (>45 gigawatt-day per metric ton heavy metal [GWd/MTHM]) SNF assemblies in storage. These high burnup SNF assemblies are packaged or will be packaged in damaged fuel cans, which eliminates the concern over the transportability of this SNF. Crystal River, Kewaunee, and San Onofre are also expected to have high burnup SNF. High burnup SNF stored in 32PTH1 canisters at Crystal River and 24PT4 canisters at San Onofre would be transportable in the MP197HB transportation cask; high burnup SNF stored in 32PT canisters at the Kewaunee site and 32PTH2 canisters at the San Onofre site would not be transportable without changes to the list of approved contents in the certificate of compliance for the MP197HB transportation cask.

TABLE I. Storage systems and transportation casks at shutdown sites.

Reactor Site	ISFSI Load Dates[a]	Storage System/Canister(s)	Transportation Cask Status	Canisters SNF/GTCC
Maine Yankee (PWR)	08/2002-03/2004	NAC-UMS/transportable storage canister	NAC-UMS UTC (Docket No. 71-9270) Certificate expires 10/31/2017. None fabricated	60/4
Yankee Rowe (PWR)	06/2002-06/2003	NAC-MPC/Yankee-MPC transportable storage canister	NAC-STC (Docket No. 71-9235) Certificate expires 05/31/2019. Foreign use versions fabricated.	15/1
Connecticut Yankee (PWR)	05/2004-03/2005	NAC-MPC/CY-MPC transportable storage canister	NAC-STC (Docket No. 71-9235) Certificate expires 05/31/2019. Foreign use versions fabricated.	40/3
Humboldt Bay (BWR)	08/2008-12/2008	Holtec HI-STAR HB/MPC-HB canister	HI-STAR HB (Docket No. 71-9261) Certificate expires 04/30/2019. Fuel in canisters in fabricated casks. No impact limiters.	5/1
Big Rock Point (BWR)	12/2002-03/2003	Fuel Solutions W150 Storage Overpack/W74 Canister	TS125 (Docket No. 71-9276) Certificate expires 10/31/2017. None fabricated.	7/1
Rancho Seco (PWR)	04/2001-08/2002	TN NUHOMS/FO-DSC, FC-DSC, and FF-DSC canisters	MP187 (Docket No. 71-9255) Certificate expires 11/30/2018. One cask fabricated. No impact limiters.	21/1
Trojan (PWR)	12/2002-09/2003	TranStor Storage Overpack/Holtec MPC-24E and MPC-24EF canisters	HI-STAR 100 (Docket No. 71-9261) Certificate expires 04/30/2019. Units fabricated but dedicated to storage at other sites. No impact limiters or spacers.	34/0
La Crosse (BWR)	07/2012-09/2012	NAC MPC-LACBWR/MPC-LACBWR transportable storage canister	NAC-STC (Docket No. 71-9235) Certificate expires 05/31/2019. Foreign use versions fabricated.	5/0
Zion 1 and 2 PWR)	Planned 2013-2015	NAC MAGNASTOR/TSC-37 canister	MAGNATRAN (Docket No. 71-9356) Application for certificate of compliance under review. None fabricated.	61/4[b]
Crystal River (PWR)	Planned 01/2018-08/2019	TN Standardized NUHOMS/32PTH1 canister	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017. Fabrication of cask expected to be completed in 2015.	39/2[b,c]
Kewaunee (PWR)	08/2009-08/2011	TN Standardized NUHOMS/32PT canister	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017. Fabrication of cask expected to be completed in 2015.	8

TABLE I. Storage systems and transportation casks at shutdown sites (continued).

Reactor Site	ISFSI Load Dates[a]	Storage System/Canister(s)	Transportation Cask Status	Canisters SNF/GTCC
Kewaunee (PWR)	07/2014-08/2014	TN Standardized NUHOMS/32PT canisters	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017. Fabrication of cask expected to be completed in 2015.	6
Kewaunee (PWR)	Planned 2016	NAC MAGNASTOR/TSC-37 canister	MAGNATRAN (Docket No. 71-9356) Application for certificate of compliance under review. None fabricated.	24/2[b,c]
San Onofre-1 (PWR)	08/2009-08/2011	TN Standardized Advanced NUHOMS/24PT1 canisters	MP187(Docket No. 71-9255) Certificate expires 11/30/2018. One cask fabricated. No impact limiters.	17/1
San Onofre-2 and -3 (PWR)	03/2007-07/2012	TN Standardized Advanced NUHOMS/24PT4 canisters	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017. Fabrication of cask expected to be completed in 2015.	33
San Onofre-2 and -3 (PWR)	Not Announced	TN Standardized Advanced NUHOMS/24PT4 and 32PTH2[d] canisters	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017. Fabrication of cask expected to be completed in 2015.	87/4[b,c]
			Total	**462/24**

a. Dates represent the dates that the used nuclear fuel was transferred to the ISFSI.
b. Estimated.
c. Additional canisters of GTCC low-level radioactive waste could be generated during decommissioning.
d. On June 25, 2014, the U.S. Nuclear Regulatory Commission withdrew the direct final rule that added the 32PTH2 canister to the list of approved contents for the Standardized Advanced NUHOMS system (Docket No. 72-1029) (79 FR 35911).
BWR= boiling water reactor
GTCC= greater-than-Class C
ISFSI= independent spent fuel storage installation
PWR= pressurized water reactor
SNF= spent nuclear fuel

All sites were found to have at least one off-site transportation mode option for removing their SNF and GTCC waste, and most sites have multiple options. Table II provides a summary of these transportation mode options for the shutdown sites. Experience with large component removals during reactor decommissioning provided an important source of information in developing Table II.

As part of the evaluation, the current condition of the transportation infrastructure at the shutdown sites was observed. In some cases, transportation infrastructure was removed during decommissioning or was not being actively maintained (see Figs. 5 and 6). In other cases, transportation infrastructure appeared to be in good condition or was being maintained as part of decommissioning activities (see Figs. 7 and 8).

TABLE II. Summary of transportation mode options.

Site	Transportation Mode Options		Comments
Maine Yankee	Direct rail	Barge to rail	The on-site rail spur is not being maintained. The condition of the Maine Eastern Railroad would need to be verified.
Yankee Rowe	Heavy haul truck to rail	–	Potential transload location at the east portal of the Hoosac Tunnel (12 km from site).
Connecticut Yankee	Barge to rail	Heavy haul truck to rail	The on-site barge slip has not been used since decommissioning but remains intact. It is uncertain whether the cooling water discharge canal is deep enough to accommodate barges without dredging. The shortest heavy haul would be about 20 km to the end of the Portland rail spur. The rail infrastructure at the end of the Portland rail spur would need to be evaluated.
Humboldt Bay	Heavy haul truck to rail	Heavy haul truck to barge to rail	The heavy haul distance to a rail siding or spur would be in the range of 260 to 420 km. The condition of the Fields Landing Terminal located 3.2 km from the Humboldt Bay site would need to be verified for barge transport.
Big Rock Point	Heavy haul truck to rail	Barge to rail	Potential transload locations in Gaylord, Michigan (84 km from site) and Petoskey, Michigan (21 km from site). The rail infrastructure at these locations would need to be evaluated.
Rancho Seco	Direct rail	–	The rail spur is not being maintained. Weight restrictions on the Ione Industrial Lead would require route clearance by the railroad or a track upgrade.
Trojan	Direct rail	Barge to rail	The on-site rail spur was removed.
La Crosse	Direct rail	Barge to rail	An on-site rail spur was used to ship the reactor pressure vessel.
Zion	Direct rail	Barge to rail	The rail spur was recently refurbished to support reactor decommissioning waste shipments.
Crystal River	Direct rail	Barge to rail	Extensive on-site rail system serves co-located fossil fuel plants. Have not conducted site visit.
Kewaunee	Heavy haul truck to rail	Heavy haul truck to barge to rail	Potential rail transload locations in Bellevue, Luxemburg, Denmark, and Manitowoc. Potential barge transload location in city of Kewaunee.
San Onofre	Direct rail	Heavy haul truck to barge to rail	The rail spur was recently refurbished to support reactor decommissioning. Have not conducted site visit.

Fig. 5. Condition of onsite rail system at Maine Yankee in 2012.

Fig. 6. Condition of barge slip at Connecticut Yankee in 2012.

Fig. 7. Onsite rail spur at La Crosse.

Fig. 8. Junction of onsite rail spur and Union Pacific Railroad at Zion.

CONCLUSIONS

A preliminary evaluation of removing SNF and GTCC waste from 12 shutdown sites was conducted. The evaluation included characterization of the sites' inventories of SNF and GTCC waste, on-site conditions, and near-site transportation infrastructure and experience. Especially important in conducting the evaluation were site visits, through which information was obtained that would not otherwise have been available. Extensive photographs taken during the site visits proved to be particularly useful in documenting the current conditions at or near the sites. Additional conclusions from this evaluation include:

- Although there are common aspects, each site has some unique features and/or conditions.
- The 12 sites use SNF storage and transportation system designs from 4 different suppliers, including 9 different (horizontal and vertical) storage systems that would require use of 8 different transportation cask designs.
- Although some regulatory actions will be required, SNF at 9 of the initial shutdown sites (Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion) is in licensed systems that can be transported, including a small amount of high-burnup fuel.
- Each site indicated that 2-3 years of advanced time is required for its preparations.
- Most sites have multiple transportation options, e.g., rail, barge, truck, as well as constraints and preferences.

It is expected that additional site visits will be conducted to update the information used in the evaluation. Additional sites may be added to the evaluation if further site closures occur.

REFERENCES

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