Preliminary[1] Evaluation of Removing Used Nuclear Fuel from Shutdown Sites – 2016 Update – 17086

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ABSTRACT

An updated evaluation of removing used or spent nuclear fuel (SNF)[2] from 13 shutdown nuclear power reactor sites was conducted during 2016. 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 included in the evaluation were Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, Zion, Crystal River, Kewaunee, San Onofre, and Vermont Yankee. 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 at the shutdown sites, (3) an evaluation of the near-site transportation infrastructure and transportation experience, including identification of gaps in information, and (4) an evaluation of the actions necessary to prepare for and remove SNF and GTCC waste. Updates to the evaluation since 2015 include incorporating spent nuclear fuel data from the GC-859 database; updating of Google Earth imagery; incorporating revisions to transportation certificates of compliance; adding information obtained from site visits to the Pacific Sun Railroad and Camp Pendleton, California; adding rail assessments for Kewaunee, Crystal River, and San Onofre to the evaluation; and adding information obtained from the site visit to Vermont Yankee. As additional sites such as Fort Calhoun, Palisades, Clinton, Quad Cities, Pilgrim, Oyster Creek, and Diablo Canyon shut down, these sites will be included in updates to 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

[1] This technical paper reflects concepts which could support future decision-making by DOE. No inferences should be drawn from this paper regarding future actions by DOE. To the extent this technical paper conflicts with the provisions of the Standard Contract, the Standard Contract provisions prevail.

[2] In this paper, the terms used nuclear fuel and spent nuclear fuel are synonymous.

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, an evaluation of removing SNF from 13 shutdown sites was conducted. The shutdown sites included were Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, Zion, Crystal River, Kewaunee, San Onofre, and Vermont Yankee (see Figure 1). These sites have no other operating nuclear power reactors at their sites. Shutdown reactors at sites having other operating reactors were not included in this evaluation.

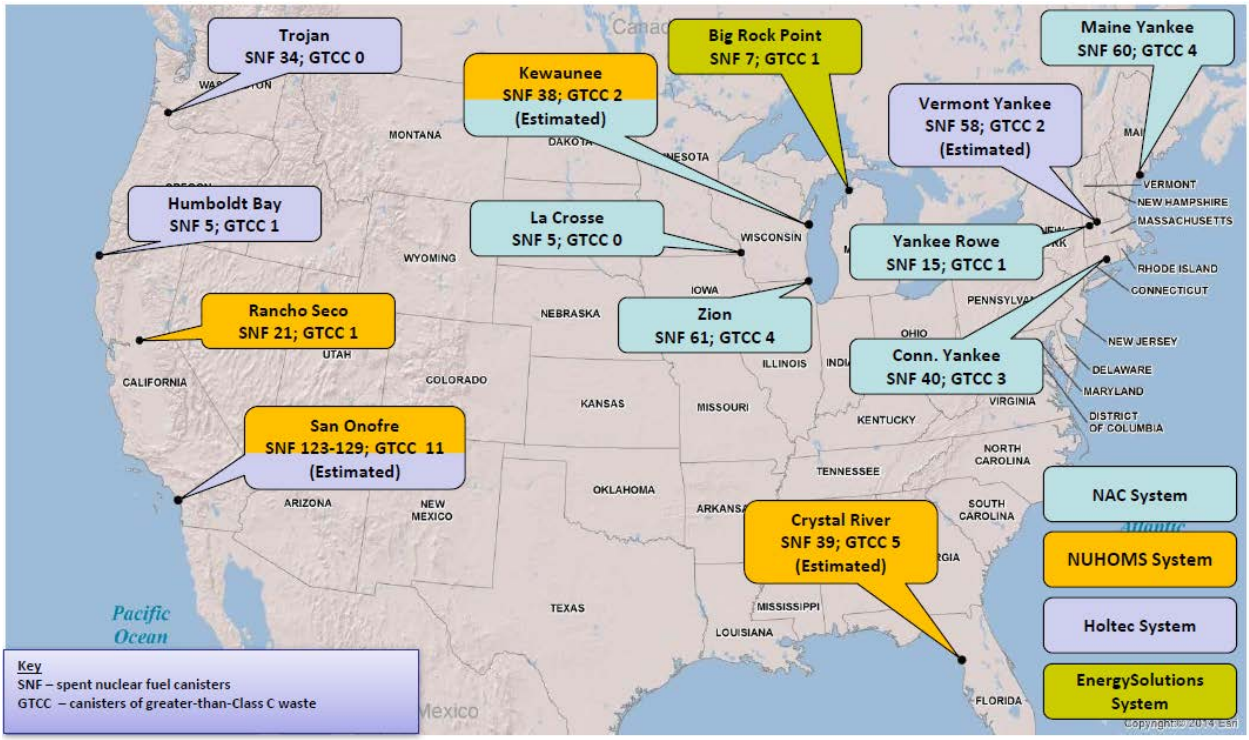

Fig. 1. Locations of shutdown sites.

EVALUATION OF SHUTDOWN SITES

The evaluation 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 at the shutdown sites
- An evaluation of the near-site transportation infrastructure and transportation experience at the shutdown sites

- An evaluation of the actions necessary to prepare for and remove SNF and GTCC waste.

Maheras et al. [3] summarizes the wide variety of sources that were used to complete the components of the evaluations listed above. The primary sources for the inventory of SNF are the U.S. Department of Energy (DOE) GC-859 and RW-859 spent nuclear fuel inventory databases. The primary sources for information on the conditions of on-site and near-site transportation infrastructure and experience included observations and information collected during site visits to the thirteen shutdown sites, information provided by managers and staff at the shutdown sites, and Google Earth imagery. Information provided by the sites coupled with the opportunity to visit each site was critical to understanding the conditions at and near the shutdown sites. Tribal, State, State Regional Group, and Federal Railroad Administration representatives have participated in ten shutdown site visits and their participation has been integral to the site visits.

RESULTS

Figure 2 illustrates the number of 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, La Crosse, and Zion represent actual canisters in storage. The number of SNF canisters at Crystal River, Kewaunee, San Onofre, and Vermont Yankee represents an estimate of the number of canisters that will be stored at the conclusion of canister loading and the number of canisters at Crystal River, Kewaunee, San Onofre, and Vermont Yankee containing GTCC waste represents an estimate of the number of canisters generated during decommissioning. There are predicted to be a total of 541 to 547 canisters in storage at the 13 sites (actual plus estimated). The number of canisters ranges from 5 at La Crosse to 134-140 at San Onofre.

Table 1 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 13 shutdown sites use designs from 4 different suppliers, including 11 different (horizontal and vertical) storage systems that would require 9 different transportation cask designs. Out of the nine transportation cask designs listed in Table 1, 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. If these HI-STAR 100s were to be re-used to ship compatible SNF canisters from the Trojan or Vermont Yankee sites, they would need to be unloaded, their contents placed in other storage overpacks, and the casks transported to the Trojan or Vermont Yankee sites. 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. However, fabrication is on hold.

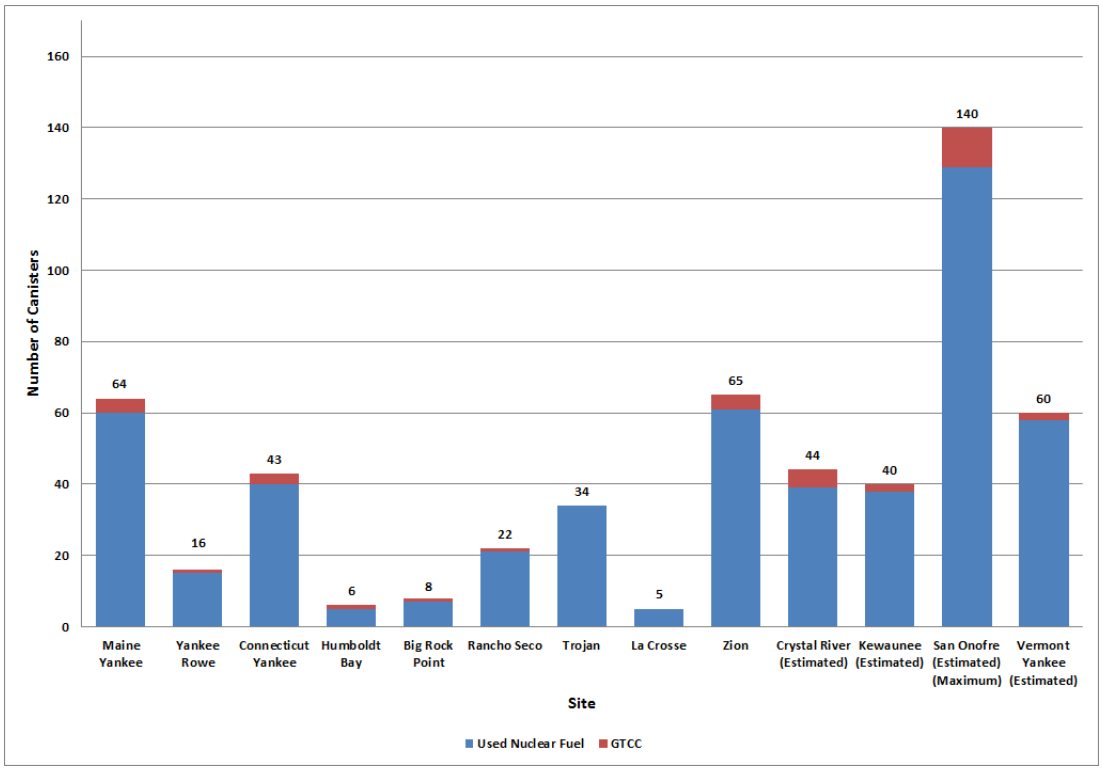

Fig. 2. Number of canisters at shutdown sites.

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. In addition, 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 at Humboldt Bay with initial enrichments of 2.08 weight percent, which is less than the minimum initial enrichment authorized by the NRC transportation certificate of compliance.

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. 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 or GTCC waste that may be stored in 32PTH2 canisters at San Onofre 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-STARHB/ 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)	12/2013-03/2015	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)	Completion by end of 02/2018	TN Standardized NUHOMS/32PTH1 canister	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017.	39/5[b,c]
Kewaunee (PWR)	08/2009-08/2014	TN Standardized NUHOMS/32PT canister	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017.	14
Kewaunee (PWR)	Late 2016-Early 2017	NAC MAGNASTOR/TSC-37 canister	MAGNATRAN (Docket No. 71-9356) Application for certificate of compliance under review. None fabricated.	24/2[b,c]
Kewaunee Total				38/2

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

Reactor Site	ISFSI Load Dates[a]	Storage System / Canister(s)	Transportation Cask Status	Canisters SNF / GTCC
San Onofre-1 (PWR)	09/2003-06/2005	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.	33
San Onofre-2 and -3 (PWR)	Completion by mid-2019	TN Standardized Advanced NUHOMS/24PT4 canisters	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017.	0-12/0-12[b,c]
San Onofre-2 and -3 (PWR)	Completion by mid-2019	TN Standardized Advanced NUHOMS/24PT4 and 32PTH2[d] canisters	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017.	0-6/0-6[b,c]
San Onofre-2 and -3 (PWR)	Completion by mid-2019	Holtec HI-STORM UMAX/MPC-37 canisters	HI-STAR 190 (Docket No. 71-9373) Application for certificate of compliance submitted in 2015.	≤73/0[b]
San Onofre Total				123-129/11
Vermont Yankee (BWR)	05/2008-06/2012	Holtec HI-STORM 100S/MPC-68 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.	13/0
Vermont Yankee (BWR)	Completion by end of 2020	Holtec HI-STORM 100S/MPC-68 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.	45/2[b,c]
Vermont Yankee Total				58/2
Total				506-512/35

a. Dates represent the dates that the spent nuclear fuel was transferred to the ISFSI.
b. Estimated.
c. Additional canisters of GTCC low-level radioactive waste could be generated during decommissioning.
d. The list of approved contents in the certificate of compliance for the MP197HB transportation cask would have to be modified to include the 32PTH2 canister.
BWR= boiling water reactor
GTCC= greater-than-Class C
ISFSI= independent spent fuel storage installation
PWR= pressurized water reactor
SNF= spent nuclear fuel

Six of the sites, Maine Yankee, Zion, Crystal River, Kewaunee, San Onofre, and Vermont Yankee, have high burnup (>45 gigawatt-day per metric ton heavy metal [GWd/MTHM]) SNF in storage. At Maine Yankee and Zion, the high burnup SNF assemblies are packaged in damaged fuel cans, which eliminates the concern over its transportability. 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 that will be stored in MPC-68 canisters at Vermont Yankee would not be transportable without changes to the list of approved

contents in the certificate of compliance for the HI-STAR 100 transportation cask. An application for a certificate of compliance for the HI-STAR 190 transportation cask has been submitted to the NRC; high burnup SNF that will be stored in MPC-37 canisters at San Onofre would be transportable if it is included in the list of approved contents in the certificate of compliance for the HI-STAR 190 transportation cask.

All sites were found to have at least one transportation mode option for removing their SNF and GTCC waste, and most sites have multiple options. Table 2 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 2.

Vermont Yankee Site Visit

A site visit to Vermont Yankee was conducted in May 2016. During this site visit, the Site Visit Team met with Vermont Yankee staff, the New England Central Railroad, and members of the Vermont Nuclear Decommissioning Citizens Advisory Panel (NDCAP) and Windham County Commission.

The Vermont Yankee site is located on the western shore of the Connecticut River, across from Hinsdale, New Hampshire, which is located on the eastern side of the Connecticut River. The site is about 5 miles southeast of Brattleboro, Vermont, and about 45 miles north of Springfield, Massachusetts. The site is located on Vernon Pond, formed by Vernon Dam and Hydroelectric Station located immediately downstream 0.75 miles from the site. Figure 5 provides an aerial view of the Vermont Yankee site.

The current Vermont Yankee Independent Spent Fuel Storage Installation (ISFSI) (see Figure 6) is located at the northern end of the Vermont Yankee site (see Figure 7). A second dry storage cask pad will be built approximately 30 feet immediately to the west of the existing ISFSI pad.

Rail service to the Vermont Yankee site is provided by the New England Central Railroad. In the past, the Vermont Yankee onsite rail system had two branches, one spur that ran to the containment access building and a second spur that ran to the turbine building. The spur that ran to the containment access building has largely been removed while portions of the spur that runs to turbine building remain intact. The spur that runs to the turbine building is shown in Figures 8 through 10.

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 Central Maine and Quebec Railway would need to be verified. It is uncertain whether the barge slip is deep enough to accommodate barges without dredging.
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 450 km. The condition of the Fields Landing Terminal located 3.2 km from the Humboldt Bay site is in use but the condition 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 on-site 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. It is uncertain whether the on-site barge slip would require dredging and leveling.
La Crosse	Direct rail	Barge to rail	An on-site rail spur was used to ship the reactor pressure vessel. It is uncertain whether the on-site barge facility could accommodate SNF transportation casks.
Zion	Direct rail	Barge to rail	The rail spur was recently refurbished to support reactor decommissioning waste shipments. The Zion barge facility was abandoned and the land on which it was located was donated to the Illinois Beach State Park. However, the barge pilings remain.
Crystal River	Direct rail	Barge to rail	Extensive on-site rail system serves co-located fossil fuel plants. Large components have also been received by barge, at an area adjacent to the coal barge unloading area.
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 decommissioning of San Onofre-1. The Del Mar Boat Basin was recently used for barge transport of steam generators.
Vermont Yankee	Direct rail	–	The on-site rail spur will be reactivated to support decommissioning.

Fig. 5. Aerial view of the Vermont Yankee site

Fig. 6. Vermont Yankee Independent Spent Fuel Storage Installation (2016)

Fig. 7. Aerial view of Vermont Yankee Independent Spent Fuel Storage Installation

Fig. 8. On-site rail spur approaching Turbine Building (2016)

Fig. 9. On-site rail spur looking south (2016)

Fig. 10. On-site rail spur approaching site exit (2016)

As mentioned previously, rail service to the Vermont Yankee site is provided by the New England Central Railroad. In the vicinity of the Vermont Yankee site, the New England Central Railroad is track class 3. Figure 11 shows the Vermont Yankee rail spur approaching the entrance to the site, Figure 12 shows the rail spur approaching the New England Central Railroad, and Figure 13 shows the junction of the Vermont Yankee rail spur and the New England Central Railroad (looking south).

The two major freight railroads that the New England Central Railroad interchanges with in the vicinity of the Vermont Yankee site are the Pan Am Southern and the CSXT. The New England Central Railroad interchanges with the Pan Am Southern in Brattleboro, Vermont and with the CSXT in Palmer, Massachusetts. Figures 14 and 15 show the railyards in these locations.

Fig. 11. Rail spur approaching Vermont Yankee site entrance (2016)

Fig. 12. Rail spur approaching New England Central Railroad mainline (2016)

Fig. 13. Junction of Vermont Yankee rail spur (left) and New England Central Railroad (right) looking south (2016)

Fig. 14. Brattleboro Railyard (2016)

Fig. 15. Palmer Railyard (2016)

CONCLUSIONS

An updated evaluation of removing SNF and GTCC waste from 13 shutdown sites was conducted during 2016. Updates to the evaluation since 2015 include incorporating spent nuclear fuel data from the GC-859 database; updating of Google Earth imagery; incorporating revisions to transportation certificates of compliance; adding information obtained from site visits to the Pacific Sun Railroad and Camp Pendleton, California; adding rail assessments for Kewaunee, Crystal River, and San Onofre to the evaluation; and adding information obtained from the site visit to Vermont Yankee. Additional conclusions from this evaluation include:

- The 13 sites use designs from 4 different suppliers involving 11 different (horizontal and vertical) dry storage systems that would require the use of 9 different transportation cask designs to remove the SNF and GTCC waste.
- Each site has unique features and/or conditions.
- Although some changes to transportation certificates of compliance will be required, the SNF at the initial 9 shutdown sites (Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion) is in dual-purpose dry storage canisters that can be transported, including a small amount of high-burnup fuel.
- Most sites indicated that 2-3 years of advance time would be required for its preparations before shipments could begin. Some sites could be ready in less time.
- Most sites have more than one transportation option, e.g., rail, barge, or heavy haul truck, as well as constraints and preferences.

As additional sites such as Fort Calhoun, Palisades, Clinton, Quad Cities, Pilgrim, Oyster Creek, and Diablo Canyon shut down, they will be added to the evaluation.

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