Preliminary Evaluation of Removing Used Nuclear Fuel from Shutdown Sites

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Nuclear Fuels Storage and Transportation Planning Project
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September 30, 2013
FCRD-NFST-2013-000238
PNNL-22676 Rev. 1

NFST Working Document: External Release Requires DOE-NE Approval

EXECUTIVE SUMMARY

This report fulfills the M2 milestone M2FT-13PN0912022, “Stranded Sites De-Inventorying Report.”

In January 2013, the U.S. Department of Energy (DOE) issued the *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* (DOE 2013). Among the elements contained in this strategy is an initial focus on accepting used nuclear fuel 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 used nuclear fuel at shutdown sites as a priority so that these sites may be completely decommissioned and put to other beneficial uses (BRC 2012). Shutdown sites are defined as those commercial nuclear power reactor sites where the nuclear power reactors have been shut down and the site has been decommissioned or is undergoing decommissioning. In this report, a preliminary evaluation of removing used nuclear fuel 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. These sites have no other operating nuclear power reactors at their sites and have also notified the U.S. Nuclear Regulatory Commission 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 are not included in this evaluation.

The evaluation was divided into four components:

- characterization of the used nuclear fuel and greater-than-Class C (GTCC) low-level radioactive 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 used nuclear fuel from the shutdown sites, including gaps in information
- an evaluation of the actions necessary to prepare for and remove used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites.

Using these evaluations, the authors developed time sequences of activities and time durations for removing the used nuclear fuel and GTCC low-level radioactive waste from a single shutdown site and from the Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion sites. The Crystal River, Kewaunee, and San Onofre sites were not included because these sites only recently shut down. Because these three sites are at the beginning stages of the decommissioning process, they generally do not have fully developed irradiated fuel management plans or post-shutdown decommissioning activities reports, making estimates of time durations for removing the used nuclear fuel and GTCC low-level radioactive waste from these sites less certain.

At the 12 shutdown sites, a total of 14,158 used nuclear fuel assemblies and a total of 5555.0 metric tons heavy metal (MTHM) of used nuclear fuel are forecast to be stored in 472 storage canisters (actual plus estimated). In addition, 24 canisters (actual plus estimated) containing GTCC low-level radioactive waste are forecast to be stored at these sites. Several issues were identified during the characterization of the used nuclear fuel and GTCC low-level radioactive waste inventory at the shutdown sites. The most important of the issues was at the Rancho Seco site, where six damaged fuel assemblies in five of the storage canisters were not placed in 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 lists of approved contents in the certificates of compliance for the TS125, HI-STAR HB, and MP187 transportation casks do not include GTCC low-level radioactive waste. Consequently, the GTCC low-level radioactive waste stored at the Big Rock Point, Humboldt Bay, Rancho Seco, and San Onofre sites would not be transportable without changes to the certificates of compliance for these transportation casks. The certificates of compliance for the TS125 and MP187 transportation casks would also need to be updated from a -85 to a -96 designation before the casks could be used. In addition, the used nuclear fuel at Crystal River and Kewaunee would not be transportable without changes 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]) used nuclear fuel assemblies in storage. These high burnup used nuclear fuel assemblies are packaged, or will be packaged in damaged fuel cans, which eliminates the concern over the transportability of this high burnup fuel. Crystal River, Kewaunee, and San Onofre are also estimated to have high burnup used nuclear fuel. This high burnup used nuclear fuel would not be transportable without changes to the list of approved contents in the certificate of compliance for the MP197HB transportation cask.

All sites were found to have at least one off-site transportation mode option for removing their used nuclear fuel and GTCC low-level radioactive waste, and some sites have two options. Table S-1 provides a summary of these transportation mode options for the shutdown sites. Large component removals during reactor decommissioning provided an important source of information in developing Table S-1. In addition, it is assumed that any refurbishment or upgrade of on-site infrastructure required prior to receipt of equipment for loading and transportation would be performed by the shutdown site organization to facilitate timely shipping of used nuclear fuel and GTCC low-level radioactive waste from the site.

Table S-1. Summary of Transportation Mode Options for Shipments from Shutdown Sites

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	–	The shortest heavy haul would be 7.5 miles to the east portal of the Hoosac Tunnel.
Connecticut Yankee	Barge to rail	Heavy haul truck to rail	The on-site barge slip was removed after decommissioning. It is uncertain whether the cooling water discharge canal is deep enough to accommodate barges without dredging. The shortest heavy haul would be about 12.5 miles to the Portland railhead. The rail infrastructure at the Portland railhead would need to be evaluated.
Humboldt Bay	Heavy haul truck to rail	Heavy haul truck to barge to rail	The heavy haul distance would be in the range of 160 to 260 miles. The condition of the Fields Landing Terminal would need to be verified for barge transport.
Big Rock Point	Heavy haul truck to rail	Barge to rail	The heavy haul would probably be about 52 miles to Gaylord, Michigan. A shorter heavy haul of 13 miles to Petoskey, Michigan may be possible. 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 a waiver 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. The location and method for loading the transportation cask and moving the transportation cask to a rail spur is uncertain.
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 for co-located fossil-fuel plants.
Kewaunee	Heavy haul truck to rail	Heavy haul truck to barge to rail	Condition of potential heavy haul truck routes and rail infrastructure would need to be evaluated.
San Onofre	Direct rail	Barge to rail	The rail spur was recently refurbished to support reactor decommissioning waste shipments for San Onofre-1.

ISFSI = independent spent fuel storage installation

The actions necessary to prepare for and remove the used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites are listed as tasks in Table S-2. Based on these tasks, the characteristics of the sites' inventories of used nuclear fuel and GTCC low-level radioactive waste, the on-site conditions, and the near-site transportation infrastructure and experience, time sequences of activities and time durations were developed to prepare for and remove the used nuclear fuel and GTCC low-level radioactive waste from a single shutdown site and from the nine shutdown sites. Figure S-1 presents the ranges in the estimates of time durations for the single-shutdown site scenario. For a single shutdown site, the estimated time to prepare for and remove the used nuclear fuel and GTCC low-level radioactive waste ranged from 6.2 to 11.2 years. These estimates were based on a range of time durations for tasks, and on varying numbers of available transportation casks, which combine to yield the upper and lower estimates in Figure S-1.

Table S-2. Activities to Prepare for and Remove Used Nuclear Fuel from Shutdown Sites

Task	Task Activity Description
Programmatic Activities to Prepare for Transport Operations from a Shutdown Site	
1 – Assemble Project Organization	Assemble management teams, identify shutdown site existing infrastructure, constraints, and transportation resource needs and develop interface procedures.
2 – Acquire Casks, Railcars, Ancillary Equipment and Transport Services	Develop specifications, solicit bids, issue contracts, and initiate preparations for shipping campaigns. Includes procurement of transportation casks and revisions to certificates of compliance as may be needed, procurement of AAR Standard S-2043 railcars, and procurement of off-site transportation services.
3 – Conduct Preliminary Logistics Analysis and Planning	Determine fleet size, transport requirements, and modes of transport for shutdown site.
4 – Coordinate with Stakeholders	Assess and select routes and modes of transport and to support training of transportation emergency response personnel.
5 – Develop Campaign[a] Plans	Develop plans, policies, and procedures for at-site operational interfaces and acceptance, support operations, and in-transit security operations.
Operational Activities to Prepare, Accept, and Transport from a Shutdown Site	
6 – Conduct Readiness Activities	Assemble and train at-site operations interface team and shutdown site workers. Includes readiness reviews, tabletop exercises and dry run operations.
7 – Load for Off-site Transport	Load and prepare casks and place on transporters for off-site transportation.
8 – Accept for Off-site Transport	Accept loaded casks on transporters for off-site transportation.
9 – Transport	Ship shutdown site casks.

AAR = Association of American Railroads

[a] A campaign plan contains step-by-step, real-time instructions for completing a shipment from an origin site.

Figure S-2 presents the representative durations and sequence of activities to prepare for and remove all used nuclear fuel and GTCC low-level radioactive waste from the nine shutdown sites. In Figure S-2 the cumulative duration of 11.5 to 14.5 years was based on staggered shipping campaigns and optimistic estimates of time durations for tasks and includes the schedule uncertainty associated with procurement of casks and railcars and coordination of shipping campaigns. As mentioned previously, the representative durations and sequence of activities shown in Figure S-2 do not include Crystal River, Kewaunee, and San Onofre.

The estimated durations presented in Figures S-1 and S-2 were most affected by the time required to load and transport the used nuclear fuel and GTCC low-level radioactive waste; procure casks, components, and campaign kits; and the time required to procure railcars that meet Association of American Railroads (AAR) Standard S-2043 (2008). While the latter two activities could take place in parallel, they still represent a significant fraction of the time it would take to prepare for and remove the used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites.

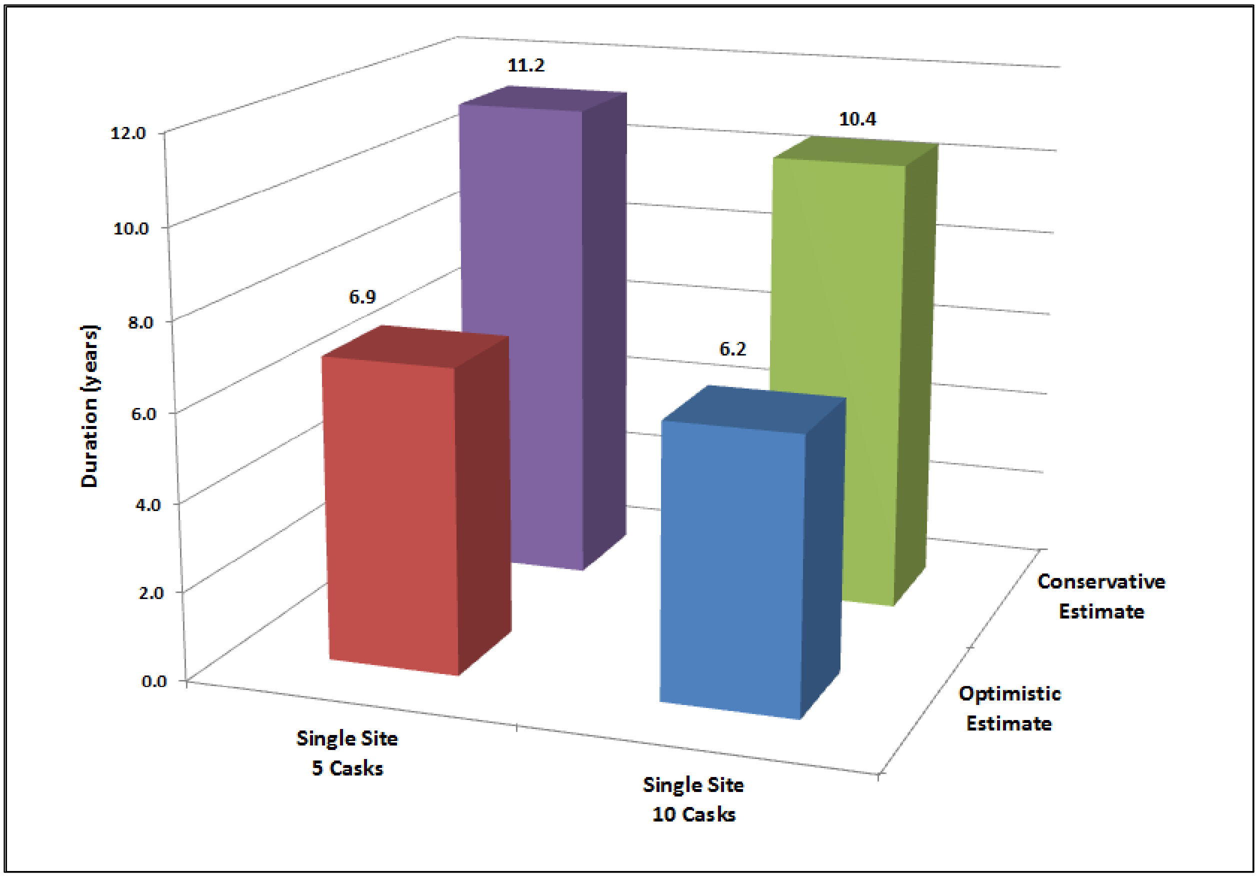

Figure S-1. Estimated Time Durations to Prepare for and Remove Used Nuclear Fuel and GTCC Low-Level Radioactive Waste from a Single Shutdown Site

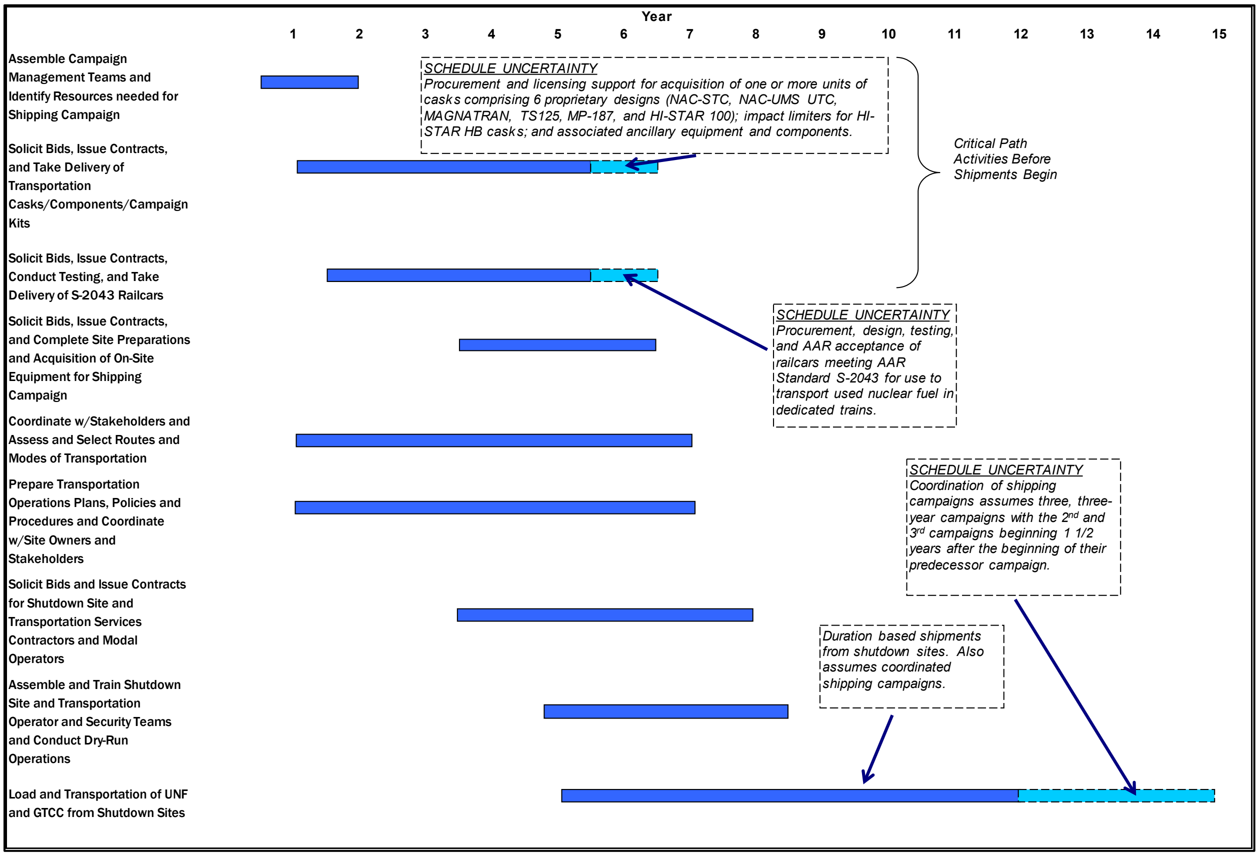

Figure S-2. Estimated Durations of Key Activities to Prepare for and Remove Used Nuclear Fuel and GTCC Low-Level Radioactive Waste from Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion

Project activities that would precede shipments from all of the shutdown sites would require only a slightly greater amount of time than that that would be required for one shutdown site. This assumes that project resources (personnel, funding, and functions such as procurement and quality assurance) would be adequate to support concurrent acquisitions of transportation casks and associated components that would include several units of each of the seven transportation casks that would be used at Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion—the NAC-STC, NAC-UMS UTC, MP187, TS-125, HI-STAR 100, HI-STAR HB, and MAGNATRAN; and to acquire and certify the fleet of cask, buffer, and escort railcars that would be needed. It also assumes that there would be flexibility in making acquisitions such as limited constraints on procuring casks and associated components from non-domestic suppliers.

As part of this preliminary evaluation, nine shutdown sites were visited: Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion. In order to refine the information in this report and to refine the estimates of activities and task durations, the authors recommend that the three remaining shutdown sites (Crystal River, Kewaunee, and San Onofre) be visited.

The estimates of durations for project tasks presented here are preliminary and depend on the many identified assumptions. Consequently, in preparing a comprehensive project plan to prepare for and remove used nuclear fuel from the shutdown sites it will be necessary to refine the estimates using improved information regarding each of the sites and their near-site transportation infrastructure, and using methods that will allow managers to gauge the importance of assumptions and project considerations. In this regard, it is recommended that DOE or other management and disposition organization use a quantitative risk analysis tool such as Primavera Risk Analysis (formerly known as Pertmaster) in conjunction with a scheduling tool such as Primavera P6 to provide estimates of project risks and opportunities. Such quantitative analyses would support estimating, managing, and funding of contingencies, and would increase confidence that the project would be successfully executed. Risk-informed estimates would also allow the project's managers to anticipate time and funding resources, and alternative courses of action that might be needed to effectively respond to changing circumstances.

DOE or other management and disposition organization should also take advantage of improved information regarding loading and transportation of used nuclear fuel from the shutdown sites to refine the data used by the DOE Transportation Operations Model (TOM) to evaluate optimizations that may be possible in acquiring and using transportation resources. TOM could also be used to conduct sensitivity analyses and identify important gaps in information that could be filled with additional data collected from the shutdown sites. Information developed using TOM could also be used in case studies conducted using the quantitative analysis tools discussed above.

ACKNOWLEDGMENTS

The authors would like to thank the participants in the visits to the shutdown sites: Jeffrey R. Williams (U.S. Department of Energy Nuclear Fuels Storage and Transportation Planning Project Director), Jay G. Jones (U.S. Department of Energy), Corinne J. Macaluso (U.S. Department of Energy), Mark D. Abkowitz (Vanderbilt University), Richard Arnold (Pahrump Paiute Tribe), Matthew R. Feldman (Oak Ridge National Laboratory), Lisa R. Janairo (Council of State Governments Midwest), Joshua J. Jarrell (Oak Ridge National Laboratory), Daniel R. Leduc (Savannah River National Laboratory), Lawrence "Mel" Massaro (Federal Railroad Administration), Peter N. Swift (Sandia National Laboratories), John C. Wagner (Oak Ridge National Laboratory), and Jim Williams (Western Interstate Energy Board).

The authors would like to thank J. Gary Lanthrum (NAC International) for the photos of storage systems, components, and transportation casks, Cameron Bragg and Andrew Richards (Bragg Crane and Rigging) for photos of barge transport, Elena A. Kalinina for TSL-CALVIN simulations, Larisa Smith for coordinating logistics, and Cornelia Brim and Susan Tackett for editing and document production assistance. The authors would also like to thank the staff at the Maine Yankee, Yankee Rowe, Connecticut, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion sites, who graciously hosted the visits to the shutdown sites, and the state representatives who participated in the visits to the shutdown sites.

Name	Affiliation	Name	Affiliation
John Arnold	Maine Yankee	Wayne A. Norton	Maine Yankee, Yankee Rowe, Connecticut Yankee
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ACRONYMS

AAR	Association of American Railroads
AC&T	American Cranes & Transport
ADAMS	Agencywide Documents Access and Management System
BRC	Blue Ribbon Commission on America's Nuclear Future
BWR	boiling water reactor
CSI	Criticality Safety Index
CY	Connecticut Yankee
DOE	U.S. Department of Energy
DSI	DeskMap Systems, Inc.
EIA	Energy Information Agency
EPRI	Electric Power Research Institute
FC-DSC	fuel with control component dry shielded canister
FF-DSC	failed fuel dry shielded canister
FO-DSC	fuel only dry shielded canister
GWd/MTHM	gigawatt-day per metric ton heavy metal
GTCC	greater-than-Class C
HBHRCD	Humboldt Bay Harbor, Recreation & Conservation District
IAEA	International Atomic Energy Agency
ISFSI	independent spent fuel storage installation
MPC	multipurpose canister
MTHM	metric tons heavy metal
MWe	megawatt electric
MWt	megawatt thermal
NRC	U.S. Nuclear Regulatory Commission
PG&E	Pacific Gas and Electric Company
PWR	pressurized water reactor
QA	quality assurance
STB	Surface Transportation Board
STC	storage transport cask

TN	Transnuclear, Inc.
TOM	Transportation Operations Model
TOPO	Transportation Operations Project Office
TSC	Transportable Storage Canister
USACE	U.S. Army Corps of Engineers
UTC	Universal Transport Cask

NUCLEAR FUELS STORAGE AND TRANSPORTATION PLANNING PROJECT

Preliminary Evaluation of Removing Used Nuclear Fuel from Shutdown Sites

1. INTRODUCTION

This report provides a preliminary evaluation of removing stranded used nuclear fuel from 12 shutdown sites. Shutdown sites are defined as those commercial nuclear power reactor sites where the nuclear power reactors have been shut down and the site has been decommissioned or is undergoing decommissioning. The shutdown sites are Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, Zion, Crystal River, Kewaunee, and San Onofre. 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 are not included in this evaluation. Reactors that have agreements to shut down in the future but that have not notified the NRC that they have permanently ceased power operations and that nuclear fuel has been permanently removed from their reactor vessels are also not included in this evaluation.

The locations of the shutdown sites are shown in Figure 1-1. The material to be removed from the shutdown sites includes both the used nuclear fuel and the greater-than-Class C (GTCC) low-level radioactive waste that is stored, or will be stored, at the independent spent fuel storage installations (ISFSIs) at each one of the sites.

The preliminary evaluation of removing the used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites was divided into four components:

- characterization of the used nuclear fuel and GTCC low-level radioactive 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 used nuclear fuel from the shutdown sites, including gaps in information
- an evaluation of actions necessary to prepare for and remove used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites.

These evaluations are contained in Section 2. Section 3 contains an overview of the requirements for off-site transportation infrastructure.

Section 4 contains time sequences of activities and their durations developed from the lists of actions that are necessary to prepare for and remove used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites. Total time durations for a single-site scenario are developed for conservative and optimistic estimates of the time durations for tasks, and assuming varying numbers of available casks. Representative durations and sequences of activities to prepare for and remove all used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites are also presented, and include the schedule uncertainty associated with procurement of casks and railcars and coordination of shipping campaigns. Crystal River, Kewaunee, and San Onofre were not included because these sites only recently shut down and are at the beginning stages of the decommissioning process. These sites generally do not have fully developed irradiated fuel management plans or post-shutdown decommissioning activities reports, making estimates of time durations for removing the used nuclear fuel and GTCC low-level radioactive waste from these sites less certain.

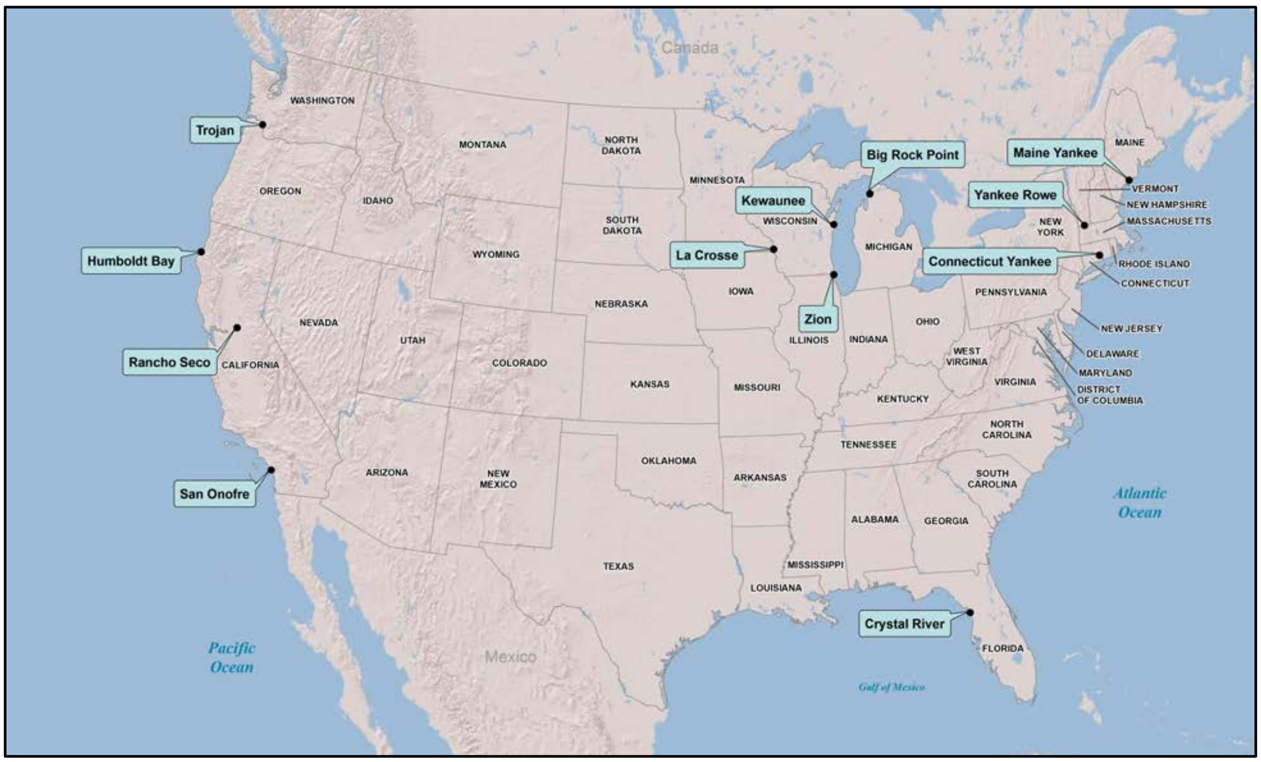

Figure 1-1. Locations of Shutdown Sites

2. SITE INVENTORY, SITE CONDITIONS, NEAR-SITE TRANSPORTATION INFRASTRUCTURE AND EXPERIENCE, AND GAPS IN INFORMATION

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the shutdown sites. The primary sources for the inventory of used nuclear fuel and GTCC low-level radioactive waste are the RW-859 database (EIA 2002), industry sources such as *StoreFUEL* and *SpentFUEL*, and government sources such as the 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, and Zion sites; information provided by managers at the shutdown sites; Facility Interface Data Sheets compiled for the U.S. Department of Energy (DOE) in 2005 (TriVis Incorporated 2005); Services Planning Documents prepared for DOE in 1993 and 1994; industry publications such as *Radwaste Solutions*; and Google Earth (Google 2013). Where on-site infrastructure upgrades or refurbishments are needed or where specialized equipment is required, they are assumed to be known by the shutdown site organization and necessary tasks are assumed to be completed by the time of the delivery of transportation casks and equipment.

Table 2-1 lists the characteristics of the commercial nuclear power reactors that operated at the shutdown sites. These reactors operated between the years 1961 and 2013. Three of the reactors (Humboldt Bay, Big Rock Point, and La Crosse) were boiling water reactors and twelve of the reactors were pressurized water reactors (Maine Yankee, Yankee Rowe, Connecticut Yankee, Rancho Seco, Trojan, Zion 1 and 2, Crystal River, Kewaunee, and San Onofre-1, -2, and -3). The licensed capacities for these reactors ranged from 165 to 3438 MWt (48 to 1130 MWe). Decommissioning has been completed for six of the sites and is ongoing at Humboldt Bay, La Crosse, Zion, and San Onofre-1. Decommissioning activities are commencing at Crystal River, Kewaunee, and San Onofre-2 and -3. At these sites, all used nuclear fuel has been removed from the reactor vessels and placed in spent fuel pools.

Figure 2-1 illustrates the number of canisters and type of storage canisters containing used nuclear fuel and GTCC low-level radioactive waste that are stored or will be stored at each of the shutdown sites. The number of canisters stored at Maine Yankee, Yankee Rowe, Connecticut Yankee, Big Rock Point, Rancho Seco, Trojan, and La Crosse represent actual canisters in storage. At Humboldt Bay, a sixth canister containing GTCC low-level radioactive waste is expected to be loaded by the end of 2013. The number of canisters for Zion, Crystal River, Kewaunee, and San Onofre represent an estimate of the number of canisters that will be stored at the conclusion of canister loading. Additional canisters containing GTCC low-level radioactive waste could also be generated at Zion, Crystal River, Kewaunee, and San Onofre as decommissioning progresses. There are expected to be a total of 496 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.

Table 2-1. Characteristics of Shutdown Site Reactors[a]

Site Location	Reactor Type	MWt	MWe (net)	Operating Period[b]	Current Status
Maine Yankee, Wiscasset, Maine	PWR	2700	860	1972-1996	DECON[c] completed
Yankee Rowe, Rowe, Massachusetts	PWR	600	167	1961-1991	DECON completed
Connecticut Yankee, Meriden, Connecticut	PWR	1825	560	1968-1996	DECON completed
Humboldt Bay, Eureka, California	BWR	200	63	1963-1976	DECON in progress
Big Rock Point, Charlevoix, Michigan	BWR	240	67	1963-1997	DECON completed
Rancho Seco, Herald, California	PWR	2772	913	1975-1989	DECON in progress
Trojan, Rainer, Oregon	PWR	3411	1130	1976-1992	DECON completed
La Crosse, Genoa, Wisconsin	BWR	165	48	1969-1987	DECON in progress
Zion 1, Zion, Illinois	PWR	3250	1040	1973-1997	DECON in progress
Zion 2, Zion, Illinois	PWR	3250	1040	1974-1996	DECON in progress
Crystal River, Crystal River, Florida	PWR	2609	860	1977-2009	UNF removed from reactor vessel 05/28/2011
Kewaunee, Kewaunee, Wisconsin	PWR	1772	574	1974-2013	UNF removed from reactor vessel 05/14/2013
San Onofre-1, San Clemente, California	PWR	1347	436	1968-1992	DECON in progress
San Onofre-2, San Clemente, California	PWR	3438	1070	1983-2013	UNF removed from reactor vessel 07/18/2013
San Onofre-3, San Clemente, California	PWR	3438	1080	1984-2013	UNF removed from reactor vessel 10/05/2012

a. Sources: NRC (2012) and IAEA (2012)
b. The operating period represents the date of commercial operation to the date of shutdown.
c. DECON is a method of decommissioning in which structures, systems, and components that contain radioactive contamination are removed from a site and safely disposed of at a commercially operated low-level radioactive waste disposal facility or decontaminated to a level that permits the site to be released for unrestricted use shortly after it ceases operation (NRC 2012).
PWR= pressurized water reactor
BWR= boiling water reactor
UNF= used nuclear fuel

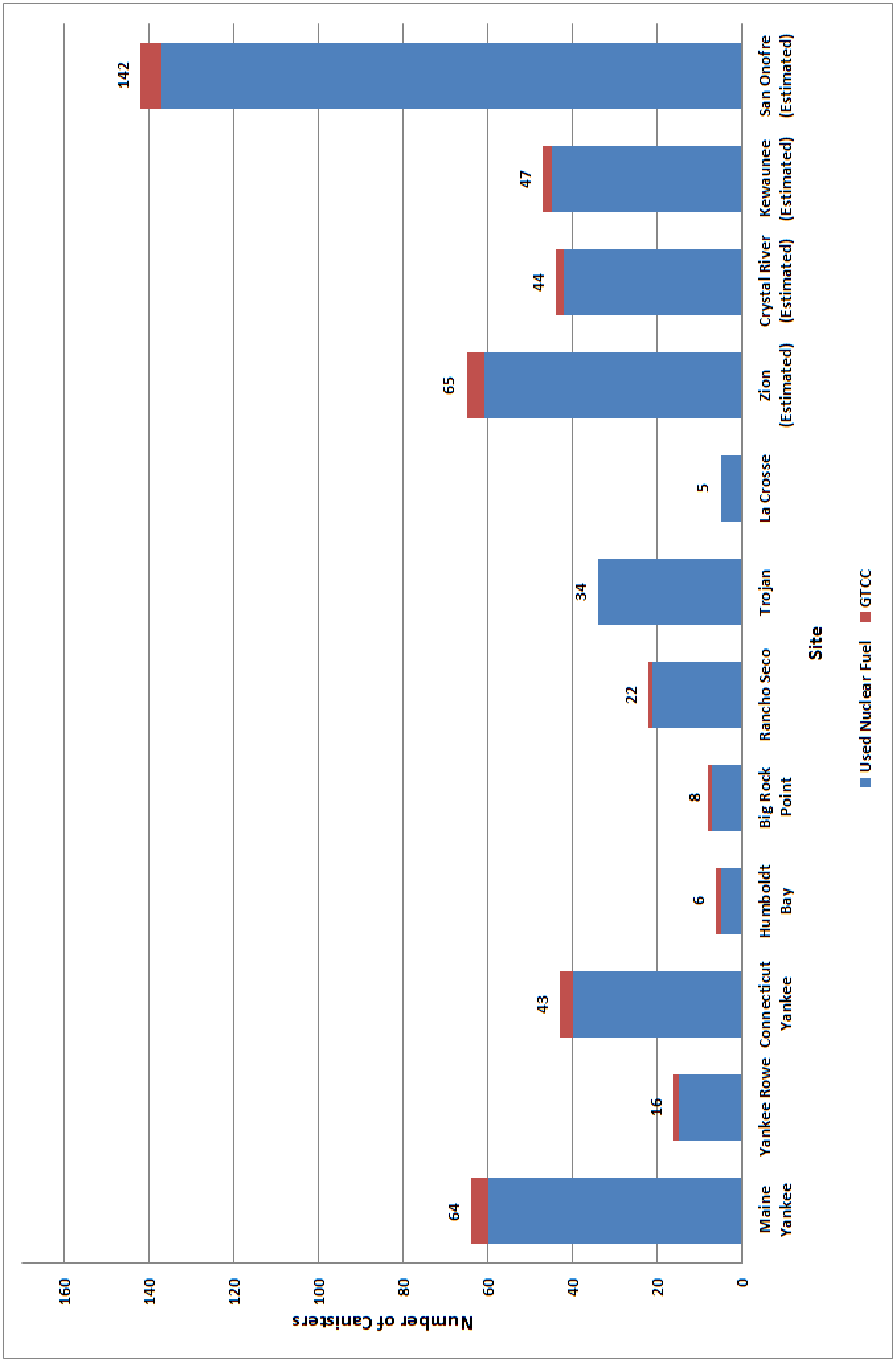

Figure 2-1. Number of Canisters at Shutdown Sites

Figure 2-2 illustrates the number of used nuclear fuel assemblies stored at each site. There are a total of 14,158 used nuclear fuel assemblies present at the shutdown sites. These assemblies are composed of 12,994 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 (12,496) of the used nuclear fuel assemblies are zirconium alloy-clad; but Yankee Rowe, Connecticut Yankee, La Crosse, and San Onofre-1 have 1662 stainless steel-clad used nuclear fuel assemblies in storage.

Figure 2-3 illustrates the same information in terms of the metric tons of heavy metal stored at each site. A total of 5555.0 metric tons heavy metal (MTHM) of used nuclear fuel at the shutdown sites consists of 5430.2 MTHM of pressurized water reactor used nuclear fuel and 124.8 MTHM of boiling water reactor used nuclear fuel. The number of assemblies and MHTM of used nuclear fuel at each shutdown site were obtained from the RW-859 database (EIA 2002), from information provided by the shutdown sites, and from projections made using the TSL-CALVIN computer code (Nutt et al. 2012), and may not include material such as fuel debris and failed fuel rods that may also be present in the storage canisters at the shutdown sites.

Table 2-2 lists the storage systems used at the shutdown sites and the corresponding transportation casks that are certified to ship the storage canisters containing used nuclear fuel and GTCC low-level radioactive waste at each of the sites.[1] Out of the eight transportation cask designs listed in Table 2-2, only three types have been fabricated for U.S. use: the HI-STAR HB, the MP187, and the HI-STAR 100. The HI-STAR HB can only be used to ship used nuclear fuel from the Humboldt Bay site. The MP187 can be used to ship used nuclear fuel from the Rancho Seco and San Onofre sites. The HI-STAR 100 casks that have been fabricated are already being used as storage casks at the Dresden and Hatch sites (Ux Consulting 2013a). For the HI-STAR 100 casks to be used to ship used nuclear fuel 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 (Washington Nuclear Corporation 2003), but not for use in the United States. Currently, there is no transportation cask licensed to ship used nuclear fuel stored in NUHOMS 32PT or 32PTH1 canisters.

[1] Appendix A lists the docket number, package identification number, revision number, certificate of compliance expiration date, and the Agencywide Documents Access and Management System (ADAMS) accession number for the transportation casks licensed to transport used nuclear fuel from the shutdown sites. Appendix A also lists the docket number, certificate of compliance number issue date, certificate of compliance expiration date, amendment number, amendment effective date, and ADAMS accession number for the general licensed storage systems used at the shutdown sites.

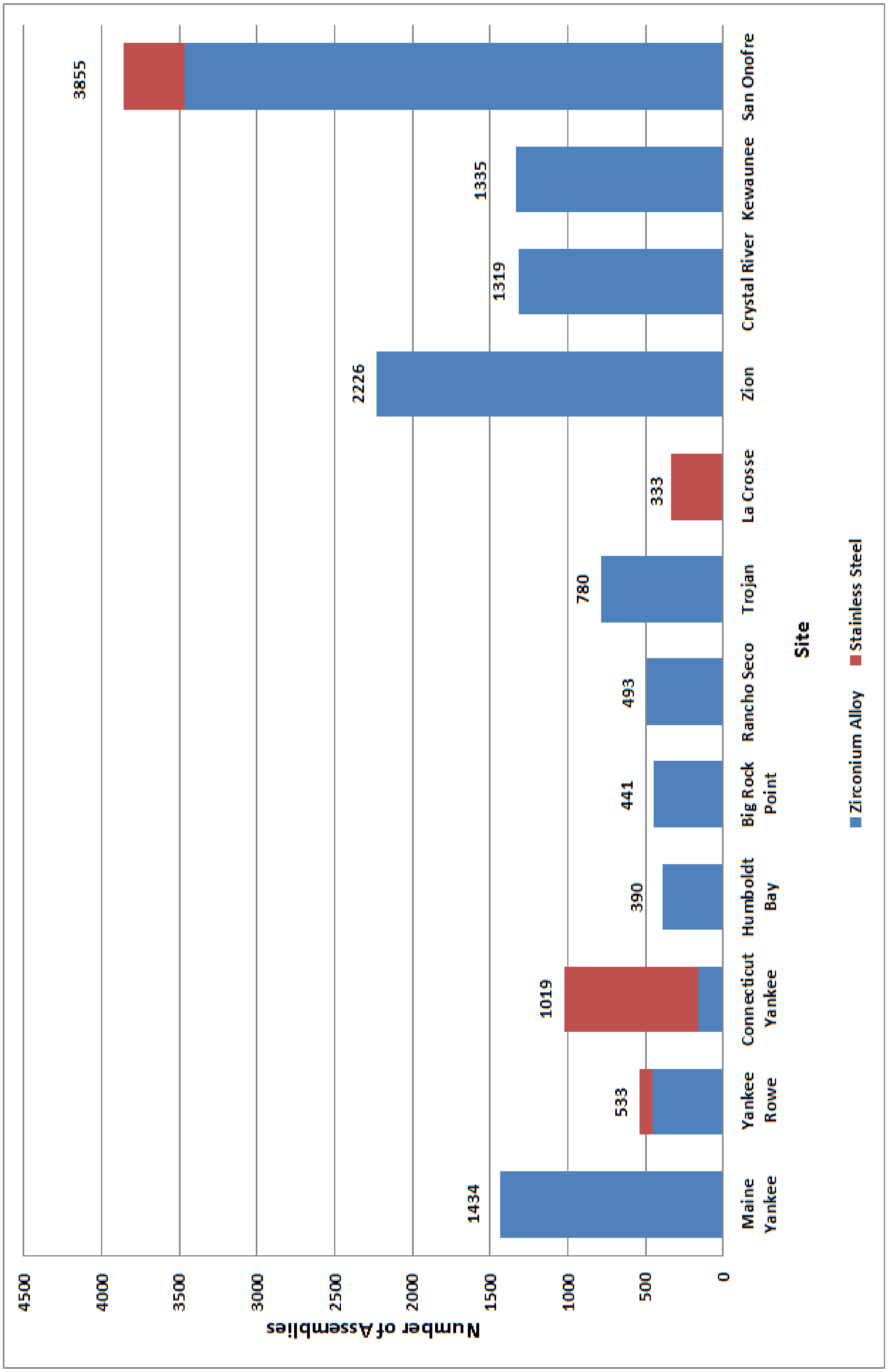

Figure 2-2. Number of Assemblies by Cladding Type at Shutdown Sites

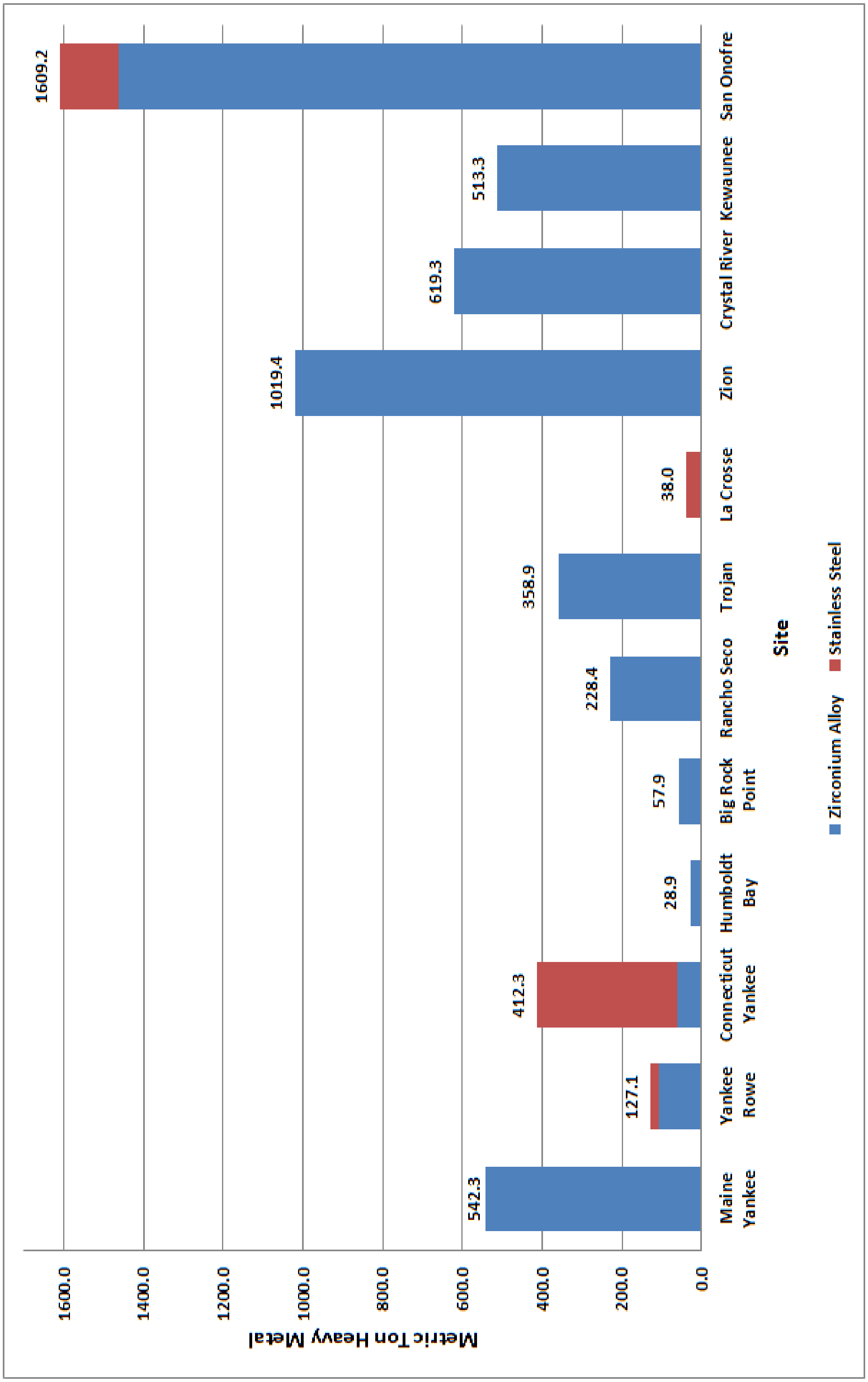

Figure 2-3. Metric Tons Heavy Metal by Cladding Type at Shutdown Sites

Table 2-2. Storage Systems and Transportation Casks Used at Shutdown Sites

Reactor Site	Type	ISFSI Load Dates[a]	Storage System/Canister(s)	Transportation Cask Status	Canisters UNF/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 05/31/2014. 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 5/31/2014. 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 3/31/2014. Fuel in canisters in fabricated casks. No impact limiters.	5/1[b]
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 11/30/2013. 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 3/31/2014. 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 5/31/2014. Foreign use versions fabricated.	5/0
Zion 1 and 2	PWR	Planned 2013	NAC MAGNASTOR/TSC-37 canister	MAGNATRAN (Docket No. 71-9356) Application for certificate of compliance under review. None fabricated.	61/4[c,d]
Crystal River	PWR	Not Announced	TN Standardized NUHOMS/32PTH1 canister	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017. 32PTH1 canister is not licensed for transport in the MP197HB. None fabricated.	42/2[c,d]

Table 2-2. (contd)

Reactor Site	Type	ISFSI Load Dates[a]	Storage System/Canister(s)	Transportation Cask Status	Canisters UNF/GTCC
Kewaunee	PWR	08/2009-08/2011	TN Standardized NUHOMS/32PT canister	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017. 32PT canister is not licensed for transport in the MP197HB. None fabricated.	8
Kewaunee	PWR	Not Announced	TN Standardized NUHOMS/32PT and 24PT canisters	MP197HB (Docket No. 71-9302) 32PT canister is not licensed for transport in the MP197HB. None fabricated.	37/2[c,d]
San Onofre-1	PWR	08/2009-08/2011	TN Standardized Advanced NUHOMS/24PT1 canisters	MP187(Docket No. 71-9255) Certificate expires 11/30/2013. 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. None fabricated.	33
San Onofre-2 and -3	PWR	Not Announced	TN Standardized Advanced NUHOMS/24PT4 and 32PTH2 canisters	MP197HB (Docket No. 71-9302) Certificate expires 08/31/2017. None fabricated.	87/4[c,d]
Total					472/24

BWR= boiling water reactor, GTCC= greater-than-Class C, ISFSI= independent spent fuel storage installation, PWR= pressurized water reactor, UNF= used nuclear fuel

a. Dates represent the dates that the used nuclear fuel was transferred to the ISFSI.

b. One canister of GTCC low-level radioactive is expected to be loaded and transferred to the Humboldt Bay ISFSI in 2013.

c. Additional canisters of GTCC low-level radioactive waste could be generated during decommissioning.

d. Estimated.

2.1 Maine Yankee

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the Maine Yankee site. The Maine Yankee site is about 25 miles south of Augusta and about 45 miles north of Portland, Maine (TOPO 1993a).

2.1.1 Site Inventory

Sixty canisters containing 1432 used nuclear fuel assemblies, 2 consolidated fuel rod containers, and 2 failed fuel rod containers (i.e., damaged fuel cans[2]) and 4 canisters of GTCC low-level radioactive waste are stored at Maine Yankee. Figure 2-4 shows the ISFSI at Maine Yankee. The storage system used at Maine Yankee is the NAC-UMS system (Docket No. 72-1015), which consists of a transportable storage canister, a vertical concrete storage cask, and a transfer cask. The transportable storage canister holds 24 pressurized water reactor used nuclear fuel assemblies. The fuel assemblies from Maine Yankee were loaded into transportable storage canisters from August 2002 through March 2004 (Leduc 2012). The fuel assemblies have Zircaloy-clad fuel rods. The transportation cask that is licensed to transport the canisters containing this used nuclear fuel or GTCC low-level radioactive waste is the NAC-UMS Universal Transport Cask (UTC) Package (Docket No. 71-9270). No NAC-UMS UTC transportation casks have been fabricated.

Figure 2-5 illustrates the number of used nuclear fuel assemblies at Maine Yankee based on their discharge year. The oldest fuel was discharged in 1974 and the last fuel was discharged in 1996. The median discharge year of the fuel is 1984.

Figure 2-6 illustrates the number of used nuclear fuel assemblies at Maine Yankee based on their burnup. The lowest burnup is 2.8 gigawatt-day per metric ton heavy metal (GWd/MTHM) and the highest burnup is 49.2 GWd/MTHM. The median burnup is 32.1 GWd/MTHM. Used nuclear fuel with a burnup greater than 45 GWd/MTHM is termed as high burnup used nuclear fuel by the NRC. There are 90 of these high burnup used nuclear fuel assemblies at Maine Yankee. These high burnup used nuclear fuel assemblies were packaged in Maine Yankee Fuel Cans (i.e., damaged fuel cans, see Figures 2-7 through 2-9) and were loaded in the four basket corner positions in the transportable storage canisters. Twenty-three transportable storage canisters containing high burnup used nuclear fuel are stored at Maine Yankee. There are also 12 transportable storage canisters containing 43 damaged fuel assemblies in damaged fuel cans stored at Maine Yankee.

[2] A damaged fuel can is a stainless steel container that confines damaged used nuclear fuel. A damaged fuel can is closed on its end by screened openings that allow gaseous and liquid media to escape, but that minimize the dispersal of gross particulate material.

Photo courtesy of Maine Yankee

Figure 2-4. Maine Yankee Independent Spent Fuel Storage Installation

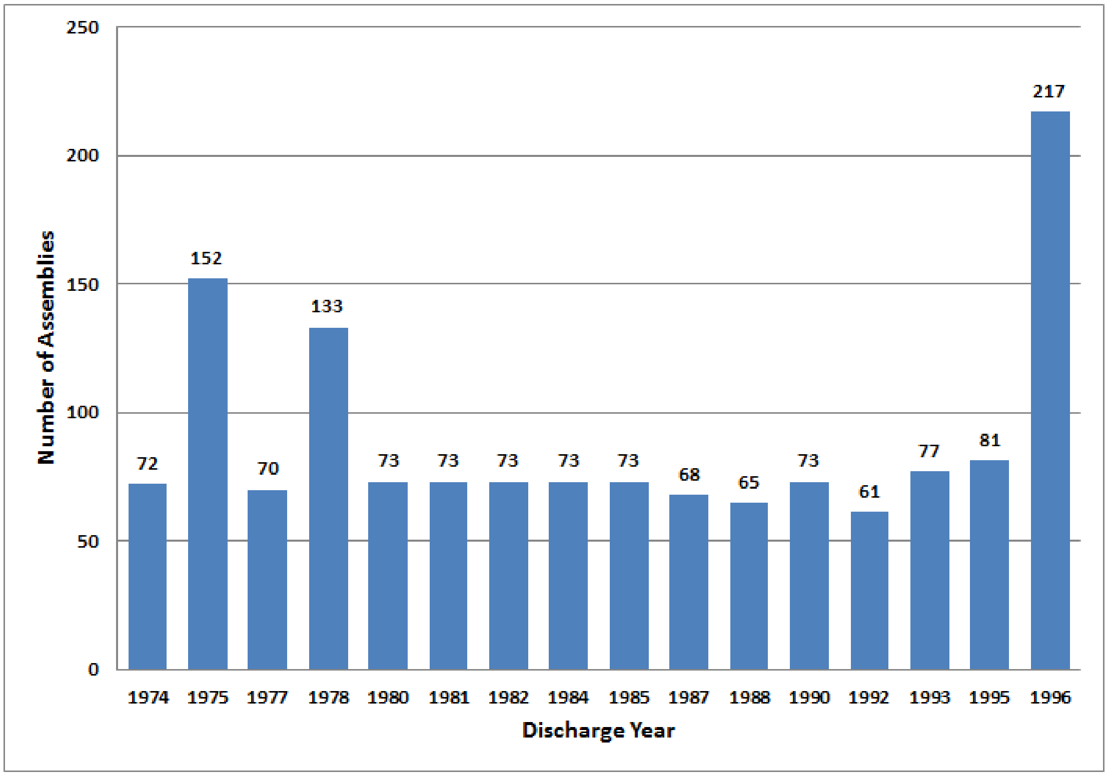

Figure 2-5. Maine Yankee Number of Assemblies versus Discharge Year (EIA 2002)

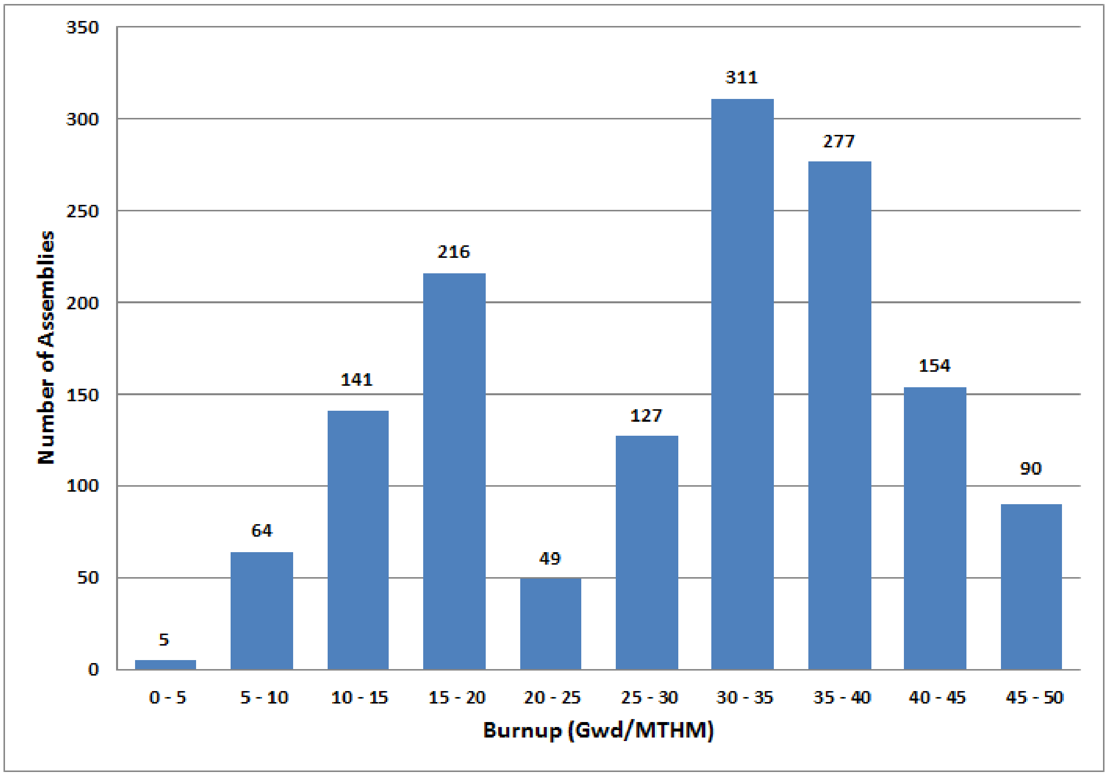

Figure 2-6. Maine Yankee Number of Assemblies versus Burnup (EIA 2002)

Photo courtesy of NAC International

Figure 2-7. Damaged Fuel Cans

Photo courtesy of NAC International

Figure 2-8. Ends of Damaged Fuel Cans with Lids

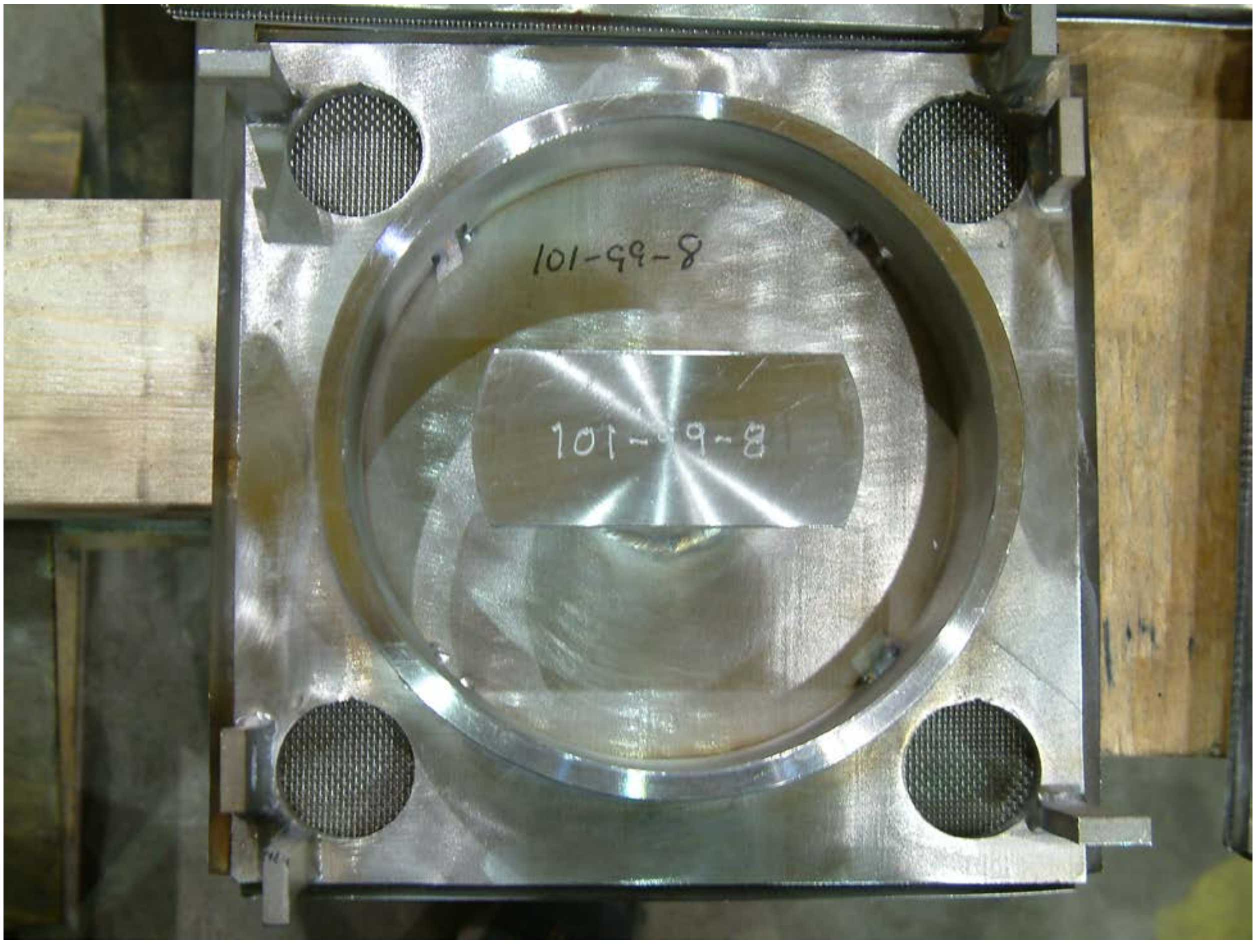

Photo courtesy of NAC International

Figure 2-9. Damaged Fuel Can Lid with Screened Openings

2.1.2 Site Conditions

Figure 2-10 provides an aerial view of the Maine Yankee site, where the Maine Yankee reactor and associated structures have been removed. Electrical power is available at the Maine Yankee ISFSI. However, mobile equipment such as cranes to unload the NAC-UMS vertical concrete storage casks used at Maine Yankee and to load the NAC-UMS UTC transportation cask that is licensed to transport the Maine Yankee used nuclear fuel and GTCC low-level radioactive waste is not present at the site. In addition, a transfer cask is not present at the site.

An on-site rail spur exists at Maine Yankee (Figure 2-11). This spur is designated as track class 1[3] and connects to the Rockland branch of the Maine Eastern Railroad at milepost 46.66, which is designated as track class 2. The Rockland branch connects to Pan Am Railways in

[3] Track class is a measure of track quality. In 49 CFR 213, the Federal Railroad Administration has categorized all track into nine classes (1-9), segregated by maximum allowable operating speed.

Brunswick, Maine. Pan Am Railways is a Class II regional railroad.[4] During decommissioning, 238 radioactive and nonradioactive waste shipments were made over the period 2000 to 2005 using this rail spur (EPRI 2005). There appears to be sufficient room within the Owner Controlled Area to permit staging of railcars. However, the rail spur has been paved over in spots (see Figure 2-12) and is not being maintained.

A barge dock that exists at Maine Yankee (Figure 2-13) would provide access to the Atlantic Ocean. The Maine Yankee steam generators, pressurizer, and reactor pressure vessel were shipped off-site using this barge dock (Wheeler 2002, Feigenbaum 2005). The three steam generators weighed 356 tons each (491 tons each when the shielding and carriage assembly are included) and the pressurizer weighed 100 tons (Radwaste Solutions 2000). These components were transported to Memphis, Tennessee for decontamination (Radwaste Solutions 2000). The reactor pressure vessel package weighed 1175 tons and was transported to the Barnwell, South Carolina low-level radioactive waste disposal facility (Feigenbaum 2005). In addition, EPRI (2005) states that the site's main power transformers were shipped off-site by barge. The barge dock is approximately 10 feet above the water and the depth of the water is about 6 feet at high tide (TOPO 1993a). The barge dock and access road were last used in 2003 (TriVis Incorporated 2005) and are not being maintained.

[4] Railroads are classified by the Surface Transportation Board based on their annual operating revenues. The class to which a carrier belongs is determined by comparing its adjusted operating revenues for three consecutive years to the following scale: Class I - \$250 million or more, Class II - \$20 million or more, and Class III - \$0 to \$20 million. The following formula is used to adjust a railroad's operating revenues to eliminate the effects of inflation: Current Year's Revenues × (1991 Average Index ÷ Current Year's Average Index). The average index (deflator factor) is based on the annual average Railroad Freight Price Index for all commodities (STB 2012).

Figure 2-10. Aerial View of the Maine Yankee Site (Google 2013)

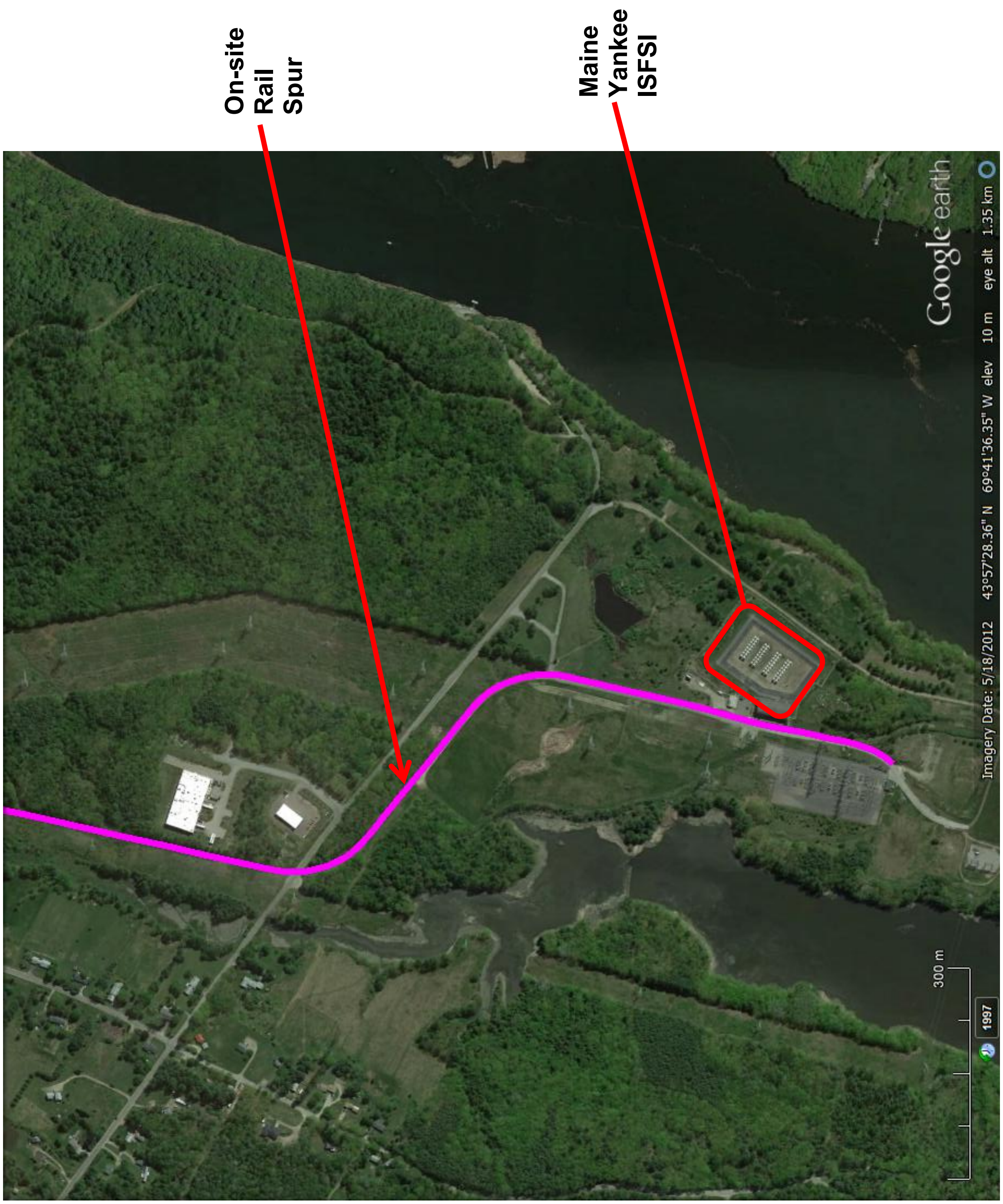

Figure 2-11. On-site Railroad Spur at the Maine Yankee Site (Google 2013)

Figure 2-12. Paved-over Railroad Tracks at the Maine Yankee Site

Figure 2-13. Barge Dock at the Maine Yankee Site

2.1.3 Near-site Transportation Infrastructure and Experience

As discussed in Section 2.1.2, Maine Yankee has direct rail access to the Maine Eastern Railroad via an on-site rail spur (see Figure 2-14). This rail spur was used for radioactive and nonradioactive waste shipments during decommissioning. There is sufficient room at Maine Yankee for a long on-site rail spur that should be able to accommodate trains having eight or more railcars (two buffer cars, a security escort car, and five or more cask cars).

The Maine Yankee site is located on Bailey Point on the Back River and has access to the Atlantic Ocean through the Sheepscot River. The Back River and Sheepscot River are navigable waterways and Maine Yankee has an on-site barge dock (see Figure 2-13) and therefore could be accessible by barges that would transport used nuclear fuel transportation casks to nearby ports served by railroads or to barge-accessible railheads. The nearest port with rail access is in Portland, Maine (DSI 2004).

As discussed in Section 2.1.2, during decommissioning at Maine Yankee, three steam generators, the pressurizer, and reactor pressure vessel were transported off-site using barges. Figures 2-15 and 2-16 show the Maine Yankee reactor pressure vessel being loaded onto a barge and being transported by barge, respectively.

For a site such as Maine Yankee that is directly accessible by barge, transportation casks would be loaded, prepared for off-site transportation, and placed onto transport skids/cradles. Because the location of the Maine Yankee ISFSI is not immediately adjacent to the barge dock, heavy-lift equipment would be used to place the casks and transport skids/cradles onto heavy haul vehicles for transport from the ISFSI to the on-site barge dock. Heavy-lift equipment would then transfer the casks from the heavy haul vehicles onto the deck of the transporting barges. Alternatively, the heavy haul transport vehicles with their transport casks could roll onto the barge, thereby not requiring heavy-lift capability at the siding/dock to move the casks from the heavy haul truck to the barge.

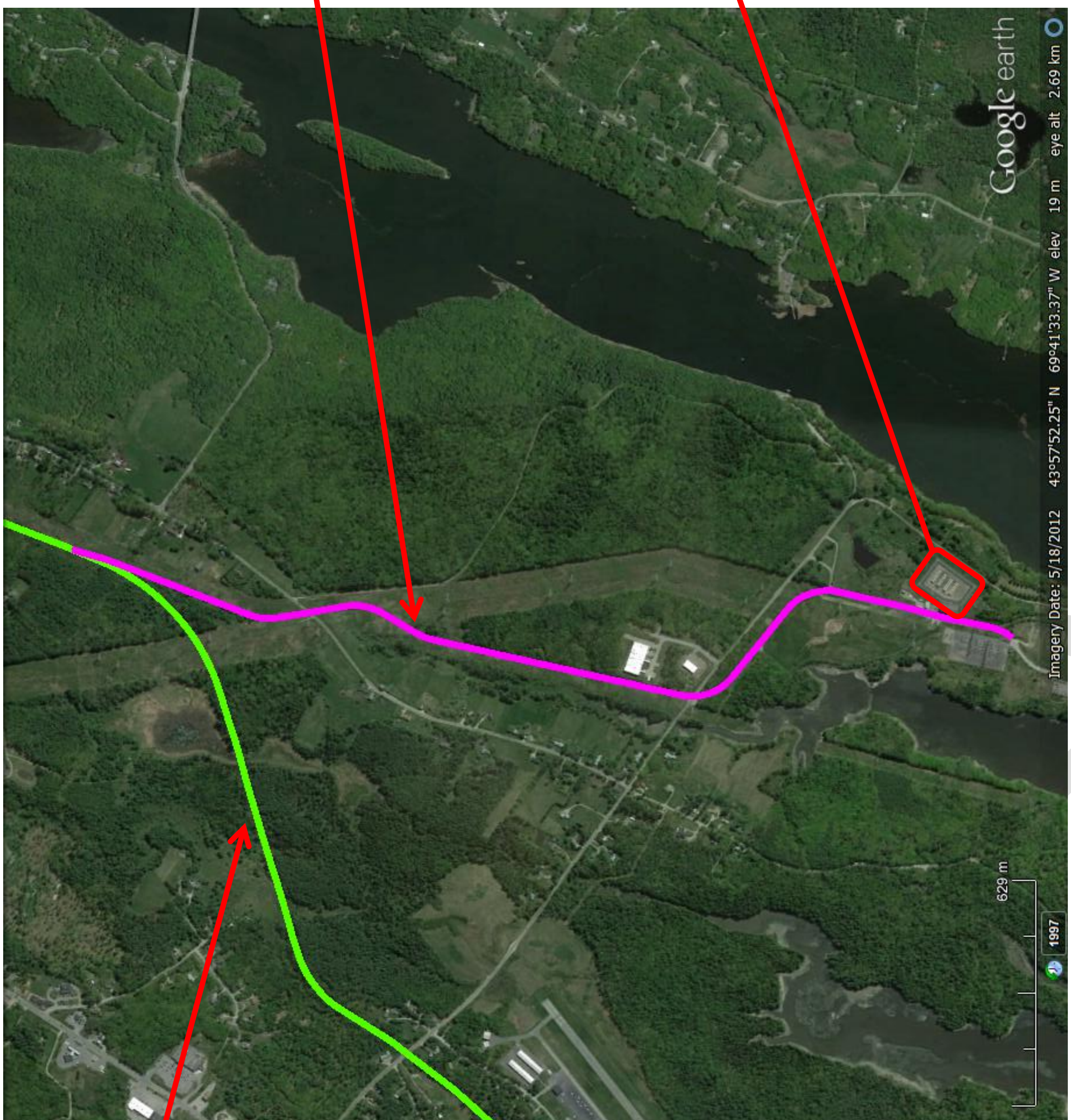

Figure 2-14. Rail Interface at Maine Yankee (Google 2013)

Photo courtesy of Maine Yankee

Figure 2-15. Maine Yankee Reactor Pressure Vessel Being Loaded onto Barge

Photo courtesy of Maine Yankee

Figure 2-16. Maine Yankee Reactor Pressure Vessel Being Transported on Barge

2.1.4 Gaps in Information

The principal question for the Maine Yankee site regarding the capability of the off-site transportation infrastructure to accommodate shipments of large transportation casks is whether the Maine Eastern Railroad is capable of accepting and moving used nuclear fuel railcars. An assessment by the Federal Railroad Administration's track safety engineers and of the Maine Eastern Railroad's maintenance-of-way staff would be necessary. If the railroad's infrastructure cannot accommodate the shipments, it would be necessary to ship casks on barges from the site to a port where they would be transferred to railcars. Because the Maine Yankee reactor pressure vessel was shipped from the site by barge, there is substantial confidence that barges could be used to move used nuclear fuel casks from the site. Nonetheless, it would be necessary to obtain a marine engineer's assessment of the condition of the channel leading to the Maine Yankee barge siding and to do any dredging and restoration of navigation aids in the channel that may be necessary.

2.2 Yankee Rowe

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the Yankee Rowe site. The Yankee Rowe site is in the northwest corner of Massachusetts, about 0.5 mile south of the Vermont border, 3.5 miles northwest of the town of Rowe, and 48 miles north of Pittsfield, Massachusetts (TOPO 1993b).

2.2.1 Site Inventory

There are 15 canisters containing 533 used nuclear fuel assemblies and 1 reconfigured fuel assembly,[5] and 1 canister of GTCC low-level radioactive waste stored at Yankee Rowe. The 15 canisters contain 7 damaged used nuclear fuel assemblies, which have been placed in damaged fuel cans.

Figure 2-17 shows the ISFSI at Yankee Rowe. The storage system used at Yankee Rowe is the NAC Multi-Purpose Canister system (NAC-MPC) (Docket No. 72-1025), which consists of a transportable storage canister, a vertical concrete storage cask, and a transfer cask. The transportable storage canister used for the Yankee Rowe used nuclear fuel is the Yankee-MPC, which holds 36 pressurized water reactor used nuclear fuel assemblies. The fuel assemblies from Yankee Rowe were loaded into NAC-MPC canisters from June 2002 through June 2003 (Leduc 2012). The fuel rods in the fuel assemblies at Yankee Rowe are either Zircaloy-clad (457 assemblies) or stainless steel-clad (76 assemblies). The NAC-STC transportation cask (Docket No. 71-9235) is licensed to transport the Yankee-MPC canisters, including canisters containing GTCC low-level radioactive waste. Figure 2-18 illustrates NAC-STC transportation cask. No NAC-STC transportation casks have been fabricated for use in the United States. Two

[5] A reconfigured fuel assembly is a stainless steel container having approximately the same external dimensions as a used nuclear fuel assembly that ensures criticality control geometry and permits gaseous and liquid media to escape while preventing the dispersal of gross particulates. A reconfigured fuel assembly may contain intact fuel rods, damaged fuel rods, and fuel debris.

NAC-STC transportation casks have been fabricated for use in China (Washington Nuclear Corporation 2003).

Figure 2-19 illustrates the number of used nuclear fuel assemblies at Yankee Rowe, based on their discharge year. The oldest fuel was discharged in 1972 and the last fuel was discharged in 1991. The median discharge year of the fuel is 1984.

Figure 2-20 illustrates the number of used nuclear fuel assemblies at Yankee Rowe based on their burnup. The lowest burnup is 4.2 GWd/MTHM and the highest burnup is 36.0 GWd/MTHM. The median burnup is 28.0 GWd/MTHM. There are no high burnup used nuclear fuel assemblies (burnup greater than 45 GWd/MTHM) stored at Yankee Rowe.

Photo courtesy of Yankee Rowe

Figure 2-17. Yankee Rowe Independent Spent Fuel Storage Installation

Photo courtesy of NAC International

Figure 2-18. NAC-STC Transportation Cask

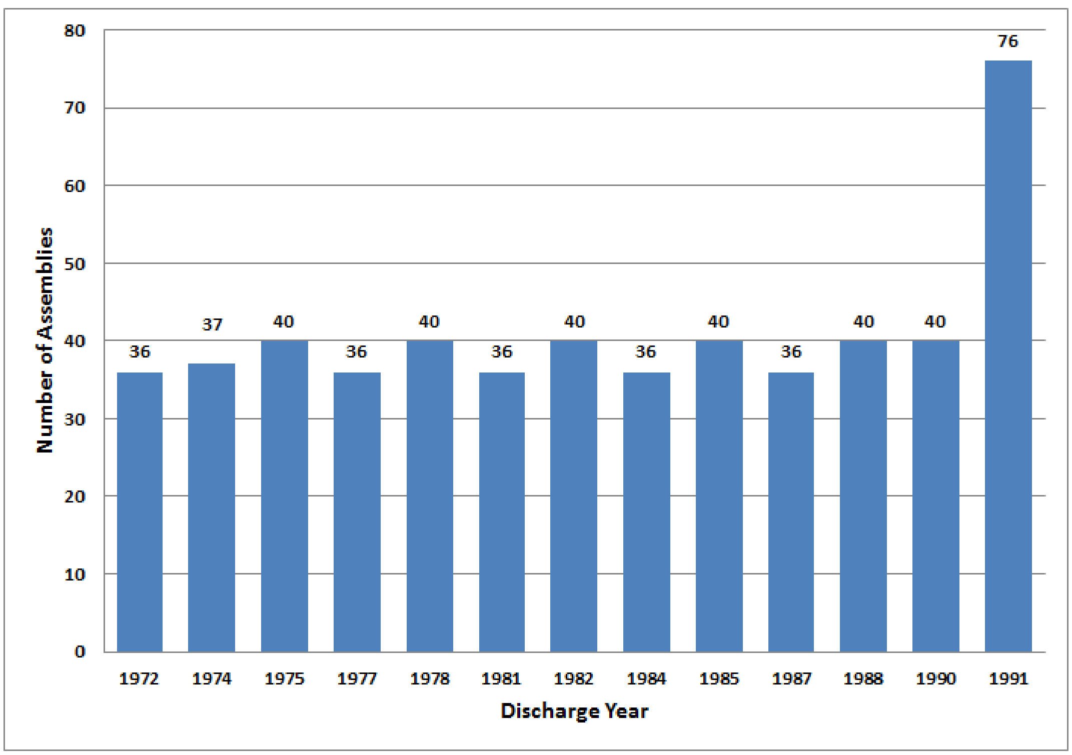

Figure 2-19. Yankee Rowe Number of Assemblies versus Discharge Year (EIA 2002)

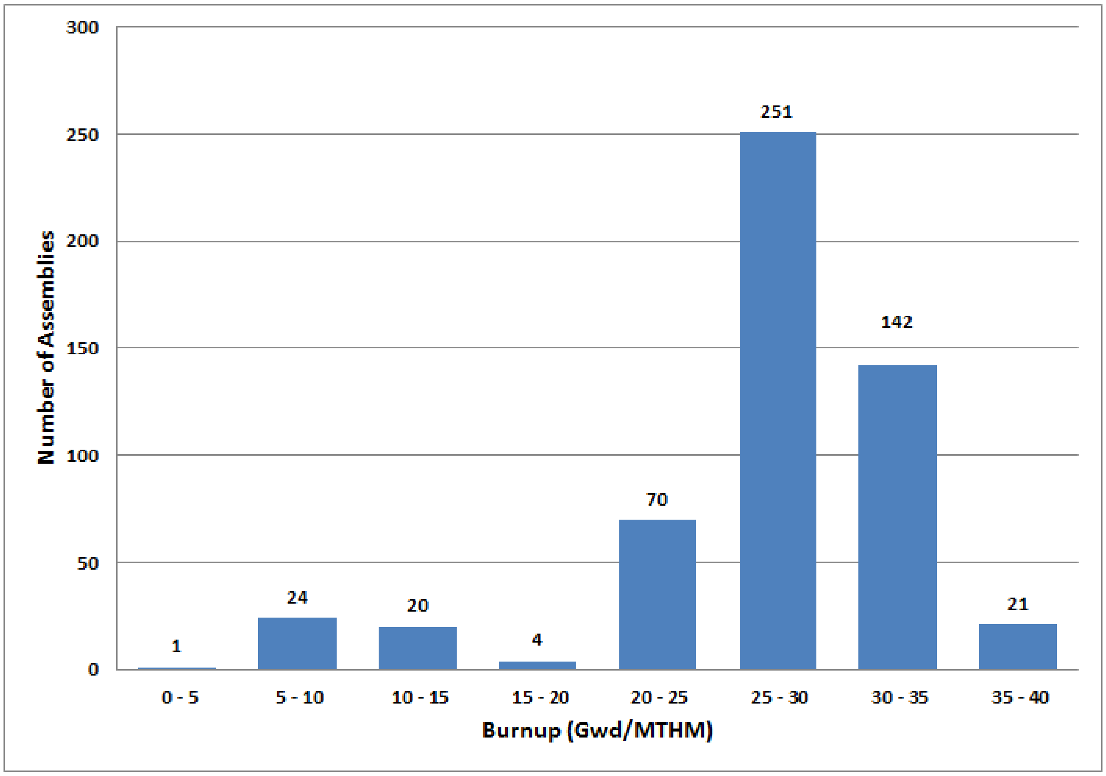

Figure 2-20. Yankee Rowe Number of Assemblies versus Burnup (EIA 2002)

2.2.2 Site Conditions

Figure 2-21 provides an aerial view of the Yankee Rowe site, where the reactor and associated structures have been removed. Electrical power is available at the Yankee Rowe ISFSI. However, mobile equipment such as cranes to unload the NAC-MPC vertical concrete storage casks used at Yankee Rowe and to load the NAC-STC transportation cask that is licensed to transport the Yankee Rowe used nuclear fuel and GTCC low-level radioactive waste is not currently present at the site. In addition, a transfer cask is not currently present at the site. There are two compatible transfer casks without doors or hydraulic components stored at the Connecticut Yankee site and one compatible transfer cask at the La Crosse site.

There is no barge access or direct rail access at the Yankee Rowe site. The nearest off-site barge facility is located in Albany, New York, a distance of 50 miles from Yankee Rowe (TriVis Incorporated 2005). Yankee Rowe had direct rail service, but the rail spur to the site was removed in the early 1970s and cannot be reinstalled because the construction of the Cockwell (formerly Bear Swamp) Pumped Storage Plant resulted in submersion of the rail line to Yankee Rowe (TOPO 1993b). The nearest railhead is at the east end of the Hoosac Tunnel, a distance of about 7.5 miles from the Yankee Rowe site. Heavy haul truck transport would be required to reach this railhead.

2.2.3 Near-site Transportation Infrastructure and Experience

The Yankee Rowe site does not have an on-site rail spur or a railroad that passes near to the site or along the site boundary. For Yankee Rowe, heavy haul trucks could be used to move transportation casks over public highways to a railhead or rail spur that provides access to a railroad that meets Federal Railroad Administration's regulatory standards and can accommodate the loaded transportation casks.

For shipments of casks containing used nuclear fuel that require the use of heavy haul trucks, the casks would be prepared for shipment at the Yankee Rowe ISFSI site and loaded onto a transport cradle that would be loaded onto the transport trailer of a heavy haul truck. The truck, led and followed by technical and security escorts, would move over an approved, designated highway route to a nearby rail siding or railhead. Heavy lift equipment would be used to transfer the cask and its cradle as a unit from the truck to a railcar at the rail siding or railhead.

Heavy haul trucks were used to move the reactor pressure vessel and steam generators from the Yankee Rowe site. For example, in 1997, the Yankee Rowe reactor pressure vessel was moved 7.5 miles on an improved county road by a heavy haul truck the from the Yankee Rowe site to a rail siding (now removed) at the east portal of the Hoosac Tunnel in western Massachusetts (see Figures 2-22 and 2-23). The siding connected to a rail line that is operated by the Pan Am Southern Railroad, a partnership of the Norfolk Southern Railroad and the Pan Am Railroad Company, a northeastern U.S. Class II regional railroad. The Pan Am Southern rail line at the Hoosac Tunnel is designated as track class 3. To reach the east portal of the Hoosac Tunnel, the heavy haul truck and reactor pressure vessel had to cross the Sherman Dam. EPRI (1998) states that the spillway bridge on the Sherman Dam was replaced prior to shipping the reactor pressure vessel and the slope stability along the roadway, as well as the roadway culverts, were assessed for the loaded cask transport conditions. The reactor pressure vessel cask package weighed 365 tons with saddle and tie downs (EPRI 1998). At the Hoosac Tunnel rail crossing, the reactor pressure vessel package was transferred from the roadway transporter to a TransAlta CAPX 1001 railcar. The railcar was equipped with a lateral shift mechanism that enabled handlers to move the cargo left or right up to 12 inches (Lessard 2000). The loaded gross weight of the railcar and cask was 1,122,700 lb. (EPRI 1998). The reactor pressure vessel was then transported to the Barnwell, South Carolina low-level radioactive waste disposal facility (Lessard 2000). During the trip to Barnwell, South Carolina, the lateral shift mechanism had to be used on six separate occasions to maneuver around structures or other railcars along the route (Lessard 2000). These shifts ranged from 3 to 12 inches (Lessard 2000).

Figure 2-24 shows the rail line at the east portal of the Hoosac Tunnel and Figure 2-25 shows the east portal of the Hoosac Tunnel. Figure 2-26 shows the Yankee Rowe reactor pressure vessel on the railcar used to transport it to the Barnwell, South Carolina low-level radioactive waste disposal facility. Figure 2-27 shows the route taken from the Yankee Rowe site to the east portal of the Hoosac Tunnel.

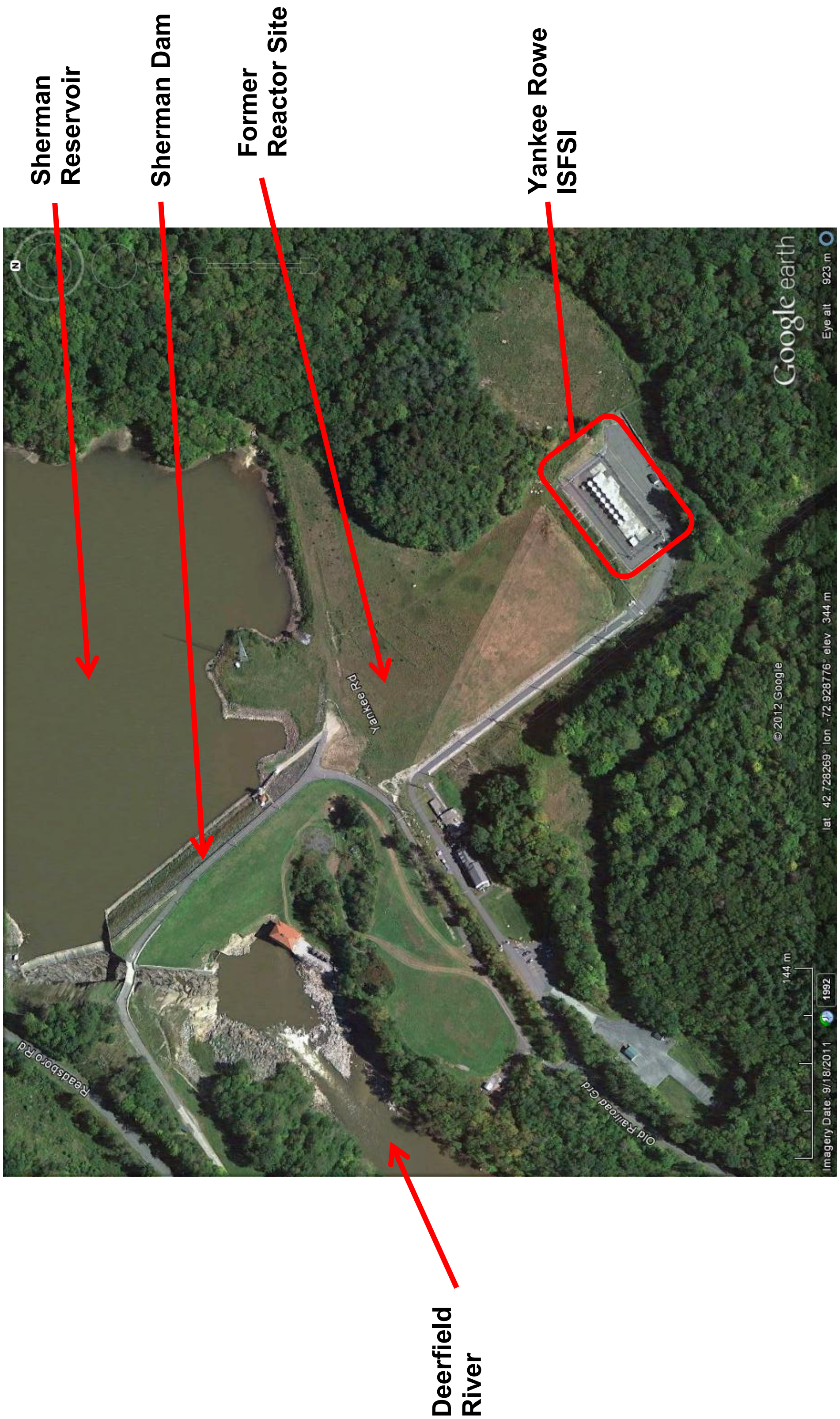

Figure 2-21. Aerial View of the Yankee Rowe Site (Google 2013)

Photo courtesy of Yankee Rowe

Figure 2-22. Yankee Rowe Reactor Pressure Vessel Being Transported by Heavy Haul Truck

Photo courtesy of Yankee Rowe

Figure 2-23. Yankee Rowe Reactor Pressure Vessel on Heavy Haul Truck Moving Under Power Lines

Figure 2-24. Rail Line at East Portal of the Hoosac Tunnel

Figure 2-25. East Portal of the Hoosac Tunnel

Photo courtesy of Yankee Rowe

Figure 2-26. Yankee Rowe Reactor Pressure Vessel on Railcar

2.2.4 Gaps in Information

The Yankee Rowe site is located inland in the western part of Massachusetts and thus does not have access to a navigable waterway. In addition, the Yankee Rowe site does not have direct rail access. Consequently, it would be necessary to use heavy haul trucks to transport casks containing used nuclear fuel from the site for a distance of about 7.5 miles over a local, improved road to the nearest location for a rail siding at the eastern portal of the Hoosac Tunnel. This would require constructing an on-site access road from the Yankee Rowe ISFSI to the Sherman Dam and obtaining authorization for the heavy haul vehicles to cross the dam. The Sherman Dam is owned and operated by TransCanada Hydro Northeast, Inc. Based on the experience during decommissioning, TransCanada would need to be notified of the intent to use the roadway and bridge to move heavy loads across the dam; the load evaluation used for the removal of the reactor pressure vessel and steam generators would have to be verified and modified if necessary, and an engineering walk down of the roadway and bridge would be needed to confirm that there had been no changes or deterioration that would invalidate the previous load evaluation.

The heavy haul truck route from Yankee Rowe to the Hoosac Tunnel can be ice covered at times during the winter and could need treatment to prepare it for shipments. A route survey and load evaluation for the heavy haul truck route would also be required. The siding that was installed at the tunnel for the purpose of loading the reactor pressure vessel onto a railcar has been removed and would need to be reinstalled before shipments of casks to this location could take place. Alternative routing for heavy haul trucks that would lead to North Adams, Massachusetts where casks could be loaded onto railcars, would require travel north over mountainous local roads into Vermont then south to the North Adams area, a distance of about 20 miles.

There is sufficient land in the Hoosac Tunnel area to stage handling equipment. This is based on the use of this area to load the reactor pressure vessel from the transporter to the railcar. However, site preparation work would most likely be required. The available space is limited for a rail siding at the Hoosac Tunnel location, making it likely that only one or two railcars could be placed for loading. It would be necessary to move loaded railcars from the siding to a staging area, possibly in North Adams, where trains with possibly two locomotives, buffer cars, and an escort car could be assembled. A staging location has not been identified.

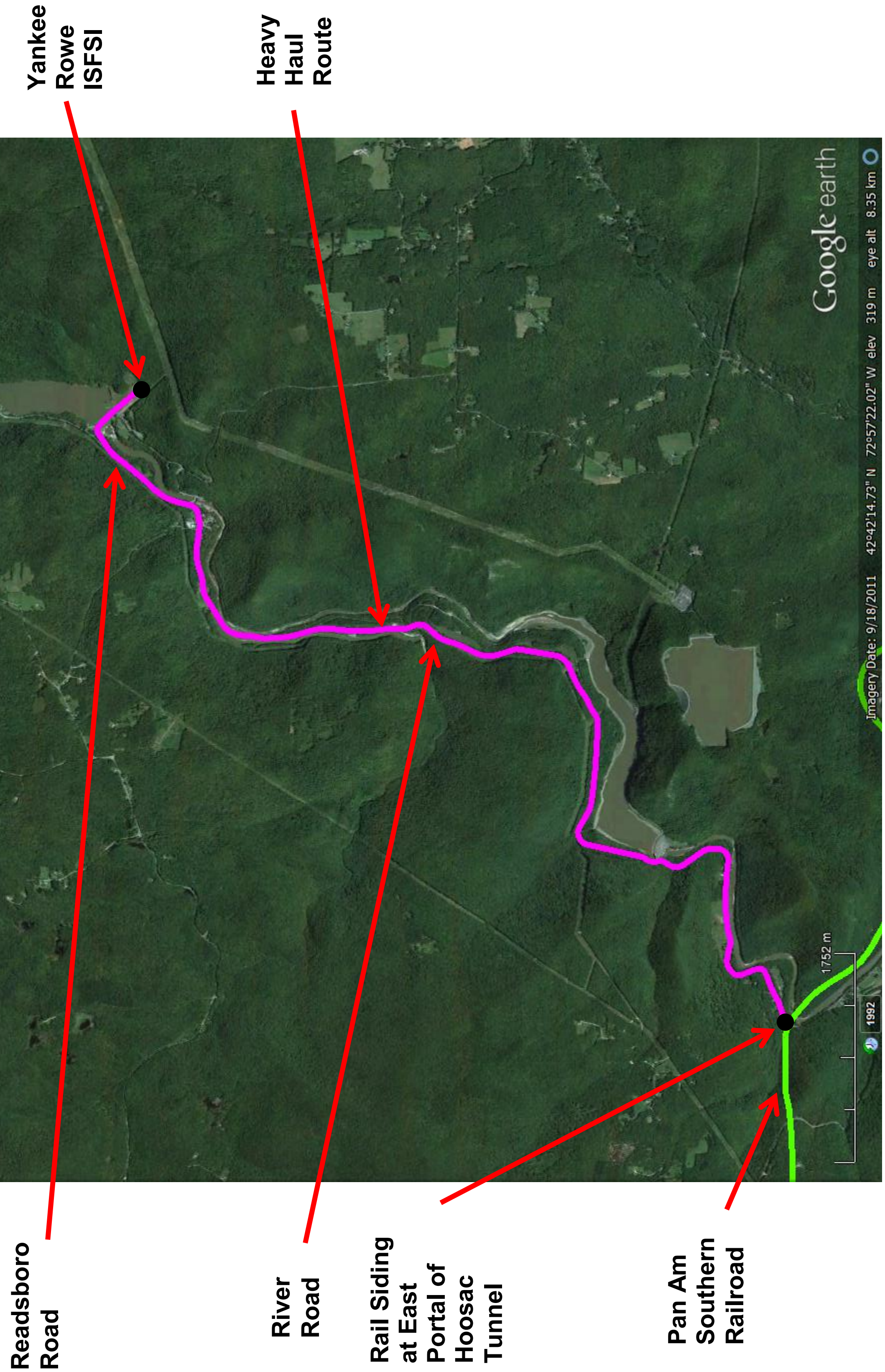

Figure 2-27. Yankee Rowe Reactor Pressure Vessel Heavy Haul Truck Route (Google 2013)

2.3 Connecticut Yankee

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the Connecticut Yankee site. The Connecticut Yankee site is located on the eastern shore of the Connecticut River near Haddam Neck, Connecticut, about 13 miles southeast of Middletown and 25 miles southeast of Hartford, Connecticut (TOPO 1993c).

2.3.1 Site Inventory

Forty canisters containing 1019 used nuclear fuel assemblies and 5 fuel storage containers, and 3 canisters of GTCC low-level radioactive waste are stored at Connecticut Yankee. The 40 canisters contain 67 damaged used nuclear fuel assemblies, which have been placed in damaged fuel cans.

Figure 2-28 shows the ISFSI at Connecticut Yankee. The storage system used at Connecticut Yankee is the NAC Multi-Purpose Canister system (NAC-MPC) (Docket No. 72-1025), which consists of a transportable storage canister, a vertical concrete storage cask, and a transfer cask. The transportable storage canister used for the Connecticut Yankee (CY) used nuclear fuel is the CY-MPC. This canister may be configured to hold 24 or 26 pressurized water reactor used nuclear fuel assemblies. The fuel assemblies from Connecticut Yankee were loaded into CY-MPC canisters from May 2004 through March 2005 (Leduc 2012). The fuel rods in the fuel assemblies at Connecticut Yankee are either Zircaloy-clad (161 assemblies) or stainless steel-clad (858 assemblies). The NAC-STC transportation cask (Docket No. 71-9235) is licensed to transport the CY-MPC canisters, including canisters containing GTCC low-level radioactive waste. No NAC-STC transportation casks have been fabricated for use in the United States. Two NAC-STC transportation casks have been fabricated for use in China (Washington Nuclear Corporation 2003).

Photo courtesy of Connecticut Yankee

Figure 2-28. Connecticut Yankee Independent Spent Fuel Storage Installation

In addition to the 43 canisters of used nuclear fuel and GTCC radioactive waste stored at the Connecticut Yankee ISFSI, two transfer casks are stored at the Connecticut Yankee ISFSI. These transfer casks could also be used at the Yankee Rowe site.

Figure 2-29 illustrates the number of used nuclear fuel assemblies at Connecticut Yankee, based on their discharge year. The oldest fuel was discharged in 1971 and the last fuel was discharged in 1996. The median discharge year of the fuel is 1984.

Figure 2-30 illustrates the number of used nuclear fuel assemblies at Connecticut Yankee, based on their burnup. The lowest burnup is 8.2 GWd/MTHM and the highest burnup is 43.0 GWd/MTHM. The median burnup is 33.1 GWd/MTHM. There is no high burnup used nuclear fuel (burnup greater than 45 GWd/MTHM) stored at Connecticut Yankee.

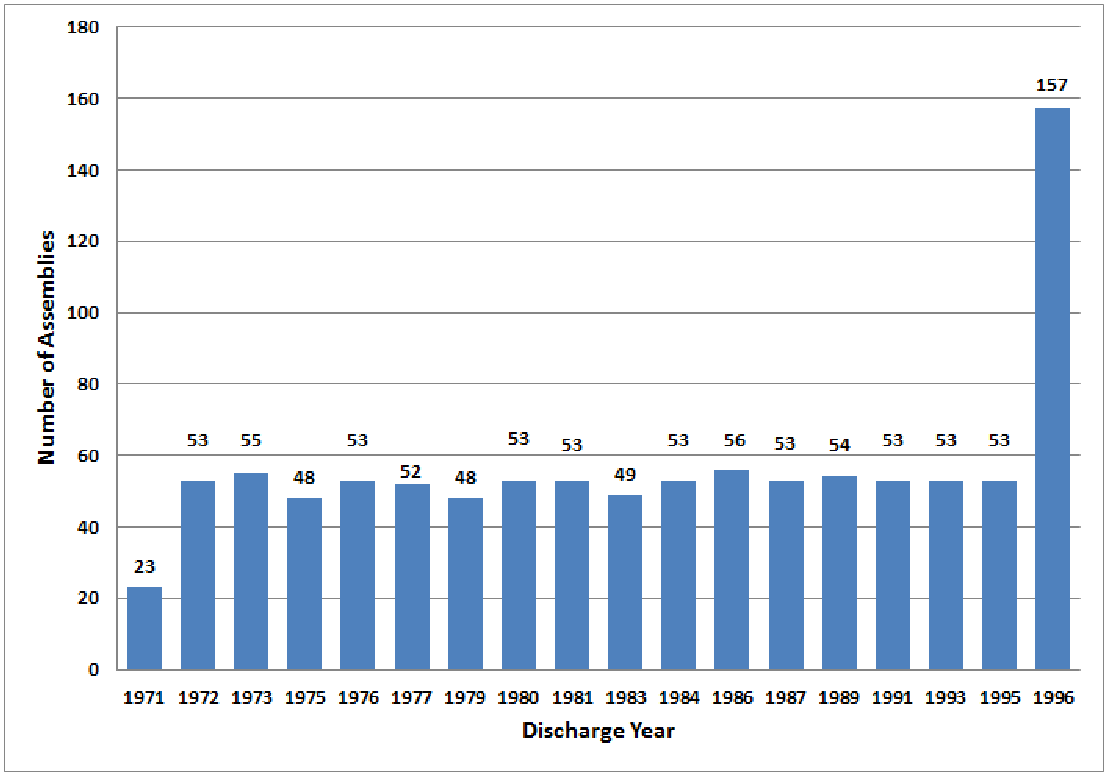

Figure 2-29. Connecticut Yankee Number of Assemblies versus Discharge Year (EIA 2002)

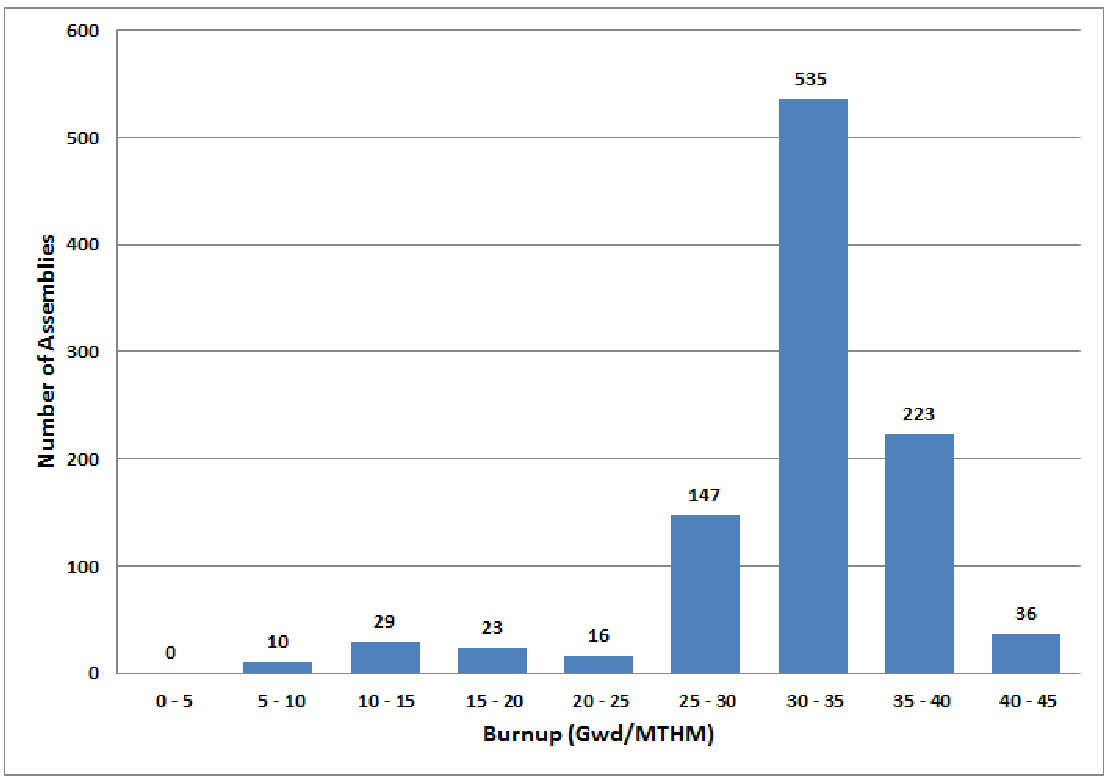

Figure 2-30. Connecticut Yankee Number of Assemblies versus Burnup (EIA 2002)

2.3.2 Site Conditions

Figure 2-31 provides an aerial view of the Connecticut Yankee site, where the reactor and associated structures have been removed. Electrical power is available at the Connecticut Yankee ISFSI. However, mobile equipment such as cranes to unload the NAC-MPC vertical concrete storage casks used at Connecticut Yankee and to load the NAC-STC transportation cask that is licensed to transport the Connecticut Yankee used nuclear fuel and GTCC low-level radioactive waste is not currently present at the site. There are two transfer casks without doors or hydraulic components stored at the Connecticut Yankee ISFSI. These transfer casks could also be used at the Yankee Rowe site.

There is no on-site rail access at Connecticut Yankee. The nearest railhead is in Portland, Connecticut near Middletown, Connecticut, about 12 miles from the Connecticut Yankee ISFSI. To reach this railhead, heavy haul truck transport would be required. The Connecticut Yankee pressurizer and steam domes[6] were removed from the site using this heavy haul route. The rail line at Portland is designated as track class 1 and connects to the Providence and Worcester Railroad in Middletown, Connecticut after crossing the Connecticut River. The condition of this bridge is unknown. The Providence and Worcester rail line in Middletown, Connecticut is designated as track class 2.

An on-site barge slip at Connecticut Yankee is located at the northeast end of the cooling water discharge canal (see Figures 2-31 and 2-32) and is about 0.9 miles from the Connecticut Yankee ISFSI. This slip provides access to the Connecticut River and Atlantic Ocean (TOPO 1993c). The barge slip and cooling water discharge canal were used to ship the reactor pressure vessel, steam generators, and transformer off-site (EPRI 2006, Connecticut Yankee 2012). At the time that the reactor pressure vessel was shipped, the cooling water discharge canal had silted up and the canal was dredged before the reactor pressure vessel was shipped (EPRI 2006). The on-site barge slip was removed after decommissioning. It is uncertain at this time whether the cooling water discharge canal is deep enough to accommodate barges without dredging.

2.3.3 Near-site Transportation Infrastructure and Experience

The Connecticut Yankee site does not have an on-site rail spur or a railroad that passes near to the site or along the site boundary. For Connecticut Yankee, heavy haul trucks could be used to move transportation casks over public highways to a railhead or rail spur that provides access to a railroad that meets Federal Railroad Administration's regulatory standards and can accommodate the loaded transportation casks.

[6] The steam dome is the upper portion of the steam generator (EPRI 2006).

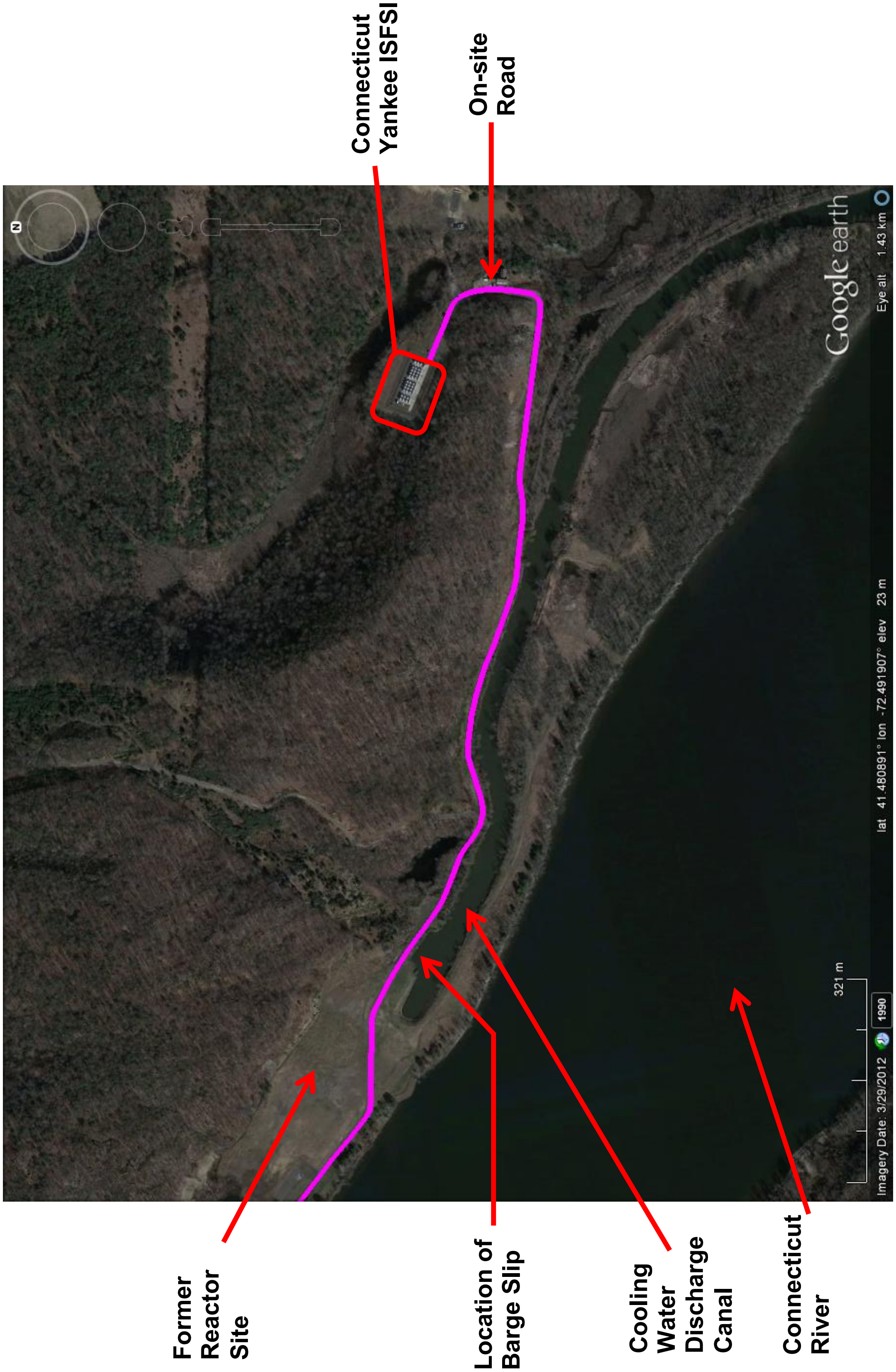

Figure 2-31. Aerial View of the Connecticut Yankee Site (Google 2013)

Figure 2-32. Barge Slip at the Connecticut Yankee Site

For shipments of casks containing used nuclear fuel that require the use of heavy haul trucks, the casks would be prepared for shipment at the Connecticut Yankee ISFSI site and loaded onto a transport cradle that would then be loaded onto the transport trailer of a heavy haul truck. The truck, led and followed by technical and security escorts, would move over an approved, designated highway route to a nearby rail siding or railhead. Heavy lift equipment would be used to transfer the cask and its cradle as a unit from the truck to a railcar at the rail siding or railhead.

In 1999 and 2001, the steam domes and pressurizer removed during demolition of the Connecticut Yankee (Haddam Neck) nuclear power plant were moved 12 miles from the plant site over local roads to the Portland railhead near Middletown, Connecticut. A total of five heavy haul truck shipments were made. Figure 2-33 shows the pressurizer on its heavy haul truck transporter and Figure 2-34 shows the route taken from the Connecticut Yankee site to the Portland railhead. Figure 2-35 shows the pressurizer at the Portland railhead and Figure 2-36 shows the condition of the Portland railhead in 2012.

If heavy haul trucks were used to move casks containing used nuclear fuel from the Connecticut Yankee site to the Middletown area railhead, the P&W Railroad, which is a Class II regional railroad, would then haul the shipments to Hartford, Connecticut. In the Hartford area, the shipments would be switched to the Pan Am Southern Railroad, the same railroad that operates the rail line that passes near the Yankee Rowe site.

Photo courtesy of Connecticut Yankee

Figure 2-33. Connecticut Yankee Pressurizer on Heavy Haul Truck Transporter

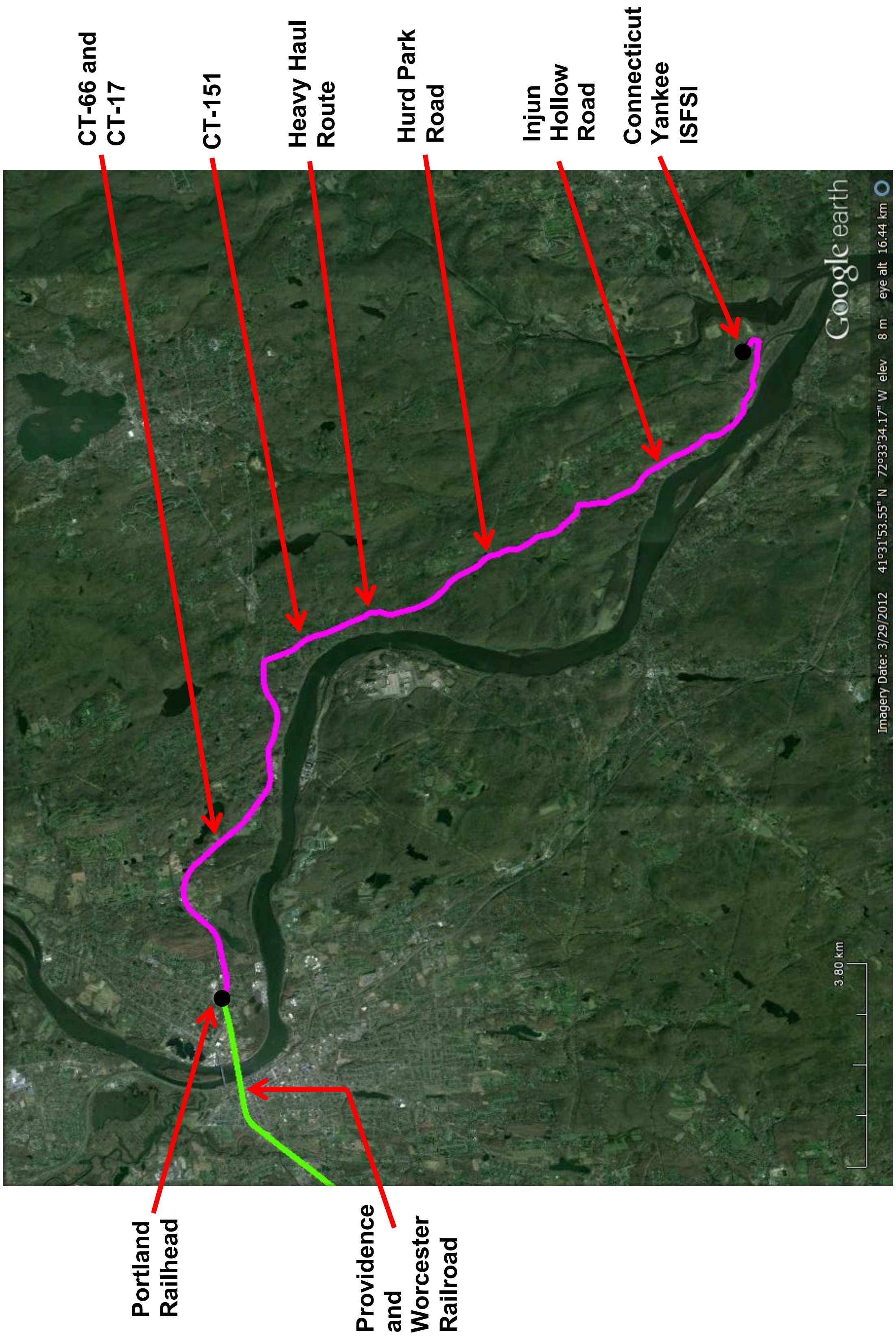

Figure 2-34. Connecticut Yankee Heavy Haul Truck Route (Google 2013)

Photo courtesy of Connecticut Yankee

Figure 2-35. Connecticut Yankee Pressurizer at Portland Railhead

Figure 2-36. Condition of Portland Railhead in 2012

The Connecticut Yankee site is located on the shores of the Connecticut River and therefore could be accessible by barges that would transport used nuclear fuel transportation casks to nearby ports served by railroads or to barge-accessible railheads. The Connecticut Yankee barge slip is shown in Figure 2-32. As discussed in Section 2.3.2, during decommissioning at Connecticut Yankee, the reactor pressure vessel, steam generators, and transformer were transported off-site using barges. Figures 2-37 through 2-39 show the Connecticut Yankee reactor pressure vessel being loaded onto a barge and being transported by barge.

Photo courtesy of Connecticut Yankee

Figure 2-37. Connecticut Yankee Reactor Pressure Vessel Being Loaded onto Barge

Photo courtesy of Connecticut Yankee

Figure 2-38. Connecticut Yankee Reactor Pressure Vessel Being Transported on Barge

Photo courtesy of Connecticut Yankee

Figure 2-39. Connecticut Yankee Reactor Pressure Vessel Being Transported on Barge in the Connecticut River

2.3.4 Gaps in Information

The Yankee Companies site managers for the Connecticut Yankee site suggested that shipments of used nuclear fuel casks from the site should use barges. However, the on-site barge slip was removed after decommissioning. It is also uncertain whether the cooling water discharge canal is deep enough to accommodate barges. In addition, the cooling water discharge canal and the Connecticut River can freeze in the winter.

Should it be necessary to use heavy haul trucks to move casks from the site, it would be necessary to work with local authorities to determine local routing and heavy haul truck operations procedures and schedules that would minimize disruption of traffic flow and other community activities in the moderately populated area. In addition, the heavy haul truck route from the Connecticut Yankee site to Portland, Connecticut can be ice covered at times during the winter and could need treatment to prepare it for shipments. An engineering review of the heavy haul route would also be required. It would also be necessary to work with the owners of the railhead to improve track structures from their current degraded condition to allow the transfer of casks from heavy haul trucks to railcars. The condition of the rail bridge over the Connecticut River that is located west of the Portland railhead would also need to be evaluated.

2.4 Humboldt Bay

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the Humboldt Bay site. The Humboldt Bay site is located on Humboldt Bay near Eureka, California, about 260 miles north of San Francisco (TOPO 1993d).

2.4.1 Site Inventory

Five canisters containing 390 used nuclear fuel assemblies are stored at Humboldt Bay. An additional canister of GTCC low-level radioactive waste is expected to be loaded and transferred to the ISFSI by the end of 2013. Figure 2-40 shows the ISFSI at Humboldt Bay. In contrast to other ISFSIs, the canisters at Humboldt Bay are stored in a below-grade vault.

The storage system used at Humboldt Bay is the Holtec HI-STAR HB system, which is a variation of the HI-STAR 100 system (Docket No. 72-1008). The system consists of a multipurpose canister inside an overpack designed and certified for both storage and transportation. The MPC-HB canister used at Humboldt Bay can hold up to 80 boiling water reactor used nuclear fuel assemblies. The fuel assemblies from Humboldt Bay were loaded from August through December 2008 (Leduc 2012). The fuel rods in the fuel assemblies are Zircaloy-clad. The HI-STAR HB storage overpack used at Humboldt Bay is also transportable (Docket No. 71-9261); however, impact limiters are required and would need to be fabricated. In addition, the HI-STAR HB transportation cask is not currently licensed for the transport of GTCC low-level radioactive waste.

Photo courtesy of Humboldt Bay

Figure 2-40. Humboldt Bay Independent Spent Fuel Storage Installation

Figure 2-41 illustrates the number of used nuclear fuel assemblies at Humboldt Bay based on their discharge year. The oldest fuel was discharged in 1971. The fuel was last critical in 1976 and was removed from the reactor vessel in 1984. The median discharge year of the fuel is 1975.

Figure 2-42 illustrates the number of used nuclear fuel assemblies at Humboldt Bay based on their burnup. The lowest burnup is 1.3 GWd/MTHM and the highest burnup is 22.9 GWd/MTHM. The median burnup is 16.4 GWd/MTHM. No high burnup used nuclear fuel (burnup greater than 45 GWd/MTHM) is stored at Humboldt Bay.

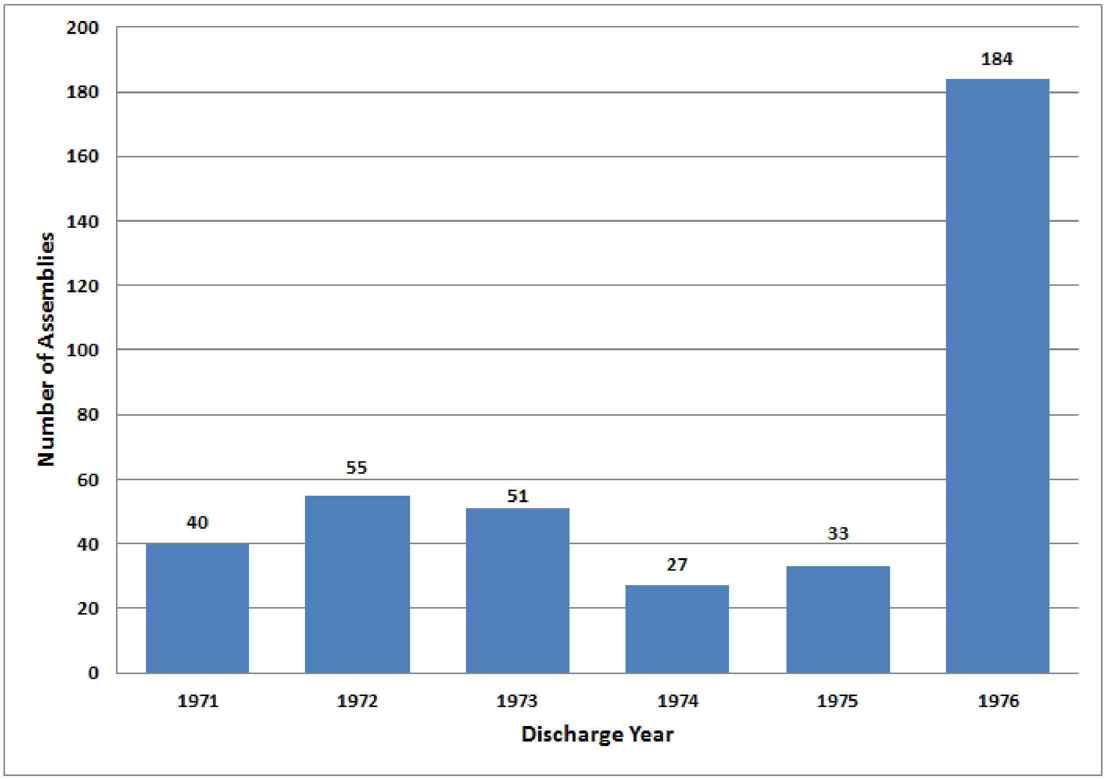

Figure 2-41. Humboldt Bay Number of Assemblies versus Discharge Year (EIA 2002)

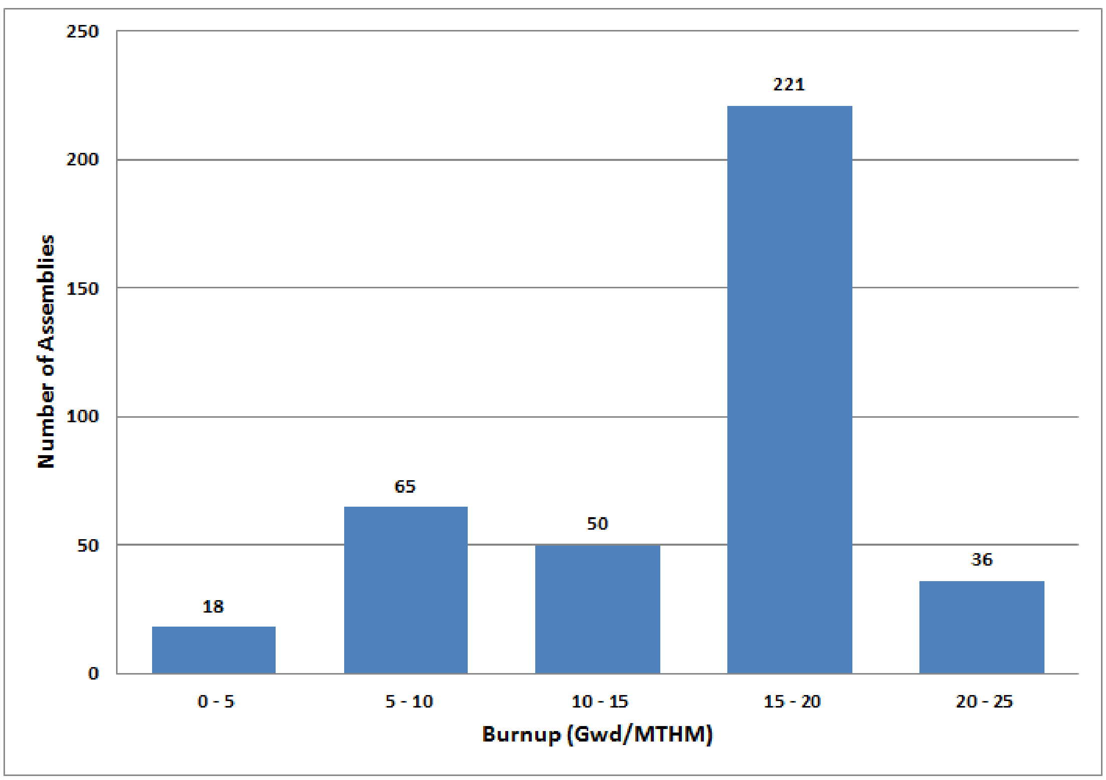

Figure 2-42. Humboldt Bay Number of Assemblies versus Burnup (EIA 2002)

2.4.2 Site Conditions

Figure 2-43 provides an aerial view of the Humboldt Bay site, which is being decommissioned, with completion anticipated in 2019. Electrical power is available at the Humboldt Bay ISFSI. The lifting device shown in Figure 2-40 which is used to remove the HI-STAR HB casks containing the Humboldt Bay used nuclear fuel or GTCC low-level radioactive waste from their below-grade vaults is shared with the Diablo Canyon site; however, mobile equipment such as cranes is not onsite. The HI-STAR HB casks are licensed for both the storage and transport of the Humboldt Bay used nuclear fuel. Consequently, a transfer cask is not required at the Humboldt Bay site. The empty HI-STAR HB casks were moved to the Humboldt Bay site using heavy haul trucks (see Figure 2-44).

The Humboldt Bay site has not been served by rail since November 1998, when the Federal Railroad Administration issued Emergency Order 21, which closed the Northwestern Pacific Railroad from Arcata, California (mile post 295.5) to mile post 49.8S (formerly designated mile post 63.4) between Schellville and Napa Junction, California, a distance of 286 miles, for failure to meet federal safety standards (63 FR 67976-67979). In May 2011, the Federal Railroad Administration allowed the Northwestern Pacific Railroad to reopen as far north as mile post 62.9 near Windsor, California (76 FR 27171-27172), about 220 miles south of the Humboldt Bay site. There is also no on-site barge access at the Humboldt Bay site (TriVis Incorporated 2005, TOPO 1993d).

2.4.3 Near-site Transportation Infrastructure and Experience

The Humboldt Bay site does not have an on-site rail spur or a railroad that passes near to the site or along the site boundary. For Humboldt Bay, heavy haul trucks could be used to move transportation casks over public highways to a railhead or rail spur that provides access to a railroad that meets Federal Railroad Administration's regulatory standards and can accommodate the loaded transportation casks. Alternatively, heavy haul trucks could be used to move loaded transportation casks from the Humboldt Bay site to a barge facility where the casks would be loaded onto barges.

For shipments of casks containing used nuclear fuel that require the use of heavy haul trucks, the casks would be prepared for shipment at the Humboldt Bay ISFSI site and loaded onto a transport cradle that would then be loaded onto the transport trailer of a heavy haul truck. The heavy haul truck, led and followed by technical and security escorts, would move over an approved, designated highway route to a rail siding or railhead or barge facility. Heavy lift equipment would be used to transfer the cask and its cradle as a unit from the heavy haul truck to a railcar at the rail siding or railhead, or onto a barge.

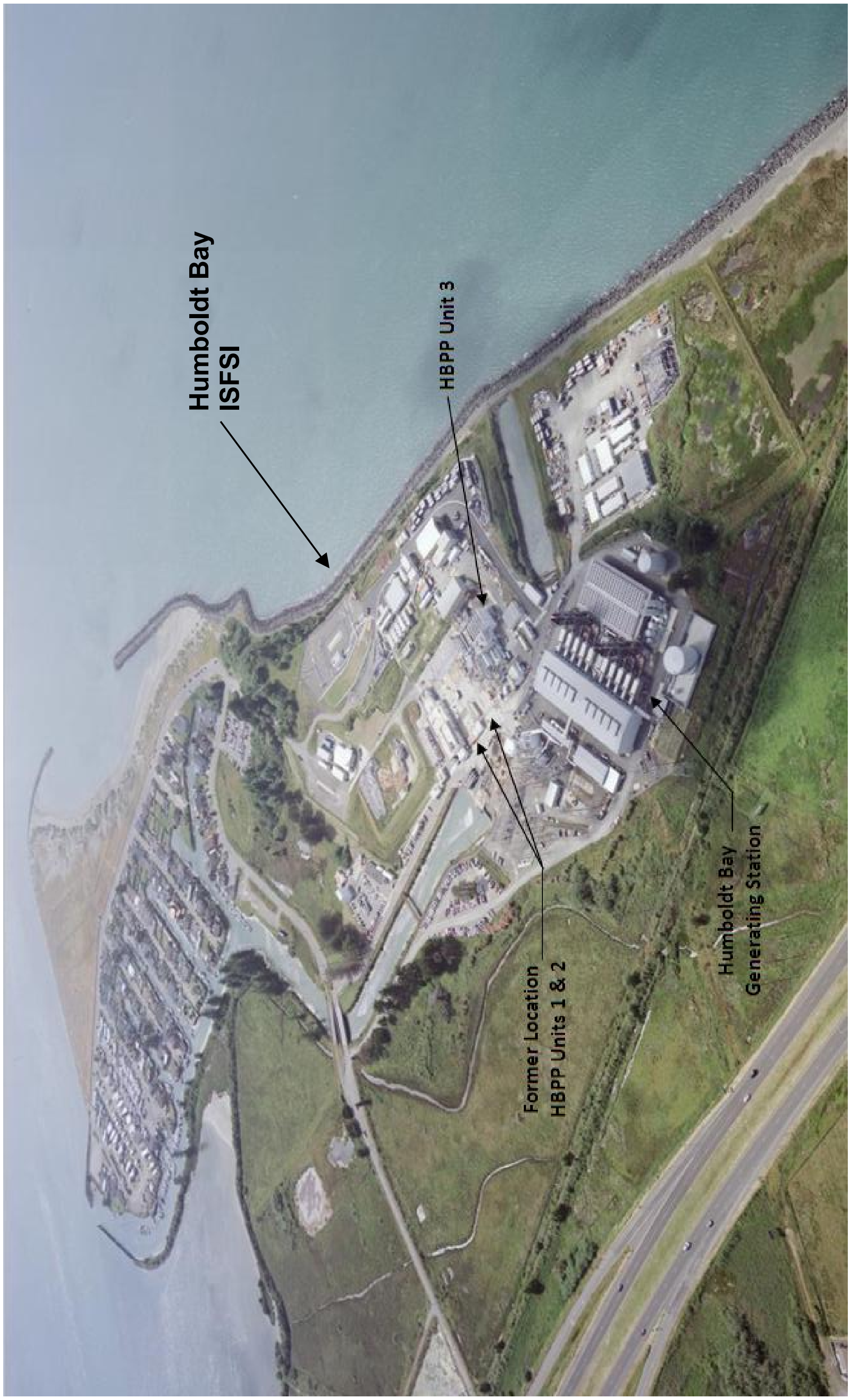

Photo courtesy of Humboldt Bay

Figure 2-43. Aerial View of Humboldt Bay Site

Photo courtesy of Humboldt Bay

Figure 2-44. Empty HI-STAR HB Cask Transported by Heavy Haul Truck

The nearest railhead is located in Redding, California, a distance of about 160 miles from Humboldt Bay. To reach this railhead, heavy haul truck transport would be required on U.S. Highway 101 and State Route 299. The Union Pacific rail line in the vicinity of Redding is designated as track class 4.

During the decommissioning of Humboldt Bay, several truck routes have been used:[7]

- U.S. Highway 101 south to California State Route 20 to Interstate 5
- U.S. Highway 101 north to U.S. Highway 199 to Interstate 5
- U.S. Highway 101 north to California State Route 299 to Interstate 5.

These routes range in length from about 160 to 230 miles.

[7] Williams JR. 2013. Email message from L Sharp (Pacific Gas and Electric Company) to JR Williams (U.S. Department of Energy), "RE: PG&E Comments to DOE Draft Report," February 25, 2013.

The Humboldt Bay site is located on the Port of Humboldt Bay and therefore could be accessible by barges that would transport used nuclear fuel transportation casks to nearby ports served by railroads or to barge-accessible railheads.

The Port of Humboldt Bay is located on the coast of northern California, approximately 225 nautical miles north of San Francisco and approximately 156 nautical miles south of Coos Bay, Oregon (USACE 2012). Humboldt Bay is the only harbor between San Francisco and Coos Bay with deep-draft channels large enough to permit the passage of large commercial ocean-going vessels. It is the second largest coastal estuary in California (USACE 2012). Humboldt Bay is reported to have seven shipping terminals: Fairhaven Terminal, Humboldt Bay Forest Products Docks, Fields Landing Terminal, Redwood Marine Terminal, Schneider Dock, Sierra Pacific Eureka Dock, and the Simpson Mill Wharf Port Facility (HBHRCD 2012). The U.S. Army Corps of Engineers dredges shipping channels in and into Humboldt Bay to depths of 35 to 40 feet. DSI (2004) identifies San Francisco Bay and Coos Bay as the closest ports to Humboldt Bay with rail access.

Although there is no on-site barge access at the Humboldt Bay site, barges were recently used to move 10 Wartsila engines weighing 680,000 lb. each and 10 generators weighing 165,000 lb. each to the Fields Landing Terminal (see Figures 2-45 and 2-46), which is about 2 miles from the Humboldt Bay Generating Station[8] (AC&T 2011). The Fields Landing Channel is 12,000 feet long and 300 feet wide, with an 800-foot-long, 600-foot-wide turning basin (USACE 2012). The engines and generators were loaded onto barges at Schneider Dock in Eureka, California, moved by barge to the Fields Landing Terminal, and offloaded. Heavy haul trucks then moved the engines and generators from Fields Landing Terminal to the Humboldt Bay Generating Station. Figure 2-45 also shows the heavy haul route taken from the Field Landing Terminal to the Humboldt Bay Generating Station. Figure 2-47 shows the conditions of the Fields Landing Terminal in 2013. Figures 2-48 through 2-52 show a Wartsila engine being loaded on a barge, a barge and Wartsila engine being towed to the Fields Landing Terminal, a barge and Wartsila engine arriving at the Fields Landing Terminal, a Wartsila engine being unloaded from the barge, and a Wartsila engine being transported by heavy haul truck to the Humboldt Bay Generating Station. Figures 2-53 and 2-54 show the location of the Schneider Dock in relation to the Humboldt Bay site.

[8] Maheras SJ. 2012. Email message from A Richards (Senior Project Manager/Special Projects, Bragg Crane & Rigging) to SJ Maheras (Pacific Northwest National Laboratory), “Andy Richards / Bragg Crane & Rigging,” October 17, 2012.

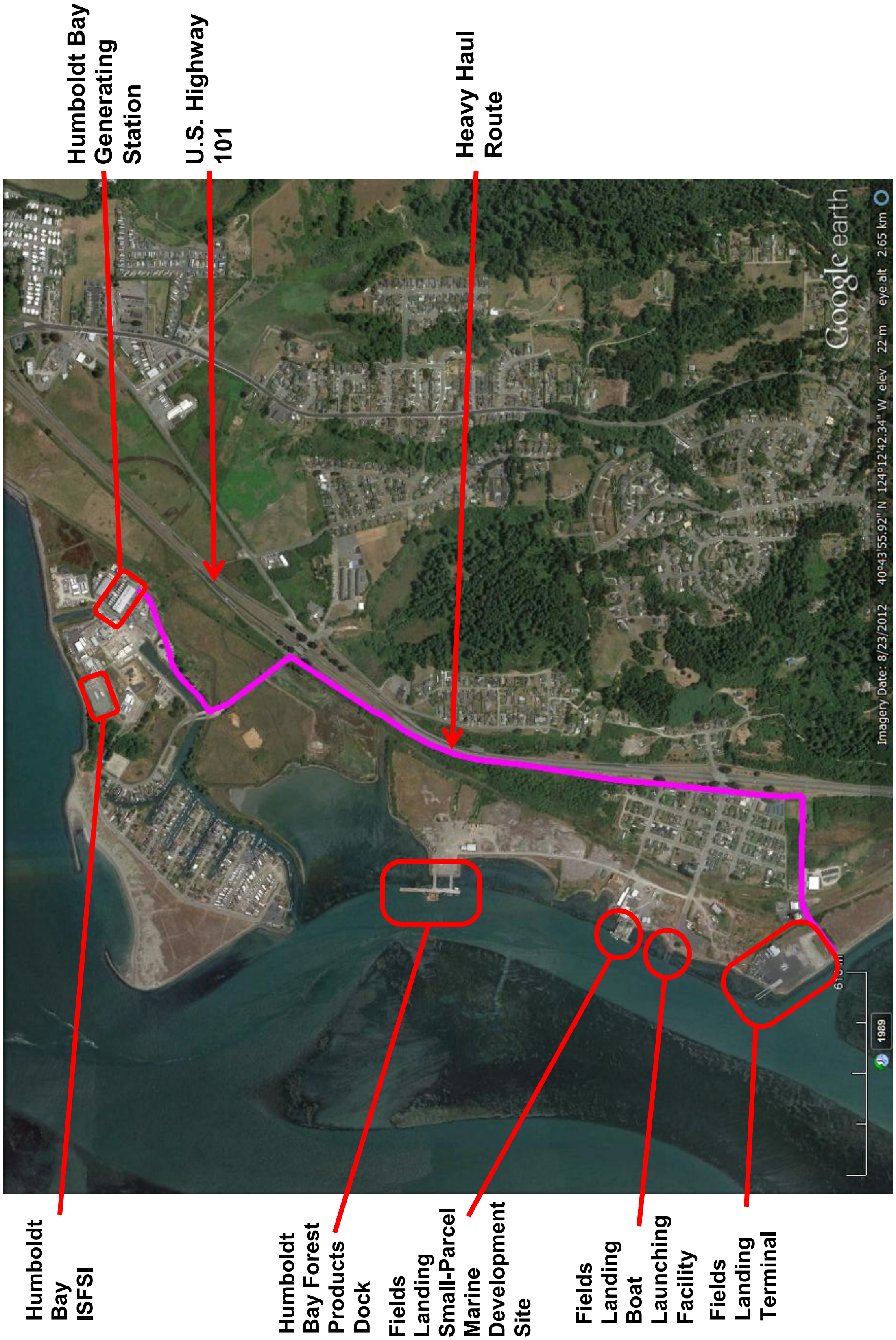

Figure 2-45. Humboldt Bay ISFSI and Fields Landing Terminal (Google 2013)

Figure 2-46. Fields Landing Terminal (Google 2013)

Photo courtesy of Federal Railroad Administration

Figure 2-47. Condition of Fields Landing Terminal in 2013

Photo courtesy of Bragg Crane & Rigging Co.

Figure 2-48. Wartsila Engine Being Loaded on a Barge

Photo courtesy of Bragg Crane & Rigging Co.

Figure 2-49. Wartsila Engine on a Barge Being Towed to Fields Landing Terminal

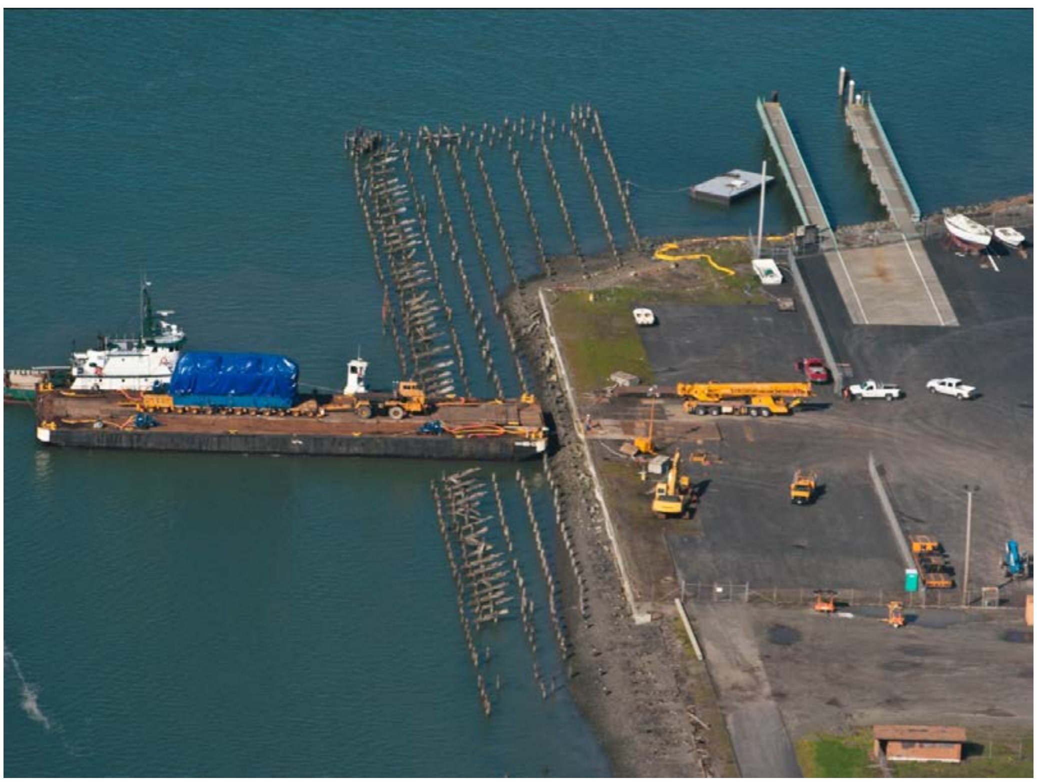

Photo courtesy of Bragg Crane & Rigging Co.

Figure 2-50. Barge with Wartsila Engine Arriving at Fields Landing Terminal

Photo courtesy of Bragg Crane & Rigging Co.

Figure 2-51. Wartsila Engine Being Unloaded at Fields Landing Terminal

Photo courtesy of Bragg Crane & Rigging Co.

Figure 2-52. Wartsila Engine Being Transported by Heavy Haul Truck to Humboldt Bay Generating Station

Figure 2-53. Humboldt Bay Site and Schneider Dock (Google 2013)

Figure 2-54. Schneider Dock (Google 2013)

2.4.4 Gaps in Information

Off-site transportation of HI-STAR HB transportation casks from the Humboldt Bay ISFSI site would require either use of heavy haul trucks for transport over 160 miles of two-lane roads that traverse California coastal mountain ranges to a railhead or use of barges to ship the casks to a port on the western U.S. coast that is served by a railroad.

As discussed in Section 2.4.2, the Humboldt Bay site has not been served by rail since 1998. In 2011, the Northwestern Pacific Railroad reopened as far north as Windsor, California, about 220 miles south of the Humboldt Bay site. The North Coast Railroad Authority hopes to have the rail line open to Willits, California by 2020, which is still about 140 miles south of the Humboldt Bay site. The nearest railhead is located in Redding, California, a distance of about 160 miles from Humboldt Bay (Table 2-3). The 160-mile trip on public highways from the site would entail travel on U.S. Highway 101 through Eureka, connecting to California Highway 299 to travel east across the coastal mountains to Redding, California. This route is illustrated in Figure 2-55. In Redding, heavy-lift equipment would be used to transfer casks from heavy haul trucks onto railcars that would be moved on the Union Pacific mainline that passes through the Redding area. One-way travel time for the heavy haul truck shipments could be greater than one week. It is likely that two of the heavy haul trucks would be moved in convoy in order to limit the overall impact on commuter traffic and business traffic that use the roads. Substantial coordination and planning of the shipments with local and California state officials would be necessary. Prior to the shipments highway engineers would need to survey the roads and road structures (bridges, culverts, and overpasses) to ensure that the shipments could be conducted safely. It is possible that temporary or even permanent improvements, such as adding passing lanes, would need to be made to sections of the roads and structures before the shipments could begin and travel might be limited to late spring through early fall because of weather and frost conditions on roads at higher elevations.

Alternative nearby railheads are located at Grants Pass, Oregon, and Williams, Marysville, and Red Bluff, California. Heavy haul truck routes to these railheads are illustrated in Figure 2-55. The distances to these railheads range from about 160 to 260 miles (see Table 2-3). Representatives of PG&E have stated that a route using U.S. Highway 101 and State Route 36 would be unacceptable for heavy haul trucks.[9]

Table 2-3. Alternative Railheads for Humboldt Bay

Railhead	Route	Heavy Haul Distance (miles)
Grants Pass, Oregon	U.S. Highway 101 to U.S. Highway 199	180
Redding, California	U.S. Highway 101 to State Route 299	160
Red Bluff, California	U.S. Highway 101 to State Route 36	160
Williams, California	U.S. Highway 101 to State Route 20	230
Marysville, California	U.S. Highway 101 to State Route 20	260

[9] Williams JR. 2013. Email message from L Sharp (Pacific Gas and Electric Company) to JR Williams (U.S. Department of Energy), "RE: PG&E Comments to DOE Draft Report," February 25, 2013.

Additional heavy haul routes could potentially be used. For example, a heavy haul to Coos Bay, Oregon would be a distance of about 220 miles along U.S. Highway 101, a heavy haul to Windsor, California would be a distance of about 210 miles along U.S. Highway 101, a heavy haul to the San Francisco Bay Area would be a distance of about 240 miles, and a heavy haul to Sacramento, California would be a distance of about 290 miles along U.S. Highway 101, California Highway 20, and Interstate 5. A heavy haul to Willits, California would be a distance of about 130 miles along U.S. Highway 101, but the Northwestern Pacific Railroad is not open to Willits. In addition, it is not known if the Northwestern Pacific Railroad will handle hazardous material shipments.[10]

Barge transportation of used nuclear fuel casks from the Humboldt Bay site along the Pacific coast to a port facility that is served by a railroad could be an alternative. However, the site does not have a barge siding or dock and it is uncertain whether barges could be landed at the shoreline of the site to allow roll-on of heavy haul trucks carrying the six HI-STAR HB casks. A marine survey has not been conducted to determine whether the depth of Humboldt Bay waters that approach the site and the bottom conditions near the shore would permit landing and securing a barge to the shoreline, safely loading it, and backing it back into a navigable channel in the bay. In addition, it is possible that approvals would be needed from California state authorities and from the U.S. Army Corps of Engineers before it would be possible to use a landed barge to load transportation casks containing used nuclear fuel.

It may be possible to use heavy haul trucks to transport the casks to a nearby shipping terminal in Humboldt Bay. Humboldt Bay is reported to have seven shipping terminals and it would be necessary to determine which, if any, of the reported shipping terminals in Humboldt Bay could be used for shipments of the casks and what routing would be used by heavy haul trucks. Ten large engines and generators were delivered to Schneider Dock in Eureka, California, transported by barge from Schneider Dock to the Fields Landing Terminal, and transported from Fields Landing Terminal to the Humboldt Bay site using heavy haul trucks (AC&T 2011). Moving casks to the Fields Landing Terminal would involve travel over approximately 2 miles of roadways including about 0.5 mile of U.S. 101 and the remainder on local roadways.

[10] Used nuclear fuel and GTCC low-level radioactive waste would be Class 7 hazardous material.

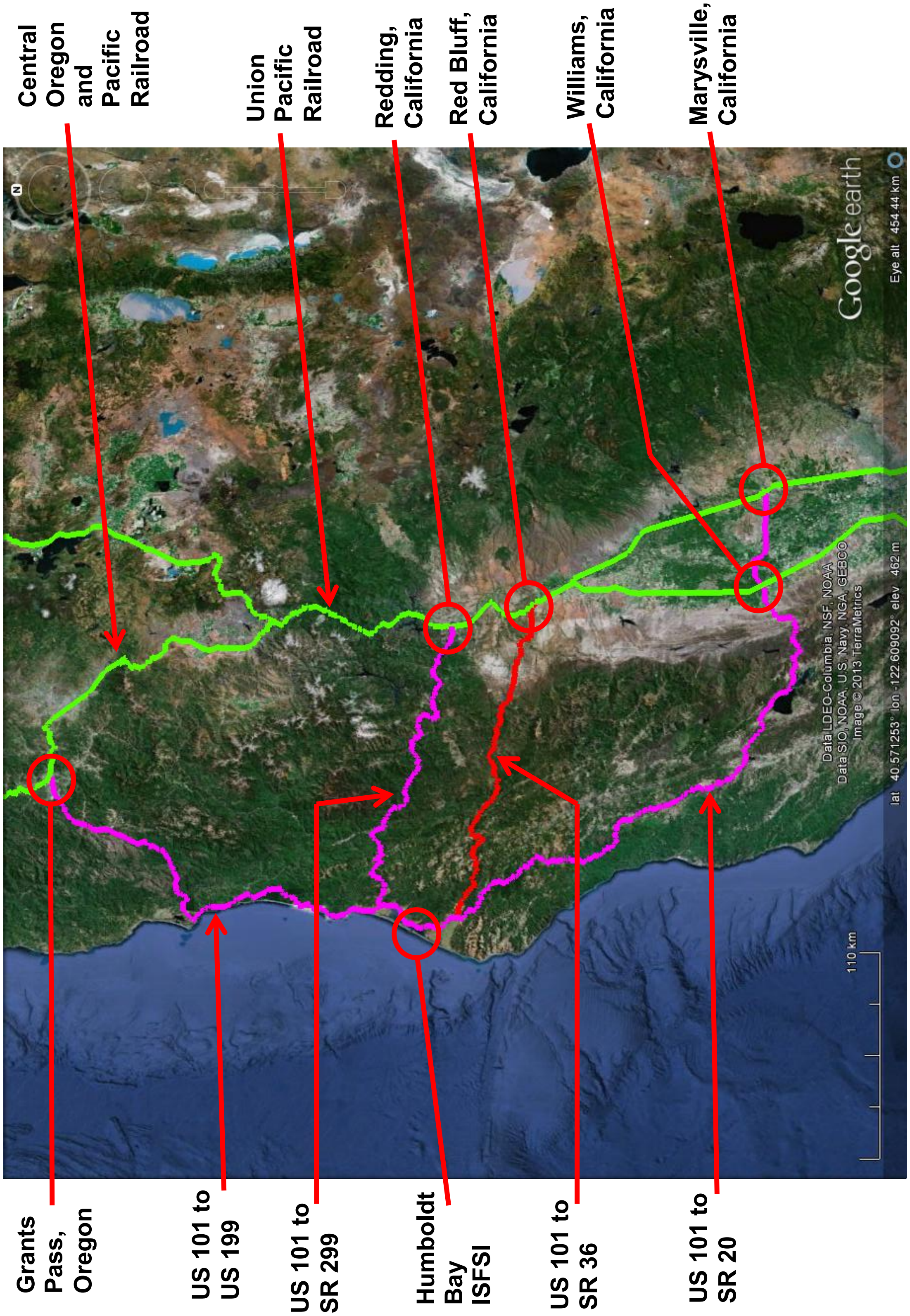

Figure 2-55. Heavy Haul Routes from Humboldt Bay ISFSI to Alternative Railheads (Google 2013)

2.5 Big Rock Point

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the Big Rock Point site. The Big Rock Point site is located on the eastern shore of Lake Michigan about 4 miles north of Charlevoix and 10 miles west of Petoskey, Michigan (TOPO 1994a).

2.5.1 Site Inventory

Seven canisters containing 441 used nuclear fuel assemblies and 1 canister of GTCC low-level radioactive waste are stored at Big Rock Point. The seven canisters contain 50 damaged used nuclear fuel assemblies which have been placed in damaged fuel cans.

Figure 2-56 shows the ISFSI at Big Rock Point. The storage system used at Big Rock Point is the FuelSolutions Storage System which consists of the W74 canister, the W150 storage cask, and the W100 transfer cask (Docket No. 72-1026). The W74 canister holds 64 Big Rock Point boiling water reactor used nuclear fuel assemblies. The fuel assemblies from Big Rock Point were loaded into W74 canisters from December 2002 through March 2003 (Leduc 2012). The fuel rods in the fuel assemblies are Zircaloy-clad. The TS125 transportation cask (Docket No. 71-9276) is licensed to transport the W74 canister. No TS125 transportation casks have been fabricated. In addition, the TS125 transportation cask is not licensed for the transport of GTCC low-level radioactive waste.

Photo courtesy of Big Rock Point

Figure 2-56. Big Rock Point Independent Spent Fuel Storage Installation

In October 2012, the NRC issued a renewed certificate of compliance to EnergySolutions for the TS125 transportation cask. The renewed certificate of compliance expires on October 31, 2017 (Waters 2012). The Safety Evaluation Report for the renewal of the certificate of compliance observes that no TS125 transportation casks have been fabricated and states that because the TS125 transportation cask has a -85 designation in its identification number (i.e., USA/9276/B(U)F-85), all fabrication of this package must have been completed by December 31, 2006, as required by 10 CFR 71.19(c). In order to fabricate TS125 transportation casks, EnergySolutions would need to apply for a -96 designation by submitting a revised safety analysis report to demonstrate that the TS125 transportation cask meets the current NRC regulations contained in 10 CFR 71. The revisions to the TS125 safety analysis report would include:

- **Revised A_1 and A_2 values**. EnergySolutions would need to update the containment analysis in Chapter 4 of the safety analysis report to incorporate revised A_2 values in 10 CFR 71, Appendix A, Table A-1. An increase in the maximum allowable leakage rates for the TS125 transportation cask would be expected.
- **Criticality Safety Index (CSI)**. EnergySolutions would need to revise Chapters 1, 5, and 6 of the TS125 transportation cask safety analysis report to incorporate the CSI nomenclature and the NRC would need to revise the certificate of compliance to delete references to the Transport Index for criticality control.
- **Expansion of Quality Assurance (QA) Requirements**. EnergySolutions would need to revise the safety analysis report for the TS125 transportation cask to demonstrate how its QA program satisfies the specific requirements of 10 CFR 71.101(a), (b), and (c).

A -96 designation must also be obtained before the TS125 transportation cask is licensed for the transport of GTCC low-level radioactive waste. The effort to accomplish these changes and to obtain NRC review and approval is estimated to range from one to three years.

Figure 2-57 illustrates the number of used nuclear fuel assemblies at Big Rock Point based on their discharge year. The oldest fuel was discharged in 1974 and the last fuel was discharged in 1997. The median discharge year of the fuel is 1988.

Figure 2-58 illustrates the number of used nuclear fuel assemblies at Big Rock Point based on their burnup. The lowest burnup is 3.5 GWd/MTHM and the highest burnup is 34.2 GWd/MTHM. The median burnup is 23.7 GWd/MTHM. No high burnup used nuclear fuel (burnup greater than 45 GWd/MTHM) is stored at Big Rock Point.

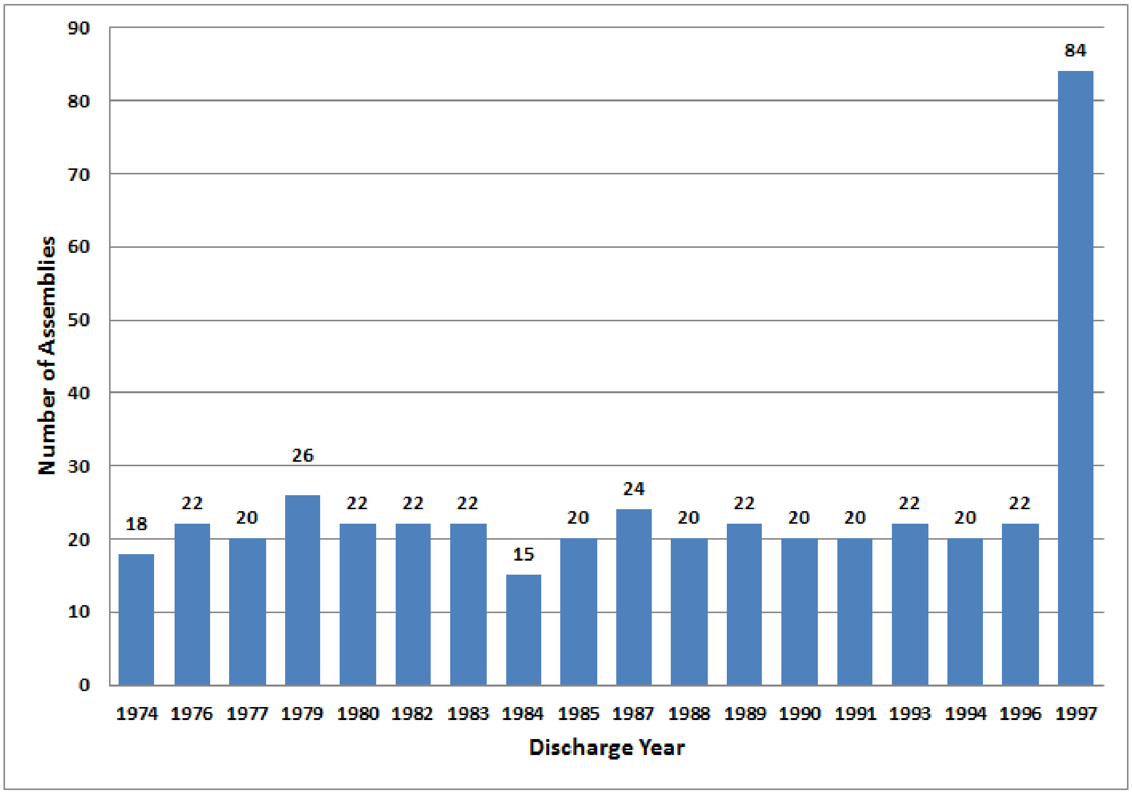

Figure 2-57. Big Rock Point Number of Assemblies versus Discharge Year (EIA 2002)

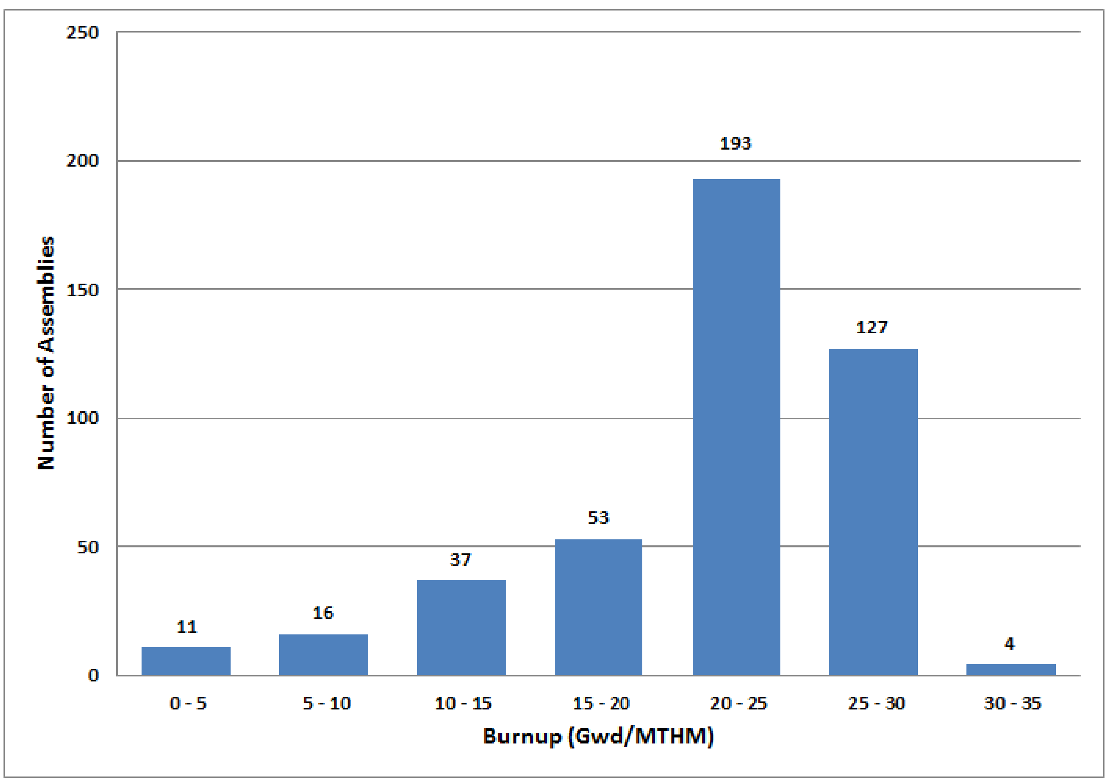

Figure 2-58. Big Rock Point Number of Assemblies versus Burnup (EIA 2002)

2.5.2 Site Conditions

Figure 2-59 provides an aerial view of the Big Rock Point site, where the reactor and associated structures have been removed. Electrical power is available at the Big Rock Point ISFSI; a transfer cask, gantry towers, horizontal transfer system and J-skid[11] are present at the ISFSI. Herron (2010) stated that the equipment needed to transfer used nuclear fuel and GTCC low-level radioactive waste in W74 canisters from the W150 storage casks to the TS125 transportation cask is in place, is tested on a periodic basis, and preventative maintenance is performed. Figure 2-60 shows the transfer cask and J-skid, Figure 2-61 shows the gantry towers, and Figure 2-62 shows the horizontal transfer system at the Big Rock Point site.

A rail spur that served the Big Rock Point site was removed in 1988 (NAC 1990). This spur was used for nine rail shipments of used nuclear fuel to West Valley, New York between 1970 and 1974 (NAC 1990). There is no on-site rail access at the Big Rock Point site (TriVis Incorporated 2005) and heavy haul truck transport would be necessary to reach nearby railheads. For example, Gaylord, Michigan was used as the railhead for shipping the reactor pressure vessel from Big Rock Point to the Barnwell, South Carolina low-level radioactive waste disposal facility (Petrosky 2004) and Petoskey, Michigan was used as the railhead for shipping the steam drum to the Energy Solutions low-level radioactive waste disposal facility in Clive, Utah (Tompkins 2006). Herron (2010) states that the heavy haul roadway no longer exists on the site and that the current access road from the ISFSI to the highway was not built to support heavy haul transfers, and may need to be rebuilt or enhanced.

TOPO (1994a) states that an on-site barge facility was used during the construction of Big Rock Point but was discontinued in the early 1960s after Big Rock Point was completed. TOPO (1994a) also identifies a potential barge area at the Big Rock Point site (see Figure 2-59). However, NAC (1990) states that Big Rock Point has never had an on-site barge facility.

[11] The J-skid is a built-up welded steel frame of heavy wide flange beams and cross members that is used to capture and engage the W150 storage cask for rotation by the gantry towers. This J-skid is also used to support the W150 storage cask in the horizontal orientation during W74 canister transfer.

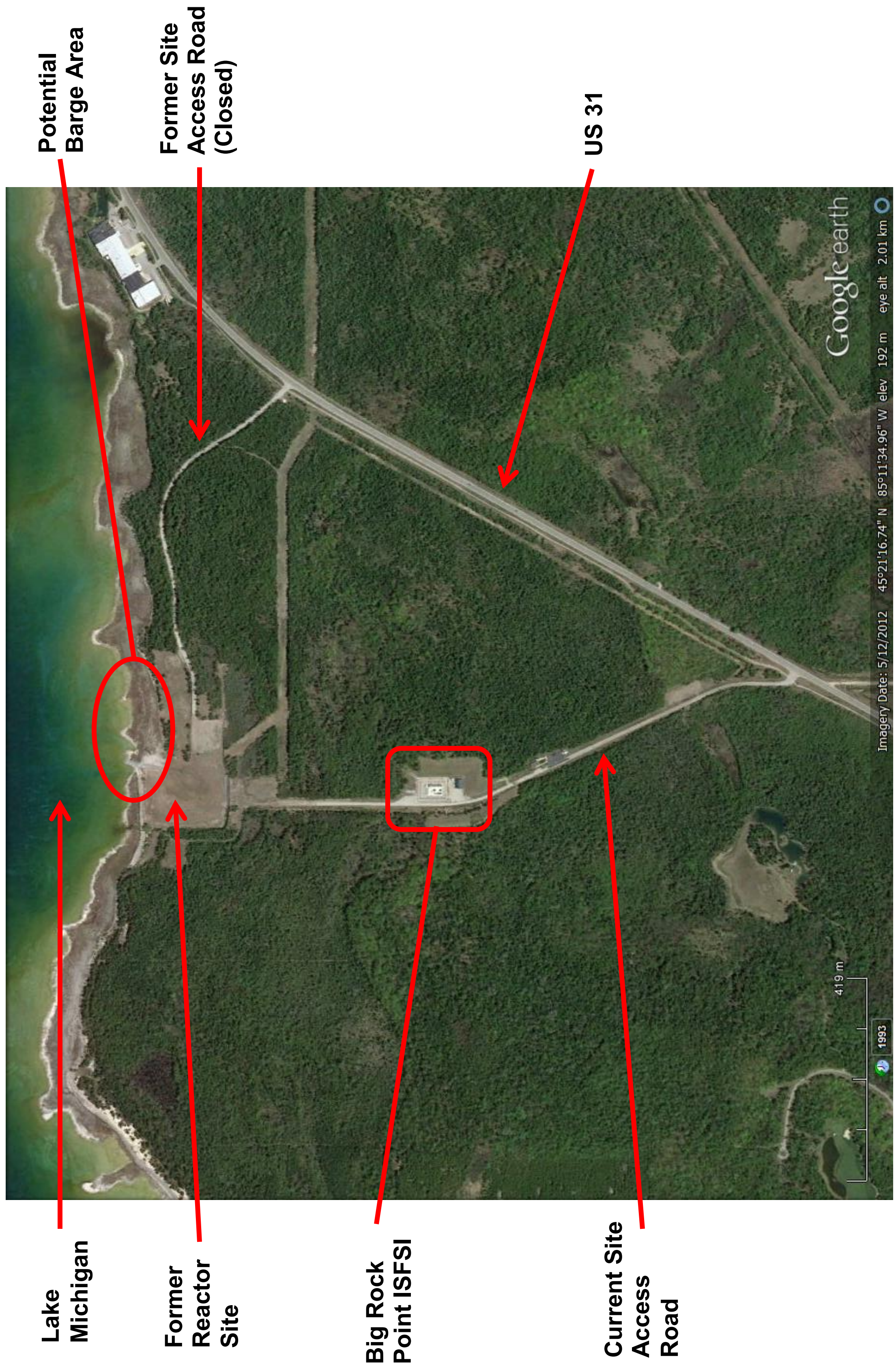

Figure 2-59. Aerial View of Big Rock Point Site (Google 2013)

Photo courtesy of Big Rock Point

Figure 2-60. Transfer Cask and J-Skid at Big Rock Big Rock Point ISFSI

Photo courtesy of Big Rock Point

Figure 2-61. Big Rock Point Gantry Towers

Photo courtesy of Big Rock Point

Figure 2-62. Big Rock Point Horizontal Transfer System

2.5.3 Near-Site Transportation Infrastructure and Experience

The Big Rock Point site does not have an on-site rail spur or a railroad that passes near to the site or along the site boundary. For Big Rock Point, heavy haul trucks could be used to move transportation casks over public highways to a railhead or rail spur that provides access to a railroad that meets Federal Railroad Administration's regulatory standards and can accommodate the loaded transportation casks. Site representatives from Big Rock Point have also stated that seasonal restrictions would likely exist during January through March because of winter conditions, and during July through September because of the large number of tourists in the Big Rock Point area.

For shipments of casks containing used nuclear fuel that require the use of heavy haul trucks, the casks would be prepared for shipment at the Big Rock Point ISFSI site and loaded onto a transport cradle that would be loaded onto the transport trailer of a heavy haul truck. The truck, led and followed by technical and security escorts, would move over an approved, designated highway route to a rail siding or railhead. Heavy lift equipment would be used to transfer the cask and its cradle as a unit from the truck to a railcar at the rail siding or railhead.

During the decommissioning of the Big Rock Point reactor, heavy haul trucks were used to move the reactor pressure vessel and steam drum from the Big Rock Point site to nearby railheads. In 2003, the reactor pressure vessel from the Big Rock Point reactor was moved by a heavy haul truck about 52 miles to a rail siding near Gaylord, Michigan and then was transported by rail to the Barnwell, South Carolina low-level radioactive waste disposal facility (Petrosky 2004). The Big Rock Point pressure vessel and its shipping package weighed more than 565,000 lb. (Figures 2-63 and 2-64). Figure 2-65 shows the route taken from the Big Rock Point site to Gaylord, Michigan. The Lake State Railway in the vicinity of Gaylord is designated as track class 2. In the vicinity of Big Rock Point, a detour was required to bypass an abandoned overhead rail bridge with inadequate vertical clearance. Figure 2-66 shows this detour and Figure 2-67 shows the bridge. Figure 2-68 shows the route taken by the reactor pressure vessel in the vicinity of Gaylord, Michigan and Figures 2-69 and 2-70 show the condition in 2013 of the rail crossing and siding used for the Big Rock Point reactor pressure vessel intermodal transfer. The track class at this crossing and siding appears to be “Excepted” and would likely require refurbishment prior to use for used nuclear fuel shipments.

The Big Rock Point steam drum was also moved by heavy haul truck about 13 miles to a rail siding near Petoskey, Michigan and then was transported to the Energy Solutions low-level radioactive waste disposal facility in Clive, Utah (Tompkins 2006). The steam drum weighed 200,000 lb. (Figures 2-71 and 2-72). The Great Lakes Central Railroad is designated as track class 1 in the vicinity of Petoskey. The height of the steam drum on its transporter was low enough so that it did not require the same detour as described for the reactor pressure vessel and was able to take U.S. 31 from the Big Rock Point site into Petoskey, Michigan (see Figure 2-65). Figure 2-73 shows the route taken by the reactor pressure vessel in the vicinity of Petoskey, Michigan and Figure 2-74 shows the condition in 2013 of the of rail crossing and siding used for Big Rock Point steam drum intermodal transfer.

Photo courtesy of Barnhart Crane & Rigging

Figure 2-63. Big Rock Point Reactor Pressure Vessel on Heavy Haul Truck

Photo courtesy of Consumers Energy

Figure 2-64. Big Rock Point Reactor Pressure Vessel on Railcar

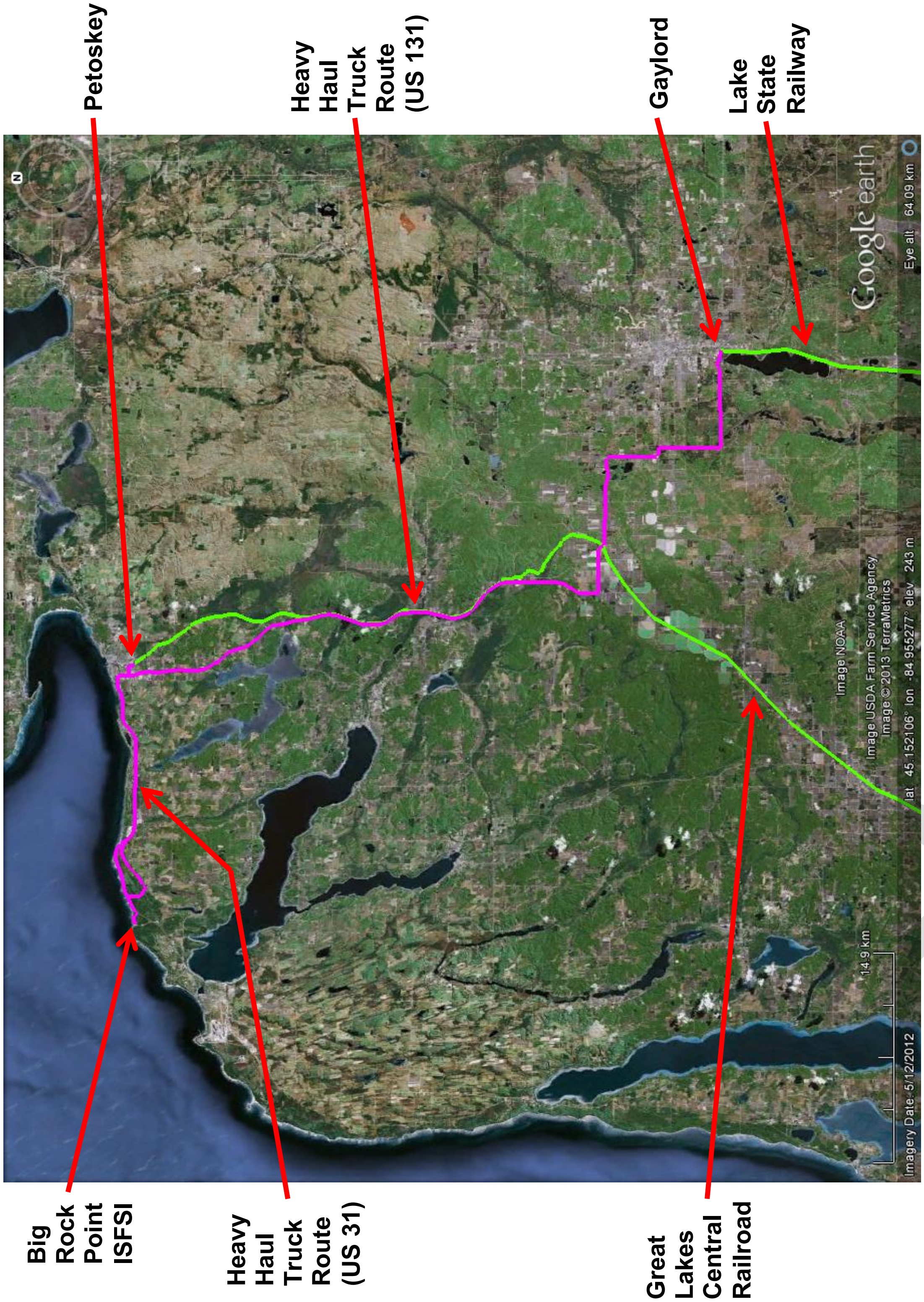

Figure 2-65. Big Rock Point Reactor Pressure Vessel Heavy and Steam Drum Haul Truck Routes (Google 2013)

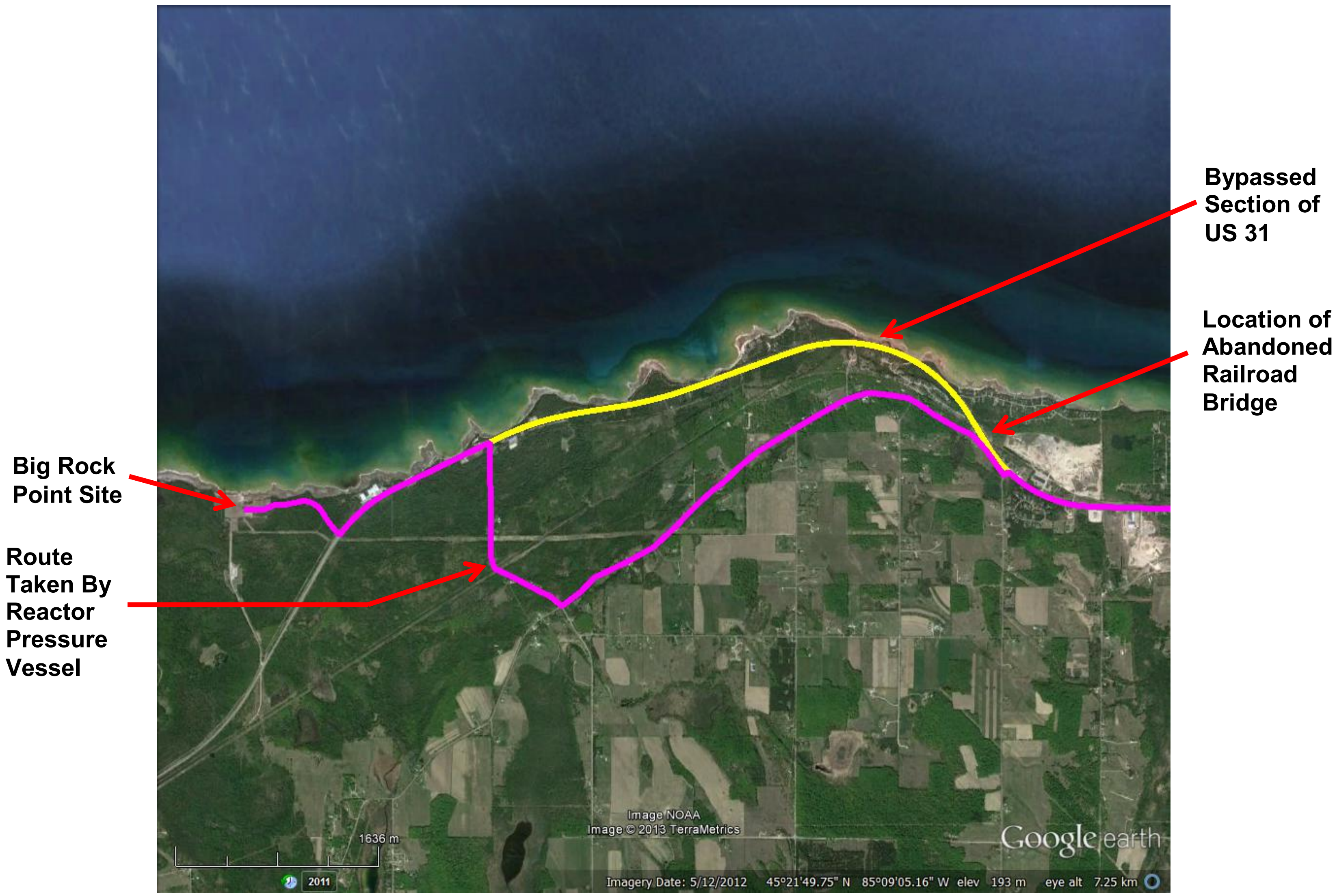

Figure 2-66. Route Taken By Reactor Pressure Vessel to Bypass Low Overhead Clearance Abandoned Railroad Bridge (Google 2013)

Figure 2-67. Low Overhead Clearance Abandoned Railroad Bridge

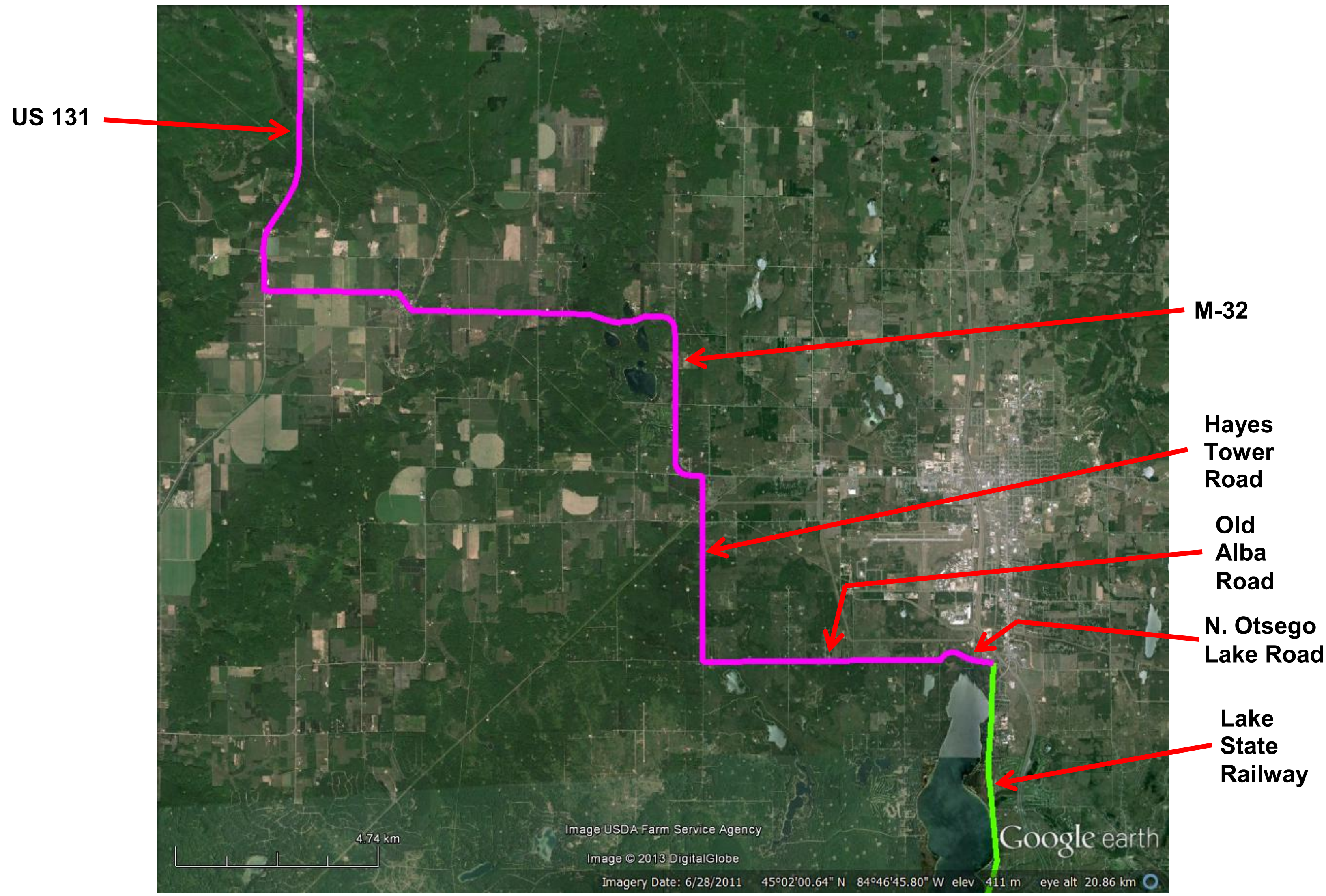

Figure 2-68. Route Taken By Reactor Pressure Vessel in the Vicinity of Gaylord, Michigan (Google 2013)

Figure 2-69. Condition of Rail Crossing in 2013 Used for Big Rock Point Reactor Pressure Vessel Intermodal Transfer (Looking North)

Figure 2-70. Condition of Rail Crossing in 2013 Used for Big Rock Point Reactor Pressure Vessel Intermodal Transfer (Looking South)

Photo courtesy of Consumers Energy

Figure 2-71. Big Rock Point Steam Drum on Heavy Haul Truck

Photo courtesy of Consumers Energy

Figure 2-72. Big Rock Point Steam Drum on Railcar

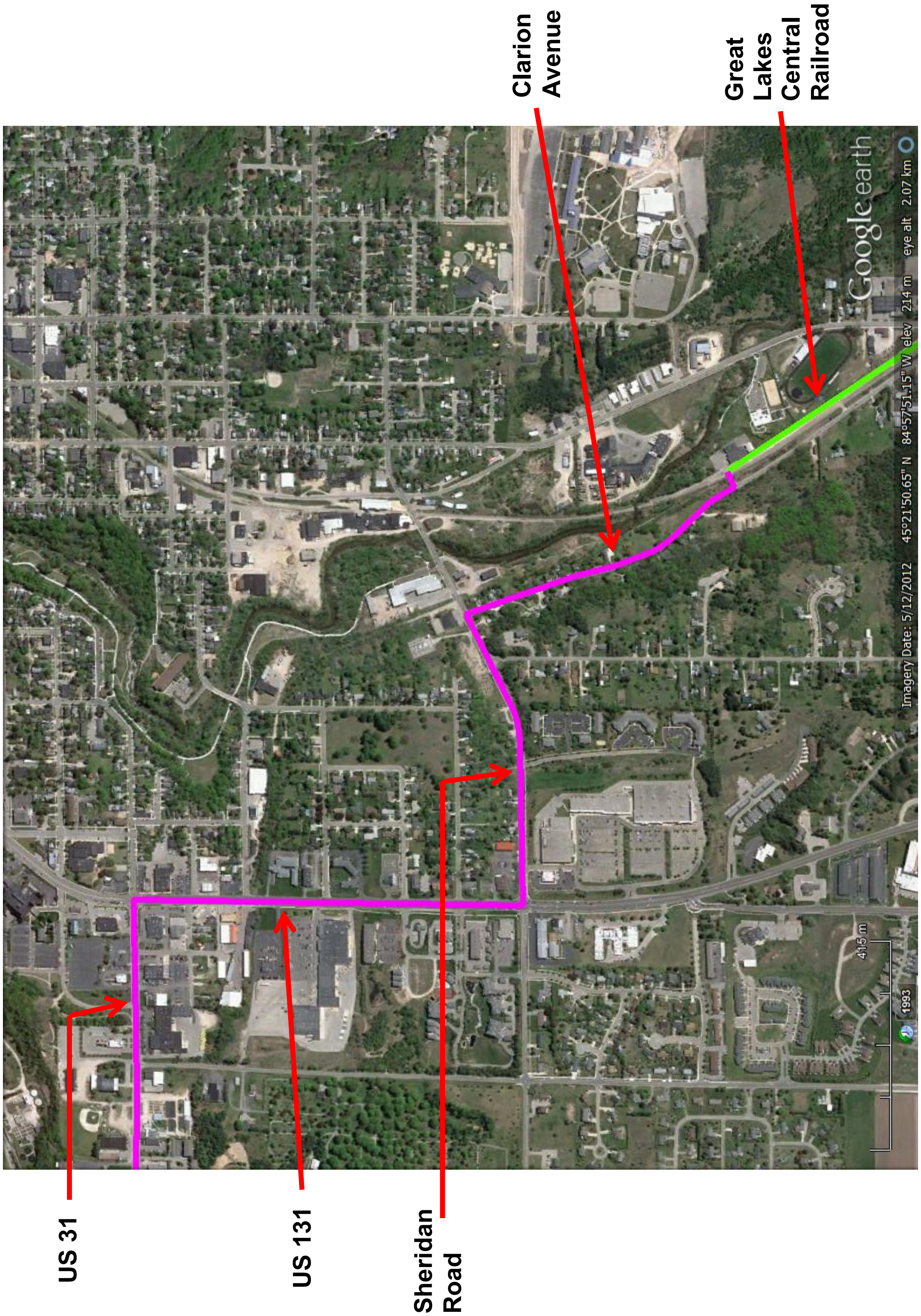

Figure 2-73. Route Taken By Steam Drum in the Vicinity of Petoskey, Michigan (Google 2013)

Photo courtesy of Federal Railroad Administration

Figure 2-74. Condition of Petoskey Railhead in 2013

The Big Rock Point site is on the shore of Lake Michigan, and therefore could be accessible by barges that would transport used nuclear fuel transportation casks to nearby ports served by railroads or to barge-accessible railheads. DSI (2004) identifies the following ports with rail access:

- Traverse City, Manistee, Muskegon, and Grand Haven as ports with rail access along the eastern shore of Lake Michigan
- Alpena, Bay City Port Huron, and Detroit as ports with rail access along the western shore of Lake Huron
- Inland, Escanaba, Green Bay, and Milwaukee as ports with rail access along the western shore of Lake Michigan
- Chicago, Indiana Harbor, Buffington, and Gary as ports with rail access along the southern shore of Lake Michigan.

The capabilities of these ports have not been investigated.

Figure 2-75 shows the condition of the shoreline in 2013 in the vicinity of the potential barge area identified in Figure 2-59.

Photo courtesy of Big Rock Point

Figure 2-75. Condition of Potential Barge Area at Big Rock Point in 2013

2.5.4 Gaps in Information

As discussed in Section 2.5.3, shipments of large reactor components have been made from the Big Rock Point site using heavy haul trucks to carry the components to rail sidings for loading onto railcars. The weight limits associated with the Great Lakes Central Railway and the Lake State Railway track that would be used would need to be evaluated, as well as the current condition of railheads that would be used.

It may also be possible to use barges to transport casks containing used nuclear fuel directly from the Big Rock Point site to a port that is served by a railroad. There is not a barge slip, dock, or landing area on the site's Lake Michigan shoreline. Also, it is unknown whether the depth of water approaching the shore at the site and the bottom conditions near the shore would permit safe operations for barges, and whether extensive grading and spreading of gravel would be required. Barge operations could use either heavy lift equipment to move casks from heavy haul transporters onto barges or the heavy haul transporters might be rolled directly onto barges. Lake Michigan is subject to freezing in the Big Rock Point area (TOPO 1994a) and barge operations would not be conducted on Lake Michigan during winter months.

2.6 Rancho Seco

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the Rancho Seco site. The Rancho Seco site is located about 25 miles southeast of Sacramento, California (NAC 1991a).

2.6.1 Site Inventory

Twenty-one canisters containing 493 used nuclear fuel assemblies and 1 canister of GTCC low-level radioactive waste are stored at Rancho Seco. Figure 2-76 shows the ISFSI at Rancho Seco. The storage system used at Rancho Seco is a site-specific model of the Standardized NUHOMS-24P system (Docket No. 72-1004), which consists of transportable canisters, reinforced concrete horizontal storage modules, and a transfer cask. The canisters used at Rancho Seco are the fuel only dry shielded canister (FO-DSC) (2 canisters), fuel with control component dry shielded canister (FC-DSC) (18 canisters), and failed fuel dry shielded canister (FF-DSC) (1 canister). The FO-DSC and FC-DSC hold 24 pressurized water reactor used nuclear fuel assemblies and the FF-DSC holds 13 pressurized water reactor used nuclear fuel assemblies. There are 48 assemblies contained in FO-DSCs, 432 assemblies contained in FC-DSCs, and 13 assemblies contained in FF-DSCs. The fuel assemblies from Rancho Seco were loaded from April 2001 through August 2002 (Leduc 2012). The fuel rods in the fuel assemblies are Zircaloy-clad. The transfer cask used at Rancho Seco is the MP187 transportation cask, which is also licensed for off-site transportation of the FO-DSC, FC-DSC, and FF-DSC (Docket No. 71-9255). The MP187 used to load the Rancho Seco ISFSI is stored at the Rancho Seco site (see Figure 2-77). The hydraulic ram used to emplace and withdraw canisters from the horizontal storage modules is also stored at the Rancho Seco site (see Figure 2-78). Impact limiters are required for the MP187 and would need to be fabricated. In addition, the MP187 transportation cask is not licensed for the transport of GTCC low-level radioactive waste.

Photo courtesy of Rancho Seco

Figure 2-76. Rancho Seco Independent Spent Fuel Storage Installation

Figure 2-77. MP187 Transportation Cask at Rancho Seco

Figure 2-78. Hydraulic Ram Used to Emplace and Withdraw Canisters from Horizontal Storage Modules at Rancho Seco

The certificate of compliance for the MP187 transportation cask has a -85 designation in its identification number (i.e., USA/9255/B(U)F-85). NRC regulation 10 CFR 71.19(c) requires that all fabrication of transportation casks with a -85 designation must have been completed by December 31, 2006. To date, one MP187 transportation cask without impact limiters has been fabricated, and before additional MP187 transportation casks are fabricated, Transnuclear would need to apply for a -96 designation by submitting a revised safety analysis report to demonstrate that the MP187 transportation cask meets the current NRC regulations contained in 10 CFR 71. The revisions to the MP187 safety analysis report would include:

- **Revised A_1 and A_2 values.** Transnuclear would need to update the containment analysis in Chapter 4 of the safety analysis report to incorporate revised A_2 values in 10 CFR 71, Appendix A, Table A-1. An increase in the maximum allowable leakage rates for the MP187 transportation cask would be expected.
- **Criticality Safety Index.** Transnuclear would need to revise Chapters 1, 5, and 6 of the MP187 transportation cask safety analysis report to incorporate the CSI nomenclature and the NRC would need to revise the certificate of compliance to delete references to the Transport Index for criticality control.
- **Expansion of QA Requirements.** Transnuclear would need to revise the safety analysis report for the MP187 transportation cask to demonstrate how its QA program satisfies the specific requirements of 10 CFR 71.101(a), (b), and (c).

Representatives of Transnuclear have also stated that the -96 designation must be obtained before impact limiters are fabricated for the existing MP187 transportation cask.[12] A -96 designation must also be obtained before the MP187 transportation cask is licensed for the transport of GTCC low-level radioactive waste. The effort to accomplish these changes and to obtain NRC review and approval is estimated to range from one to three years.

There are six damaged fuel assemblies stored in five FC-DSCs at Rancho Seco. Table 2-4 lists the details of these damaged fuel assemblies. When this fuel was originally packaged in canisters, the fuel was visually inspected and classified as damaged if cladding failures with breaches greater than 25 percent of the circumference of the fuel pin and at least the length of a fuel pellet were present (Redeker 2006). This equates to a cladding failure that is 0.34 inches across the cladding and 0.7 inches along the cladding. Fuel assemblies not classified as damaged using this definition were classified as intact. The current definition of intact fuel is more restrictive, where fuel assemblies are classified as intact if they contain no cladding breaches (NRC 2007). Assemblies are classified as undamaged if they have no defects greater than hairline cracks or pinhole leaks (NRC 2007). This change in the definition of damaged and intact fuel resulted in the six fuel assemblies formerly classified as intact being reclassified as damaged, using the new definition. The Rancho Seco storage license was amended to recognize this situation; however, the certificate of compliance for the MP187 transportation cask requires that damaged fuel assemblies are shipped in FF-DSCs, not in FC-DSCs, so the requirements for transporting the six damaged fuel assemblies in the five FC-DSCs would need to be determined. In addition, the Safety Evaluation Report for the Rancho Seco ISFSI (NRC 2009) noted that

[12] Best RE. 2013. Email message from P Murray (AREVA) to RE Best (PNNL Consultant), "MP187 Question," April 2, 2013.

visual examination alone is no longer a sufficient method for classifying assemblies as damaged or intact. NRC (2009) also stated that prior to transporting the used nuclear fuel stored at Rancho Seco, fuel classification may need to be revisited, and the damaged fuel assemblies (and potentially some fuel assemblies currently classified as intact) may need to be placed into damaged fuel cans to be transportable.

Table 2-4. Details of Damaged Fuel Assemblies at Rancho Seco[a]

Fuel Assembly	Estimated Flaw Size	Canister Number
2G6	0.25 in. × 0.04 in.	FC24P-P16
OEL	0.75 in. long with 0.2 in. hole	FC24P-P10
ODY	0.2 in. hole	FC24P-P10
17G	Unknown	FC24P-P17
1C34	1 in. × 0.1 in.	FC24P-P18
1C04	0.3 in. holes (two)	FC24P-P03

a. Source: Transnuclear (2008)

Figure 2-79 illustrates the number of used nuclear fuel assemblies at Rancho Seco based on their discharge year. The oldest fuel was discharged in 1977 and the last fuel was discharged in 1989. The median discharge year of the fuel is 1983.

Figure 2-80 illustrates the number of used nuclear fuel assemblies at Rancho Seco based on their burnup. The lowest burnup is 10.0 GWd/MTHM and the highest burnup is 38.2 GWd/MTHM. The median burnup is 28.0 GWd/MTHM. No high burnup used nuclear fuel (burnup greater than 45 GWd/MTHM) is stored at Rancho Seco.

2.6.2 Site Conditions

Figure 2-81 provides an aerial view of the Rancho Seco site. The reactor building equipment and spent nuclear fuel pool have been decommissioned and removed, but the cooling towers, reactor containment building, and other associated structures remain on-site. Low-level radioactive waste is also stored on-site. Electrical power is available at the Rancho Seco ISFSI. Also available on-site is the hydraulic ram used to unload the canisters from the NUHOMS reinforced concrete horizontal storage modules and to load the MP187 transportation cask that is licensed to transport the Rancho Seco used nuclear fuel. The MP187 transportation cask (without impact limiters) is also stored on-site. The MP187 transportation cask is not licensed for the transport of GTCC low-level radioactive waste.

There is no on-site barge access at the Rancho Seco site (TriVis Incorporated 2005) and Rancho Seco is not near a navigable waterway (NAC 1991a). A 1-mile-long on-site rail spur exists at Rancho Seco. A short length of track runs adjacent to the ISFSI and a longer length of track runs into the Rancho Seco reactor site (see Figure 2-81). Figure 2-82 shows the junction of the short track running adjacent to the ISFSI and the longer track running into the Rancho Seco site. Figure 2-83 shows the longer track running into the Rancho Seco site.

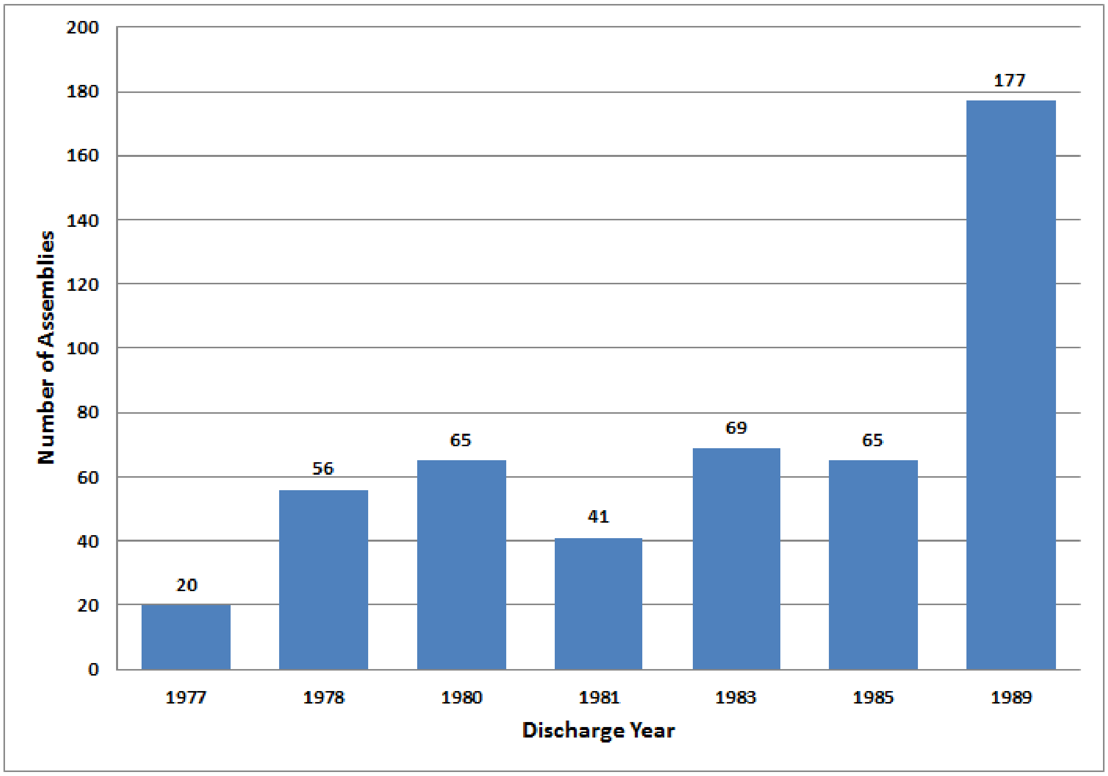

Figure 2-79. Rancho Seco Number of Assemblies versus Discharge Year (EIA 2002)

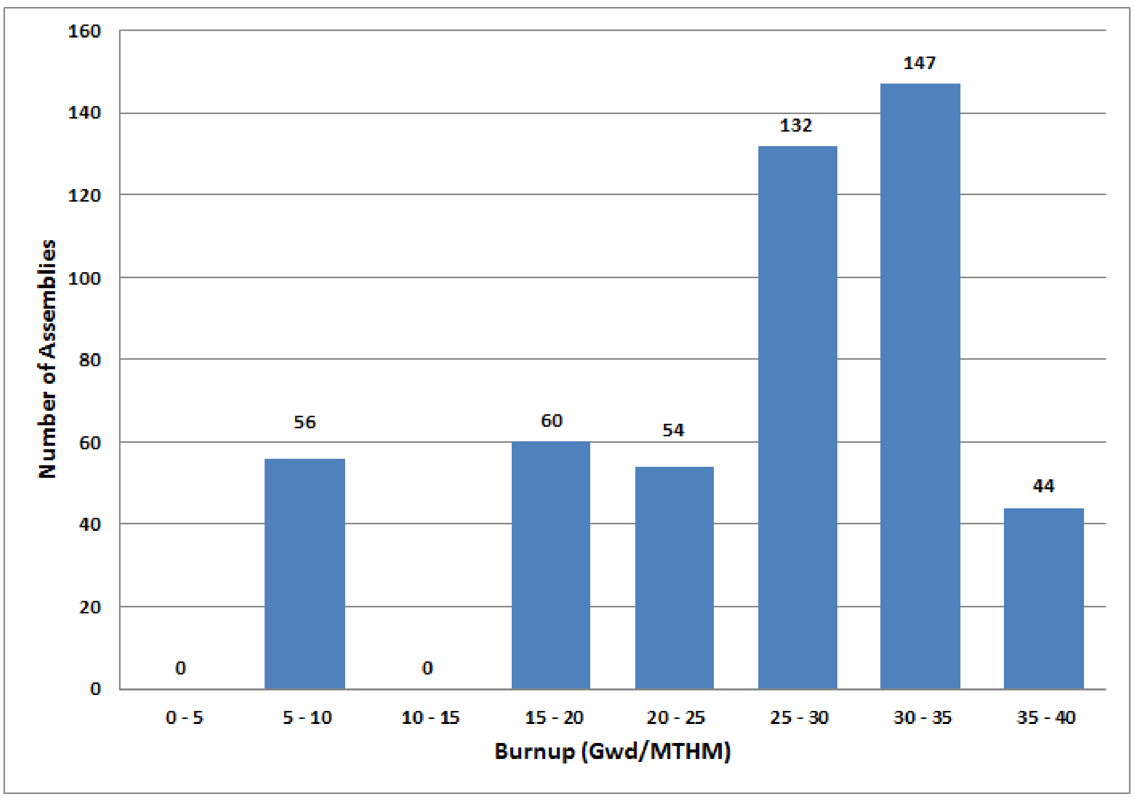

Figure 2-80. Rancho Seco Number of Assemblies versus Burnup (EIA 2002)

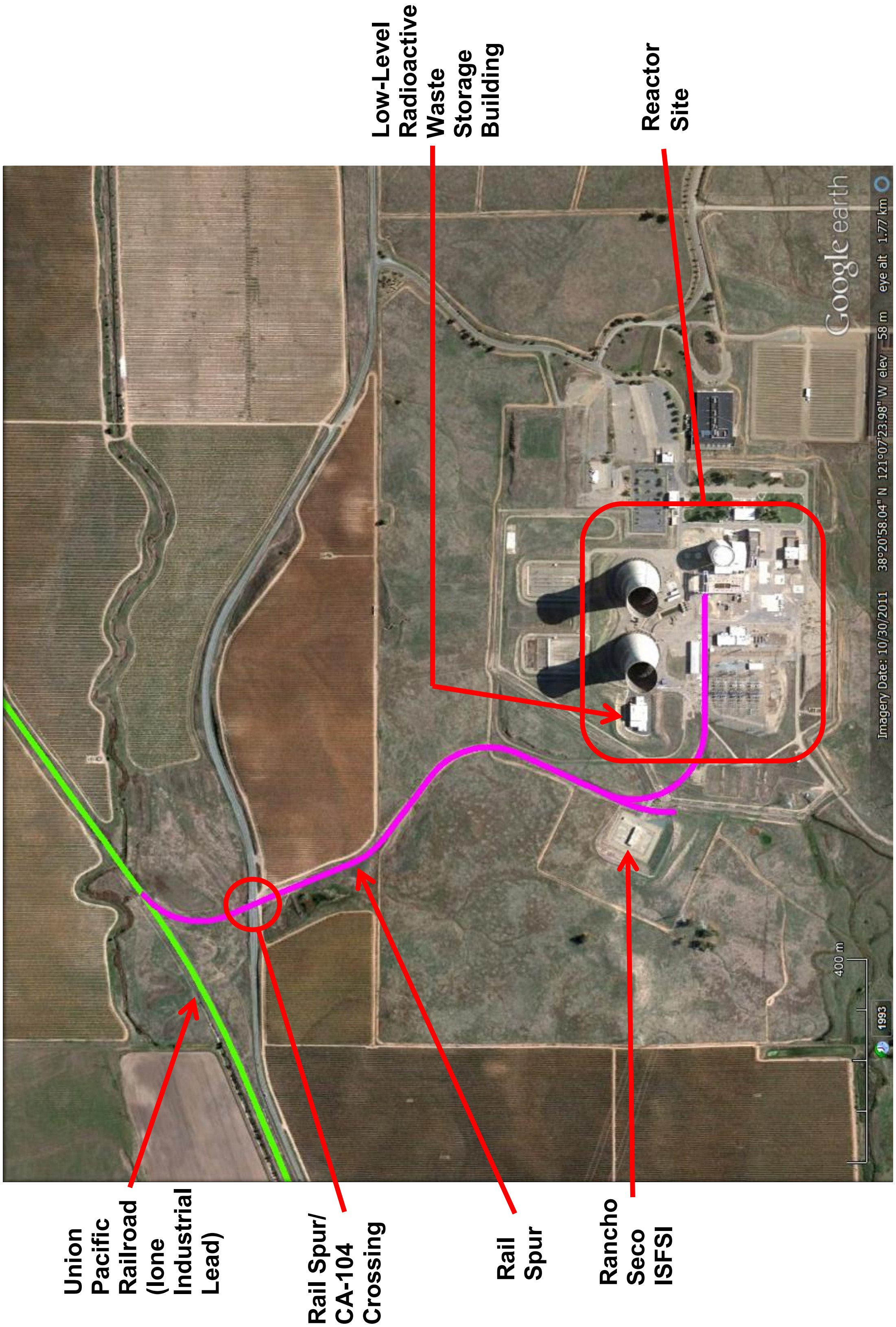

Figure 2-81. Aerial View of Rancho Seco Site (Google 2013)

Figure 2-82. Junction of the On-site Track Spur Running Adjacent to the ISFSI (Left) and the Longer Track Running into the Rancho Seco Site (Right)

Figure 2-83. On-site Rail Spur Running into Rancho Seco Site

2.6.3 Near-site Transportation Infrastructure and Experience

Rancho Seco owns the rail spur that provides access to the Union Pacific's Ione Industrial Lead, which runs west from the Rancho Seco site to the Union Pacific mainline in Galt, California (see Figure 2-84). The Union Pacific mainline is designated as track class 5 and the Ione Industrial Lead is designated as track class 2. The maximum gross weight of railcars on the Ione Industrial Lead between Rancho Seco and Galt is 158 tons, and 6-axle locomotives are prohibited. A loaded MP187 transportation cask would weigh 133 to 136 tons and a cask-carrying railcar would weigh at least 43 tons, so the weight limit of 158 tons is likely to be exceeded, requiring either a track upgrade or a waiver. California State Route 104 crosses the rail spur (see Figure 2-81). The rail spur was not maintained after shutdown in 1989; but was restored to operating condition in the early 2000s to support decommissioning. During decommissioning, this rail spur was used to transport four reactor coolant pumps (50 tons each), the pressurizer (150 tons), and two steam generators (550 tons each) to the Energy Solutions low-level radioactive waste disposal facility in Clive, Utah (Johnson 2006). The rail spur was last maintained and certified in 2008; but is not being maintained. Past restoration of the rail spur to pass inspection was a relatively inexpensive, straightforward project.[13]

Heavy haul trucks have also been used to ship materials to and from the Rancho Seco site. For example, in 2000, Transnuclear, Inc. contracted with a heavy haul truck operator to ship the 100-ton (empty and without impact limiters) MP187 transportation cask from the eastern United States to the Rancho Seco site (see Figure 2-85).

[13] Ross SB. 2012. E-mail from ET Ronningen (Superintendent, Rancho Seco Assets Power Generation, Sacramento Municipal Utility District) to SB Ross (Pacific Northwest National Laboratory), "Re:Request for Info," September 17, 2012.

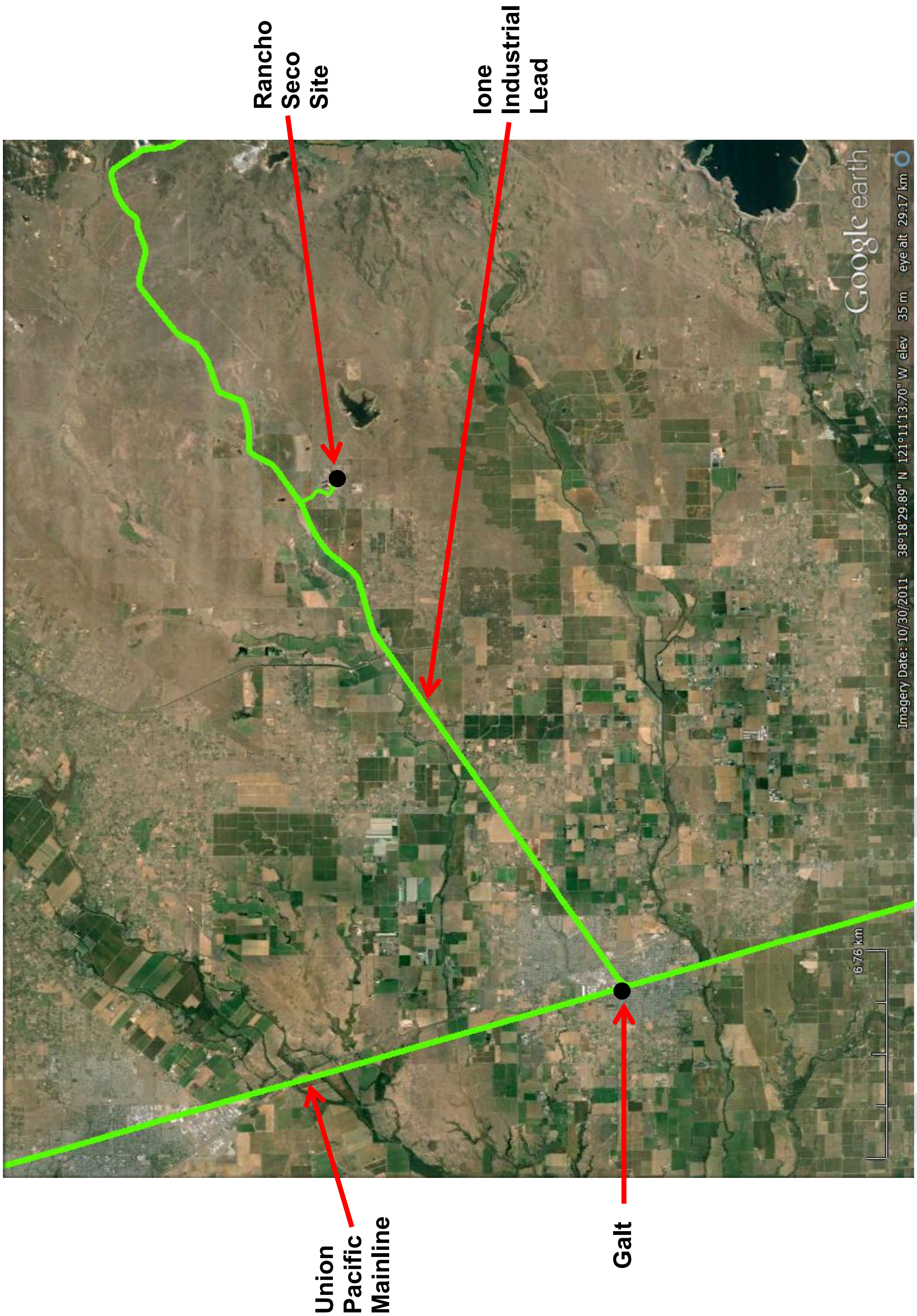

Figure 2-84. Aerial View of Ione Industrial Lead and Union Pacific Mainline (Google 2013)

Photo courtesy of Rancho Seco

Figure 2-85. MP187 Cask Transported by Heavy Haul Truck

2.6.4 Gaps in Information

The principal question for the Rancho Seco site regarding the capability of the off-site transportation infrastructure to accommodate shipments of large transportation casks is the weight limit (158 tons) associated with the Ione Industrial Lead, which would make it necessary to obtain waivers from the Union Pacific Railroad or to upgrade the track to ship the MP187 transportation cask. In addition, it would be necessary to obtain NRC authorization to transport non-failed-fuel canisters containing damaged fuel assemblies in the MP187 transportation cask.

2.7 Trojan

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the Trojan site. The Trojan site is located in northwestern Oregon on the Columbia River about 40 miles northwest of Portland, Oregon (NAC 1991b).

2.7.1 Site Inventory

Thirty-four canisters containing used nuclear fuel assemblies and no canisters of GTCC low-level radioactive waste are stored at the Trojan site. The 34 canisters contain 780 intact assemblies, 10 partial assemblies, 8 process can capsules, 1 failed fuel can containing 8 bottom nozzles and 2 process cans, 1 fuel rod storage rack containing 23 ruptured or damaged fuel rods, and 1 assembly skeleton.

Figure 2-86 shows the ISFSI at Trojan. The storage system used at Trojan is a hybrid of two storage systems (EPRI 2010), and consists of TranStor concrete storage overpacks and Holtec MPC-24E and MPC-24EF canisters. The MPC-24E and the MPC-24EF canisters hold 24 pressurized water reactor used nuclear fuel assemblies. The fuel assemblies from Trojan were loaded into Holtec canisters from December 2002 through September 2003 (Leduc 2012). The fuel rods in the fuel assemblies are Zircaloy-clad. The HI-STAR 100 transportation cask (Docket No. 71-9261) is licensed to transport the MPC-24E and the MPC-24EF canisters. Although HI-STAR 100 casks have been constructed for use in the United States, these casks are already being used as storage casks at the Dresden (4 casks) and Hatch (3 casks) sites (Ux Consulting 2013a). For these HI-STAR 100 casks to be used to ship used nuclear fuel 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 these HI-STAR 100 casks.

Photo courtesy of Trojan

Figure 2-86. Trojan Independent Spent Fuel Storage Installation

Figure 2-87 illustrates the number of used nuclear fuel assemblies at Trojan based on their discharge year. The oldest fuel was discharged in 1978 and the last fuel was discharged in 1992. The median discharge year of the fuel is 1988.

Figure 2-88 illustrates the number of used nuclear fuel assemblies at Trojan based on their burnup. The lowest burnup is 5.0 GWd/MTHM and the highest burnup is 42.1 GWd/MTHM. The median burnup is 33.4 GWd/MTHM. No high burnup used nuclear fuel (burnup greater than 45 GWd/MTHM) is stored at Trojan.

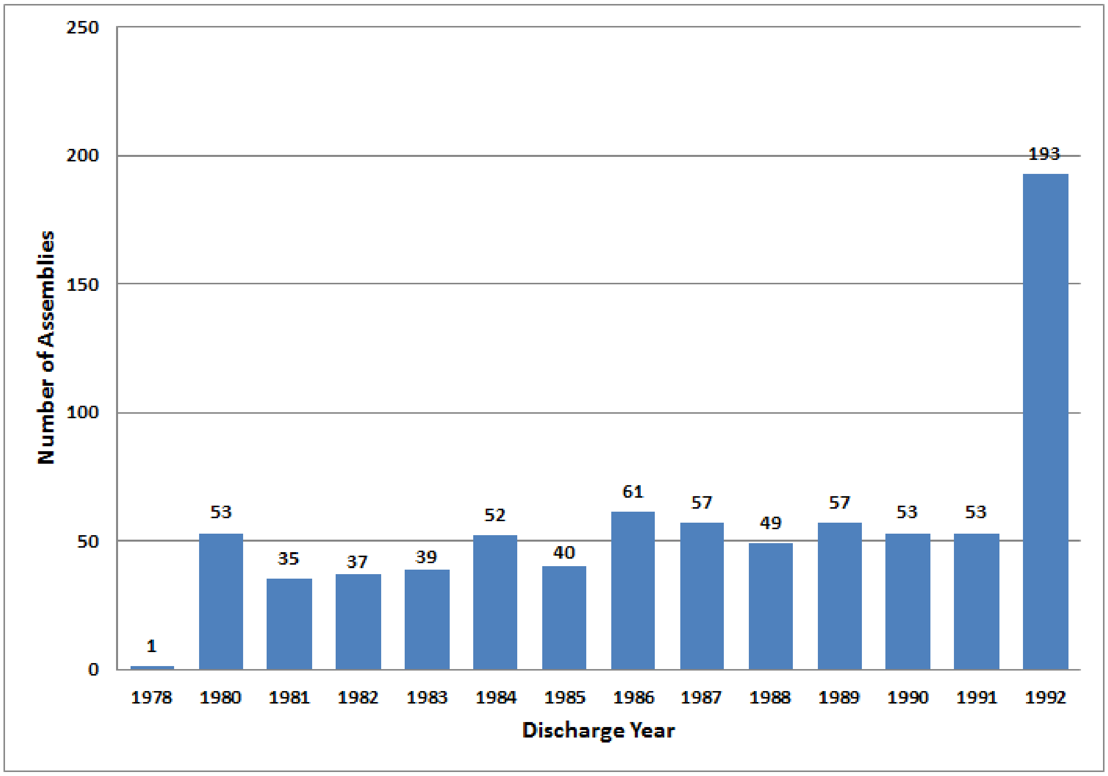

Figure 2-87. Trojan Number of Assemblies versus Discharge Year (EIA 2002)

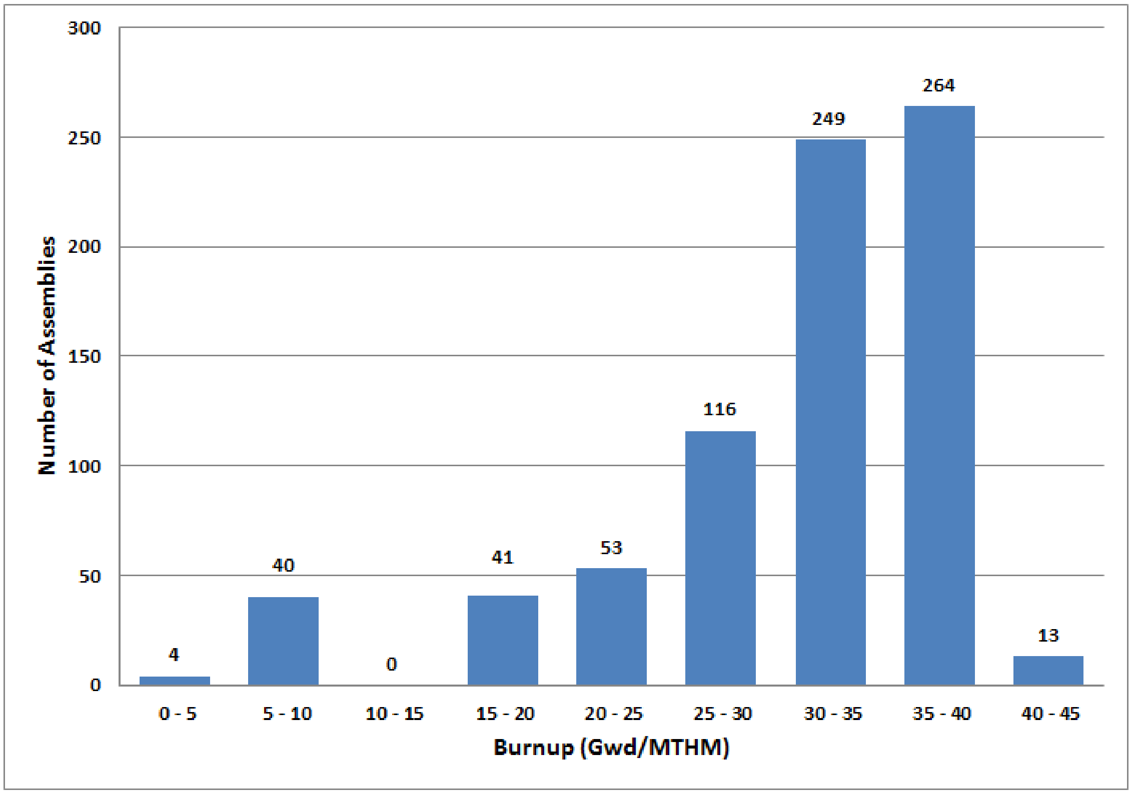

Figure 2-88. Trojan Number of Assemblies versus Burnup (EIA 2002)

2.7.2 Site Conditions

Figure 2-89 provides an aerial view of the Trojan site, where the reactor and associated structures have been removed. Electrical power is available at the Trojan ISFSI. However, mobile equipment such as cranes to unload the TranStor vertical concrete storage overpacks containing the Holtec multipurpose canisters used at Trojan, and to load the HI-STAR 100 transportation casks is not present at the site. The HI-STAR 100 transportation cask is licensed to transport the Trojan used nuclear fuel. A transfer cask, transfer station, and air pad system are also located at the Trojan ISFSI. Figure 2-90 shows the transfer station and Figure 2-91 shows the transfer station with the transfer cask and mobile crane.

The Portland and Western Railroad rail line passes through the Trojan site approximately 700 feet from the Trojan ISFSI (TriVis Incorporated 2005). This rail line is designated as track class 2. A rail spur formerly came into the protected area (NAC 1991b). This spur has been removed, but could be rebuilt in preparation for shipping used nuclear fuel.[14]

A barge slip is located on the Trojan site about 3000 feet south of the Trojan ISFSI. The barge slip provides for roll-on/roll-off capability. The barge slip is not being maintained and dredging is usually required prior to use. There is no crane or other permanently installed handling or lifting equipment at the barge slip.

2.7.3 Near-site Transportation Infrastructure and Experience

At the Trojan site, a rail spur used to run from the Portland and Western Railroad to the site (see Figure 2-92). The rail spur was located at milepost 40.8 on the Astoria District of the Portland and Western Railroad and has been removed. In addition, during decommissioning a short spur was installed for rail shipments of waste. This spur has also been removed.

Figure 2-93 shows the Portland and Western Railroad in the vicinity of the Trojan site, Figure 2-94 shows the location of the former junction of the rail spur with the Portland and Western Railroad, and Figure 2-95 shows the railbed of the former rail spur. Remnants of this spur exist on-site (see Figure 2-96). There appears to be sufficient room at the Trojan site for additional track to accommodate trains having eight or more railcars (two buffer cars, a security escort car, and five or more cask cars).

As discussed in Section 2.7.2, a barge slip is also present at the Trojan site and provides access to the Columbia River. Figure 2-89 shows the location of the barge slip. Figure 2-97 shows the access road to the barge slip, and Figure 2-98 shows the condition of the barge slip in 2013.

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[14] Ross SB. 2012. Email message from JP Fischer (Trojan ISFSI Manager, Portland General Electric Company) to SB Ross (Pacific Northwest National Laboratory), "Re: Request for Info," September 17, 2012.

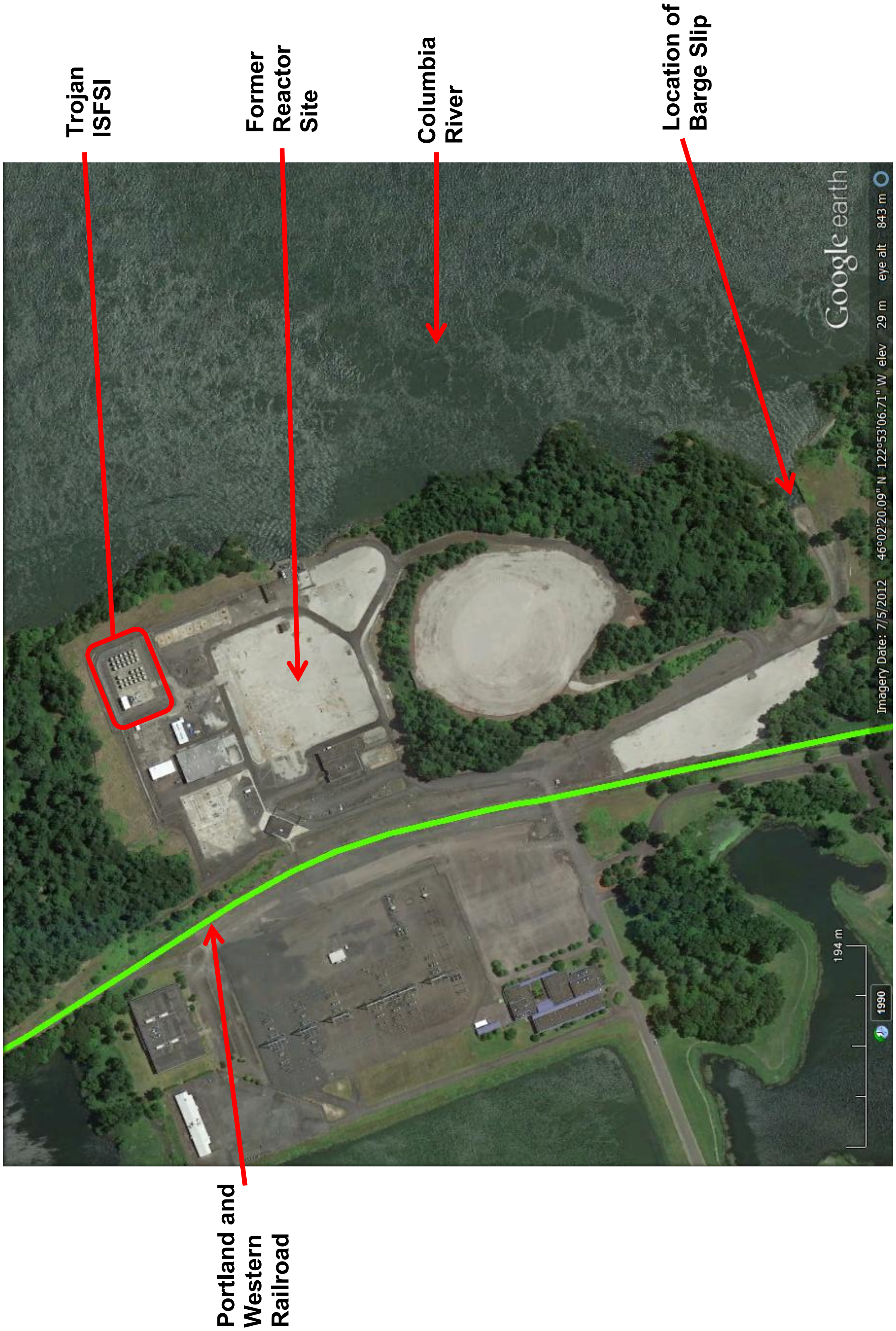

Figure 2-89. Aerial View of Trojan Site (Google 2013)

Photo courtesy of Trojan

Figure 2-90. Trojan Transfer Station

Photo courtesy of Trojan

Figure 2-91. Trojan Transfer Station with Transfer Cask and Mobile Crane

Figure 2-92. Rail Interface at Trojan (Google 2013)

Figure 2-93. Portland and Western Railroad in the Vicinity of the Trojan Site

Figure 2-94. Location of Former Junction of Portland and Western Railroad and Trojan Rail Spur

Figure 2-95. Former Trojan Rail Spur Railbed

Figure 2-96. Remnants of On-site Rail Spur at Trojan

Photo courtesy of Federal Railroad Administration

Figure 2-97. Barge Slip Access Road

Photo courtesy of Federal Railroad Administration

Figure 2-98. Trojan Barge Slip

During decommissioning, Trojan shipped four steam generators, the pressurizer, and the reactor pressure vessel from this barge slip to the US Ecology low-level radioactive waste disposal facility near Richland, Washington. The steam generator packages weighed 450 tons each and the pressurizer package weighed 125 tons (Lackey and Kelly 1996, 1997). The reactor pressure vessel package weighed 1000 tons (Radwaste Magazine 1999). Figures 2-99 through 2-102 show a steam generator being loaded at the Trojan barge slip, and the Trojan reactor pressure vessel being transported by barge, passing through locks on the Columbia River, and being transported by heavy haul truck to the US Ecology low-level radioactive waste disposal facility.

Photo courtesy of Portland General Electric Company

Figure 2-99. Trojan Steam Generator Being Loaded at Barge Slip

Photo courtesy of Portland General Electric Company

Figure 2-100. Trojan Reactor Pressure Vessel Being Transported by Barge

Photo courtesy of Portland General Electric Company

Figure 2-101. Trojan Reactor Pressure Vessel Passing Through Locks on the Columbia River

Photo courtesy of Portland General Electric Company

Figure 2-102. Trojan Reactor Pressure Vessel Being Transported by Heavy Haul Truck

2.7.4 Gaps in Information

Both rail and barge modes are feasible for transporting used nuclear fuel from the Trojan site. The Portland and Western Railroad rail line passes through the Trojan site approximately 700 feet from the Trojan ISFSI. In the past, a rail spur came into the protected area. The spur was disconnected, but according to site representatives, could be rebuilt in preparation for shipping used nuclear fuel. The Portland and Western Railroad is a Class II railroad whose track is expected to be capable of accommodating shipments of HI-STAR 100 casks from the Trojan site. The Trojan site also has an on-site barge slip and it is likely the barge slip could be used for shipping used nuclear fuel transportation casks on barges.

2.8 La Crosse

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the La Crosse site. The La Crosse site is located in western Wisconsin on the east bank of the Mississippi River, about 1 mile south of Genoa and 17 miles south of La Crosse, Wisconsin (TOPO 1993e).

2.8.1 Site Inventory

Five canisters containing 333 used nuclear fuel assemblies are stored at La Crosse. The five canisters contain 176 intact used nuclear fuel assemblies, 157 damaged used nuclear fuel assemblies, and 1 fuel debris can. The 157 damaged assemblies have been placed in damaged fuel cans. La Crosse is undergoing decommissioning; however, because the La Crosse reactor pressure vessel has been shipped off-site for disposal (Radwaste Solutions 2007), GTCC low-level radioactive waste would not be generated.

Figure 2-103 shows the ISFSI at La Crosse. The storage system used at La Crosse is the NAC Multi-Purpose Canister system (NAC-MPC) (Docket No. 72-1025), which consists of a transportable storage canister, a vertical concrete storage cask, and a transfer cask. The transportable storage canister used for the La Crosse used nuclear fuel is the MPC-LACBWR. This canister holds 68 La Crosse boiling water reactor used nuclear fuel assemblies. The fuel assemblies from La Crosse were loaded into MPC-LACBWR canisters from July through September 2012. The fuel rods in the fuel assemblies are stainless steel-clad. The NAC-STC transportation cask (Docket No. 71-9235) is licensed to transport the MPC-LACBWR canister. No NAC-STC transportation casks have been fabricated for use in the United States. Two NAC-STC transportation casks have been fabricated for use in China (Washington Nuclear Corporation 2003).

Figure 2-104 illustrates the number of used nuclear fuel assemblies at La Crosse, based on their discharge year. The oldest fuel was discharged in 1972 and the last fuel was discharged in 1987. The median discharge year of the fuel is 1982.

Figure 2-105 illustrates the number of used nuclear fuel assemblies at La Crosse based on their burnup. The lowest burnup is 4.7 GWd/MTHM and the highest burnup is 21.5 GWd/MTHM. The median burnup is 15.7 GWd/MTHM. No high burnup used nuclear fuel (burnup greater than 45 GWd/MTHM) is stored at La Crosse.

Photo courtesy of La Crosse

Figure 2-103. La Crosse Independent Spent Fuel Storage Installation

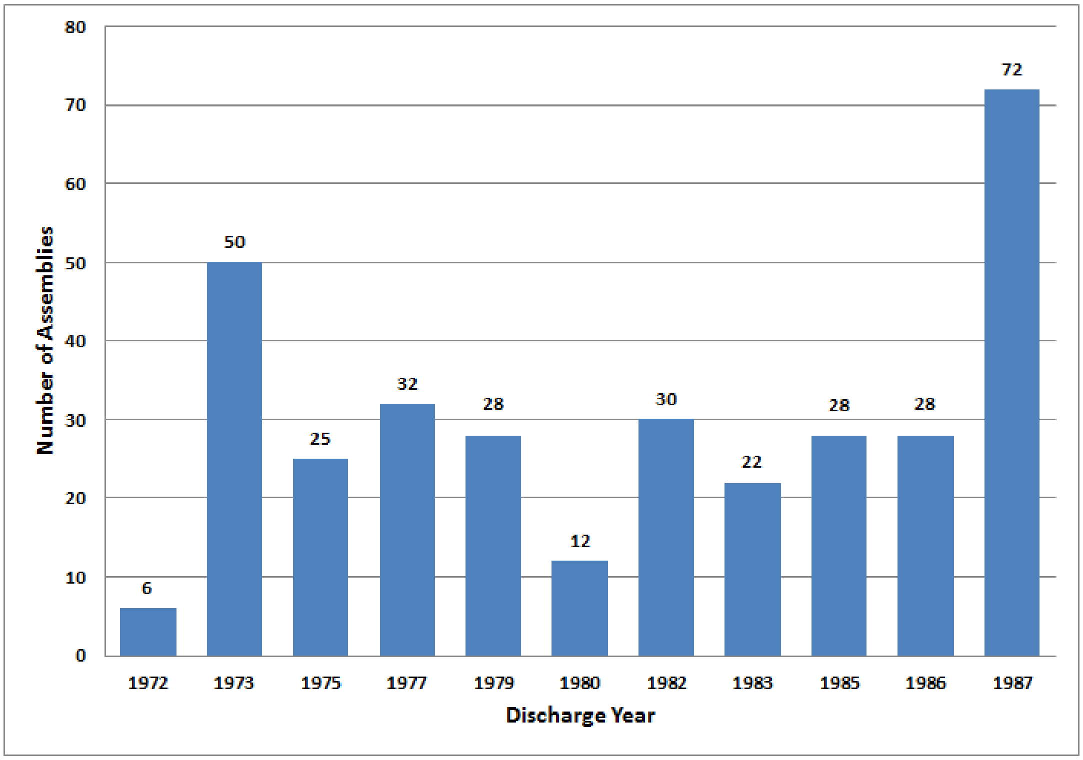

Figure 2-104. La Crosse Number of Assemblies versus Discharge Year (EIA 2002)

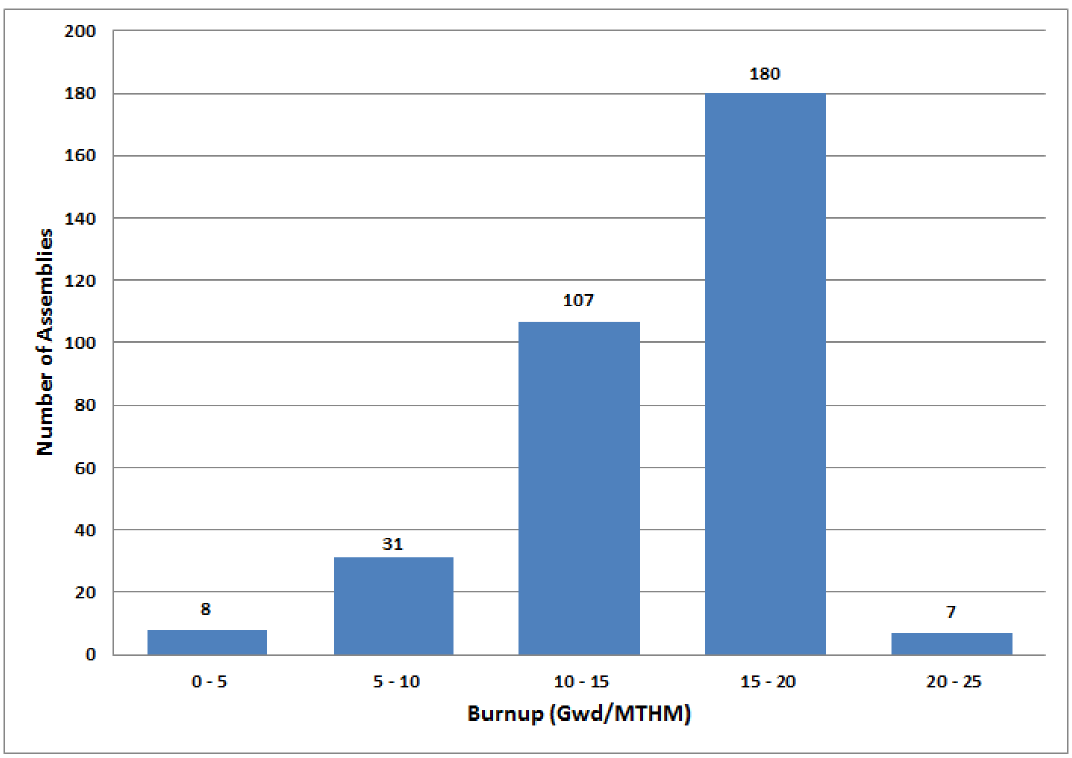

Figure 2-105. La Crosse Number of Assemblies versus Burnup (EIA 2002)

2.8.2 Site Conditions

Figure 2-106 provides an aerial view of the La Crosse site, where the nuclear power plant is being decommissioned. As seen in Figure 2-106, the La Crosse ISFSI is located south of the La Crosse reactor site and the Genoa #3 coal-fired power plant. Electrical power is available at the La Crosse ISFSI. However, mobile equipment such as cranes or a gantry system to unload the NAC-MPC vertical concrete storage casks used at La Crosse and to load the NAC-STC transportation cask that is licensed to transport the La Crosse used nuclear fuel is not present at the site. A transfer cask is available on-site and is owned by the Dairyland Power Cooperative. This transfer cask could also be used at the Yankee Rowe and Connecticut Yankee sites.

Rail service to the La Crosse site is provided by the BNSF Railroad that is east of the La Crosse ISFSI. This rail line is designated as track class 4. La Crosse does not have an active on-site rail system,[15] however, remnants of an on-site rail system exist at the site (see Figure 2-107). There is a short on-site spur at the north end of the La Crosse site (see Figure 2-108). Figure 2-109 shows the junction of junction of the on-site rail spur with the BNSF Railroad. In 2007, this on-site rail spur was used during the transport of the La Crosse reactor pressure vessel to the Barnwell, South Carolina low-level radioactive waste disposal facility (Radwaste Solutions 2007). The reactor pressure vessel was transported on a specially designed 20-axle railcar and the shipment weighed 310 tons.

On-site barge access is available about 0.2 miles north of the La Crosse reactor site (see Figure 2-110). The dock area is approximately 500 feet long by 100 feet wide with a minimum 9-foot water depth (TOPO 1993e). The barge facility is located on the Mississippi River and has direct access to the shipping channel. The barge facility is routinely used for the removal of covers from coal barges using a portable crane. The coal is subsequently unloaded several hundred yards downstream adjacent to the Genoa #3 coal-fired power plant. A large number of barge mooring/securing posts are available. Barge service is not available December through February and is limited by local weather conditions (TOPO 1993e). Mobile rental cranes of the required capacity are available (TriVis Incorporated 2005). TOPO (1993e) reports that dredging or other dock area refurbishment is likely to be required.

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[15] Ross SB. 2012. Email message from DG Egge (Plant Manager, LACBWR, Dairyland Power Cooperative) to SB Ross (Pacific Northwest National Laboratory), "Re: La Crosse Information," October 17, 2012.

Figure 2-106. Aerial View of La Crosse Site (Google 2013)

Photo courtesy of La Crosse

Figure 2-107. Remnants of the On-site Rail System at La Crosse Site

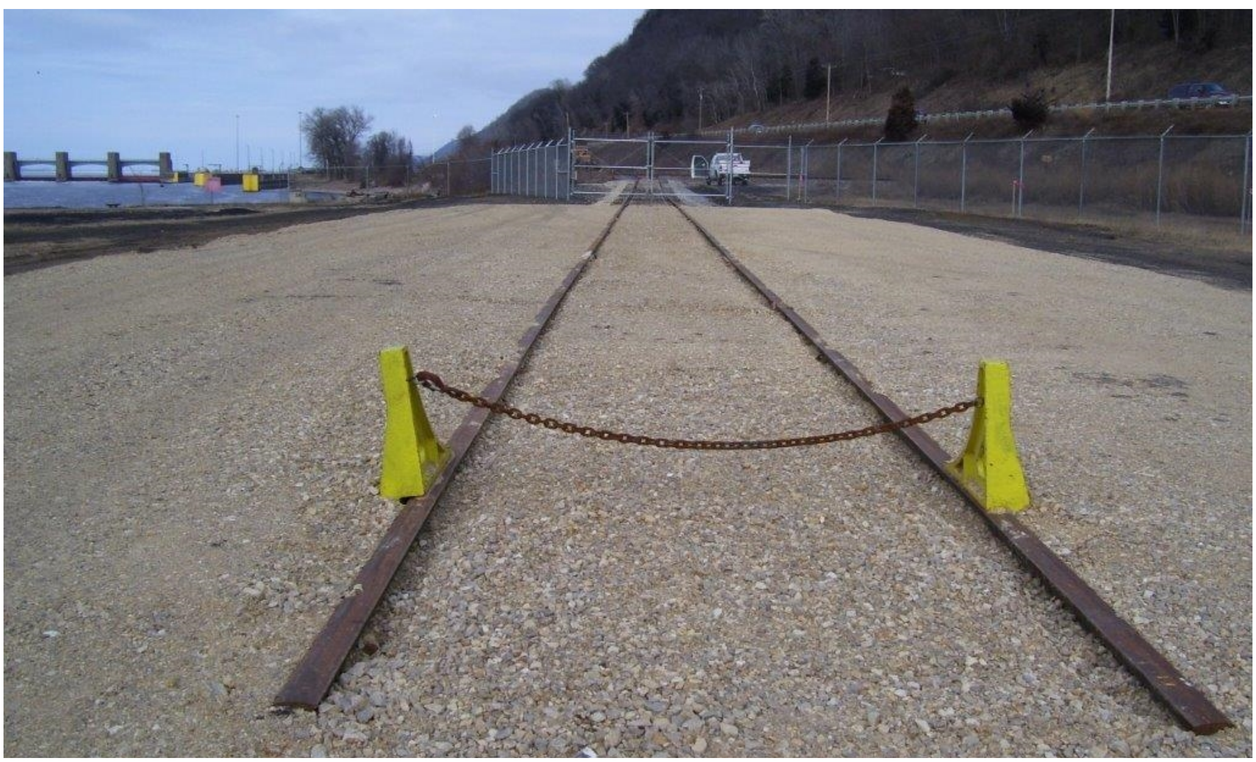

Photo courtesy of La Crosse

Figure 2-108. On-site Rail Spur at Northern End of La Crosse Site

Photo courtesy of La Crosse

Figure 2-109. Junction of On-site Rail Spur with BNSF Railroad at La Crosse Site

Figure 2-110. Coal Barge at Barge Dock Area at La Crosse Site

2.8.3 Near-site Transportation Infrastructure and Experience

At the La Crosse site, a short on-site rail spur exists that provides direct rail access to the BNSF Railroad. There appears to be adequate room at the La Crosse site to extend this spur to accommodate trains having eight or more railcars (two buffer cars, a security escort car, and five or more cask cars). As discussed in Section 2.8.2, in 2007, this on-site rail spur was used to transport the La Crosse reactor pressure vessel to the Barnwell, South Carolina low-level radioactive waste disposal facility. Figures 2-111 and 2-112 show the La Crosse reactor pressure vessel on the on-site spur and on the BNSF Railroad. The La Crosse site is also on the Mississippi River and has on-site barge access. However, barges have not been used for radioactive waste shipments from La Crosse.

2.8.4 Gaps in Information

Rail service to the La Crosse site is provided by the BNSF Railroad that is east of the La Crosse ISFSI using a short on-site rail spur and there appears to be adequate room at the La Crosse site to extend this spur to accommodate trains having eight or more railcars (two buffer cars, a security escort car, and five or more cask cars). The location and method for loading the transportation cask and moving the transportation cask to a rail spur is uncertain.

On-site barge access is available about 0.2 miles north of the La Crosse reactor site. It is uncertain whether the on-site barge facility could accommodate used nuclear fuel transportation casks.

Assuming that the on-site rail spur into the La Crosse site is maintained or refurbished as may be needed, it is unlikely that heavy haul trucks would be used to remove transportation casks containing used nuclear fuel from the site.

Photo courtesy of La Crosse

Figure 2-111. La Crosse Reactor Pressure Vessel on Rail Spur

Photo courtesy of La Crosse

Figure 2-112. La Crosse Reactor Pressure Vessel on BNSF Railroad

2.9 Zion

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the Zion site. The Zion site is located in the northeastern corner of Illinois on the western shore of Lake Michigan, about 40 miles north of Chicago (TOPO 1994b).

2.9.1 Site Inventory

At Zion, used nuclear fuel has not yet been loaded into dry storage canisters and transferred to an ISFSI. It is estimated that there will be 61 canisters containing 2226 used nuclear fuel assemblies that were discharged from the Zion 1 and Zion 2 reactors (Leduc 2012) and 4 canisters containing GTCC low-level radioactive waste generated during the decommissioning of the Zion site. The storage system that will be used at Zion is the NAC MAGNASTOR system (Docket No. 72-1031) with the TSC-37 canister (see Figure 2-113), which holds 37 pressurized water reactor used nuclear fuel assemblies. The fuel rods in the fuel assemblies at Zion are all Zircaloy-clad. It is expected that the loading of the canisters and the MAGNASTOR system will start in 2013. The transportation cask that will be licensed to transport this used nuclear fuel is the NAC MAGNATRAN (Docket No. 71-9356). The application for a license for the MAGNATRAN is currently under review by the NRC. It is anticipated that the certificate of compliance for the MAGNATRAN will be issued in 2014.

Figure 2-114 illustrates the number of used nuclear fuel assemblies at Zion, based on their discharge year. The oldest fuel was discharged in 1976 and the last fuel was discharged in 1997. The median discharge year of the fuel is 1987.

Figure 2-115 illustrates the number of used nuclear fuel assemblies at Zion based on their burnup. The lowest burnup is 14.2 GWd/MTHM and the highest burnup is 55.1 GWd/MTHM. The median burnup is 33.1 GWd/MTHM. There are 36 used nuclear fuel assemblies at Zion with burnups greater than 45 GWd/MTHM. These 36 fuel assemblies are classified by the NRC as high burnup used nuclear fuel. Ux Consulting (2013b) states that for the MAGNATRAN transportation cask, all fuel with a burnup great than 45 GWd/MTHM will be canned in damaged fuel cans and that each TSC-37 canister can accommodate up to four damaged fuel cans. An additional assembly (J47B) with a burnup of 44.945 GWd/MTHM will also be treated as high burnup used nuclear fuel and will be placed in a damaged fuel can.

In addition to the 37 used nuclear fuel assemblies discussed above, 57 used nuclear fuel assemblies identified as damaged, 2 loose fuel rod storage containers holding 28 fuel rods, and 1 used nuclear fuel assembly (C15R) with a dummy fuel rod will also be placed in damaged fuel cans.

Photo courtesy of NAC International

Figure 2-113. TSC-37 Canister Showing Internal Baskets Which Hold Used Nuclear Fuel Assemblies

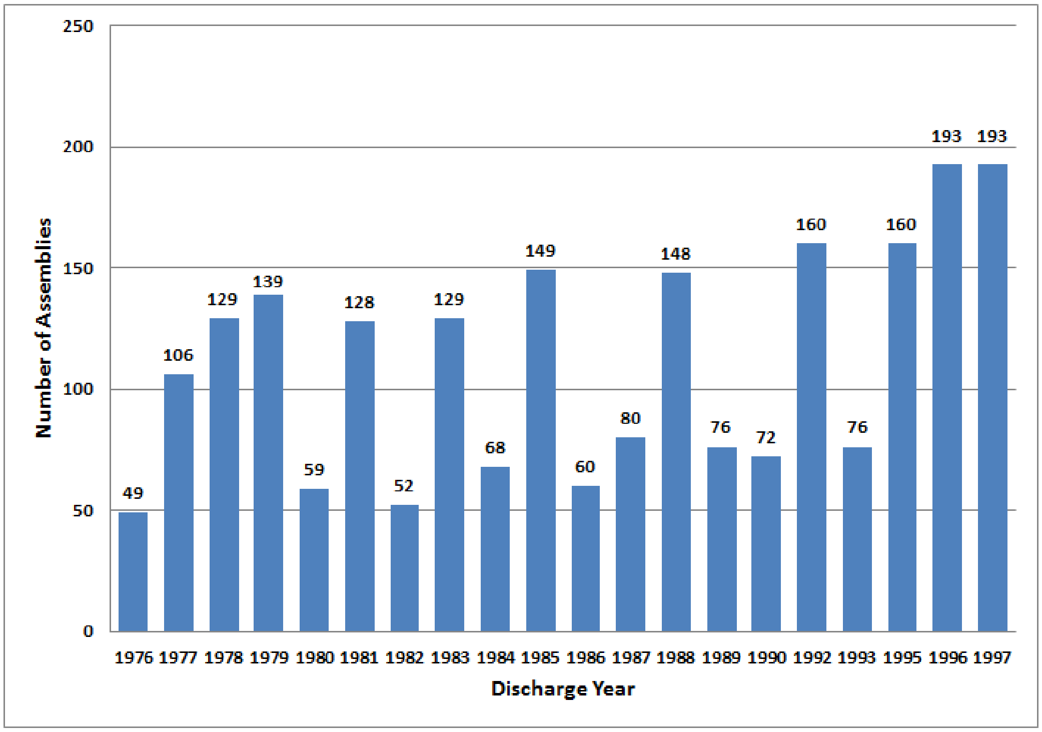

Figure 2-114. Zion Number of Assemblies versus Discharge Year

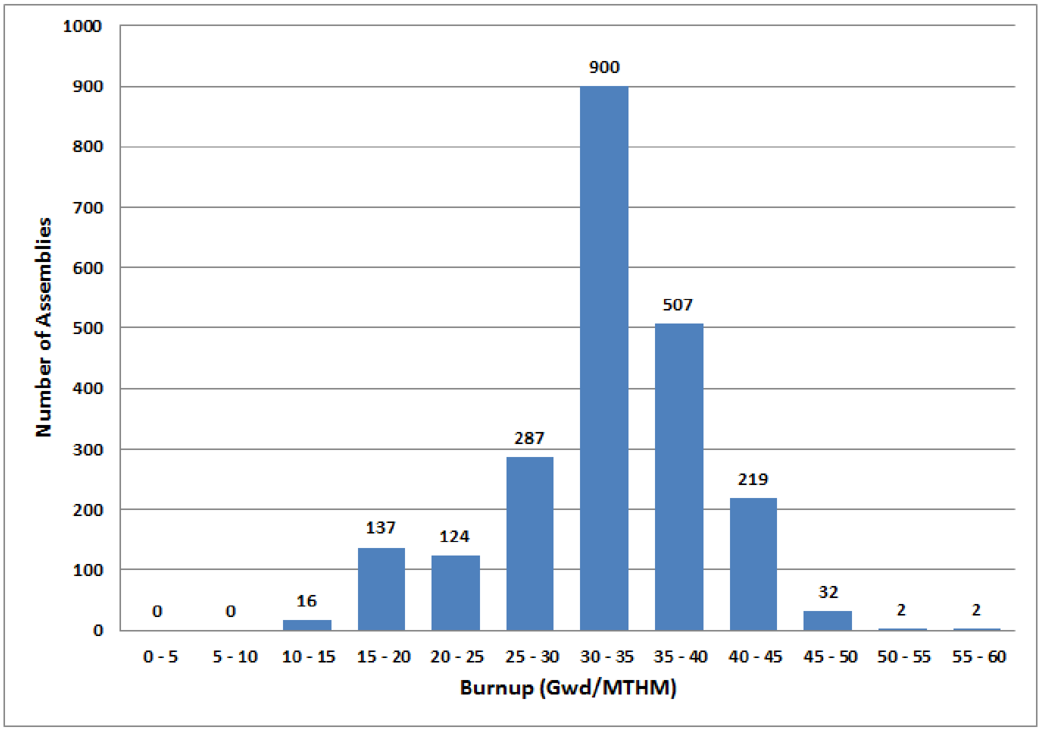

Figure 2-115. Zion Number of Assemblies versus Burnup

2.9.2 Site Conditions

Figure 2-116 provides an aerial view of the Zion site, which is being decommissioned. The Zion ISFSI is currently under construction and is located at the southern end of the Zion site (see Figure 2-117). At the northern end of the Zion site, 65 vertical concrete storage casks are staged prior to being loaded. Figure 2-118 provides a close-up view of these vertical concrete storage casks. Figure 2-116 also shows the Zion on-site rail spur which was recently refurbished and which is being used for low-level radioactive waste shipments from the site. This rail spur provides access to the Union Pacific Railroad. The Union Pacific rail line in the vicinity of the Zion site is designated as track class 4.

At the Zion site, the used nuclear fuel has not been transferred from the spent nuclear fuel pool to dry storage at an ISFSI. This transfer is expected to be completed during 2014. Figure 2-119 shows the TSC-37 transportable storage canisters into which the used nuclear fuel will be placed. These canisters will then be placed inside vertical concrete storage casks and moved to the Zion ISFSI. Figure 2-120 shows the transporter that will be used to move the loaded vertical concrete storage casks to the ISFSI.

During construction of the Zion site, barges were used to move materials and components to the site. The Zion barge facility used during plant construction has been abandoned and the land upon which it was located was donated to the Illinois Beach State Park (TOPO 1994b).

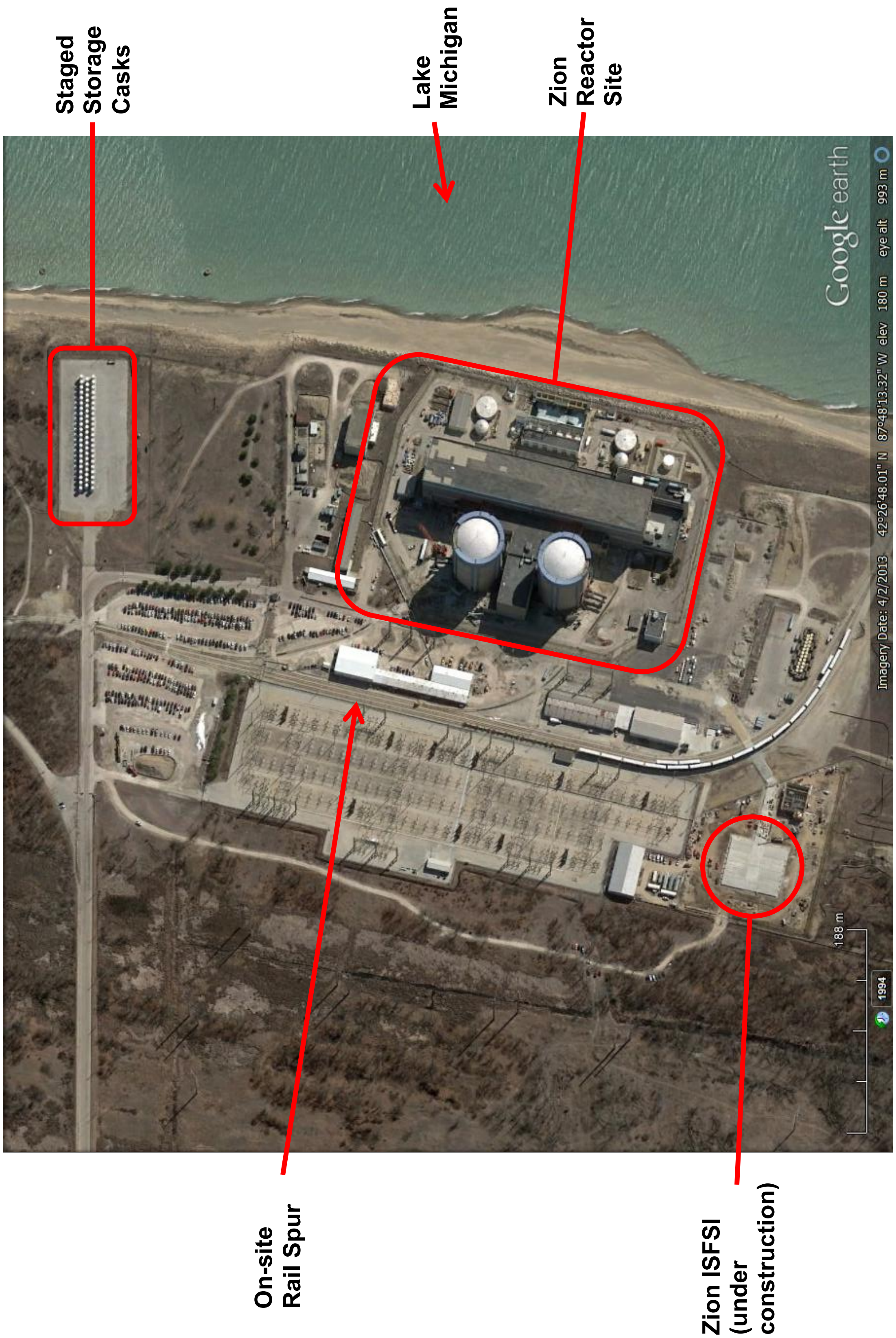

Figure 2-116. Aerial View of Zion Site (Google 2013)

Figure 2-117. Aerial View of Zion ISFSI Under Construction (Google Earth 2012)

Figure 2-118. Vertical Concrete Storage Casks Staged at Zion

Figure 2-119. Empty Used Nuclear Fuel Transportable Storage Canisters at Zion

Figure 2-120. Transporter Used to Move Vertical Concrete Storage Casks

2.9.3 Near-site Transportation Infrastructure and Experience

At the Zion site, an on-site rail spur provides direct rail access to the Union Pacific Railroad (see Figure 2-121). In addition, there is currently enough room on the Zion site to accommodate trains having eight or more railcars (two buffer cars, a security escort car, and five or more cask cars). Figure 2-122 shows the Trackmobile that is being used to move railcars on-site. Figure 2-123 shows the rail spur entering the Zion site and Figure 2-124 shows the junction of Zion on-site rail spur with Union Pacific Railroad. Figure 2-124 also shows the concrete rail ties that were used in the reconstructing the curves of the on-site rail spur.

As mentioned in Section 2.9.2, the Zion site was served by barges during construction. However, the barge facility was abandoned and the Zion site does not plan to reestablish the barge facility for radioactive waste shipments during decommissioning.

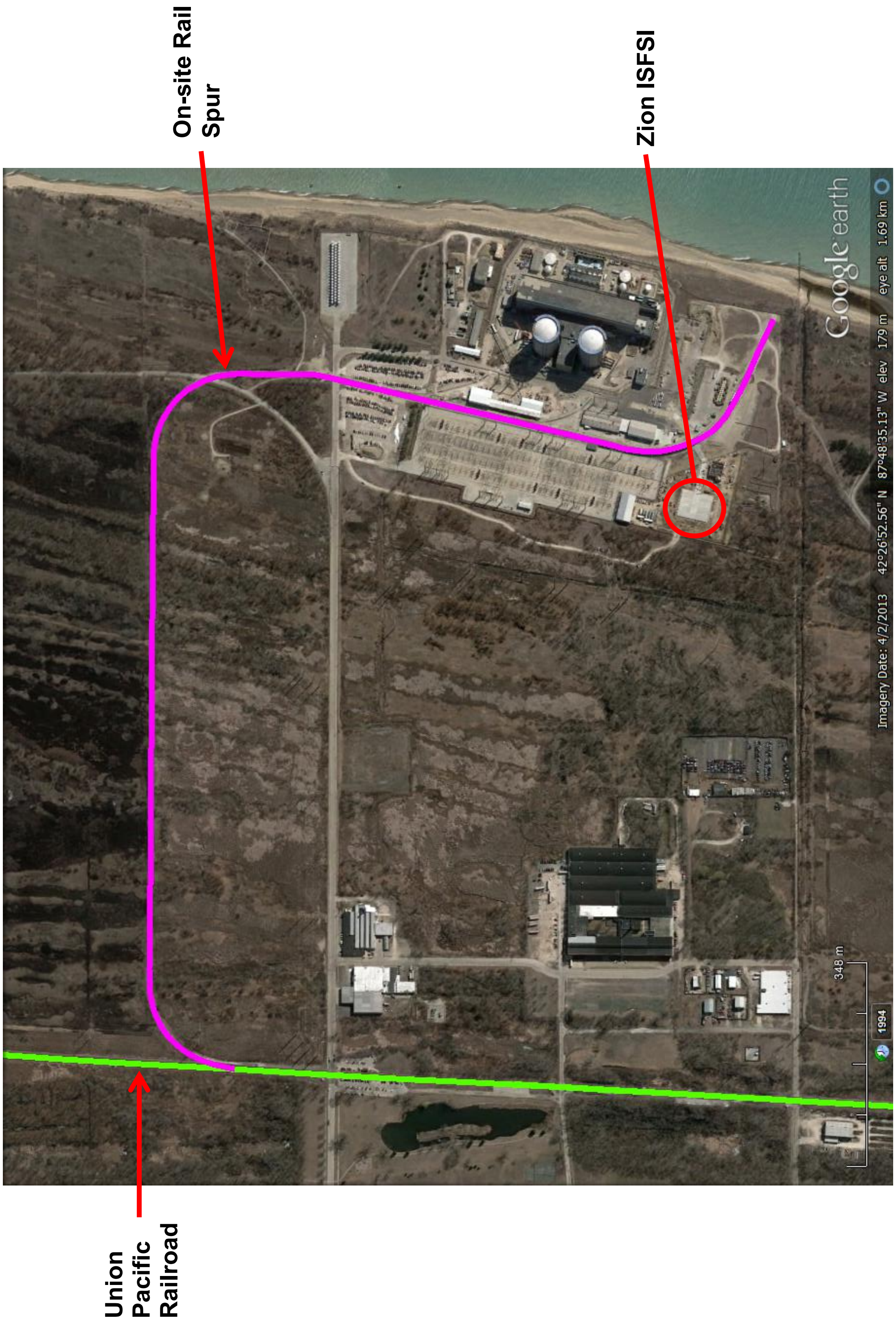

Figure 2-121. Rail Interface at Zion (Google 2013)

Figure 2-122. Trackmobile Used to Move Railcars On-site

Photo courtesy of Federal Railroad Administration

Figure 2-123. On-site Rail Spur Entering Zion Site

Figure 2-124. Junction of Zion On-site Rail Spur with Union Pacific Railroad Showing Concrete Rail Ties

In addition to rail, Zion has used heavy haul trucks to ship radioactive waste off-site for disposal. For example, in 2011, ZionSolutions, which is decommissioning the Zion reactors, shipped the Zion Unit 2 reactor head from the Zion site to Clive, Utah for disposal. The reactor head was approximately 17 feet in diameter and weighed 225,000 lb. (Troher 2011). A heavy haul truck was used for this shipment because the Zion Unit 2 reactor head was too large for shipment by rail. The heavy haul truck travelled 1,500 miles from the Zion site north of Chicago, Illinois to the EnergySolutions disposal facility in Clive, Utah. Figure 2-125 shows the Zion reactor head on its heavy haul truck transporter.

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Figure 2-125. Zion Reactor Head on Heavy Haul Truck Transporter

2.9.4 Gaps in Information

At the Zion site, a rail spur connects to the Union Pacific Railroad mainline that runs between Milwaukee, Wisconsin, and Chicago, Illinois. The Union Pacific Railroad is a Class I railroad that is expected to have the capability to move shipments of used nuclear fuel in NAC MAGNATRAN transportation casks. However, the status of this rail spur after decommissioning of the Zion site has been completed has not been determined.

The Zion barge facility used during plant construction was abandoned and the land upon which it was located was donated to the Illinois Beach State Park, making shipment of used nuclear fuel by barge unlikely.

2.10 Crystal River

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the Crystal River site. The Crystal River site is located in northwestern Florida near the Gulf of Mexico on the Crystal River about 46 miles southeast of Gainesville, Florida, and 70 miles north of Tampa, Florida (TOPO 1994c).

2.10.1 Site Inventory

The Crystal River Unit 3 Nuclear Generating Plant (CR-3) has been shut down since September 26, 2009 and the final removal of used nuclear fuel from the reactor vessel was completed on May 28, 2011 (Franke 2013). There are 1319 pressurized water reactor used nuclear fuel assemblies (619.3 MTHM) stored in the spent fuel pool and there is no used nuclear fuel in dry storage at Crystal River (Carter and Leduc 2013). This includes 76 assemblies that were loaded into the reactor for restart but not brought to critical. The Crystal River site is considering options for reusing these assemblies, such as using them in another reactor or returning them to the fuel fabricator for uranium recovery.[16]

The fuel rods in the fuel assemblies are Zircaloy- or M5-clad. Crystal River is planning on using the Standardized NUHOMS System (Docket No. 72-1004) with the 32PTH1 dry shielded canister for dry storage of used nuclear fuel at an ISFSI. This system consists of transportable 32PTH1 dry shielded canisters, reinforced concrete horizontal storage modules, and a transfer cask. The 32PTH1 dry shielded canister holds 32 pressurized water reactor used nuclear fuel assemblies. Forty-two 32PTH1 canisters would be required to store the 1319 used nuclear fuel assemblies at Crystal River.

Revision 5 of the certificate of compliance for the MP197HB transportation cask (Docket No. 71-9302) currently allows transport of low burnup used nuclear fuel (< 45 GWd/MTHM) in the 69BTH, 61BTH, 61BT, and 24PT4 dry shielded canisters, and radioactive waste. However, Revision 5 of the certificate of compliance for the MP197HB transportation cask does not authorize transport of used nuclear fuel in the 32PTH1 dry shielded canister. Therefore, the used nuclear fuel at Crystal River that would be placed in 32PTH1 dry shielded canisters currently would not be transportable based on Revision 5 of the certificate of compliance for the MP197HB transportation cask.

Used nuclear fuel was first discharged from Crystal River in 1978. The RW-859 database (EIA 2002) contains used nuclear fuel discharge data through December 31, 2002. To estimate used nuclear fuel discharges from January 1, 2003 through September 26, 2009, the TSL-CALVIN computer code (Nutt et al. 2012) was used.

[16] Nesbit S. 2013. Email messages from S Nesbit (Duke Energy Corporation) to SJ Maheras (Pacific Northwest National Laboratory), "Fw: Request for Review of DOE Document," September 24-26, 2013.

Figure 2-126 illustrates the estimated number of used nuclear fuel assemblies at Crystal River, based on their discharge year. The oldest fuel was discharged in 1978 and the last fuel was discharged in 2009. The estimated median discharge year of the fuel is 1996.

Figure 2-127 illustrates the estimated number of used nuclear fuel assemblies at Crystal River based on their burnup.[17] The lowest burnup is in the range of 0 to 5 GWd/MTHM and the highest burnup is in the range of 50 to 55 GWd/MTHM. The median burnup is in the range of 35 to 40 GWd/MTHM. There are 428 used nuclear fuel assemblies at Crystal River that have burnups greater than 45 GWd/MTHM. These 428 fuel assemblies are classified by the NRC as high burnup used nuclear fuel.

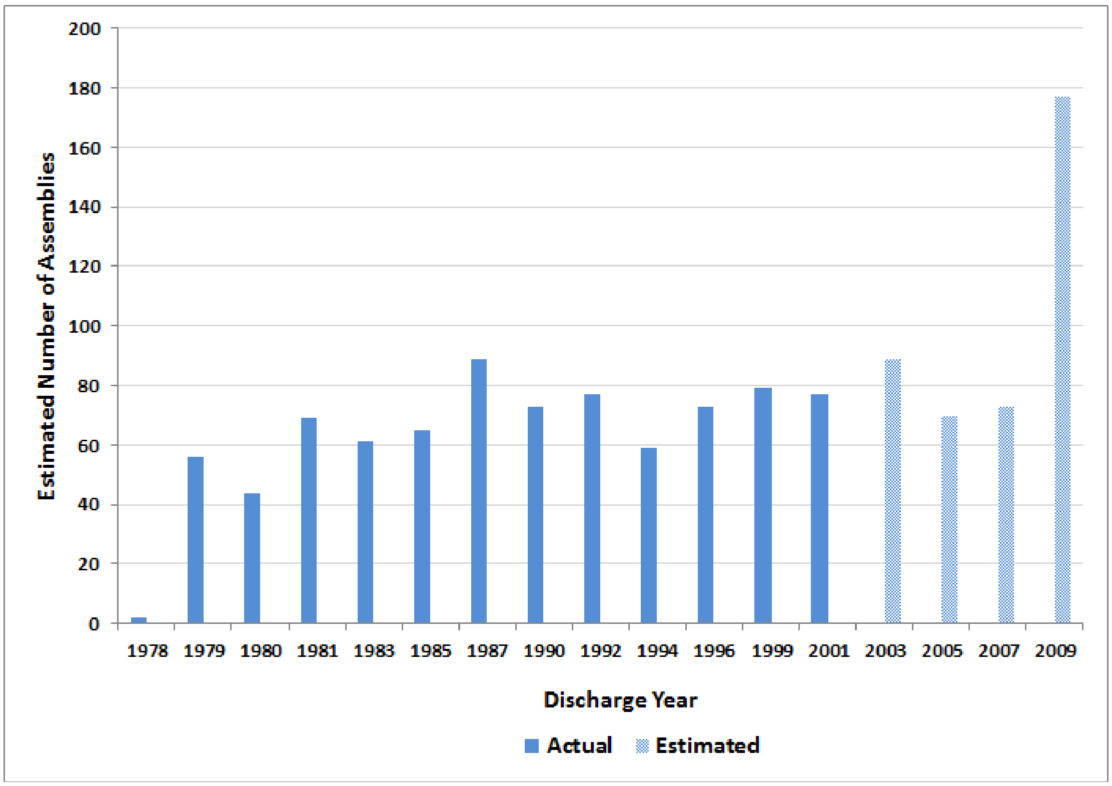

Figure 2-126. Crystal River Estimated Number of Assemblies versus Discharge Year

[17] Nesbit S. 2013. Email messages from S Nesbit (Duke Energy Corporation) to SJ Maheras (Pacific Northwest National Laboratory), "Fw: Request for Review of DOE Document," September 24-26, 2013.

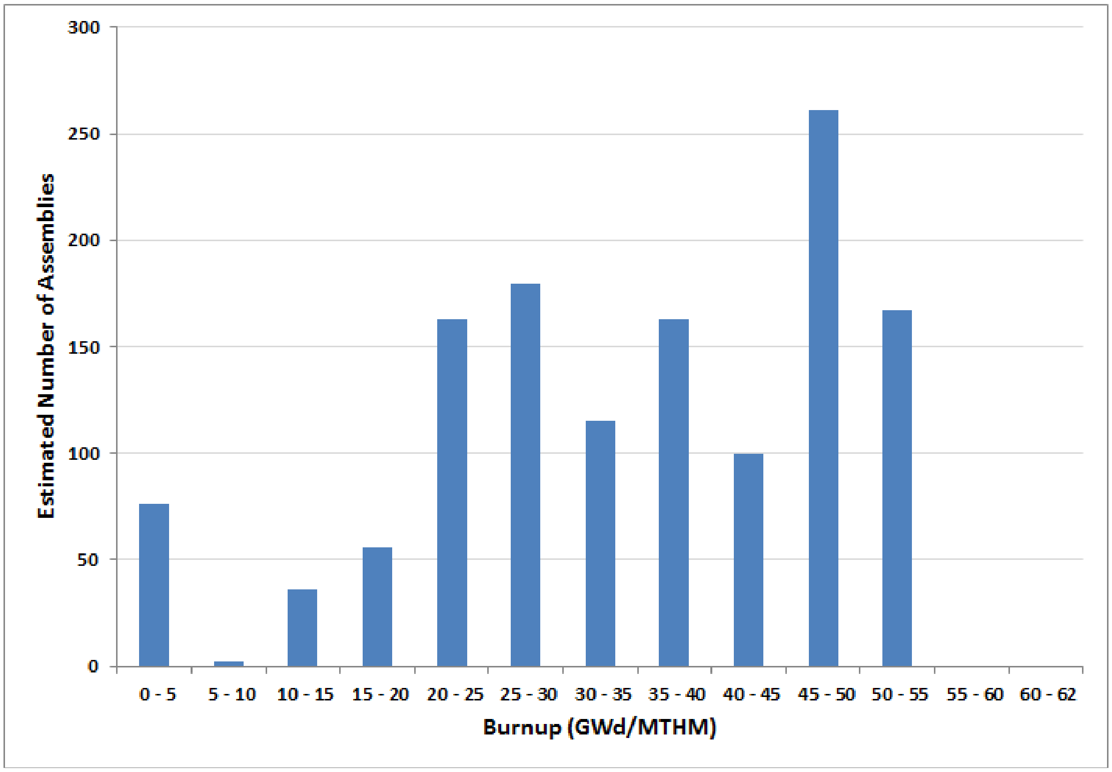

Figure 2-127. Crystal River Estimated Number of Assemblies versus Burnup

2.10.2 Site Conditions

The Crystal River Unit 3 Nuclear Generating Plant (CR-3) (see Figure 2-128) is part of the larger Crystal River Energy Complex (CREC), which includes the single nuclear unit and four fossil-fueled units, Crystal River Units 1, 2, 4, and 5 (CR-1, CR-2, CR-4, and CR-5). Figure 2-129 provides an aerial view of the Crystal River Energy Complex showing the location of the CR-1 through CR-5, the on-site rail system, potential barge area, and intake and discharge canals. Figure 2-130 shows a potential location of the future ISFSI at the Crystal River site discussed in Section 2.10.1. With the closure of Crystal River Unit 3, both the potential location and need for the ISFSI are being reevaluated.

Crystal River has an extensive on-site rail system used for coal shipments to the 4 fossil-fueled units with service provided by the CSXT Railroad (TOPO 1994c, TriVis Incorporated 2005). However, the rails do not extend to the cask receiving area of the Crystal River reactor. There is sufficient track outside of the Crystal River protected area to assemble or store more than 20 railcars, but storage cannot interfere with coal shipments.

Intake and discharge canals at the Crystal River site withdraw water from and discharge water to the Gulf of Mexico (see Figure 2-131). The Crystal River site has on-site barge access through the intake canal but loading a transportation cask onto a barge would require a crane to boom out over 30 feet to avoid a coal conveyer. The intake canal, which extends into the Gulf of Mexico, is 14 miles long. It has a minimum depth of 20 feet to accommodate barge traffic used to deliver coal for the fossil fuel units. Southern and northern dikes parallel the intake canal for about

3.4 miles offshore. The southern dike terminates at this point, while the northern dike extends an additional 5.3 miles into the Gulf of Mexico. The dikes are about 50 to 100 feet wide on top and are elevated about 10 feet above the water surface at mean low tide. Starting at the east end, the intake canal is 150 feet wide for 2.8 miles; 225 feet wide for the next 6.3 miles; and 300 feet wide for the last 4.9 miles. Dredging occurs in the intake canal every 5 to 7 years (NRC 2011).

Photo courtesy of Progress Energy

Figure 2-128. Crystal River Unit 3 Nuclear Generating Plant

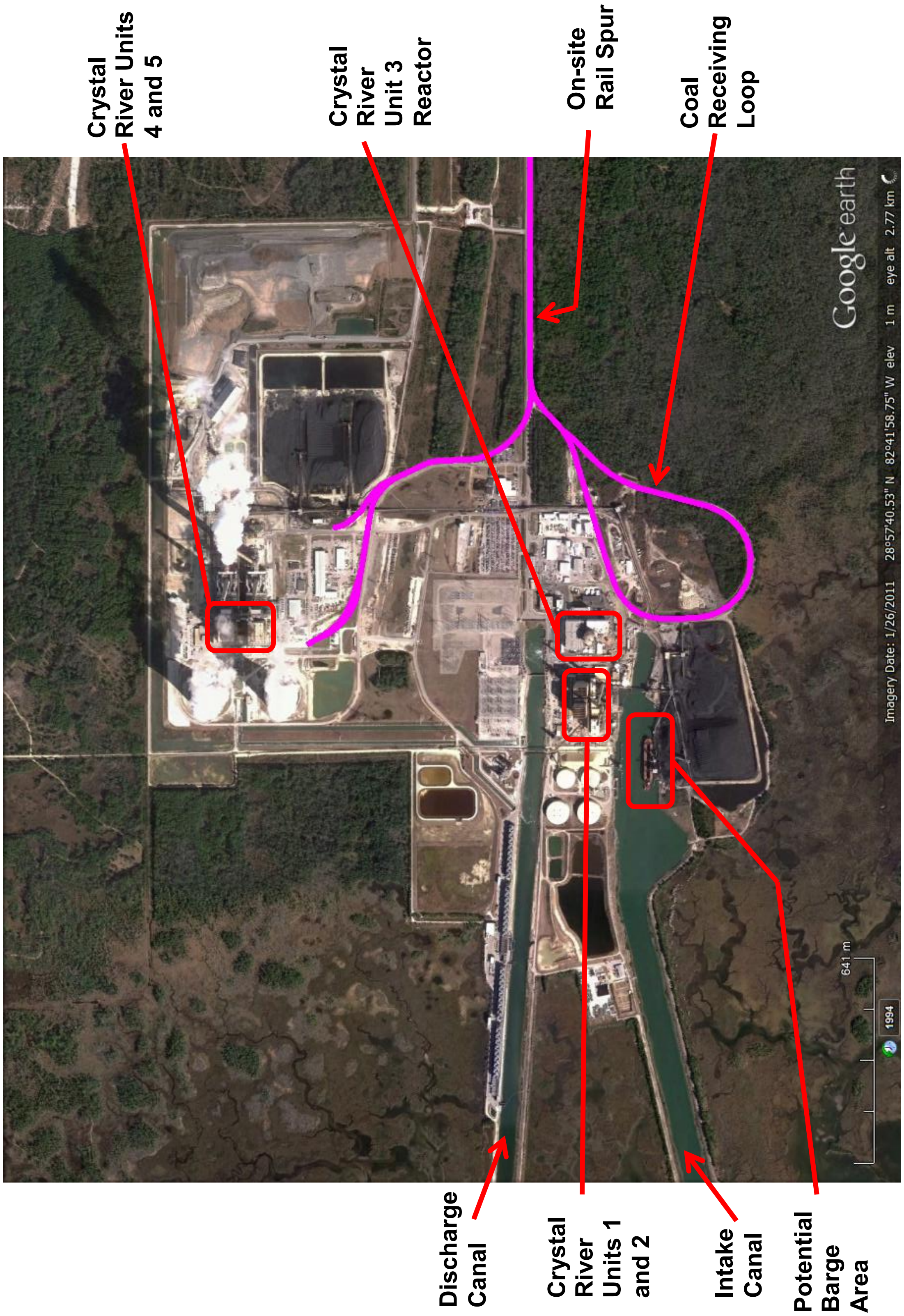

Figure 2-129. Aerial View of the Crystal River Energy Complex (Google 2013)

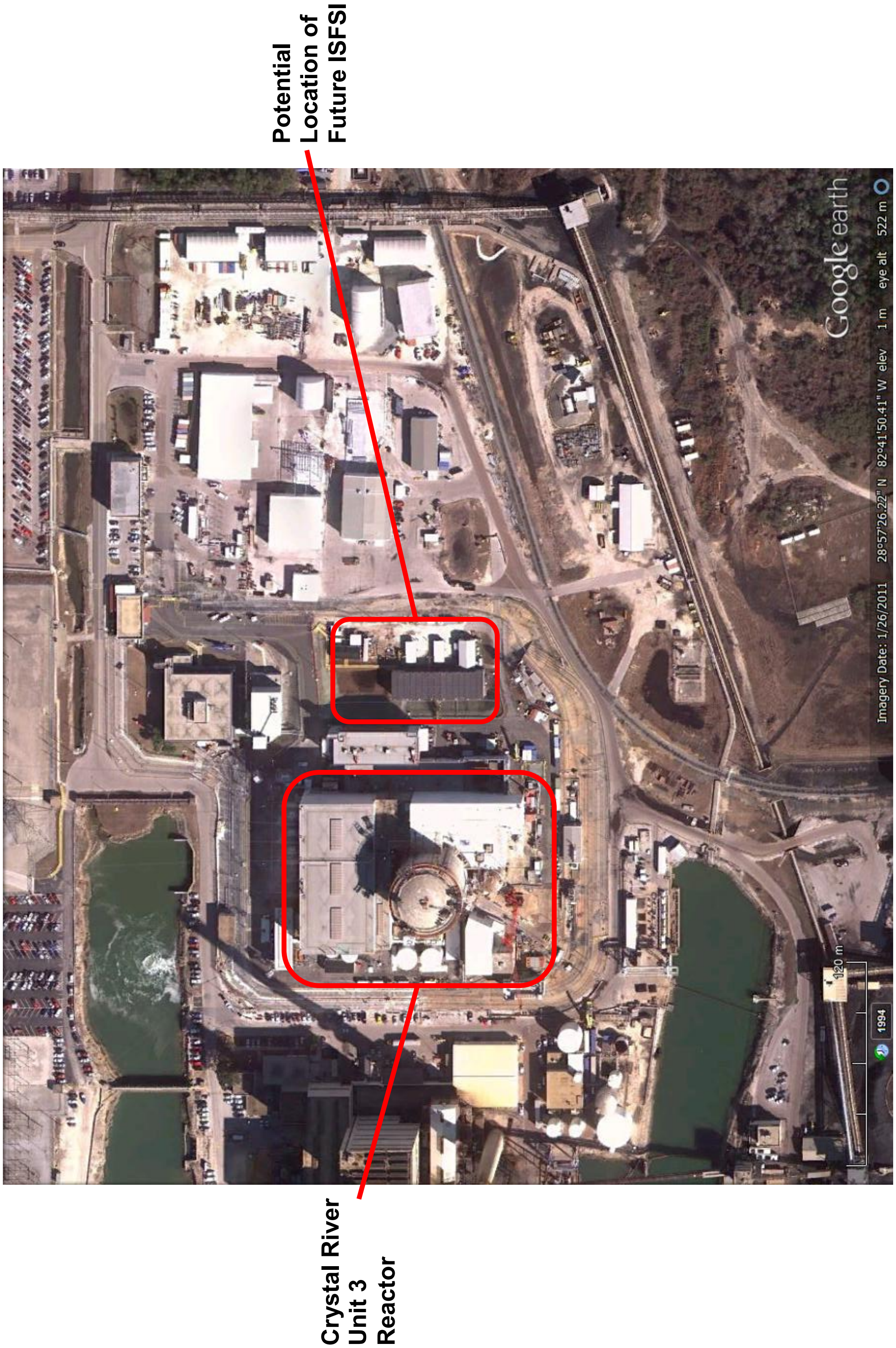

Figure 2-130. Location of Future Crystal River ISFSI (Google 2013)

Figure 2-131. Aerial View of the Crystal River Intake and Discharge Canals (Google 2013)

2.10.3 Near-site Transportation Infrastructure and Experience

At the Crystal River site, an on-site rail spur provides direct rail access to the CSXT Railroad at Red Level Junction (see Figure 2-132). The on-site rail spur connects with the mainline 3.8 miles east of the Crystal River site (TOPO 1994c). The track south of Red Level Junction has been abandoned. The rail spur and mainline are designated as track class 1. As discussed in Section 2.10.2, Crystal River also has barge access to the Gulf of Mexico through the intake canal at the site.

2.10.4 Gaps in Information

At the Crystal River site, an on-site rail spur provides direct access to the CSXT Railroad and consequently, barge or heavy haul truck transport of used nuclear fuel and GTCC low-level radioactive waste would be unlikely from the Crystal River site.

Revision 5 of the certificate of compliance for the MP197HB transportation cask does not allow the transport of used nuclear fuel contained in 32PTH1 canisters. Also, there are 428 used nuclear fuel assemblies at Crystal River that have burnups greater than 45 GWd/MTHM. Revision 5 of the certificate of compliance for the MP197HB transportation cask does not authorize transport of this high burnup fuel. Consequently, the certificate of compliance for the MP197HB would have to be revised before used nuclear fuel could be transported from the Crystal River site.

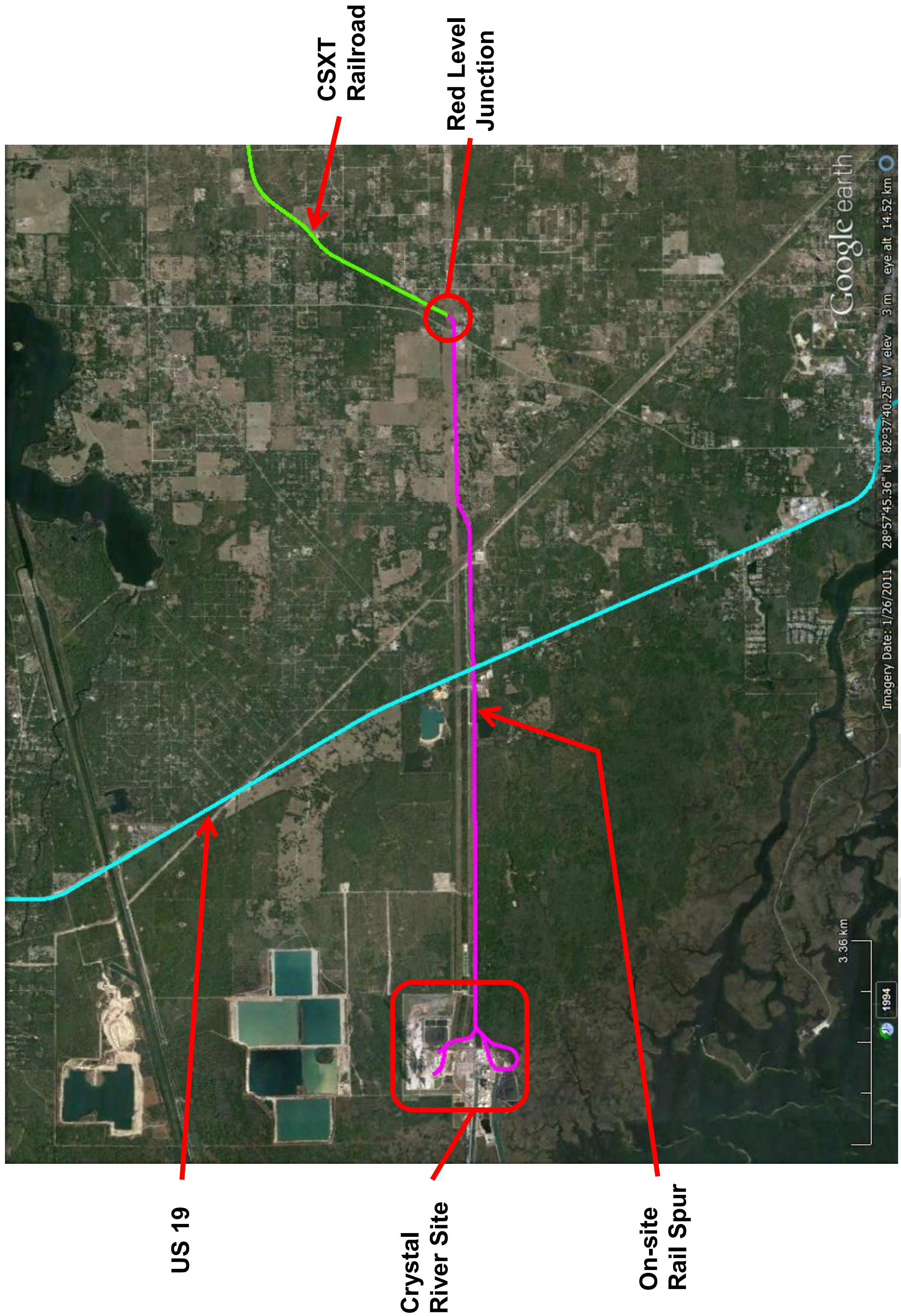

Figure 2-132. Aerial View of the Crystal River Rail Spur and CSXT Railroad (Google 2013)

2.11 Kewaunee

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the Kewaunee site. The Kewaunee site is located on the western shore of Lake Michigan between the towns of Manitowoc and Kewaunee about 30 miles southeast of Green Bay and 98 miles north of Milwaukee, Wisconsin (TOPO 1994d).

2.11.1 Site Inventory

Kewaunee has been shut down since May 7, 2013 and final removal of used nuclear fuel from the reactor vessel was completed on May 14, 2013 (Stoddard 2013a, 2013b). There are 1079 pressurized water reactor used nuclear fuel assemblies stored in the spent fuel pool (Stoddard 2013c). The fuel rods in the fuel assemblies are Zircaloy- or ZIRLO-clad. Kewaunee uses the Standardized NUHOMS System (Docket No. 72-1004) for dry storage of used nuclear fuel. This system consists of transportable dry shielded canisters, reinforced concrete horizontal storage modules, and a transfer cask. The specific dry shielded canister that has been used at Kewaunee is the 32PT, which holds 32 pressurized water reactor used nuclear fuel assemblies. There are 256 pressurized water reactor used nuclear fuel assemblies in 8 dry shielded canisters in dry storage at Kewaunee (Stoddard 2013c). A total of 1335 used nuclear fuel assemblies are stored at Kewaunee (Stoddard 2013c). Stoddard (2013c) estimated that these used fuel assemblies would be stored in 45 canisters. In addition to the 8 32PT canisters already in dry storage, 6 32PT canisters would be loaded in 2014, 18 32PT canisters would be loaded in 2017, and 13 24PT canisters would be loaded in 2019. Stoddard (2013d) states that GTCC low-level radioactive waste would not be packaged until 2070.

Revision 5 of the certificate of compliance for the MP197HB transportation cask (Docket No. 71-9302) currently allows transport of low burnup used nuclear fuel (< 45 GWd/MTHM) in the 69BTH, 61BTH, 61BT, and 24PT4 dry shielded canisters, and radioactive waste. However, Revision 5 of the certificate of compliance for the MP197HB transportation cask does not authorize transport of used nuclear fuel in the 32PT dry shielded canister. Therefore, the used nuclear fuel at Kewaunee contained in 32PT dry shielded canisters currently would not be transportable based on Revision 5 of the certificate of compliance for the MP197HB transportation cask.

Used nuclear fuel was first discharged from Kewaunee in 1976. The RW-859 database (EIA 2002) contains used nuclear fuel discharge data up through December 31, 2002. To estimate used nuclear fuel discharges and assembly burnups from January 1, 2003 through May 7, 2013, the TSL-CALVIN computer code (Nutt et al. 2012) was used.

Figure 2-133 illustrates the estimated number of used nuclear fuel assemblies at Kewaunee, based on their discharge year. The oldest fuel was discharged in 1976 and the last fuel was discharged in 2013. The estimated median discharge year of the fuel is 1994.

Figure 2-134 illustrates the estimated number of used nuclear fuel assemblies at Kewaunee based on their burnup. The lowest burnup is 14.5 GWd/MTHM and the highest burnup is 59.8 GWd/MTHM. The estimated median burnup is 36.8 GWd/MTHM. It is estimated that there would be 303 used nuclear fuel assemblies at Kewaunee that would have burnups greater than 45 GWd/MTHM. These 303 fuel assemblies would be classified by the NRC as high burnup used nuclear fuel.

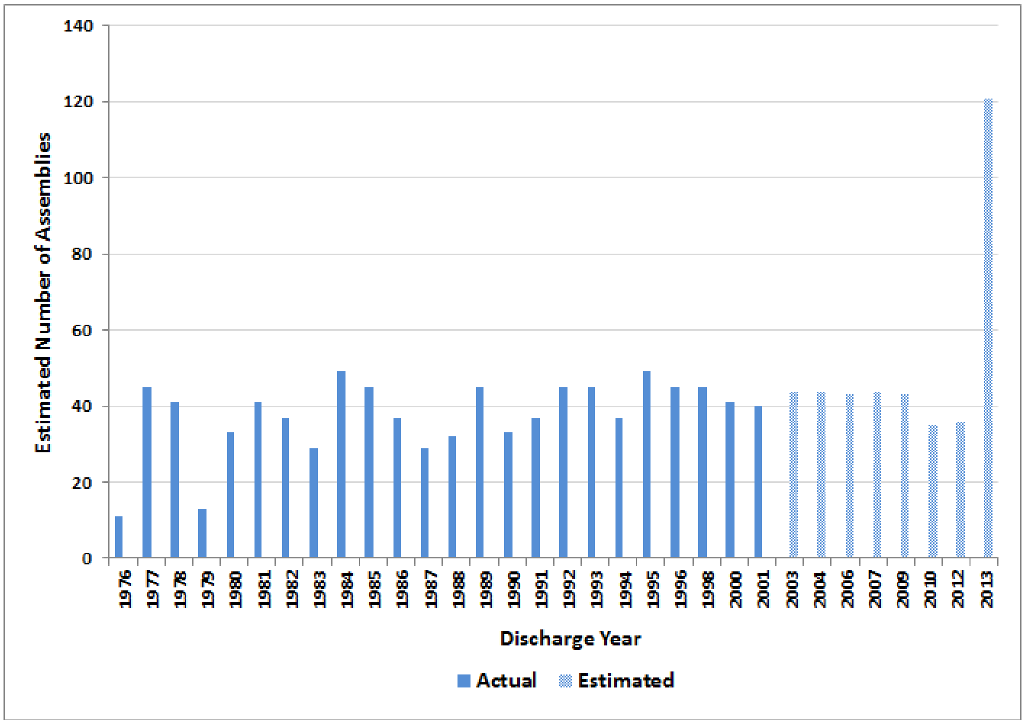

Figure 2-133. Kewaunee Estimated Number of Assemblies versus Discharge Year

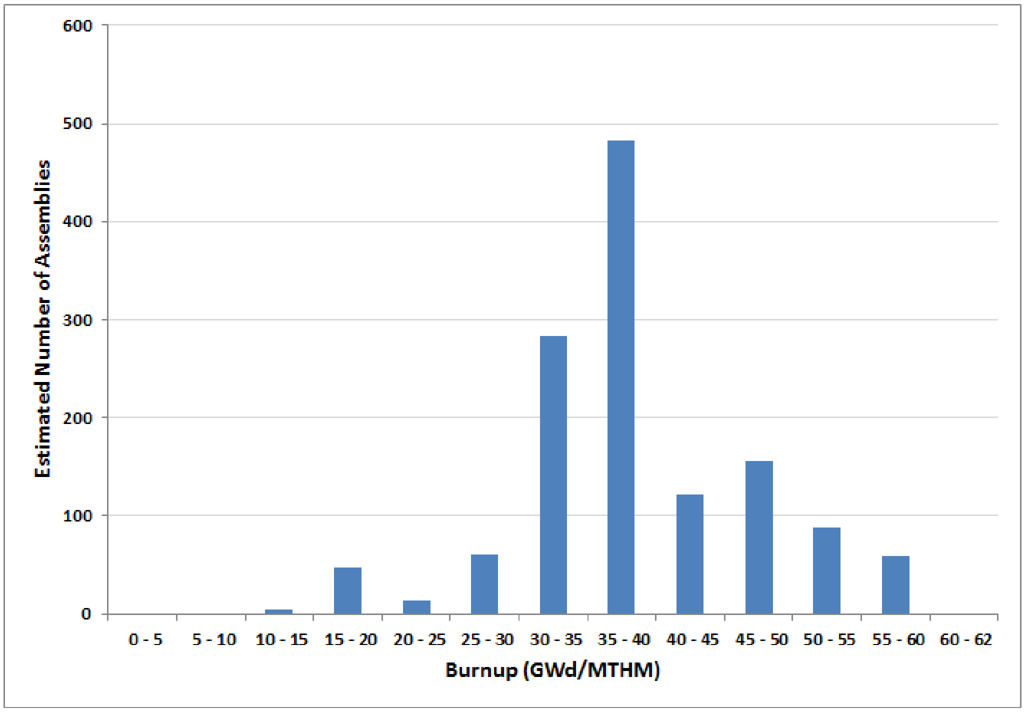

Figure 2-134. Kewaunee Estimated Number of Assemblies versus Burnup

2.11.2 Site Conditions

The Kewaunee site is located on the western shore of Lake Michigan (see Figures 2-135 and 2-136). Figure 2-136 provides an aerial view of the Kewaunee site. The Kewaunee ISFSI is located at the northern end of the site (see Figure 2-136). There is no direct rail or barge service to the site (TOPO 1994d). The nearest rail access is in Denmark, Wisconsin, about 16 miles from the site, and the nearest barge terminal is in Kewaunee, Wisconsin, about 10 miles from the site. There was an on-site barge facility during plant construction, but it was disassembled, and reestablishment would require a major restoration (TriVis Incorporated 2005).

Photo courtesy of Dominion Energy

Figure 2-135. Kewaunee Power Station

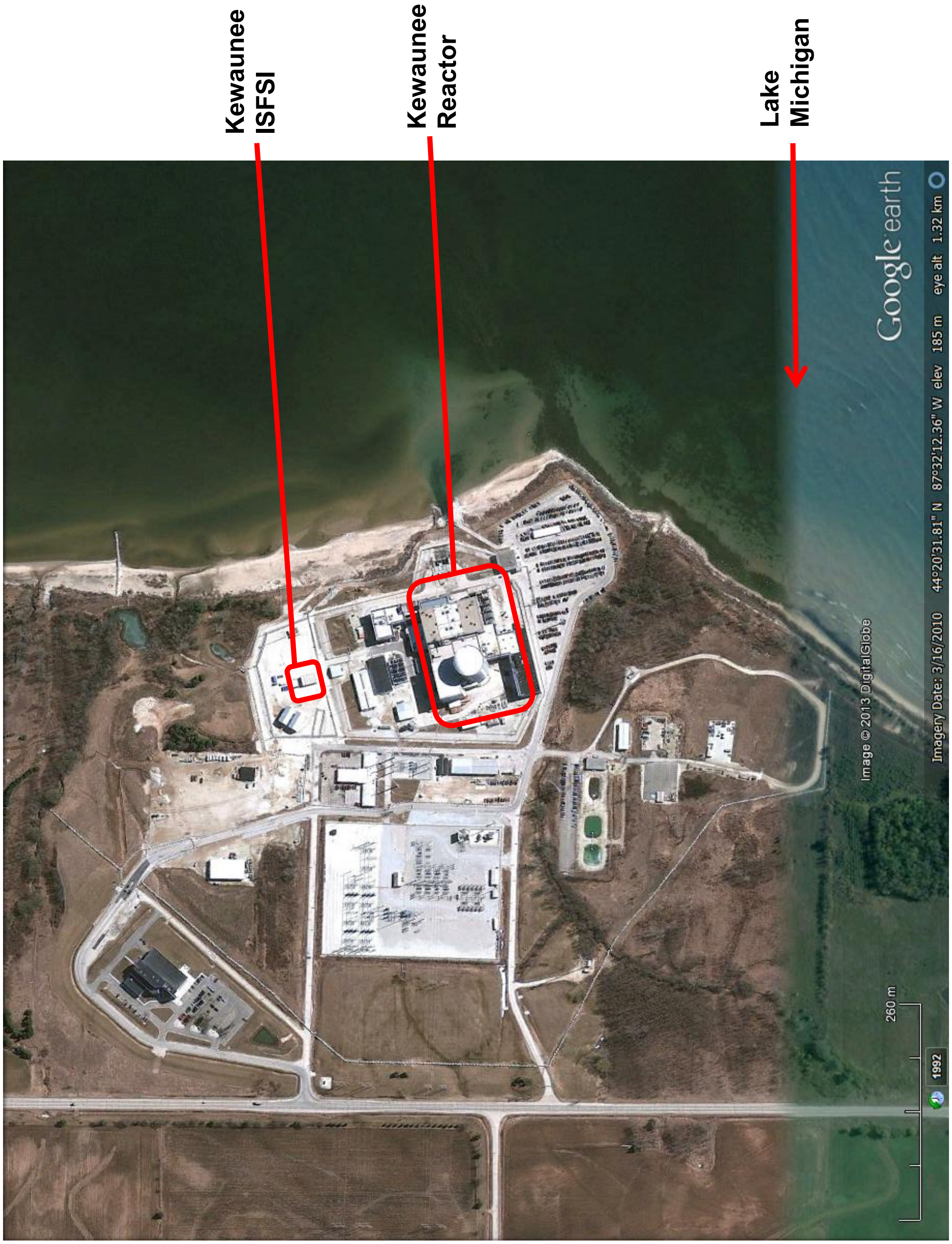

Figure 2-136. Aerial View of Kewaunee Site (Google 2013)

2.11.3 Near-site Transportation Infrastructure and Experience

The Kewaunee site does not have an on-site rail spur or a railroad that passes near to the site or along the site boundary. For Kewaunee, heavy haul trucks could be used to move transportation casks over public highways to a railhead or rail spur that provides access to a railroad that meets Federal Railroad Administration's regulatory standards and can accommodate the loaded transportation casks.

For shipments of casks containing used nuclear fuel that require the use of heavy haul trucks, the casks would be prepared for shipment at the Kewaunee ISFSI site and loaded onto a transport cradle that would be loaded onto the transport trailer of a heavy haul truck. The truck, led and followed by technical and security escorts, would move over an approved, designated highway route to a nearby rail siding or railhead. Heavy lift equipment would be used to transfer the cask and its cradle as a unit from the truck to a railcar at the rail siding or railhead.

Table 2-5 lists distances to the nearest railheads to the Kewaunee site at Luxemburg, Denmark, Bellevue, Rockwood, and Manitowoc, Wisconsin (see Figure 2-137). The rail lines in the vicinity of Luxemburg, Denmark, and Bellevue are designated as track class 1. These rail lines connect to the Fox River Subdivision of the Canadian National which is designated as track class 2. The rail line in the vicinity of Rockwood is designated as track class 1. After merging with the mainline at Manitowoc, the rail line is designated as track class 2. Figure 2-137 also shows the location of the Point Beach Nuclear Plant, which is about 4.5 miles south of the Kewaunee site.

Table 2-5 also provides potential routes that heavy haul trucks might use to get to the railheads. These routes have not been evaluated for attributes such as weight limitations, bridge and tunnel limitations, turning radii, vertical or horizontal clearances, seasonal restrictions, presence of culverts, etc.

Table 2-5. Potential Kewaunee Railheads

Railhead	Distance From Kewaunee Site(mile)	Potential Route
Luxemburg	23.4	WI-42 North to WI-29 West to County Road AB North
Denmark	16.0	WI-42 South to County Road BB West to County Road R North
Denmark	26.4	WI-42 South to Nuclear Road West to County Road B South to WI-147 North to I-43 North to County Road KB East
Bellevue	27.6	WI-42 North to WI-29 West
Rockwood	19.5	WI-42 South to WI-310 West
Manitowoc	21.5	WI-42 South

The closest barge terminal to the Kewaunee site is located in the city of Kewaunee, about 10 miles from the Kewaunee site. Figure 2-138 shows an aerial view of the Kewaunee dock facilities. Figure 2-139 shows a route that a heavy haul truck might use to get from the Kewaunee site to the dock facilities. As with the routes to the railheads, this route has not been evaluated for attributes such as weight limitations, bridge or tunnel limitations, turning radii, vertical or horizontal clearances, seasonal restrictions, presence of culverts, etc.

Heavy haul truck and barge transport has been used to move large components to and from the Kewaunee site. For example, in 2001, heavy haul truck transport was used to move two steam generators from the Kewaunee site to the city of Kewaunee dock facilities where they were shipped to Memphis, Tennessee for decontamination. The replacement steam generators were shipped to the city of Kewaunee dock facilities by ship and also moved to the Kewaunee site using heavy haul truck transport. In addition, the Kewaunee reactor vessel head was transported to Clive, Utah for disposal using a heavy haul truck.

2.11.4 Gaps in Information

The Kewaunee site does not have direct rail access or an on-site barge facility. Off-site transportation of transportation casks from the Kewaunee site would require either the use of heavy haul trucks for transport to nearby railheads or the use of heavy haul trucks for transport to a nearby barge facility, likely followed by barge transport to a port on the Great Lakes that is served by a railroad. Potential nearby railheads include Luxemburg, Denmark, Bellevue, Rockwood, and Manitowoc, Wisconsin; these railheads are 16 to 28 miles from the Kewaunee site. The city of Kewaunee dock facilities are located 10 miles from the Kewaunee site. However, the roads to these locations have not been evaluated for attributes such as weight limitations, bridge or tunnel limitations, turning radii, vertical or horizontal clearances, seasonal restrictions, presence of culverts, etc.

Revision 5 of the certificate of compliance for the MP197HB transportation cask does not allow the transport of used nuclear fuel contained in 32PT canisters. Also, it is estimated that there would be 303 used nuclear fuel assemblies at Kewaunee that would have burnups greater than 45 GWd/MTHM. Revision 5 of the certificate of compliance for the MP197HB transportation cask does not authorize transport of this high burnup fuel. Consequently, the certificate of compliance for the MP197HB would have to be revised before used nuclear fuel could be transported from the Kewaunee site.

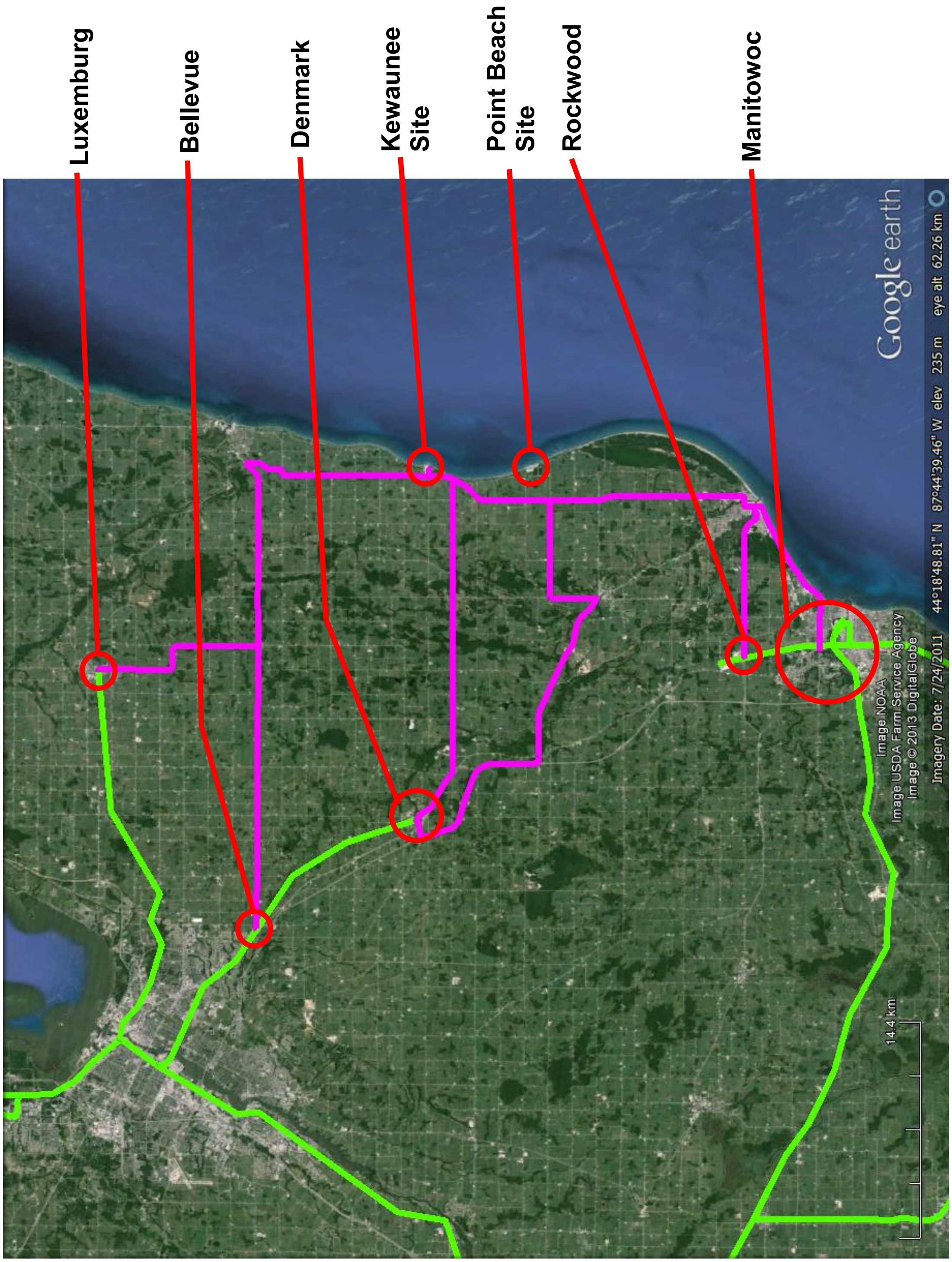

Figure 2-137. Railheads and Potential Heavy Haul Truck Routes for the Kewaunee Site (Google 2013)

Figure 2-138. Aerial View of the City of Kewaunee Dock Facilities (Google 2013)

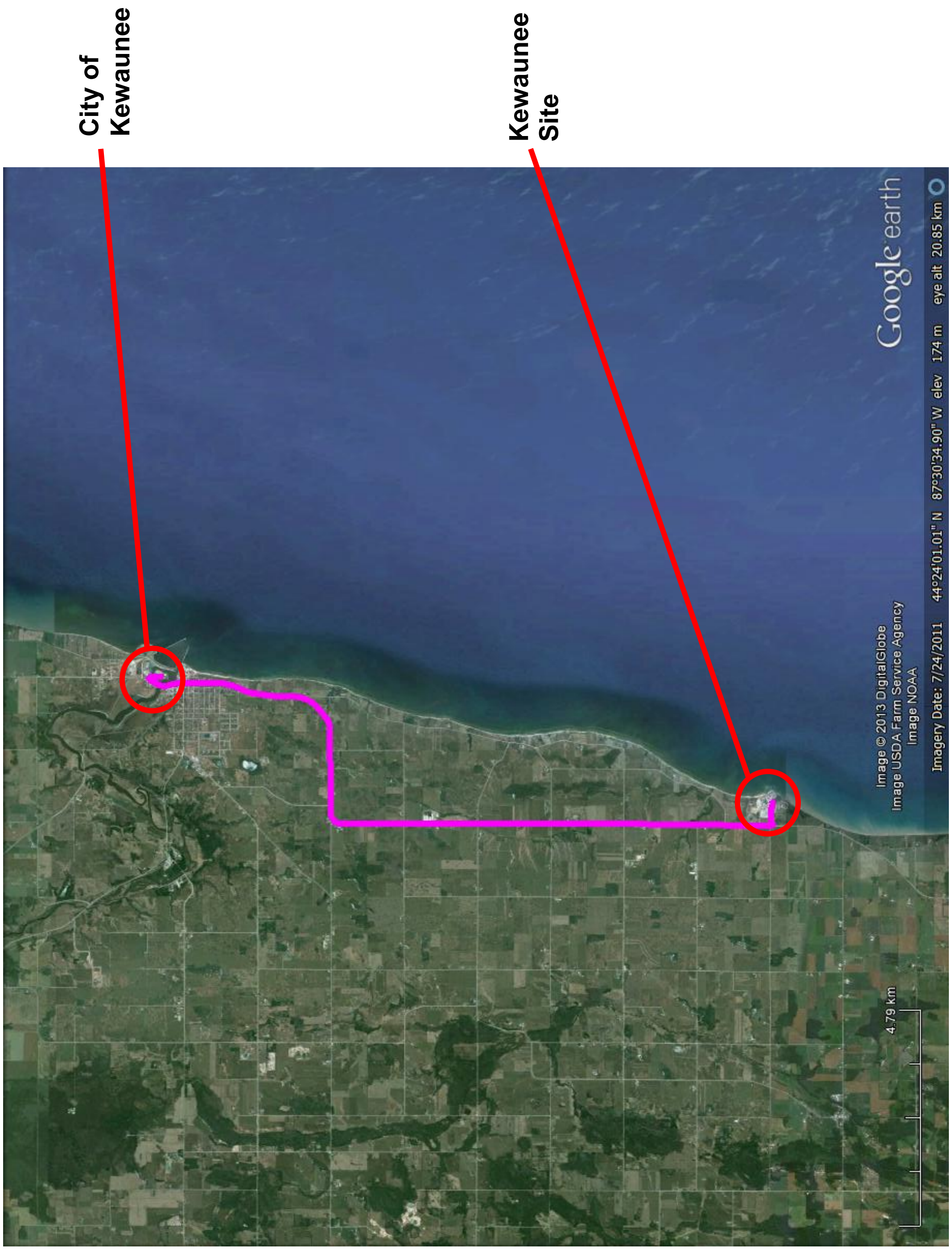

Figure 2-139. Potential Heavy Haul Route to City Of Kewaunee Dock Facilities (Google 2013)

2.12 San Onofre

This section describes the inventory of used nuclear fuel and GTCC low-level radioactive waste, site conditions, near-site transportation infrastructure and experience, and gaps in information for the San Onofre site. The San Onofre site is located on California's Pacific coast, about 70 miles southeast of Los Angeles and about 60 miles northwest of San Diego (TOPO 1993f, Google 2013).

2.12.1 Site Inventory

San Onofre Unit 1 (San Onofre-1) ceased operation in 1992 and San Onofre Units 2 and 3 (San Onofre-2 and -3) ceased operation on June 7, 2013 (Dietrich 2013a), although the reactors did not operate after January 2012. The final removal of used nuclear fuel from the San Onofre-2 reactor vessel was completed on July 18, 2013 (Dietrich 2013b). Final removal of used nuclear fuel from the San Onofre-3 reactor vessel was completed on October 5, 2012 (Dietrich 2013c).

San Onofre uses the Standardized Advanced NUHOMS System (Docket No. 72-1029) for dry storage of used nuclear fuel. This system consists of transportable dry shielded canisters, reinforced concrete horizontal storage modules, and a transfer cask. The specific dry shielded canisters that have been used at San Onofre are the 24PT1 and 24PT4, which each hold 24 pressurized water reactor used nuclear fuel assemblies. San Onofre has also notified the NRC that it intends to use the 32PTH2 canister in 2014 (St. Onge 2012), which would hold 32 pressurized water reactor used nuclear fuel assemblies. The 32PTH2 canister is not licensed for use in storage or transportation.

There are 395 pressurized water reactor used nuclear fuel assemblies in 17 24PT1 dry shielded canisters from San Onofre-1 in dry storage at the San Onofre site (Ux Consulting 2013a). There is also one 24PT1 dry shielded canister containing GTCC low-level radioactive waste from San Onofre-1 stored at the San Onofre site.

The MP187 transportation cask (Docket No. 71-9255) is licensed to ship used nuclear fuel in the 24PT1 canister. However, the MP187 transportation cask is not licensed for the transport of GTCC low-level radioactive waste. As discussed in Section 2.6.1, a single MP187 transportation cask is stored at the Rancho Seco site, but impact limiters would need to be fabricated before the MP187 could be used to ship used nuclear fuel or GTCC low-level radioactive waste. A -96 designation must be obtained before impact limiters are fabricated for the existing MP187 transportation cask. A -96 designation must also be obtained before the MP187 transportation cask is licensed for the transport of GTCC low-level radioactive waste. The effort to accomplish these changes and to obtain NRC review and approval is estimated to range from one to three years.

There are also 792 pressurized water reactor used nuclear fuel assemblies in 33 24PT4 dry shielded canisters from San Onofre-2 and -3 stored at the San Onofre site (Ux Consulting 2013a). The MP197HB transportation cask (Docket No. 71-9302) is licensed to ship used nuclear fuel in the 24PT4 canister. The MP197HB is also licensed to ship radioactive waste.

There are 395 used nuclear fuel assemblies (146.2 MTHM) from San Onofre-1 stored at the San Onofre site. The fuel rods in these fuel assemblies are stainless steel-clad. There are also an additional 270 stainless steel-clad used nuclear fuel assemblies from San Onofre-1 that are stored in Morris, Illinois. Figure 2-140 illustrates the number of used nuclear fuel assemblies from San Onofre-1 stored at the San Onofre site, based on their discharge year. The oldest fuel was discharged in 1971 and the last fuel was discharged in 1992. The median discharge year of the fuel is 1988.

Figure 2-141 illustrates the number of used nuclear fuel assemblies from San Onofre-1 stored at the San Onofre site based on their burnup. The lowest burnup is 6.8 GWd/MTHM and the highest burnup is 39.3 GWd/MTHM. The median burnup is 30.0 GWd/MTHM. No high burnup used nuclear fuel (burnup greater than 45 GWd/MTHM) from San Onofre-1 is stored at the San Onofre site.

There are a total of 3460 used nuclear fuel assemblies (1463 MTHM) from San Onofre-2 and -3 stored at the San Onofre site.[18] This total includes the 792 assemblies in dry storage and 2668 assemblies stored in the spent fuel pools at the San Onofre site. This total does not include 108 fuel assemblies that were inserted into the San Onofre-2 reactor but that were not made critical. The San Onofre site is making arrangements to decontaminate these fuel assemblies and return them to the fuel fabricator for uranium recovery. The fuel rods in these fuel assemblies are Zircaloy- or ZIRLO-clad. A total of 120 dry shielded canisters (45 24PT4 canisters and 75 32PTH2 canisters) would be required to store the 3460 used nuclear fuel assemblies.

Figure 2-142 illustrates the number of used nuclear fuel assemblies from San Onofre-2 and -3, based on their discharge year. The oldest fuel was discharged in 1984 and the last fuel was discharged in 2012. The median discharge year of the fuel is 1999.

Figure 2-143 illustrates the number of used nuclear fuel assemblies from San Onofre-2 and -3 based on their burnup. The lowest burnup is in the range of 5 to 10 GWd/MTHM and the highest burnup is in the range of 55 to 60 GWd/MTHM. The median burnup is in the range of 40 to 45 GWd/MTHM. There are 1123 used nuclear fuel assemblies from San Onofre-2 and -3 that have burnups greater than 45 GWd/MTHM. These 1123 fuel assemblies are classified by the NRC as high burnup used nuclear fuel.

[18] Granaas R. 2013. Email messages from R Granaas (San Onofre Nuclear Generating Station) to SJ Maheras (Pacific Northwest National Laboratory), "RE: san onofre sections of draft shutdown sites report," September 11-24, 2013.

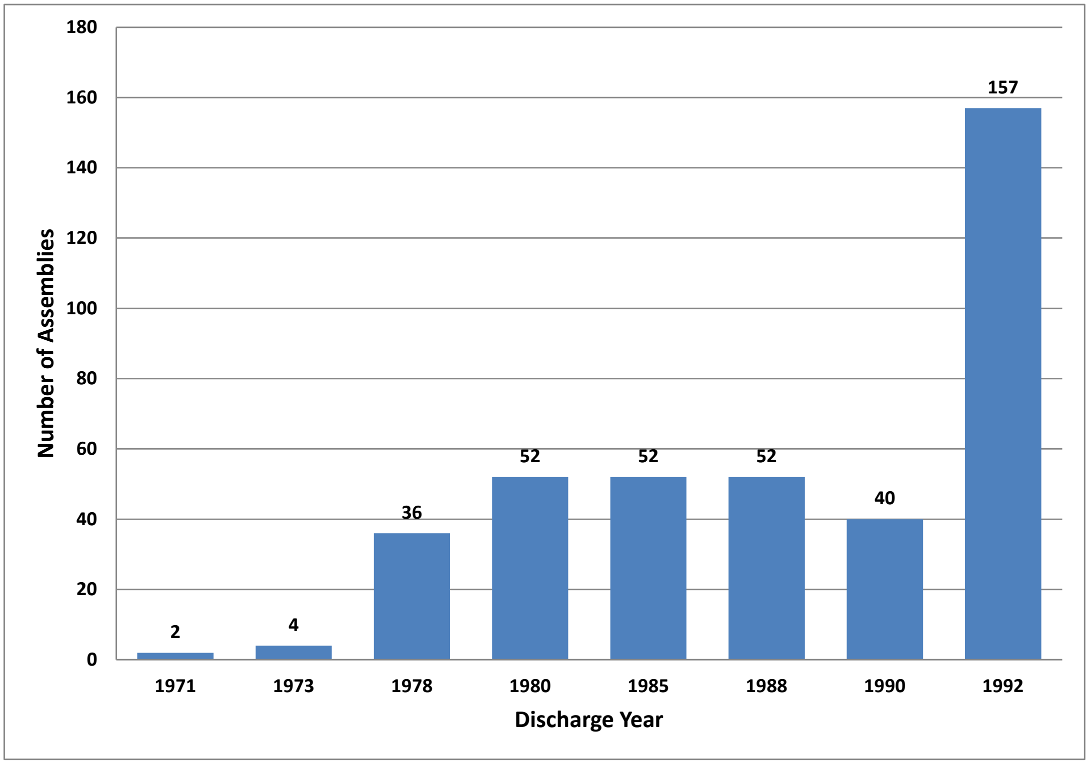

Figure 2-140. San Onofre-1 Number of Assemblies versus Discharge Year (EIA 2002)

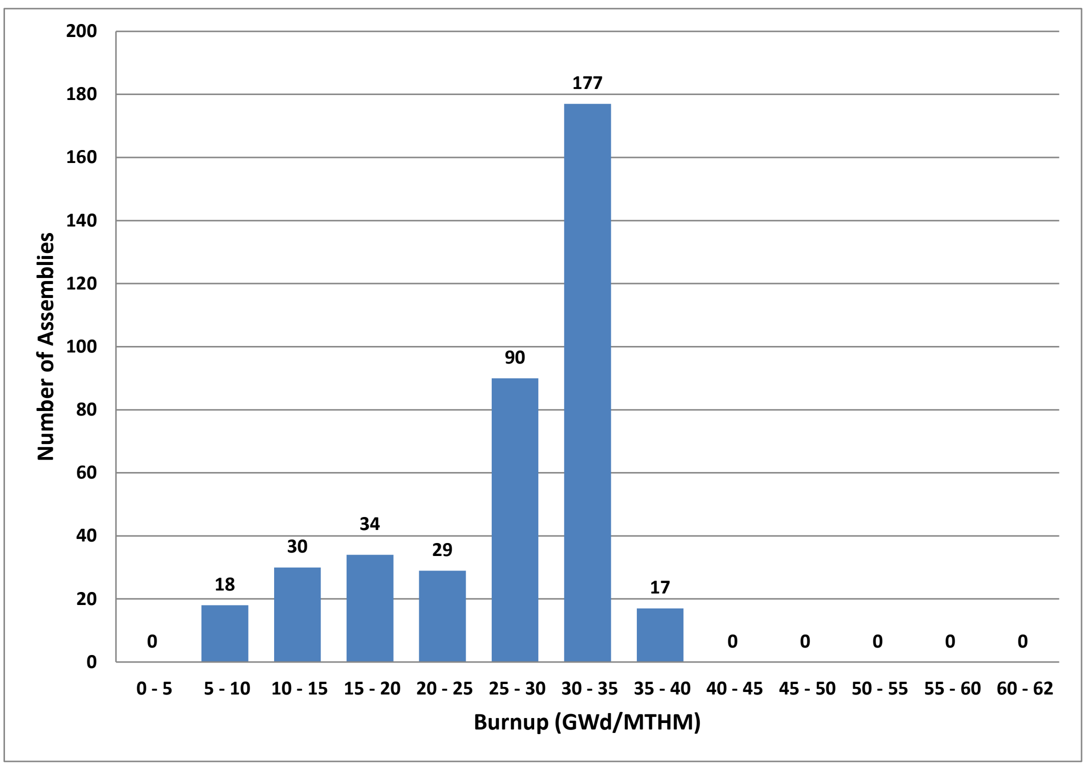

Figure 2-141. San Onofre-1 Number of Assemblies versus Burnup (EIA 2002)

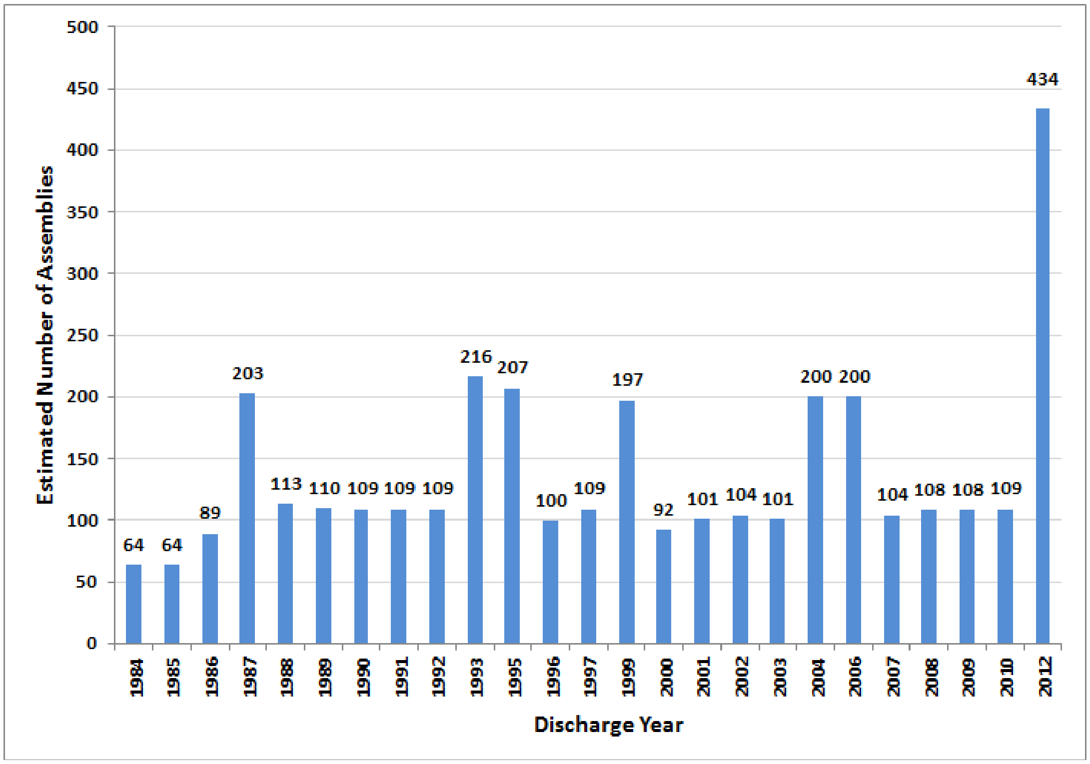

Figure 2-142. San Onofre-2 and -3 Number of Assemblies versus Discharge Year

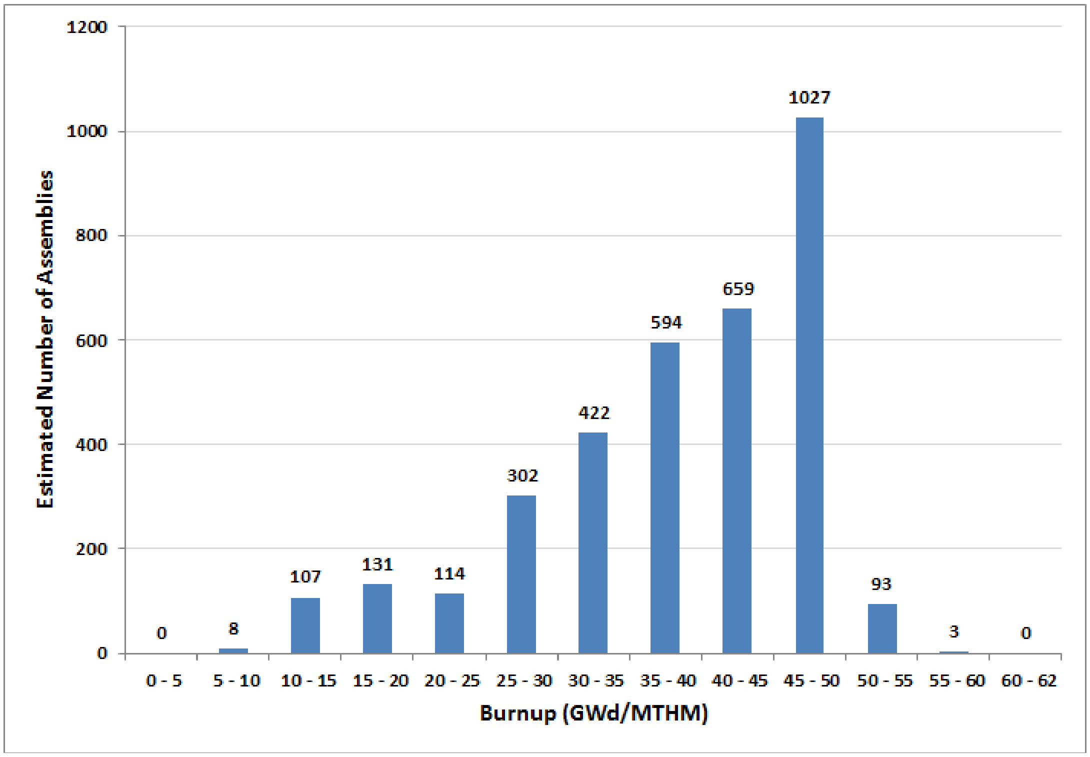

Figure 2-143. San Onofre-2 and -3 Number of Assemblies versus Burnup

2.12.2 Site Conditions

The San Onofre site is located on the Pacific coast in southern California (see Figures 2-144 and 2-145). Figure 2-145 provides an aerial view of the San Onofre site. The San Onofre ISFSI is located at the northwestern end of the site (see Figure 2-145).

The San Onofre site is served by the BNSF Railroad and has an on-site rail spur (TOPO 1993f, TriVis Incorporated 2005). The rail spur is about 0.8 mile long and was originally built in the 1960s to support construction of San Onofre-1 and was subsequently used to support construction of San Onofre-2 and -3 in the 1970s (Gilson 2005, Gilson and Blythe 2005). The rail spur connects with the BNSF mainline about 0.6 mile northwest of the site. The rail spur is designated as track class 1 and the BNSF mainline is designated as track class 4. The rail spur was reactivated in 2000 to support the decommissioning of San Onofre-1 (Gilson 2005, Gilson and Blythe 2005).

The San Onofre site has no on-site barge facilities (TOPO 1993f, TriVis Incorporated 2005). A temporary barge facility would have to be located on a section of public beach immediately west of the site and it is considered unlikely that the state would issue the required permits to allow construction of a temporary barge facility (TOPO 1993f). Consequently, it considered to be impractical to establish an on-site barge facility (TriVis Incorporated 2005).

Photo courtesy of Southern California Edison

Figure 2-144. San Onofre Nuclear Generating Station

Figure 2-145. Aerial View of San Onofre Nuclear Generating Station (Google 2013)

2.12.3 Near-Site Transportation Infrastructure and Experience

As discussed in Section 2.12.2, the San Onofre site has direct rail access to the BNSF Railroad through an on-site rail spur and the rail spur has been used to ship several large turbine shells, turbine rotors, three steam generators, and a pressurizer (Gilson 2005, Gilson and Blythe 2005).

In addition to rail shipments of large components, heavy haul truck transport was used to ship four steam generators from San Onofre to Clive, Utah for disposal. Truck shipments of 270 used nuclear fuel assemblies were also made from San Onofre-1 to Morris, Illinois from 1972 through 1980 (NAC 1986).

2.12.4 Gaps in Information

At the San Onofre site, an on-site rail spur provides direct access to the BNSF Railroad and consequently, barge or heavy haul truck transport of used nuclear fuel and GTCC low-level radioactive waste would be unlikely from the San Onofre site.

There are 1123 used nuclear fuel assemblies at San Onofre-2 and -3 that have burnups greater than 45 GWd/MTHM. Revision 5 of the certificate of compliance for the MP197HB transportation cask does not authorize transport of this high burnup fuel and the certificate of compliance for the MP197HB would have to be revised before this used nuclear fuel could be transported from the San Onofre site.

3. OVERVIEW OF REQUIREMENTS FOR OFF-SITE TRANSPORTATION INFRASTRUCTURE

Off-site transportation of rail/intermodal casks containing used nuclear fuel will require that the off-site rail network, roads, or navigable waters (herein referred to as transportation infrastructure) in the vicinity of each of the shutdown sites be capable of accommodating the size and weight of the rail/intermodal casks containing used nuclear fuel and of the transport vehicles that will be used to move the casks. It will also be necessary for the operational capacities (e.g., traffic flow or re-routing capacity) of the off-site infrastructure to be capable of accommodating the movement of casks on transporters.

3.1 Railroad Requirements

Off-site railroads, either Class I (mainline railroads), II (typically regional railroads), or III (typically shortline railroads) railroads, might be used to transport casks at sites that have either direct rail access (Maine Yankee, Rancho Seco, Trojan, La Crosse, Zion, Crystal River, and San Onofre sites) or near-site rail access with an acceptable branch line or rail siding where casks would be transferred to railcars from heavy haul trucks or barges (Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, and Kewaunee sites).

Rail infrastructure components including roadbed, track geometry and track structure to meet Class 2 Track Safety Standards, and over- and under-grade bridges, must be sufficient to ensure that these features of a railroad are capable of supporting a 6-, 8-, or 12-axle cask-railcar that conforms to AAR Standard S-2043 (AAR 2008) and has a gross loaded weight up to 500,000 lb. The railroad's infrastructure must comply with the regulatory standards of the Federal Railroad Administration and also have the capability to accommodate a train consisting of up to five cask-railcars, two or more buffer cars containing ballast, two locomotives, and an escort car.

The height and width clearances of the track alignment also must be sufficient to accommodate a loaded cask-railcar having an overall height up to 15 feet and a width up to 12 feet. Clearance along track curves must be sufficient to accommodate a railcar having a length up to 100 feet and a width of up to 12 feet. The radius of track curves (including curves in switching yards that may be used) must be sufficient to accommodate a 6-, 8-, or 12- axle railcar with a distance between the front and rear truck bolsters up to 80 feet.

For sidings or railheads where casks would be transferred from heavy haul trucks or barges to railcars, the length of rail should accommodate a minimum of one cask-railcar having a length up to 100 feet and a width up to 12 feet. The curvature of the turnout for the siding should allow for a 6-, 8-, or 12-axle cask-railcar with spacing between the front and rear truck bolsters up to 80 feet. Sidings where intermodal transfers will be conducted should include a cleared and level adjacent operations area that can support heavy vehicles and equipment and that is no less than 200 feet long and 50 feet wide. For sidings where only one- or two-cask railcars can be accommodated, there should be a nearby rail siding or rail yard where the train can be assembled.

For some sites it may be necessary to conduct intermodal operations at a nearby rail siding that has limited operating space and is close to a railroad's operating track. For such sidings it may not be possible to conduct concurrent railroad train operations on the main rail line while intermodal transfer and switching operations necessary for cask shipments are being conducted. To use such sidings, it will be necessary for the railroad to have a flexible operations schedule for, or alternative routing around, the affected track.

3.2 Highway Requirements

All 12 shutdown sites have on-site roads that connect to local roads or highways. Five of these sites (Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, and Kewaunee sites) do not have direct access to a railroad. The standards used for the design, construction, and maintenance of local roads and highways depend on several factors, including whether the road or highway is designated as an interstate highway, U.S. highway, state highway, or local road.

Interstate and U.S. Highway standards are established by the Federal Highway Administration. These standards establish the mechanical requirements for lane width, road shoulder, overhead clearance, grade, curvature, road-bed, bridges and culverts, and primary pavement materials and thickness for all roads designated as Interstates and U.S. Highways. The standards are the basis for federal weight and size limits for trucks and buses. States are authorized to issue special permits for vehicles that exceed these limits for weight and size for trucks and buses. The special permits that states issue typically consider the route to be used, normal traffic on the route, time of day and duration of use, total weight of the permitted vehicle, wheel loads, distribution of the total weight of a vehicle over multiple wheels, axle spacing, and the frequency of overweight and oversize vehicles using the permitted roadways. The permits also consider the condition of designated highways and the load capacities of the highway's bridges, overpasses, and culverts.

Standards for state highways are typically less prescriptive than standards for federal highways. Many state highways are narrower and have steeper grades and sharper curves than do federal highways and often have narrow shoulders and less overhead clearance. In addition, many state highways do not have the substantial roadbed and pavement federal highways do. State highway bridges and culverts also typically have less load capacity than do bridges and culverts for federal highways. State highway departments issue permits for overweight and oversize vehicles that use the state highways. State permitting processes for overweight and oversize vehicles that travel on state highways are generally the same as those for oversize and overweight vehicles that travel on federally designated highways.

For local roads, standards adopted by local governments consider anticipated traffic densities, truck traffic use, climate, terrain, and geology. Local roads may be wide or narrow, often have short-radius curves and sharp corners, may have substantial sub-base and pavements or may be only intended for light vehicle use, and often have low overhead clearances because of utility lines or limited overpass grade separations. Weight limits for bridges and culverts for local roads are typically less than for the same kinds of structures on state or federal highways. In addition, local roads pass through residential and local business communities often with businesses and residences being located close to the right-of-way. These local roads provide commuter, employee, and pickup and delivery vehicles access to retail and other businesses, and provide connectors to state and federal highways.

Although the shutdown sites are generally located in rural areas, all are served by local roads that, if applicable and if practical, would be used by heavy haul vehicles. Local authorities would issue permits for overweight and/or oversize vehicles to travel on nonstate, nonfederal, local roads. Such permits may be issued following consultation with local elected officials and thus may consider factors (e.g., desirability of removal of overhanging tree branches) that are in addition to technical factors concerning the proposed vehicle, load, route, and conditions of roads and road structures, and time of day for operations.

It is likely that the travel speeds of the vehicles from the shutdown site to a nearby railhead or siding would be limited to an average of less than 5 miles per hour. This slow pace, based on experience, is because the local roads that would be used typically have limited capacity to accommodate oversize and overweight vehicles that would transport rail/intermodal casks from a shutdown site to a nearby railhead. Owners of sites such as Yankee Rowe and Connecticut Yankee, who have contracted for the use of heavy haul vehicles to move heavy equipment from their sites to railheads, report that travel times can be expected to be 8 hours or more even for distances of less than 10 miles. In addition, the heavy haul vehicle would likely block the flow of traffic on most local roads because of its size and because the roads often have two, relatively narrow (10- or 12-feet) lanes and limited shoulders. Thus, one or more alternate routes must be available for use by local traffic at times when the heavy haul vehicle is on the road.

Additional requirements for roads that would be used by heavy haul trucks include the following:

- Overhead clearances must be (or be moveable or clearable to) 15 feet or greater above the roadway.
- The side-to-side width of the narrowest section of a road should be sufficient to allow passage of a 14-foot-wide vehicle.
- Curves and corners must have sufficient inside clearances to allow a 100-foot-long center section of a heavy haul vehicle to negotiate the turns without interference (the greatest requirement is for a clearance of 34 feet on the inside of a 90º corner for a 20-foot-wide road).
- Bridges, bridge supports, dam crossings, and culverts must be capable of supporting the distributed load of the heavy haul vehicle (approximately 4,000 lb. [2 tons] per lineal foot of roadway) or must have spans that are short enough to allow use of jumper bridge-deck reinforcements.
- Road sub-grade and pavement must be firm and stable and be capable of supporting the distributed load of the heavy haul vehicle (approximately 4,000 lb. [2 tons] per lineal foot of roadway over a length of 100 feet). Weak areas of roadway may be temporarily improved by use of top-ballast or jumper reinforcements.

3.3 Navigable Waterway Requirements

Off-site navigable waterways that might be used by barge operators to transport rail/intermodal casks could be accessed directly from on-site barge landings at the Maine Yankee, Trojan, and La Crosse sites; from on-site canals that connect on-site landings to a waterway at the Connecticut Yankee and Crystal River site; or from off-site landings where rail/intermodal casks would arrive on heavy haul trucks and be off-loaded onto barges at the Humboldt Bay and Kewaunee site. Barge landings may be docks or unimproved shorelines. Barges might be loaded at shorelines along navigable waterways. The Humboldt Bay, Big Rock Point, and San Onofre sites have unimproved shorelines that might be used to land barges.

Requirements for using navigable waterways to ship rail/intermodal casks containing used nuclear fuel include the following:

- The waterway is an inland or inter-coastal navigable waterway used by commercial maritime traffic and is maintained by the U.S. Army Corps of Engineers, port authorities, or other federal authorities (e.g., Tennessee Valley Authority).
- Docks or shoreline landings for barges must have securing stanchions or other securing points adequate for securing a barge (sea-going, lake, or river barge, depending on the route) having a minimum cargo capacity of 2,000 deadweight tons.
- Navigation from a dock or shoreline landing (where rail/intermodal casks would be on- and off-loaded to and from barges) to the navigable section of the waterway is direct and can be determined by inspection of maritime charts to be safe and clear of marine hazards.

4. ACTIONS NECESSARY TO REMOVE USED NUCLEAR FUEL FROM SHUTDOWN SITES

The tasks that would need to be undertaken to remove used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites may be divided into two phases: 1) programmatic activities to prepare for transport operations from a shutdown site, and 2) operational activities to prepare, accept, and transport from a shutdown site. Table 4-1 provides a high-level summary of the tasks that would take place during these two phases. The tasks are described in the following sections. In the descriptions of these tasks, the terms accept or acceptance are sometimes used. In this report, these terms mean that a shipment has been properly prepared for transport. It should be noted that DOE has not made any decisions regarding the priority or preference for removing used nuclear fuel from shutdown sites. In addition, it is assumed that any refurbishment or upgrade of on-site infrastructure required prior to receipt of equipment for loading and transportation will be performed by the shutdown site organization to facilitate timely shipping of used nuclear fuel and GTCC low-level radioactive waste from the site.

Table 4-1. Activities to Prepare for and Remove Used Nuclear Fuel from Shutdown Sites

Task	Task Activity Description
Programmatic Activities to Prepare for Transport Operations from a Shutdown Site	
1. Assemble Project Organization	Assemble management teams, identify shutdown site existing infrastructure, constraints, and transportation resource needs and develop interface procedures.
2. Acquire Casks, Railcars, Ancillary Equipment, and Transport Services	Develop specifications, solicit bids, issue contracts, and initiate preparations for shipping campaigns. Includes procurement of transportation casks and revisions to certificates of compliance as may be needed, procurement of AAR Standard S-2043 railcars, and procurement of off-site transportation services.
3. Conduct Preliminary Logistics Analysis and Planning	Determine fleet size, transport requirements, and modes of transport for shutdown site.
4. Coordinate with Stakeholders	Assess and select routes and modes of transport and to support training of transportation emergency response personnel.
5. Develop Campaign Plans[a]	Develop plans, policies, and procedures for at-site operational interfaces, support operations, and in-transit security operations.
Operational Activities to Prepare, Accept, and Transport from a Shutdown Site	
6. Conduct Readiness Activities	Assemble and train at-site operations interface team and shutdown site workers. Includes readiness reviews, tabletop exercises and dry run operations.
7. Load for Off-site Transport	Load and prepare loaded casks and place on transporters for off-site transportation.
8. Accept for Off-site Transport	Accept loaded casks on transporters for off-site transportation.
9. Transport	Ship shutdown site casks.

AAR = Association of American Railroads

a. A campaign plan contains step-by-step, real-time instructions for completing a shipment from an origin site.

4.1 Programmatic Activities to Prepare for Transport Operations from a Shutdown Site

Activities that would need to be taken to prepare for transport operations at each of the shutdown sites and to ship the fuel to an off-site destination can be rolled up to the first five major groups of activities listed in Table 4-1.

4.1.1 Task 1 – Assemble Project Organization

For the initial project organization, it would be necessary to assemble the personnel and supporting resources to begin planning, collecting information, conducting analyses, developing interface procedures, and undertaking other preparations to remove used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites. These activities would establish organizations, policies, plans, and procedures necessary for the project to begin the work necessary to acquire and qualify the physical and personnel resources that would be needed to make the shipments of used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites.

Among the key activities would be to develop and implement the quality assurance plan for

- acquisitions of transportation casks and safety-related components
- selection and training of management and operations personnel
- used nuclear fuel transportation interface operations
- transportation cask maintenance and support operations.

At a minimum, the quality assurance plan would meet the requirements of 10 CFR 71, Subpart H.

Another key activity would be to establish interface procedures for each of the shutdown sites. Areas addressed in these interface procedures could include

- description of the transportation casks, associated equipment, and transportation vehicles/conveyances that would be delivered to the shutdown site
- delivery of transportation casks and associated ancillary equipment to the shutdown site
- description of the assistance available to train and advise site personnel regarding the operation and use of transportation casks and ancillary equipment at the shutdown site
- descriptions of the used nuclear fuel and GTCC low-level radioactive waste that would be loaded into the transportation casks at the shutdown site
- descriptions of the canisters that contain the used nuclear fuel and GTCC low-level radioactive waste that, with their contents, would be loaded into transportation casks by the shutdown site operations organization.

During this stage, it is assumed that any necessary site work and equipment acquisitions would occur in a timely manner to support transportation operations. In general, it would be necessary for DOE or another management and disposition organization to determine its transportation resource needs and assemble the organizational elements needed to be capable of transporting used nuclear fuel from each shutdown site and to conduct efficient campaigns of shipments from the sites. To ensure effective coordination of planning, preparatory, and operational activities for shipping used nuclear fuel from the shutdown sites, the resulting organization would establish communications and working interfaces with the organizations responsible for each of the shutdown sites.

4.1.2 Task 2 – Acquire Casks, Railcars, Ancillary Equipment, and Transport Services

It would be necessary to acquire a fleet of transportation casks, ancillary equipment and railcars to conduct the shipping campaigns from the shutdown sites. In the acquisition of transportation casks from cask vendors, transportation certificates of compliance would be updated, as is necessary, to accommodate all used nuclear fuel to be shipped from the shutdown sites (including damaged fuel assemblies in fuel control dry shielded canisters in storage at the Rancho Seco site) and GTCC low-level radioactive waste that is stored in canisters at the shutdown sites.

Technical specifications would need to be developed for each kind of transportation cask and for major separable components (e.g., impact limiters) as well as the cask's associated ancillary equipment and consumables. There would be a minimum of eight procurement specifications for the eight kinds of transportation casks, components, ancillary equipment, and consumables that would need to be procured.

In addition, specifications would be developed for railcars that would be needed to transport the transportation casks. Three kinds of railcars would need to be procured: railcars for transportation casks, buffer cars, and escort cars. Based on previous transportation planning conducted for used nuclear fuel shipments (DOE 2009), all three types of railcars would be specially designed cars that would need to be tested to verify their conformance to AAR Standard S-2043 (AAR 2008); however, it may be possible to use empty cask cars as buffer cars, reducing the types of railcars that would need to be procured. Testing services would need to be procured for the railcars.

Because the transportation casks that would be used to transport used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites would be similar in size and weight, it is possible that only one design for a cask railcar would be needed. It may also be possible to use, with only minor modifications, the design and specification developed and qualified by the U.S. Navy for railcars it is procuring for the shipment of M-290 transportation casks for naval used nuclear fuel. In addition, it may be possible to adopt the design and specification being developed by the U.S. Navy for escort railcars. A buffer railcar design may be jointly developed with the Navy.

To obtain AAR's non-provisional certification that the three types of railcars would perform in accordance with the provisions of the AAR Standard, it would be necessary to conduct train tests in which all cars in the train comply with the car standards of AAR Standard S-2043 and for which the cask cars have representative loads.

Last, it would be necessary to procure transportation services for the off-site transportation of casks that contain used nuclear fuel and GTCC low-level radioactive waste and for unloaded casks that would be returned to shutdown sites for loading. These services will include long-haul transport services provided by Class I (Mainline), Class II (Regional), and Class III (Short Line) railroads as well as services provided by operators of heavy haul trucks, barge and port operators, and heavy lift equipment operators for intermodal transfer operations. The services of private security companies for physical security services in all stages of transit from departure from the shutdown sites to delivery to a destination site may also be procured. In-transit security personnel may also be accompanied by health physics support personnel if it is determined that this is required.

4.1.3 Task 3 – Conduct Preliminary Logistics Analysis and Planning

In this task, the information needed to estimate the amount of time that would be required to load and ship casks containing used nuclear fuel and GTCC low-level radioactive waste from each of the shutdown sites would be collected. It would also be necessary to estimate the time that would be required at the destination facility to receive, unload, inspect, and maintain, and return casks for their next shipments.

The time required for loading and preparing a cask for transportation is expected to be unique for each of the shutdown sites. The differences would arise because of differences in the resources that the sites may deploy and differences in the transportation casks that would be used. Examples of such differences include the number of transfer casks that could be used to transfer canisters from storage modules to transportation casks that are available at a site, and whether it would be necessary to move the loaded transportation casks from the loading station to the transport vehicle, e.g., on-site transfer onto a barge such as may occur at the Connecticut Yankee site versus directly onto a railcar, which would be expected to occur at the Maine Yankee, Rancho Seco, Trojan, La Crosse, Zion, Crystal River, and San Onofre sites. In addition, at the Humboldt Bay site the canisters that contain used nuclear fuel and GTCC low-level radioactive waste are stored in HI-STAR HB transportable overpacks, thereby making transfers from storage modules to transportation casks unnecessary. It would still be necessary to conduct inspections and tests to verify that the HI-STAR HB casks comply with the requirements of their certificates of compliance before shipments can be made. In addition, it would be necessary to install impact limiters on the HI-STAR HB casks, place the casks onto transport skids, and load the assembled transport packages onto a transport vehicle at the site.

The amount of time that would be required to transport loaded and unloaded casks from and to the shutdown sites, and to and from a destination site would also vary among the shutdown sites. Some of the differences would be because the travel distances to a destination site from the shutdown sites would be different. Other differences among the shutdown sites could have a greater influence on time in transit for shipments than the distance from the destination site. For example, if it is necessary to use heavy haul trucks to transport HI-STAR HB casks 160 to 260 miles from the Humboldt Bay site to a nearby railhead and then transfer the casks to railcars to complete the transport to a destination site, the time in transit would be significantly different than that for shipments from the Trojan or Rancho Seco sites in the western states region of the United States. The Trojan and Rancho Seco sites have direct access to a railroad and thus would be able to load casks onto railcars at the sites.

Conversely, shipments from the Humboldt Bay site would be one-way movements with no return of the transportation casks to the site for reloading whereas shipments of transportation casks from all eight of the remaining sites would require returns of unloaded transportation casks for reloading. At the Connecticut Yankee, Yankee Rowe, Big Rock Point, and Kewaunee sites outbound loaded shipments would involve heavy haul truck or barge shipments to nearby railheads and transfers of casks from the heavy haul trucks, or possibly from barges, to railcars. Returning shipments of unloaded casks would require the reverse of the sequence for the outbound shipments. Although unlikely, barges could also be used to ship transportation casks to nearby railheads or ports from the Maine Yankee, La Crosse, and Trojan sites.

The above factors that would affect the time required to make shipments would also affect the transportation resource requirements and the resource requirements at the shutdown sites and the durations of activities to remove used nuclear fuel and GTCC low-level radioactive waste from each of the sites and collectively from all of the shutdown sites. These factors along with the funding resources would be analyzed to assess the efficacy of alternative orders for shipments to be made from the shutdown sites and the numbers of each type of transportation cask (and components) and the number of cask cars, buffer cars, and escort cars to procure for each alternative set of assumptions. This information would be used to inform managers to support decisions regarding modes of transport, acquisition decisions, staffing decisions, and allocations of resources.

4.1.4 Task 4 – Coordinate with Stakeholders

Coordination with stakeholders to assess and select routes and modes of transport and to support training of transportation emergency response personnel of states and tribes would be an essential activity. It would build on similar coordination efforts currently supported by the DOE Office of Environmental Management through the National Transportation Stakeholder Forum and through support of state regional groups: the Southern States Energy Board, the Western Interstate Energy Board/Western Governors' Association, Midwestern Office of the Council of State Governments, and the Eastern Regional Conference of the Council of State Governments.

A key activity would be to develop and implement policy and procedures to provide technical and funding assistance to states and tribes that would be affected by the transport of used nuclear fuel through and near to their jurisdictions. The funding and technical support would be similar to that described in Section 180(c) of the Nuclear Waste Policy Act, as amended (42 U.S.C. 10101 et seq.) and would be to assist the states and tribes in training of state, tribal, and local officials who would be responsible for helping to ensure the safe transport of used nuclear fuel through their jurisdictions as well as emergency response to transportation accidents that may involve the shipments of used nuclear fuel from the shutdown sites.

In addition to developing and implementing procedures for technical and funding support to states and tribes for safe transportation and emergency response for transportation accidents, the transportation operations organization would work collectively with the affected states and the tribes to determine the modes of transportation that could be used to move used nuclear fuel from the shutdown sites as well as the routes that would be used. This would be a collaborative effort in which the transportation operations organization, transportation carriers, and the states and tribes would identify and weigh factors that would influence the selections to be made. Achievement of consensus among the involved parties regarding the modes and routes to be used for the shipments, as well as procedures to be implemented to ensure and provide confidence that the shipments would be made safely, would be the objective of this activity.

4.1.5 Task 5 – Develop Campaign Plans

As activities progress to procure resources needed to conduct shipping campaigns from the shutdown sites, it would be necessary to plan for and assemble staff who would conduct shipment operations. This planning effort would include determining the structure and organization of the work to be performed to conduct shipment operations, acquiring and training the staff who would conduct operations, developing operational procedures, and establishing the necessary supporting organizational infrastructure.

The major elements of the work structure for the transport operations activities would include transportation fleet management, shipping campaign management, and in-transit operations management. Sub-elements within these three management elements would include:

- transportation cask, ancillary equipment, and railcar maintenance and servicing
- campaign kit assembly and distribution[19]
- scheduling and expediting of shipping campaigns including shipments (loaded and unloaded casks), equipment, field personnel, and in-transit security and safety escort personnel
- coordination of shipment notifications, in-transit tracking, in-transit physical security, and emergency response operations
- field services including technical support as required.

In addition to training that would be conducted to prepare for operations, activities for the operations staff before the transport operations begin would include:

- developing operations procedure
- establishing operational interfaces with the operations organizations at each of the shutdown sites

[19] Campaign kits are collections of special tools and equipment that would be needed at shipping sites to load and prepare casks for transport and at intermodal transfer locations where casks would be transferred to and from railcars from and to another mode of transportation.

- establishing operational interfaces with officials of state, tribal, and local governments whose jurisdictions would be affected by transportation of used nuclear fuel from the shutdown sites
- establishing operational interfaces with transportation carriers and providers of special transportation services that may be needed
- establishing operational interfaces with the operator of the destination facility.

Establishing organizations (or elements matrixed from other organizations) that would support shipment operations activities would also be necessary. The support organizations would include: quality assurance, licensing and regulatory compliance (to ensure that certificates of compliance are current and encompass the used nuclear fuel that would be shipped), training, procurement, public information, and field engineering. Each of these supporting organizational elements would need to acquire its own staff and resources and develop its own policies, plans, and procedures that would be tailored to meet their unique needs.

4.2 Operational Activities to Prepare, Accept, and Transport from a Shutdown Site

The activities to prepare, accept, and transport used nuclear fuel from each of the shutdown sites are rolled up into the four major groups of activities listed in the second half of Table 4-1. These are expected to include tabletop exercises that would support training for shipments and dry run activities at shipping sites and at intermodal transfer locations. These readiness activities would be followed by loading of casks at the shutdown sites, acceptance of the casks loaded and prepared for transport, shipment of the casks to the destination facility, inspection and maintenance of casks following shipment, and return of unloaded casks to shipping sites.

4.2.1 Task 6 – Conduct Readiness Activities

Tabletop exercises would involve the transportation operations organization and the shutdown site operations organization along with participation by state, tribal, and local officials. It is also anticipated that in-transit tabletop exercises would involve participation by transportation planning and operations organizations and officials from affected states, tribes, and local governments. The tabletop exercises would be in-office drills designed to identify gaps in planning, procedures, and training for the full sequence of operations that would be involved in making shipments of used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites to a destination facility. These exercises would be developed jointly by the operations, training, and quality assurance organizations.

Following the tabletop exercises, the transportation and shutdown site operations organizations would conduct dry run operations to establish the operational basis for determining readiness to make shipments. The dry run operations would not involve removal of canisters containing used nuclear fuel from storage systems but would otherwise involve the full sequence of operational steps. These steps would include handling, loading, and preparation of casks for shipment; loading of the casks onto transport vehicles; and intermodal transfers of casks from heavy haul trucks or barges to railcars and the reverse operation.

Readiness reviews would be conducted jointly by the transportation operations organization, the shutdown site operations organization, and transportation service operators to review the results of tabletop and dry run activities and to verify that open issues identified in these exercises have been appropriately resolved. Readiness reviews would also be conducted with state, tribal, and local officials to ensure that there are no outstanding issues that would need to be addressed to ensure effectiveness of emergency response and in-transit security operations that the transited jurisdictions may provide.

4.2.2 Task 7 – Load for Off-site Transport

Shutdown site operations organizations would remove the transportable dry storage canisters containing used nuclear fuel or GTCC low-level radioactive waste from on-site storage systems, load the canisters into transportation casks, prepare the loaded casks for shipment, and load the prepared casks onto transport vehicles. Unloaded casks would be delivered to each of the shutdown sites either on railcars, heavy haul trucks, or barges. Following delivery of unloaded casks, it is assumed that each shutdown site operations organization

- receives casks at its site, prepares the casks to be loaded and verifies the casks are suitable for loading with canisters that contain the site's used nuclear fuel
- is registered with the NRC as a user of the transportation cask that would be loaded at the site
- uses equipment designed by the vendor of the storage system and transportation cask and follows on-site procedures to transfer canisters containing used nuclear fuel or GTCC low-level radioactive waste from its on-site storage system into the transportation cask body
- prepares the transportation cask for shipment including assembly of all components and conduct of tests to verify proper assembly for shipment specified by the cask's certificate of compliance
- places the transportation cask on a shipping skid/cradle, load the cask-on-cradle unit onto the transport vehicle, and provides the documentation required to verify that the shipment has been properly packaged for off-site transportation
- takes an average of up to one calendar week to complete the sequence of operations from receipt of an unloaded cask through to delivery of the cask for off-site transportation.

Used nuclear fuel at the Humboldt Bay site is stored in storage/transport canisters in HI-STAR HB cask bodies. The HI-STAR HB cask, when impact limiters are attached, is certified by NRC to transport the used nuclear fuel from the Humboldt Bay site. Thus, the site's operator would not have to transfer canisters from a storage system to a transportation cask. Nonetheless, the shutdown site operations organization would be required to remove the already-loaded HI-STAR HB casks from their sub-grade storage locations, complete assembly of the casks for transport including installing impact limiters, conduct pre-shipment tests that are specified in the cask's certificate of compliance, load the casks onto transport vehicles, and provide the documentation required to verify that the shipment of used nuclear fuel has been properly packaged for off-site transportation.

4.2.3 Task 8 – Accept for Off-site Transportation

At each of the shutdown sites and for each cask shipped from the sites, the transportation operations organization would accept loaded casks that have been prepared for shipment and placed onto transport vehicles. The transportation operations organization would also take possession of the used nuclear fuel or GTCC low-level radioactive waste that is contained in the casks at the same time it accepts the shipment. For each such shipment, preparation would be made in advance to ensure that the contents of the shipment are verified and that the requirements of the transportation certificate of compliance have been met. The transportation operations organization field operations staff would inspect documentation for each shipment that has been prepared and provided by the owner of the shutdown site and, as appropriate, conduct physical inspections of the loaded transportation cask on its transport vehicle.

4.2.4 Task 9 – Transport

The complexity of off-site transportation of casks containing used nuclear fuel or GTCC low-level radioactive waste from the shutdown sites would vary among the sites. Shipment operations from sites that would require use of heavy haul trucks or barges to move casks to nearby railheads would be significantly more complex than those from sites where the casks could be directly loaded onto railcars for off-site shipment. In addition, sites where there is a practical limit of one or two casks that can be placed on railcars for shipment in a single train would require a greater application of resources than would be the case for sites that have on-site rail spurs that can accommodated many railcars and connect to a railroad that can accommodate trains hauling five or more of the heavily loaded cask cars.

Shipment operations would involve advance scheduling and notification of state and tribal governments; coordination among the transportation physical security force and state, tribal, and local security officials; coordination between transportation companies and the transportation operations organization for shipments that involve intermodal operations; and cross-country coordination among the rail carriers and the transportation operations organization to ensure that shipment schedules are known and maintained. The transportation operations organization would use satellite tracking to monitor the progress of each shipment containing used nuclear fuel or GTCC low-level radioactive waste en route. The transportation operations organization may also use satellite tracking along with expediting services to expedite return shipments of unloaded casks to shutdown sites.

In-transit operations for shipments of used nuclear fuel and GTCC low-level radioactive waste would principally involve real-time tracking of shipment locations and deployment of physical security personnel, and possibly radiological safety technicians, who would observe shipments from the escort railcars that would be included in each used nuclear fuel rail shipment.

The transportation operations organization would maintain an emergency operations center that would maintain readiness to direct resources to respond to any in-transportation event that may occur during shipment of used nuclear fuel or GTCC low-level radioactive waste from the shutdown sites. The emergency operations center would coordinate U.S. Government response efforts with those of state, tribal, and local officials in a jurisdiction that may be involved.

A typical shipment of a loaded casks containing used nuclear fuel or GTCC low-level radioactive waste would require 1 to 2 weeks of transit time to complete. Shipments over distances of 500 to 1,000 miles and where railcars are loaded at shipping sites would generally be completed in about 1 week. Shipments over distances that exceed 1,000 miles and that require use of intermodal transportation would generally require about 2 weeks. Based on the experience of the U.S. Navy, shipments of unloaded casks returning to a site for reloading, if not expedited, can require up to a month.

4.3 Results

In this section, representative time sequences of activities listed in Table 4-1 and their durations were developed for scenarios involving removing used nuclear fuel from one shutdown site and for removing used nuclear fuel and GTCC low-level radioactive waste from the Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion sites.

4.3.1 Removal of Used Nuclear Fuel from One Shutdown Site

In this section, representative time sequences of activities listed in Table 4-1 and their durations were first developed for four scenarios involving a single site that was assumed to be served by a railroad. For the purposes of this analysis, Maine Yankee was assumed to be representative, where 60 canisters of used nuclear fuel and 4 canisters of GTCC low-level radioactive waste are stored. The Maine Yankee site was used in constructing this scenario only for the purposes of analysis. DOE has not made any decisions regarding the priority or preference for removing used nuclear fuel from shutdown sites.

The four scenarios are described as follows:

In the first scenario used nuclear fuel was removed from one shutdown site. The time sequence presented in this scenario provides an initial estimate of the duration for key activities and the total duration for removing used nuclear fuel and GTCC low-level radioactive waste from a single site that is served by a railroad. For the purposes of the scenario, the analysis assumed that DOE would procure five transportation casks that would be dedicated to shipping used nuclear fuel and GTCC low-level radioactive waste from the site. The time durations used for the scenario were based on conservative estimates of the time durations for tasks. Figure 4-1 illustrates the time sequence of activities and their estimated durations for this scenario.

The second scenario was similar to the first scenario, but optimistic estimates of the time durations for tasks were used. Figure 4-2 illustrates the time sequence of activities and their estimated durations for this scenario.

The third scenario that assumed that DOE would procure 10 casks that would be dedicated to shipping used nuclear fuel and GTCC low-level radioactive waste from the site, and that would be operated in two, five-cask trains. The time durations used for the scenario were based on conservative estimates of the time durations for tasks. The fourth scenario was similar to the third scenario, but optimistic estimates of the time durations for tasks were used.

Figure 4-3 presents the total time durations for the four scenarios for comparison. The estimated time from the start of the project to the completion of the last shipment of used nuclear fuel and GTCC low-level radioactive waste from this single site was shown to range from 6.2 years to 11.2 years. The estimated durations were most affected by the time required to procure casks, components, and campaign kits, and the time required to develop and procure railcars that meet AAR Standard S-2043 (AAR 2008). For procuring casks, components, and campaign kits, the estimated time durations ranged from 36 to 48 months. For procuring railcars that meet AAR Standard S-2043, the estimated time durations ranged from 36 to 66 months.

As illustrated in Figures 4-1 and 4-2 the tasks to procure casks and railcars were assumed to take place in parallel. The Humboldt Bay site does not require the procurement of casks, although procurement of impact limiters and S-2043 compliant railcars would be required. Because the amount of time required to obtain AAR approved railcars would be independent of the site from which shipments were made, and because obtaining AAR-approved railcars is a critical path activity, the total time required for a project to remove used nuclear fuel and GTCC low-level radioactive waste from the Humboldt Bay site would not be significantly shorter than that for the single site example and would range from about 5 to 6 years.

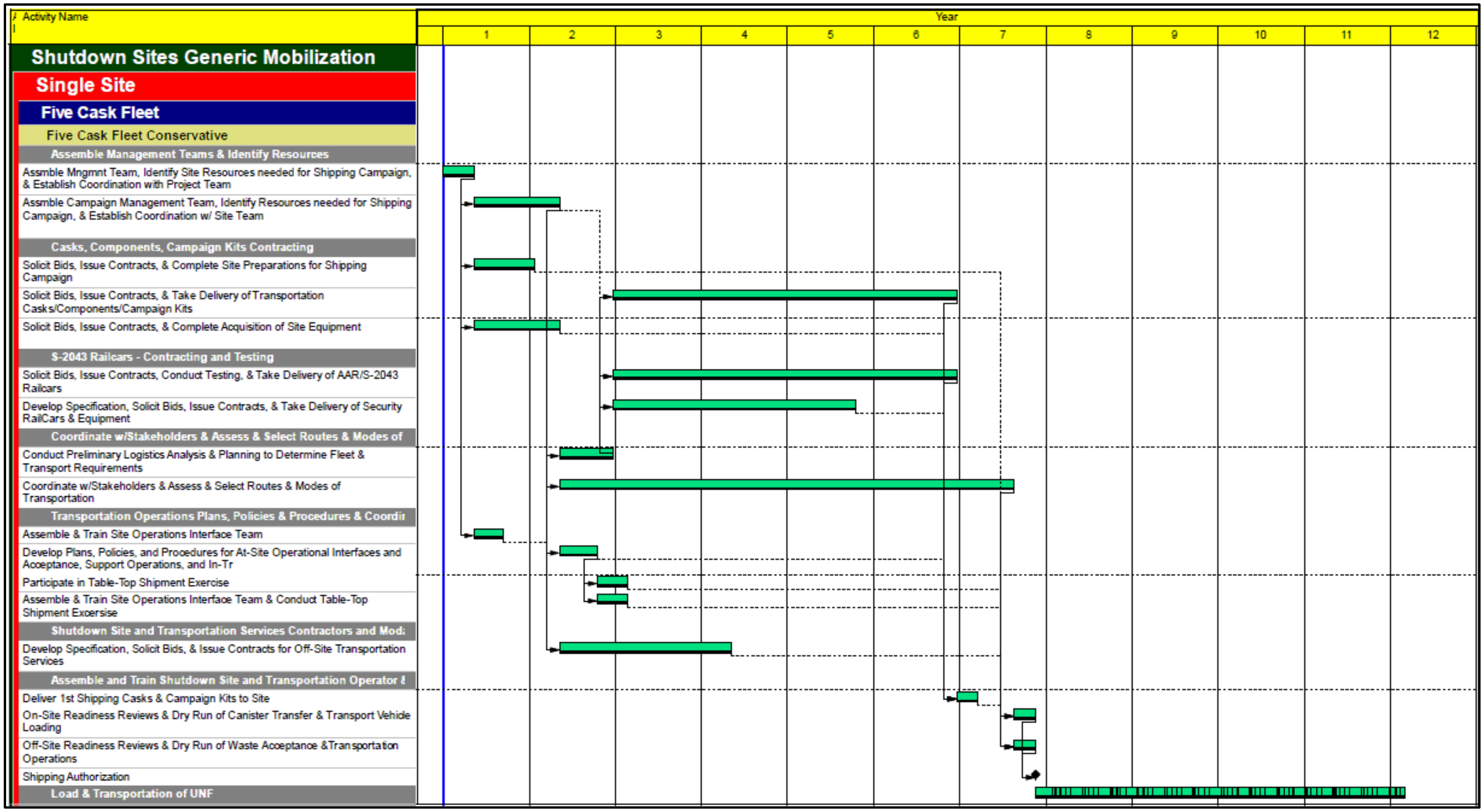

Figure 4-1. Time Sequences of Activities and Estimated Durations to Prepare for and Remove Used Nuclear Fuel from a Single Shutdown Site Based on Five Casks and Conservative Task Durations

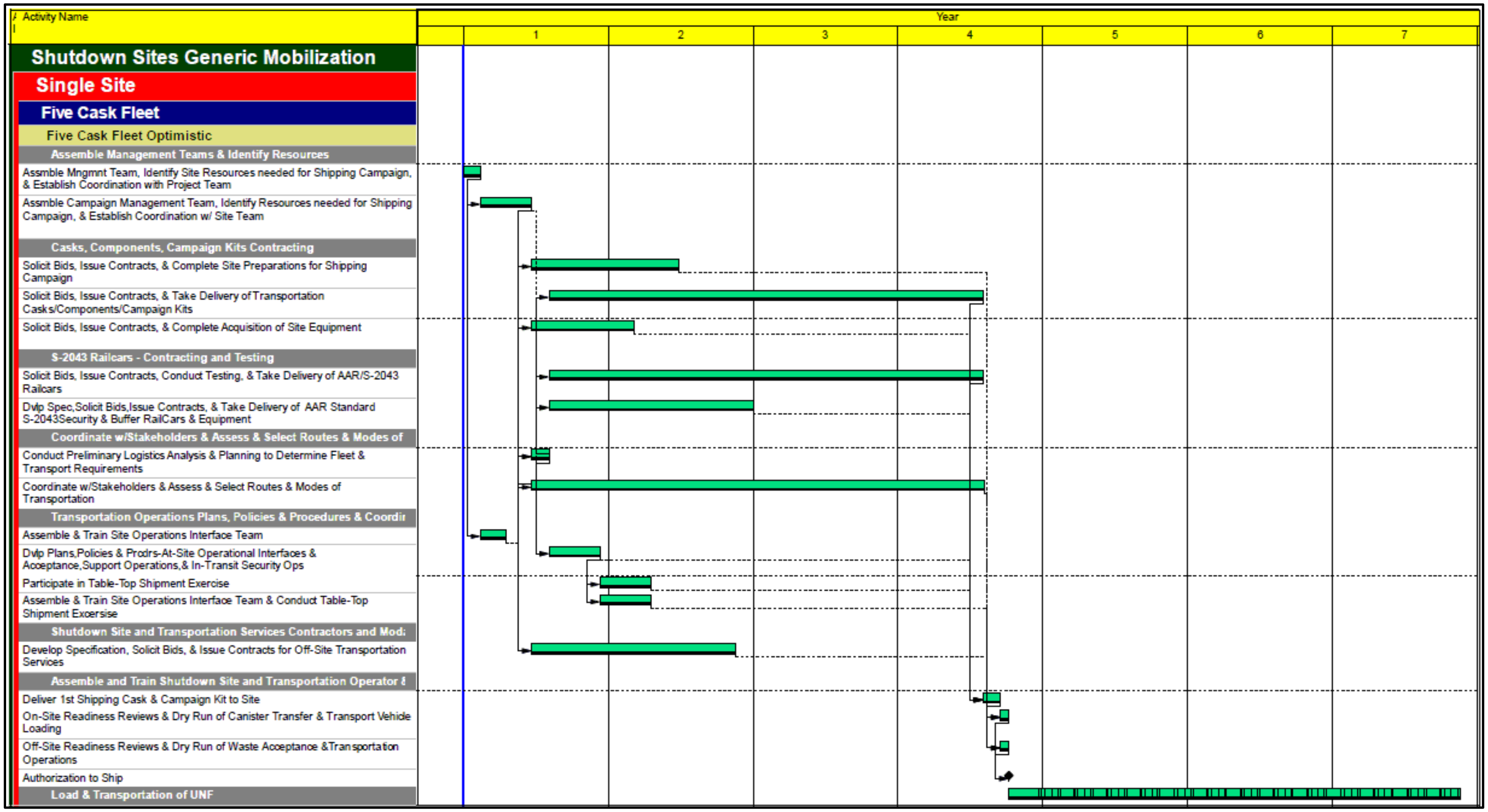

Figure 4-2. Time Sequences of Activities and Estimated Durations to Prepare for and Remove Used Nuclear Fuel from a Single Shutdown Site Based on Five Casks and Optimistic Task Durations

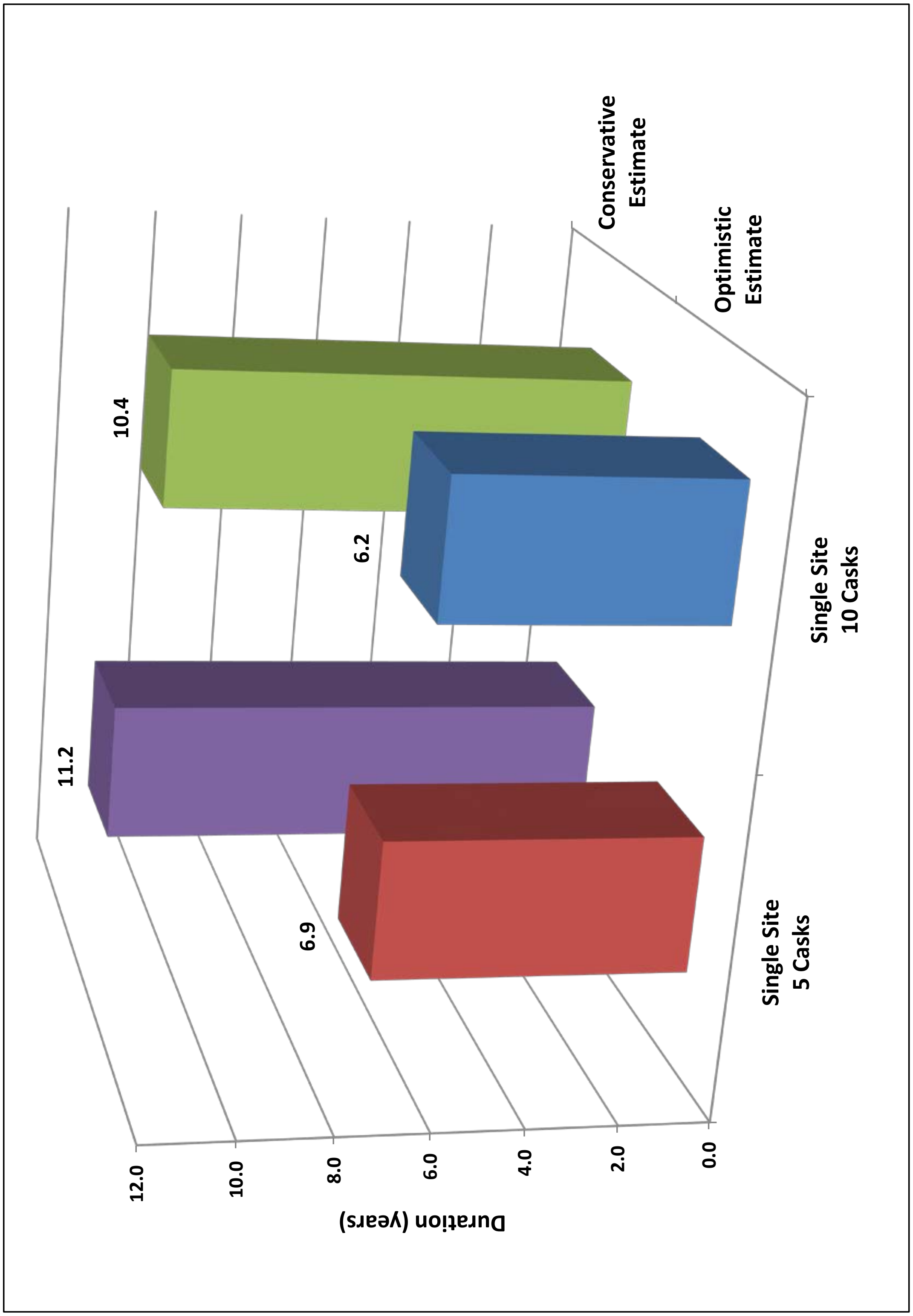

Figure 4-3. Estimated Time Durations for Four Scenarios to Prepare for and Remove Used Nuclear Fuel from a Single Shutdown Site

4.3.2 Removal of Used Nuclear Fuel and GTCC Low-Level Radioactive Waste from the Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion Sites

Figure 4-4 shows the representative durations and sequence of activities to prepare for and remove all used nuclear fuel and GTCC low-level radioactive waste from the Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion sites. The cumulative duration of 11.5 to 14.5 years shown in Figure 4-4 for the project to prepare for and remove all used nuclear fuel and GTCC low-level radioactive waste from the sites includes the schedule uncertainty associated with procurement of casks (4.5 to 5.5 years) and railcars (4 to 5 years) and coordination of shipping campaigns (7 to 10 years). The representative durations and sequence of activities shown in Figure 4-4 do not include Crystal River, Kewaunee, and San Onofre because these sites only recently shut down, are at the beginning stages of the decommissioning process, and generally do not have fully developed irradiated fuel management plans or post-shutdown decommissioning activities reports. These factors make estimates of time durations for removing the used nuclear fuel and GTCC low-level radioactive waste from these sites less certain.

Project activities that would precede shipments from all shutdown sites would require only a slightly greater amount of time than that that would be required for one shutdown site. This assumes that project resources (personnel, funding, and functions such as procurement and quality assurance) would be adequate to support concurrent acquisitions of transportation casks and associated components that would include several units of each of the seven transportation casks that would be used at the shutdown sites—the NAC-STC, NAC-UMS UTC, MP187, MP197HB, TS-125, HI-STAR 100, HI-STAR HB, and MAGNATRAN; and to acquire and certify the fleet of AAR Standard S-2043 compliant railcars that would be needed. It also assumes that there would be flexibility in making acquisitions such as limited constraints on procuring casks and associated components from non-domestic suppliers.

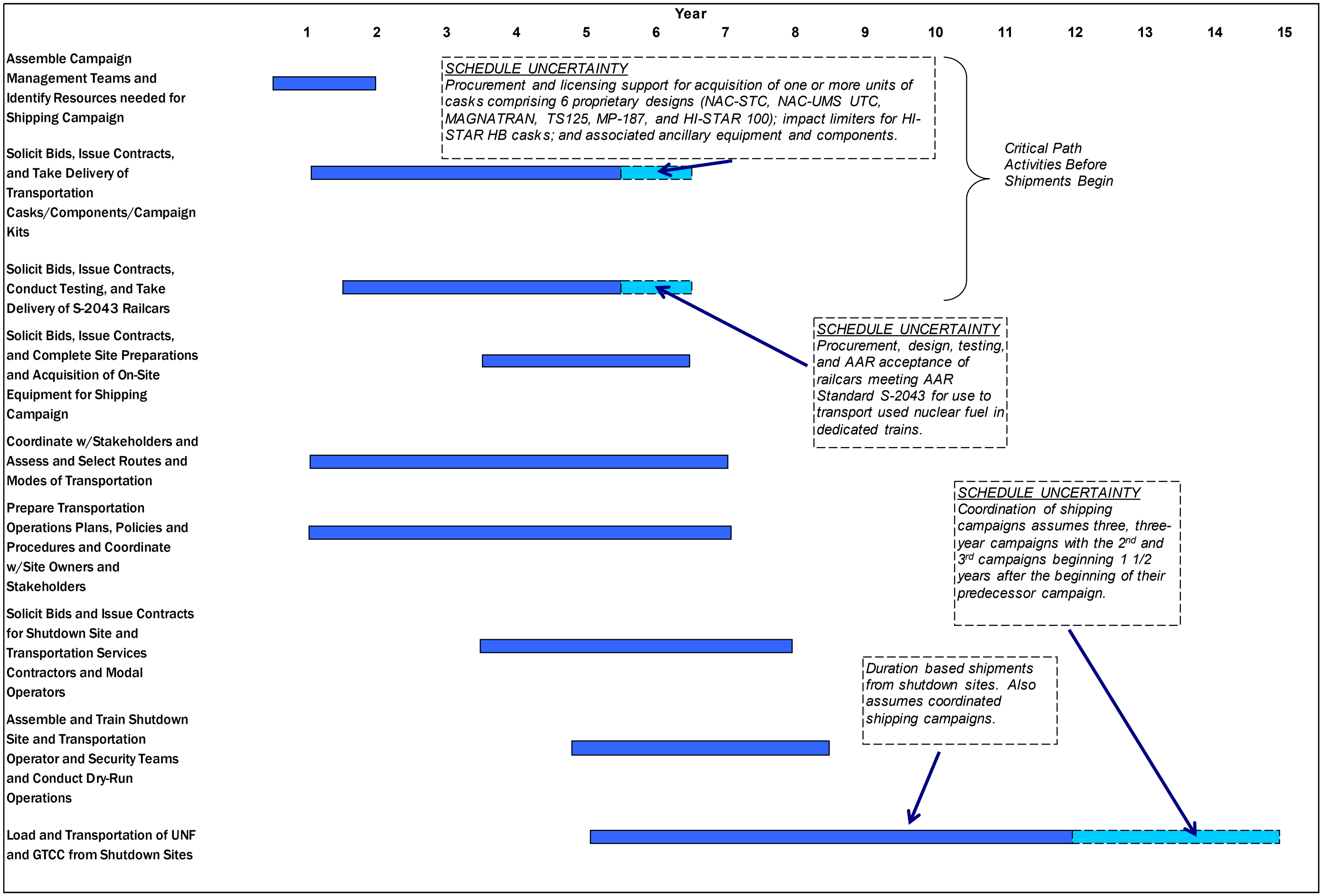

Figure 4-4. Estimated Durations of Key Activities to Prepare for and Remove Used Nuclear Fuel from the Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion Sites

5. CONCLUSIONS AND RECOMMENDATIONS

In this report, a preliminary evaluation of removing used nuclear fuel from twelve shutdown sites was conducted. The evaluation was divided into four components:

- characterization of the used nuclear fuel and GTCC low-level radioactive 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 used nuclear fuel from the shutdown sites, including gaps in information
- an evaluation of the actions necessary to prepare for and remove used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites.

From the evaluations, time sequences of activities and time durations were developed for preparing for and removing the used nuclear fuel and GTCC low-level radioactive waste from a single shutdown site and for the Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion sites. Crystal River, Kewaunee, and San Onofre were not included because these sites only recently shut down, are at the beginning stages of the decommissioning process, and generally do not have fully developed irradiated fuel management plans or post-shutdown decommissioning activities reports, which makes estimates of time durations for removing the used nuclear fuel and GTCC low-level radioactive waste from these sites less certain.

Several issues were identified with the used nuclear fuel and GTCC low-level radioactive waste inventory at the shutdown sites. The most important of the issues was that there are six damaged fuel assemblies in five of the storage canisters at Rancho Seco that were not placed in failed fuel dry shielded canisters. 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 lists of approved contents in the certificates of compliance for the TS125, HI-STAR HB, and MP187 transportation casks do not include GTCC low-level radioactive waste. Consequently, the GTCC low-level radioactive waste stored at the Big Rock Point, Humboldt Bay, Rancho Seco, and San Onofre sites would not be transportable without changes to the certificates of compliance for these transportation casks. The certificates of compliance for the TS125 and MP187 transportation casks would also need to be updated from a -85 to a -96 designation before the casks could be used. In addition, the used nuclear fuel at Crystal River and Kewaunee would not be transportable without changes to the list of approved contents in the certificate of compliance for MP197HB transportation cask.

Two of the sites, Maine Yankee and Zion, have high burnup used nuclear fuel in storage. The 90 high burnup used nuclear fuel assemblies at Maine Yankee are packaged in Maine Yankee Fuel Cans (i.e., damaged fuel cans). This option for transporting high burnup used nuclear fuel is allowed by the certificate of compliance for the NAC-UMS UTC transportation cask (Docket No. 71-9270), and eliminates the concern over its transportability. Ux Consulting (2013b) states that for the MAGNATRAN transportation cask, all high burnup fuel will be canned in damaged fuel cans. This would also eliminate the concern over transportability of the 36 high burnup used nuclear fuel assemblies at Zion. Crystal River, Kewaunee, and San Onofre are also estimated to have high burnup used nuclear fuel. This high burnup used nuclear fuel would not be transportable without changes to the list of approved contents in the certificate of compliance for the MP197HB transportation cask.

The used nuclear fuel at the shutdown sites was loaded into canisters and placed in ISFSIs as early as 2001. The initial storage licenses granted under 10 CFR 72 were for a period of 20 years, so renewals will need to occur starting in about 2018 to 2020 and it is likely that the NRC will have questions about the condition of the stored used nuclear fuel during the storage license renewal process. In addition, transportation cask certificates of compliance are for 5-year periods, so these certificates will also need to be renewed on a regular basis. This will require a long-term commitment by the owners of the certificates of compliance to maintain these certificates.

Table 5-1 summarizes the mode options for transporting used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites. The modes listed in Table 5-1 were based on the evaluations of on-site transportation conditions at the shutdown sites and the near-site transportation infrastructure and off-site transportation experience at the shutdown sites, particularly during large component removals during reactor decommissioning. An important observation regarding Table 5-1 is that all shutdown sites have at least one off-site transportation mode option for removing their used nuclear fuel and GTCC low-level radioactive waste, and some shutdown sites have two options. In addition, it is assumed that any refurbishment or upgrade of on-site infrastructure required prior to receipt of equipment for loading and transportation will be performed by the shutdown site organization to facilitate timely shipping of used nuclear fuel and GTCC low-level radioactive waste from the site.

Based on the activities and task durations presented in Section 4 of this report, preparing for and removing the used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites could be accomplished in 11.5 to 14.5 years (see Figure 4-4). This estimate did not include removing used nuclear fuel and GTCC low-level radioactive waste from Crystal River, Kewaunee, and San Onofre. This time period was largely driven by the time required to load and transport the used nuclear fuel and GTCC low-level radioactive waste; procure casks, components, and campaign kits; and the time required to procure railcars that meet AAR Standard S-2043. While the latter two activities could take place in parallel, they still represent a significant fraction of the time it would take to prepare for and remove the used nuclear fuel and GTCC low-level radioactive waste from the shutdown sites.

As part of this preliminary evaluation, nine shutdown sites were visited: Maine Yankee, Yankee Rowe, Connecticut Yankee, Humboldt Bay, Big Rock Point, Rancho Seco, Trojan, La Crosse, and Zion. In order to confirm the information in this report and to refine the estimates of activities and task durations, it is recommended that the three remaining shutdown sites (Crystal River, Kewaunee, and San Onofre) be visited.

Table 5-1. Summary of Transportation Mode Options for Shipments from Shutdown Sites

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	–	The shortest heavy haul would be 7.5 miles to the east portal of the Hoosac Tunnel.
Connecticut Yankee	Barge to rail	Heavy haul truck to rail	The on-site barge slip was removed after decommissioning. It is uncertain whether the cooling water discharge canal is deep enough to accommodate barges without dredging. The shortest heavy haul would be about 12.5 miles to the Portland railhead. The rail infrastructure at the Portland railhead would need to be evaluated.
Humboldt Bay	Heavy haul truck to rail	Heavy haul truck to barge to rail	The heavy haul distance would be in the range of 160 to 260 miles. The condition of the Fields Landing Terminal would need to be verified for barge transport.
Big Rock Point	Heavy haul truck to rail	Barge to rail	The heavy haul would probably be about 52 miles to Gaylord, Michigan. A shorter heavy haul of 13 miles to Petoskey, Michigan may be possible. 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 a waiver or a track upgrade.
Trojan	Direct rail	Barge to rail	The on-site rail spur was removed.
La Crosse	Direct rail	Barge to rail	The on-site rail spur was used to ship the reactor pressure vessel. The location and method for loading the transportation cask and moving the transportation cask to a rail spur is uncertain.
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 for co-located fossil-fuel plants.
Kewaunee	Heavy haul truck to rail	Heavy haul truck to barge to rail	Condition of potential heavy haul truck routes and rail infrastructure would need to be evaluated.
San Onofre	Direct rail	Barge to rail	The rail spur was recently refurbished to support reactor decommissioning shipments for San Onofre-1.

The estimates of durations for project tasks presented here are preliminary and depend on the many identified assumptions. Consequently, in preparing a comprehensive project plan to prepare for and remove used nuclear fuel from the shutdown sites it will be necessary to refine the estimates using improved information regarding each of the sites and their near-site transportation infrastructure and using methods that will allow managers to gauge the importance of assumptions and project considerations. In this regard, it is recommended that DOE or other management and disposition organization use a quantitative risk analysis tool such as Primavera Risk Analysis (formerly known as Pertmaster) in conjunction with a scheduling tool such as Primavera P6 to provide estimates of project risks and opportunities. Such quantitative analyses would support estimating, managing, and funding of contingencies, and would increase confidence that the project would be successfully executed. Risk-informed estimates would also allow the project's managers to anticipate time and funding resources, and alternative courses of action that might be needed to effectively respond to changing circumstances.

DOE or other management and disposition organization should also take advantage of improved information regarding loading and transportation of used nuclear fuel from the shutdown sites to refine the data used by the DOE Transportation Operations Model (TOM) to evaluate optimizations that may be possible in acquiring and using transportation resources. TOM could also be used to conduct sensitivity analyses and identify important gaps in information that could be filled with additional data collected from the shutdown sites. Information developed using TOM could also be used in case studies conducted using the quantitative analysis tools discussed above.

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Appendix A

U.S. Nuclear Regulatory Commission Certificates of Compliance

Appendix A
U.S. Nuclear Regulatory Commission Certificates of Compliance

Table A-1 lists the docket number, package identification number, revision number, certificate of compliance expiration date, and ADAMS accession number for the transportation casks licensed to transport used nuclear fuel from the shutdown sites. Table A-2 lists the docket number, certificate of compliance number issue date, certificate of compliance expiration date, amendment number, amendment effective date, and ADAMS accession number for the general licensed storage systems used at the shutdown sites. It should be noted that Humboldt Bay, Rancho Seco, and Trojan store used nuclear fuel based on a site-specific license.

Table A-1. Transportation Casks Licensed to Transport Used Nuclear Fuel from the Shutdown Sites

Transportation Cask	Docket	Package Identification Number	Revision	Certificate of Compliance Expiration Date	ADAMS Accession Number
NAC-STC	71-9235	USA/9235/B(U)F-96	12	05/31/2014	ML102780253
MP187	71-9255	USA/9255/B(U)F-85	10	11/30/2013	ML083300410
HI-STAR 100 and HI-STAR HB	71-9261	USA/9261/B(U)F-96	8	03/31/2014	ML102860108
NAC-UMS UTC	71-9270	USA/9270/B(U)F-96	4	10/31/2017	ML12306A440
TS125	71-9276	USA/9276/B(U)F-85	4	10/31/2017	ML12306A387
MP197 and MP197HB	71-9302	USA/9302/B(U)F-96	5	08/31/2017	ML12263A007
MAGNATRAN	71-9356	--	--	--	--

ADAMS= Agencywide Documents Access and Management System (http://www.nrc.gov/reading-rm/adams.html)

Table A- 2. General Licensed Storage Systems Used at the Shutdown Sites

Storage System	Docket	Certificate of Compliance Issue Date	Certificate of Compliance Expiration Date	Amendment	Amendment Effective Date	ADAMS Accession Number
Standardized NUHOMS	72-1004	01/23/1995	01/23/2015	10	08/24/2009	ML092290186
NAC-UMS	72-1015	11/20/2000	11/20/2020	5	01/12/2009	ML090120408
NAC-MPC	72-1025	04/10/2000	04/10/2020	6	10/04/2010	ML102920618
Fuel Solutions Storage System	72-1026	02/15/2001	02/15/2021	4	07/03/2006	ML061910527
Standardized Advanced NUHOMS	72-1029	02/05/2003	02/05/2023	1	05/16/2005	ML051520016
MAGNASTOR	72-1031	02/04/2009	02/04/2029	3	07/25/2013	ML13207A245

ADAMS= Agencywide Documents Access and Management System (http://www.nrc.gov/reading-rm/adams.html)