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Engineering Information Record

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Project No.:	02057.00.0001	**Project Name:**	Early Site Permit FOA		
Title:	FOA 1817 Generic Design Support Activities for Advanced Reactors: Site Reuse Deployment Guidance Project – Final Infrastructure Assessment and Modern D&D Methods				

Summary:

This report provides an evaluation of the current conditions and opportunities for potential reuse of existing Portsmouth Gaseous Diffusion Plant Site (PORTS) infrastructure based on information collected as part of the PORTS infrastructure assessment. The objectives of this assessment are to describe the availability and viability of the existing infrastructure including services, facilities, systems, and structures to support a future advanced reactor siting at a previously used site such as PORTS and to provide generic recommendations for Decontamination and Decommissioning (D&D) techniques that are based on recent commercial experience. These recommendations would support D&D of a DOE site and/or future advanced reactor at a previously used site such as PORTS once reaching the end of the operating license.

The Southern Ohio Diversification Initiative (SODI) team reviewed potential infrastructure, structures, or building foundations that could be reused for a future reactor siting such as connection to the electrical grid, rail spurs, and distribution yards. This report identifies the potential infrastructure that could be reused for an advanced reactor demonstration, which includes current conditions of the infrastructure, viability of the infrastructure to remain serviceable for a prolonged period to allow for reactor construction, potential buildings to reuse, foundations, or D&D material for reuse in a reactor suitable in siting of an advanced reactor, considering site excavation and construction.

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List of Acronyms

Acronym	Definition
3-D	3-Dimensional
ACP	American Centrifuge Project
AEC	Atomic Energy Commission
ALARA	As Low as Reasonably Achievable
ARIS	Advanced Reactors Information System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CRO	Community Reuse Organization
CSX	CSX Transportation Corporation
D&D	Decontamination and Decommissioning
DCGL	Derived Concentration Guideline Level
DOE	United States Department of Energy
DOE EM	DOE Office of Environmental Management
DUF_6	Depleted Uranium Hexafluoride
DWS	Diamond Wire Saw
EA	Environmental Assessment
EIS	Environmental Impact Statement
EM	Office of Environmental Management
Environs	Environmental Soil Areas
ESP	Early Site Permit
FACA	Federal Advisory Committee Act
FBP	Fluor-BWXT Portsmouth, LLC
FERC	Federal Energy Regulatory Commission
G&W	Genesee & Wyoming Inc.
GDP	Gaseous Diffusion Plant (system)
GNEP	Global Nuclear Energy Partnership
GTCC	Greater than Class C
HASP	Health and Safety Plan
HAZMAT	Hazardous Material
HPFW	High Pressure Fire Water
HSA	Historical Site Assessment
IAEA	International Atomic Energy Agency
ISFSI	Independent Spent Fuel Storage Installation
LLRW	Low-Level Radioactive Waste

MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
NAA	Neutron Activation Analysis
NEPA	National Environmental Policy Act
NERC	North American Electric Reliability Corporation
NGNP	Next Generation Nuclear Plant
NRC	U.S. Nuclear Regulatory Commission
NS	Norfolk Southern Corporation
ODOT	Ohio Department of Transportation
PGDPUIP	Portsmouth Gaseous Diffusion Plant Utilities Infrastructure Plan
PHFS	Primary Highway Freight System
PORTS	Portsmouth Gaseous Diffusion Plant Site
PWR	Pressurized Water Reactor
RAD	Radiological Material
RCW	Recirculating Cooling-Water
REMP	Radiological Environmental Monitoring Program
ROD	Record of Decision
RSL	Regional Screening Level
SODI	Southern Ohio Diversification Initiative
SSAB	Site-Specific Advisory Board
SSCs	Surfaces, Systems, and Components
SSCs	Structures, Systems, and Components
STB	Surface Transportation Board
UF_6	Uranium Hexafluoride
U.S.	United States
U.S. EPA	U.S. Environmental Protection Agency
USEC	United States Enrichment Corporation
WCS	Waste Control Specialists

1.0 EXECUTIVE SUMMARY

This report has been developed to satisfy requirements stated in contract DE-NE0008934 under subcontract number SODI-ESP-0004 issued by Southern Ohio Diversification Initiative (SODI) to Orano Federal Services (OFS). The United States (U.S.) Department of Energy (DOE) is exploring options for providing carbon-free electricity to the grid as well as high-quality, carbon-free heat to support non-grid industrial needs which can be produced by small advanced nuclear reactors in an integrated energy system.

The purpose of this report is to assist the DOE and other interested stakeholders in the evaluation and potential reuse of sites as locations for new missions including advanced reactors. DOE and other site stakeholders are either planning or actively performing decommissioning activities which present a unique opportunity to repurpose the existing assets for continued benefit to the public.

This report also considers the application of modern decommissioning techniques which have been and/or are currently used at commercial facilities for possible use at DOE sites and an assessment of the Portsmouth Gaseous Diffusion Plant's current infrastructure status including considerations for the assessment of infrastructure at other similar sites being considered for reuse. Based on the evaluation of the infrastructure at the Portsmouth Site as well as generic sites, several major conclusions are captured in this report.

In cases where a formerly active DOE site is undergoing the Decontamination and Decommissioning (D&D) process, it is recommended that a Community Reuse Organization (CRO) approach DOE with a clear business plan for site reuse as soon as practical. This proposed business plan should clearly define the future use of the site or portion of the site as well as relevant factors that the DOE can act upon. By providing the DOE with well-defined objectives for beneficial reuse of DOE properties, both parties may be able to negotiate a mutually satisfactory outcome that best uses the DOE's resources and provides the community with economic opportunities that otherwise would go unrealized. It is also important to emphasize the importance of the CRO to maintain an ongoing dialogue with the DOE.

Existing site infrastructure at the Portsmouth Gaseous Diffusion Plant Site (PORTS) as well as generic sites were evaluated for possible reuse to support the construction and operation of advanced reactors. Advanced reactor designs vary greatly and, as such, their respective needs for infrastructure vary as well. Once specific advanced assessments for each of the leading designs are performed, it is recommended to closely match infrastructure needs to both the PORTS site and generic reuse sites to determine needs and ensure availability and preservation of existing infrastructure.

This report also provides an assessment of the applicability of current commercial D&D practices and evolving technology at former operating DOE facilities. This report provides generic recommendations for D&D techniques that are based on recent commercial experience. These recommendations would support D&D of a future advanced reactor at a previously used site such as PORTS once reaching the end of the operating license. It is important to incorporate long term D&D planning that includes future reuse scenarios that utilize existing infrastructure to the greatest extent practical. Furthermore, by applying modern D&D technology to large scale decommissioning projects, there could be considerable opportunity for savings in cost and schedule. More importantly, improvements in ALARA (as low as reasonably achievable) and personnel safety can be achieved by incorporating detailed planning that includes 3-D modeling, remote segmentation, and efficient waste packaging/handling techniques.

2.0 SITE HISTORY

Uranium enrichment began in the early 1940s as a U.S. defense initiative to produce fissionable material for the atomic bomb. The enrichment program was eventually transferred to the Atomic Energy Commission (AEC), and the nation's first gaseous diffusion plant, K-25, at Oak Ridge, Tennessee, went online in 1945. In August 1952, the AEC selected a tract of land in the Ohio Valley along the Scioto River in Pike County for the site of the Portsmouth Gaseous Diffusion Plant. Site selection was based on the availability of a vast expanse of relatively flat terrain with the original tract of 4,000 acres and availability of large amounts of electrical power, a dependable source of water, local labor, and suitable transportation routes.

In March 1956, the PORTS facility was completed six months ahead of schedule by construction contractor Peter Kiewit Sons of Nebraska at a cost of $750 million, which was considerably less than the estimated $1.2 billion construction cost. Construction required 69 million man-hours, more than 68,000 drawings, and as many as 22,500 construction workers at its peak in the summer of 1954. There were more than 1,200 acres cleared and more than 4.5 million cubic yards of earth moved during construction. In the 1960s, the mission of PORTS changed from enriching uranium for nuclear weapons to one focused on producing fuel for commercial nuclear power plants.

PORTS and its sister facility in Paducah, Kentucky, worked in tandem to enrich uranium for use in commercial nuclear power plants. The Paducah plant enriched Uranium-235 up to 2.75% and then shipped it to PORTS for further enrichment to approximately 4-5%. The DOE PORTS Reservation established in 1952 produced highly enriched uranium for military use until 1991 and became a major producer of low enriched uranium for use in nuclear power generation facilities from the late 1960s until 2001.

In the early 1980s, DOE built a separate Gas Centrifuge Enrichment Plant (GCEP) at Portsmouth. Two 303,000 square foot process buildings, a centrifuge recycle and assembly building, and several support facilities were constructed before the project was terminated in 1985 before going into full production.

An extensive environmental cleanup program began at PORTS in 1989 as a result of a Consent Decree signed between DOE and the state of Ohio and an Administrative Consent Order with DOE and the U.S. Environmental Protection Agency (U.S. EPA) (amended in 1997 to a tri-party agreement between DOE, U.S. EPA, and Ohio EPA).

In July 1993, the United States Enrichment Corporation (USEC) assumed the uranium enrichment operations from DOE at PORTS and Paducah gaseous diffusion plants in accordance with the Energy Policy Act of 1992. USEC leased and operated the plants from

DOE to enrich uranium as a government corporation. Regulatory oversight of the enrichment plants officially transferred from DOE to the Nuclear Regulatory Commission in March 1997. USEC completed the privatization process in July 1998 and became USEC Inc., an investor-owned corporation.

Uranium enrichment operations at PORTS were discontinued in May 2001, and the plant was placed in cold shutdown in September 2005 at the request of DOE. As part of cold shutdown, PORTS systems were permanently disengaged and equipment was prepared for eventual D&D. USEC returned the PORTS facilities to DOE in 2011 for performance of D&D activities. Currently, the site is undergoing the D&D process under direction of the DOE by contractors selected by the DOE. It is expected that the overall process will be completed in FY 2035.

3.0 MODERN D&D METHODS

This section provides an applicability assessment of current commercial D&D practices and evolving technology at former operating DOE facilities.

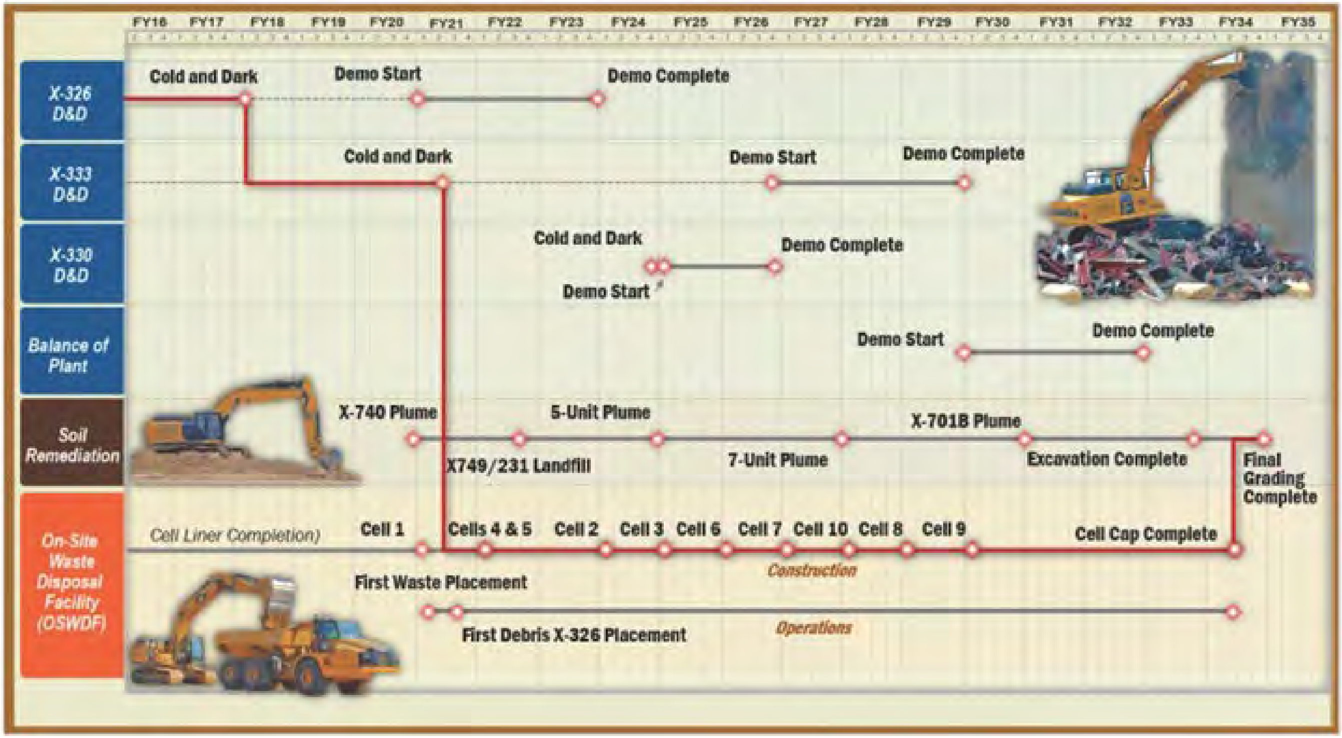
3.1 Review of PORTS Site Decommissioning Plan

The PORTS site decommissioning plan was not made available for review over concerns that suggested changes could affect public acceptance of the current negotiated ROD with the State of Ohio. Further, renegotiation of the agreed upon ROD could impact the current bid processes for the PORTS D&D contractor. Instead of reviewing the decommissioning plan, the SODI team reviewed the following documents:

- 2015 06-30, PPPO-03-3018616-15, FINAL ROD for the WD Evaluation Project [R-3].
- DOE EA-1856, PORTS Property Conveyance Final EA, 06-29-17 [R-1].
- Portsmouth & Paducah Fiscal Year 2019-2023 Real Property Five Year Site Plan, September 2019 [{R-?}].
- DOE GNEP Detailed Site Report, Portsmouth Reservation, Piketon, Ohio, Affected Environment and Regulatory and Environmental Permitting/Licensing Requirements [R-16].
- Fluor-BWXT I Portsmouth, FBP-DD-UT-PL-0001, Rev. 7, Utilities Infrastructure Plan [R-45].
- Portsmouth D&D Critical Path Summary (see Figure 3-1).

These documents provide a reasonable view of the scope of the PORTS Site decommissioning as well as the general approach. Based on review of these documents, the project team's D&D subject matter experts have concluded that the decommissioning is progressing in a logical manner using lessons learned from both PORTS and commercial decommissioning. Therefore, there are no specific recommendations for the application of modern decommissioning techniques to the PORTS site; however, modern D&D methods presented in this document can be evaluated for PORTS and other potential D&D activities and projects.

Figure 3-1: Portsmouth D&D Critical Path Summary



3.2 D&D Techniques Based on Commercial Technology and Experiences

The following provides generic recommendations for D&D techniques based on recent commercial experience. These recommendations would support D&D of a future advanced reactor at a previously used site such as PORTS once reaching the end of the operating license.

3.2.1 Project Planning and General Considerations

Planning, as with most projects, is critical for the success of a D&D project. D&D of a once operational nuclear facility, site and/or commercial power reactor, including an advanced reactor, will entail carefully planned and executed activities such as reactor deactivation and de-fueling, dismantlement of the highly radioactive reactor and the reactor primary cooling support systems, as well as potentially contaminated secondary support systems, structural surfaces, systems, and components (SSCs), and remediation of impacted environmental areas. Unlike other more conventional projects, proper planning for D&D of a nuclear facility must start with a technical activity rather than typical Work Breakdown Structure and schedule development.

According to the guidance provided by the U.S. Nuclear Regulatory Commission (NRC) in NUREG-1757, Consolidated Decommissioning Guidance [R-75], the initial D&D technical activity is to perform the radiological characterization of the SSCs to be decommissioned. For bulk-type SSCs such as buildings, process piping, cable trays, and similar, this is a relatively simple process that can often be done using historical knowledge and/or a sampling process as described in NUREG-1757 for a Group 1 Decommissioning site up to a comprehensive site characterization for a Groups 5 through 7 Decommissioning site. The NRC together with the U.S. EPA and DOE has published detailed guidance for the performance of this type of characterization (NUREG-1575, Rev. 1, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)) [R-76]. See Figure 3-2 for the Table of Contents of an example site characterization report. The characterization of highly radioactive components, such as a power reactor and its internals, requires a more analytical approach, which is described below.

Performing site characterization using historical data in conjunction with surveys and sampling performed according to a characterization plan developed in compliance with MARSSIM guidance will define what SSCs and/or environmental soil areas (environs) are radiologically impacted and what are non-impacted. Delineating impacted from non-impacted SSCs and/or environs must be known during planning and before waste generating activities begin to determine the most effective methods for remediation of impacted SSCs and/or environs for waste handling, packaging, shipping, and disposal. Waste types generated from reactor D&D include the following:

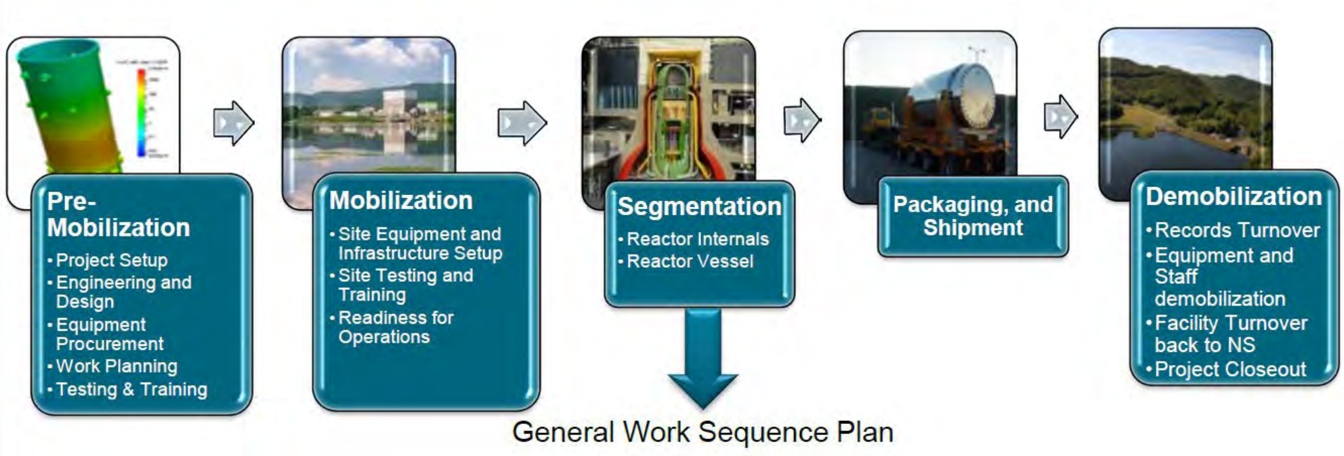
- Radiologically clean construction and other debris.
- Decommissioned materials or very low-level radioactive waste.
- Low-level radioactive waste (LLRW) – Class A, Class B, or Class C per 10 CFR Part 61 [R-77].
- Greater than LLRW Class C (GTCC).
- High-level radioactive waste – spent fuel.

Up to half of the decommissioning cost can be attributed to waste packaging, shipping, and disposal, which necessitates the need to adequately characterize the packaging, shipping, and disposal of waste generated from D&D. Knowledge gained from characterization is the basis for Licensee Termination Plan and DCE development and is of the utmost importance to estimate, plan, and successfully perform all downstream D&D processes.

Once characterization is complete, decisions can be made as to where D&D generated radioactive waste will be disposed and how this waste will be processed (segmented), packaged, and transported. This process is discussed below and is also shown in Figure 3-3. With these decisions in place, proper planning for D&D can be performed.

Figure 3-2: Example Site Characterization Report TOC

Figure 3-3: Reactor Segmentation General Work Sequence Plan



3.2.2 Radiological Considerations

As discussed above, bulk commodities with relatively low levels of radioactivity can be adequately characterized for packaging, shipping, and disposal using historical data in conjunction with surveys and sampling performed according to a characterization plan developed in compliance with MARSSIM [R-76] guidance or as required to develop an accurate estimate of the concentration of radionuclides important to waste disposal, consistent with typical practices.

The most accurate means to characterize more highly radioactive, activated components is Neutron Activation Analysis (NAA). NAA is a tool that has been used for determining radiological characteristics of activated SSCs, power reactors, and their internal components. The NAA will provide calculation of radioactivity specific to component geometry, chemistry, and irradiation history.

The NAA, which has been refined over time, is scalable based on the complexity of the components to be analyzed. Increasing accuracy with the goal of minimizing segmentation, packaging, transportation, and disposal costs can be provided through progression from 1-Dimensional models to 3-Dimensional (3-D) models. 3-D NAA provides the most detailed component activation gradients, which can be used to define accurate cut lines and optimize shipping package segregation.

In addition, shipping package shielding can be optimized using source terms derived from the NAA. Also, the NAA can be used to characterize activated components for disposal.

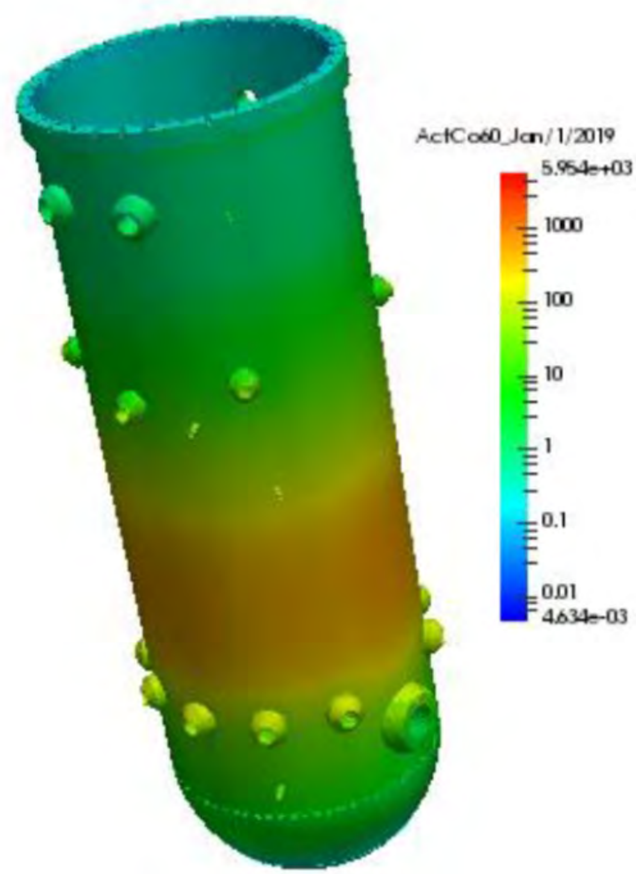
The NAA consists of the following tasks based on the required input data:

1. Develop a geometrical model of the activated component(s). The model detail should reflect the complexity of the component geometry and radiological condition.
2. Determine cross sections for the materials and components in the geometrical model.

3. Develop a core source term based on available irradiation history data. Methodology data ranging from pin-by-pin by axial node powers for hundreds of time steps per cycle to simple core and cycle averages over multiple cycles can be accommodated.
4. Perform detailed neutron transport calculations for using the core source term developed for the available irradiation history data.
5. Develop “maps” of fluxes, adjust these fluxes by the benchmark data to normalize them, and determine the fluxes seen by the various components over time.
6. Results from the above models provide the fluence input to determine specific activities for purposes of performing waste classification analyses. The ORIGEN-S tool from Oak Ridge National Laboratory SCALE suite of tools and libraries is often used to determine the specific activities of components. Read more at: https://www.ornl.gov/scale

See Figure 3-4 for an example of NAA results.

Figure 3-4: Example Reactor Vessel NAA Results



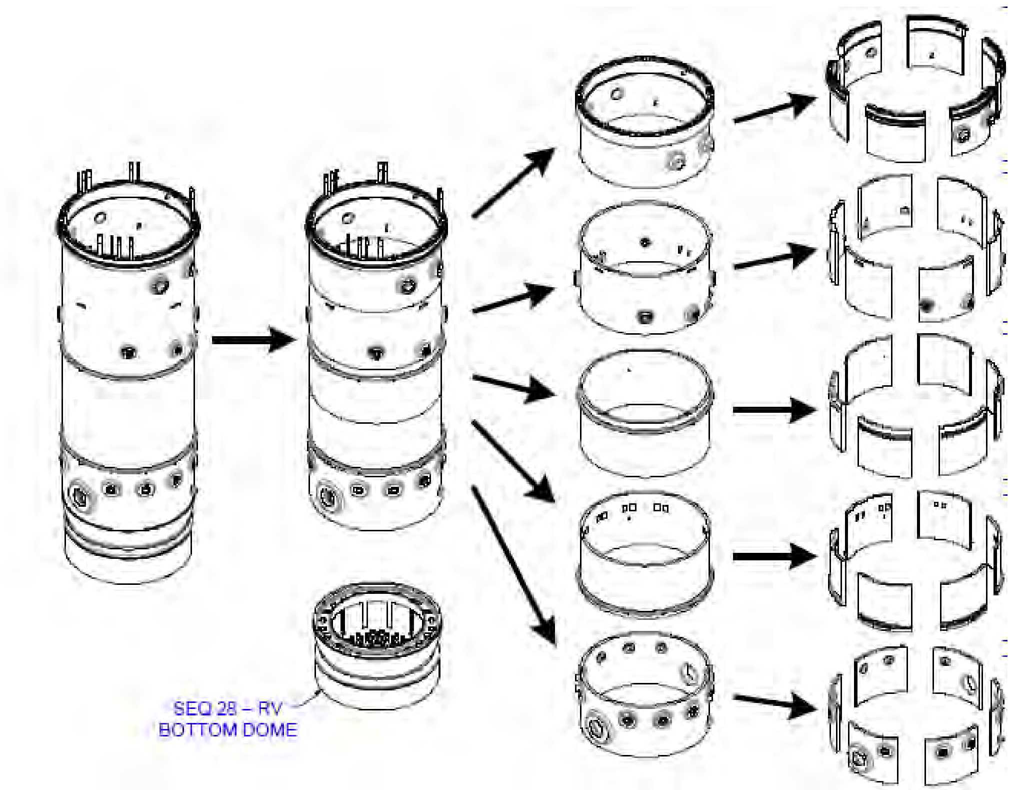
3.2.3 Infrastructure Considerations

In general, larger packages of radioactive waste are more economical to ship and dispose while minimizing the effort to downsize the waste. The infrastructure available to support handling and transporting waste packages is a key input in determining what size package can reasonably be shipped economically. Key infrastructure items include building size and access, crane capacity and reach limits, particularly within site structures, onsite haul path size and weight limits, and size and weight limits imposed by the transportation infrastructure (road, rail, barge) between the site and waste disposal facility.

As examples of impact of infrastructure on packaging and shipping, the Maine Yankee, Connecticut Yankee, Trojan, SONGS Unit 1, LaCrosse reactor vessels, and West Valley melters were shipped for disposal mostly intact along with the majority of their internal components (See Figure 3-5). However, Vermont Yankee, principally because of the limits imposed by access to the site, has chosen to fully segment the reactor vessel and its internal components (Figure 3-6). Typically, the presented methodologies that follow can be applied to various large, contaminated vessels; the larger and more contaminated the vessel the more beneficial the segmentation results.

Figure 3-5: Figure showing MY, CY, and Trojan RV Packages

Figure 3-6: VY Reactor Segmentation Plan



3.2.4 Waste Disposal Considerations

Another key input to D&D planning is the final destination of the radioactive waste, whether onsite or at a licensed disposal site. Planning inputs from this decision include site waste acceptance criteria and transportation access (road, rail, barge, and associated size and weight limits).

The waste acceptance criteria determines what forms and types of waste the disposal facility can accept. For example, the Energy Solutions facility in Utah can accept LLRW Class A but cannot accept LLRW Class B or Class C per 10 CFR Part 61 [R-77], whereas the Waste Control Specialists (WCS) facility in Texas can accept Class A, Class B, and Class C LLRW.

3.2.5 Waste Packaging and Transport Considerations

Once the above information regarding characterization, infrastructure, and disposal site has been gathered, the process of developing segmentation and packaging plans can begin. It should be noted that this process (as discussed in Sections 3.2.3, 3.2.4, and 3.2.5) is iterative.

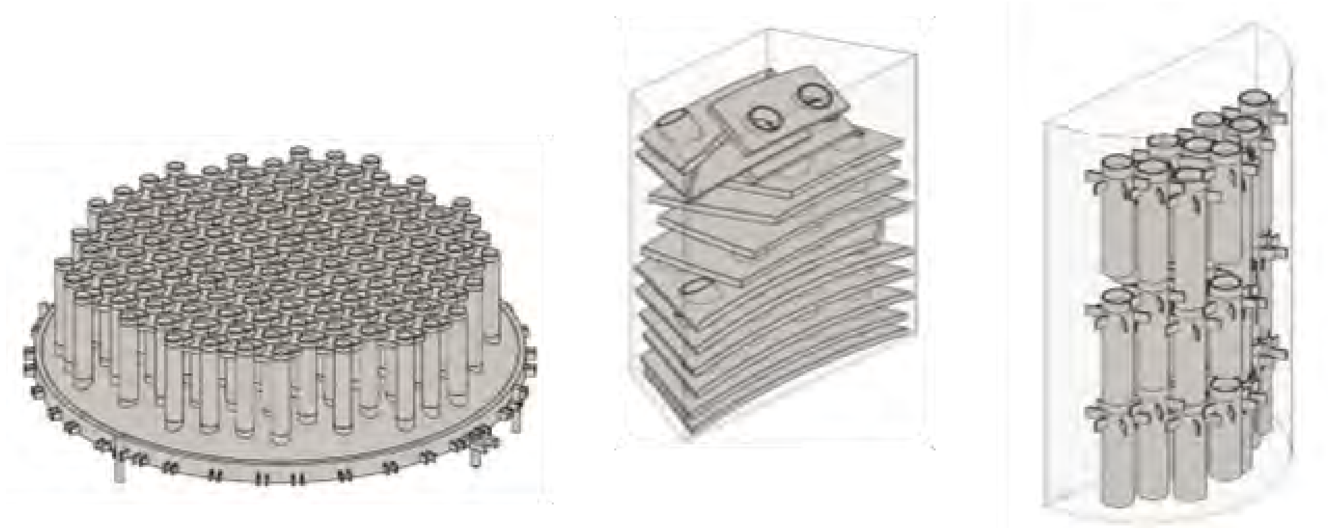
Key drivers for segmentation and packaging include:

- Minimizing cuts and maximizing size of low activity components.
- Using the largest shipping boxes that meet size and weight constraints of handling and transport via rail.
- Meeting radiological constraints, typically 2-meter unshielded dose.
- Minimizing the number of higher activity containers such as RT-100, 8-120B, etc.
- Planning segmentation to minimize Class B and Class C radwaste.
- Minimizing overall number of radwaste containers.
- Requires sometimes intricate cutting and loading planning.
- Using staging baskets to sequence work and loading.

For low radioactivity bulk commodities such as concrete rubble and soil, the most cost-efficient means of transport is rail. As needed, covered and/or shielded rail cars are available for transport.

The next step in developing packaging and transport plans for higher radioactivity, more complex SSCs (e.g., reactor vessels and internals) is development of 3-D models using software such as SolidWorks® or similar along with choosing the waste packaging (see Figure 3-7).

Figure 3-7: SolidWorks Segmentation Model



3.2.6 Concrete Decontamination

As the primary material of construction for nuclear facilities, concrete naturally represents the largest fraction of contaminated material in decommissioning plants by surface area. Particularly challenging in the decontamination of concrete is the variable depth of contamination resulting from the porosity of the material, presence of cracks and penetrations, and history of the various concrete structures in a typical nuclear power plant. This typically translates to the need for iterative labor-intensive survey work during the planning and execution of concrete decontamination projects. Moreover, currently used techniques for decontamination of contaminated concrete are generally slow and labor-intensive to apply and changes / advancements in these techniques have been limited in the past 20 years. Where performed, decontamination of concrete thus remains a major activity during decommissioning projects.

Appendix C, Concrete Decontamination presents currently available and developing concrete decontamination techniques to assess (1) the state of readiness of these techniques for deployment at commercial nuclear power plants and (2) the ease of use and effectiveness of these concrete decontamination techniques.

3.2.7 Development of Digital Tools for Decommissioning

Development and deployment of digital tools is a rapidly growing area in decommissioning. A workshop series, DigiDecom (www.digidecom.com), has been established to cover the general topic. The workshop is managed by IFE (Norway). The next workshop is scheduled for October 2022 and will be held as a hybrid event (that is, in person in Norway or virtual participation via Zoom). A comprehensive review of this topical area would be difficult, but some highlights are provided below.

Artificial Intelligence/Machine Learning (AI and ML): researchers in the U.S. (e.g., Florida International University, FIU) and Europe (for example, iUS in Germany) are beginning to explore ways in which AI/ML may be beneficially used to support decommissioning. However, limitations in the availability of data for commercial reactors is seen as an obstacle.

Virtual Reality/Augmented Reality: As with AI/ML, many researchers in the US and Europe are developing uses of VR/AR to support work in nuclear facilities, primarily in the areas of training and work planning. As examples, technology developed by FIU are currently in use within the DOE and SOGIN has developed VR and AR tools for use with an integrated digital twin for decommissioning activities at their Garigliano plant.

Remotely Operated Vehicles/Unmanned Aerial Systems (ROV/UAS): EPRI report 3002010599, Evaluation of System Automation and Robotics for Decommissioning Applications, and Section 6 of the SHARE project report D3.1 Detailing Applicable Technologies/Methodologies provide an overview of some ROV/UAS in use at nuclear facilities. While too numerous to cover here, many other systems are in use or under development. Some examples include an autonomous system for radiological characterization developed by EPRI (see EPRI 3002018420, Design and Demonstration of an Autonomous System for Radiological Characterization).

Concerns with physical and cyber security related to use of autonomous systems are very site specific, but such concerns have largely been manageable with minimal effort.

Global Information Systems/Building Information Models (GIS/BIM): The use of BIMs to support decommissioning planning, worker training and communications has become more common during the past five years. Some examples include the Zion and SONGS projects in the U.S., the Garigliano project in Italy and the Bohunice project in the Czech Republic.

To-date, applications have been performed using customized approaches developed by vendors or utilities using commercial software so there is no standard approach. For example, BIM development service in the U.S. is provided by Radiation Safety and Control Services (RSCS), and Nucleco provides BIM development service in Italy. To address this, the European Commission has funded project PLEIADES to provide guidance and standardization for BIM development. The project is scheduled to conclude in 2023 (see https://pleiades-platform.eu/).

3.3 ALARA Planning and Implementation

3.3.1 Initial Planning and Updates

The goal of an ALARA plan is to maintain dose to workers as low as reasonably achievable. The scope of the ALARA plan will include all activities and work groups associated with work in radiologically controlled areas as well as handling of radioactive materials in all areas. The plan is typically a project level document.

The initial ALARA plan will be based on planning information such as segmentation and packaging plans and site characterization data. The plan should evaluate and establish specific RP controls and establish radiological control criteria to ensure safety and maintain radiation exposures ALARA. A primary method to maintain exposure ALARA focuses on the use of established work practices, facility and equipment design features, and specialized engineering controls. The plan will establish and track a total project dose goal. Additionally, sub-dose goals as needed to track the larger sub-projects should be established. See Figure 3-8 for an example ALARA plan table of contents.

The plan should be updated on an ongoing basis to incorporate changes in project scope, methods, and goals and as radiological conditions become better known.

Figure 3-8: Example ALARA Plan TOC

3.3.2 Implementation

3.3.2.1 Dry Segmentation

A key consideration for dry segmentation of radioactive components is contamination control, as segmentation operations can cause dispersal of both loose and fixed radiological contamination. The worst case is if contamination becomes airborne.

Minimizing airborne contamination can be successfully performed using:

- Isolation of the component with temporary or permanent tents of other enclosures. Temporary enclosures constructed from scaffolding components and Herculite or similar can easily be erected and dismantled. As needed, filtered ventilation can be added.
- Choice of segmentation method. Thermal methods generally have the highest potential to disperse contamination, while mechanical methods generally result in minimal

dispersal. If mechanical methods are not appropriate, thermal segmentation in an enclosure with appropriate ventilation can be performed with minimal dispersal. It should be noted that flame retardant materials may be needed and ventilation may become complicated.

- Application of fixatives. The application of fixatives, typically a latex paint or similar, is widely used to prevent dispersal of radiological contamination. Depending on area dose rates, the fixative can be applied with rollers or brushes. Where area dose rates are higher, remote application methods using spray are appropriate.

3.3.2.2 Underwater Segmentation

Underwater work at depths greater than about 5 feet generally provides sufficient shielding to minimize worker dose. Another benefit is that the risk of airborne contamination is minimized, provided some precautions are taken.

Precautions to prevent spread of contamination include isolation of cutting and segmentation areas and active filtration of both bulk and isolated pools of water.

3.4 Segmentation Tooling

Factors driving the choice of segmentation tooling include:

1. Packaging plans: Packaging into smaller packages requires finer and more precise cutting.
2. Radiological conditions: Segmentation of higher dose components will require underwater and/or remote cutting.
3. Site conditions: Key considerations are available space and condition of the site infrastructure including availability of water, air, power, and cranes.
4. Cutting technologies: Efficiently applying various cutting technologies to a range of cuts and components (i.e., flexibility to make different cuts on different components) minimizes costs associated with equipment and spare parts, reduces time needed for operator training, and reduces equipment setup times.
5. Technology use: Use of proven, readily available technologies will reduce or eliminate risks associated with one-off or custom tooling.

3.4.1 Component Size Reduction

Segmentation tooling can be divided into four general types:

- Thermal (torch, plasma arc);
- Large mechanical (saws, milling machines, diamond wire saws);
- Water abrasive; and
- Small tools such as band saws, jig saws, and shears.

Advantages and disadvantages of each of the first three types are described below. Small tools are used to make specialty cuts and/or dismantlement, not the types of production cuts performed using thermal, large mechanical, or water abrasive tooling. Listings of typical small tools and potential uses are also provided below. See Figure 3-9 through Figure 3-13 for example tools.

Table 3-1: Thermal Tool Segmentation Considerations

Pros	Cons
Substantial experience cutting highly radioactive components	Control of off-gases and cutting byproducts from RAD and HAZMAT (e.g., hexavalent chromium from stainless steel)
Can cut quickly	Most suitable for cutting in dry conditions • If used underwater, difficulty controlling generation of bubbles and subsequent airborne contamination and high pool surface dose rates
Flexible – can cut varying thicknesses and geometries	
Relatively insensitive to maintaining the kerf	
Remote from cut line, minimizing potential to become stuck	
Relatively easy setup	

Table 3-2: Large Mechanical Tools Segmentation Considerations

Pros	Cons
Substantial experience cutting highly radioactive components	Minimal Flexibility • Generally, must be specifically designed for the component and geometries to be cut
Suitable for cutting in dry or underwater conditions	Relatively complicated setup and requires higher level of operational expertise
Can cut quickly	Can be messy, depending on lubrication use
Clean – minimal byproducts	Sensitive to maintaining the kerf
	Cutting mechanism has the potential to become stuck in cut line

Table 3-3: Diamond Wire Saw (DWS) Segmentation Considerations

Pros	Cons
Flexibility • Material that can be cut • Geometries that are supported	Slow
Suitable for cutting in dry or underwater conditions	Underwater use has perceived RP challenges
Clean – not many byproducts	Can be messy, depending on amount of water lubrication used
Mechanical cutting technology, but reaction forces are very low	Underwater use has perceived RP challenges Sensitive to maintaining the kerf
	Wires will break or get stuck
	May need to create guide holes, typically by drilling

Table 3-4: Water Abrasive Tools Segmentation Considerations

Pros	Cons
Effective underwater	High secondary waste volume
Has lots of flexibility • Geometry • Material thickness • Material composition	Filtration and water clarity • Requires scheduled settlement time • Abrasive is difficult to filter
Works fairly quickly, depending on thickness	System itself requires constant monitoring, maintenance, and repair • Can restrict uptime • Cost and schedule impact
Low reaction force	Relatively complicated setup and requires higher level of operational expertise
Low radiological impact in terms of releases during operation	Relatively insensitive to maintenance of kerf
Because there is such flexibility, it allows more efficient segmenting and packaging of high-activity components	

3.4.2 Miscellaneous Small Tools

Following is a list of small tools recommended to supplement the larger segmentation tooling listed above.

- Portable band saw
- Portable jig saw
- Hydraulic shears
- Standard magnetic attachment drill
- Impact wrench (in multiple sizes, torque ranges)

Saws and shears are efficient and cost effective for performing smaller or specialty cuts that are not done efficiently by larger tooling.

3.4.3 Nozzle and Pipe Segmentation

There is extensive experience in cutting pipes, particularly at vessel nozzles in radiological environments. For smaller, thinner pipe, mechanical cutting using standard pipe cutters or Sawzall type saws is the standard approach. In addition, where radiological conditions allow, thermal methods can be utilized.

For more substantial (thicker, larger diameter) piping and, in particular, reinforced nozzles at vessels, split lathe type cutting tools (or similar) are extremely effective. Another benefit of split lathes is the actual cutting can be monitored remotely with only setup and take down required to be hands on. This will result in a substantial reduction in personnel dose in high dose areas. In addition, there is only minor secondary debris (metal chips, shavings) generated that is very easy to control. Another benefit is that split lathe tooling is easy to clean and decontaminate.

Drawbacks to use of split lathes is that split lathes are designed for cutting only a narrow range of pipe diameters. If a vessel has multiple nozzle sizes, such as a boiling water reactor vessel, then multiple split lathes will be required. See Figure 3-13 for an example split lathe.

DWS is an alternative that has been used for large diameter, large material thickness piping including Pressurized Water Reactor (PWR) coolant system piping at reactor vessel nozzles. DWS benefits include the ability to effectively cut larger diameters and thicknesses than split rings, to cut through differing adjacent materials such as carbon steel pipe with stainless steel safe ends with no change to the cutting wire, and to be operated remotely. There is essentially no limit to the diameter size or material thickness that can be cut with DWS. An additional key benefit is that DWS can readily be adapted to cut sloping geometries such as those associated with larger diameter reinforced vessel nozzles.

Under similar conditions, DWS setup and actual cutting times can be significantly greater than with split rings.

Figure 3-9: Thermal Cutting System

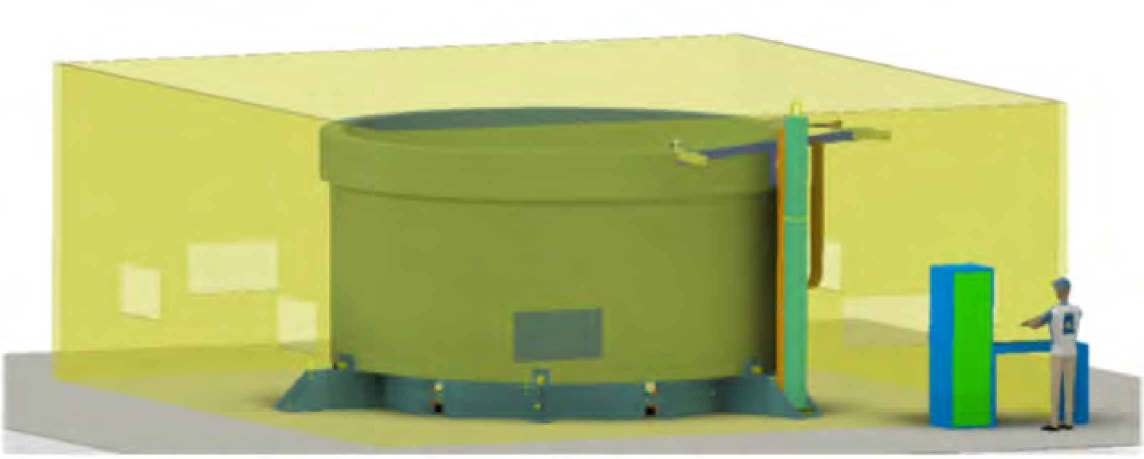


Figure 1 - RAST on Refuel Floor with Modular Containment and RV Ring 1

Figure 3-10: Mechanical Cutting System

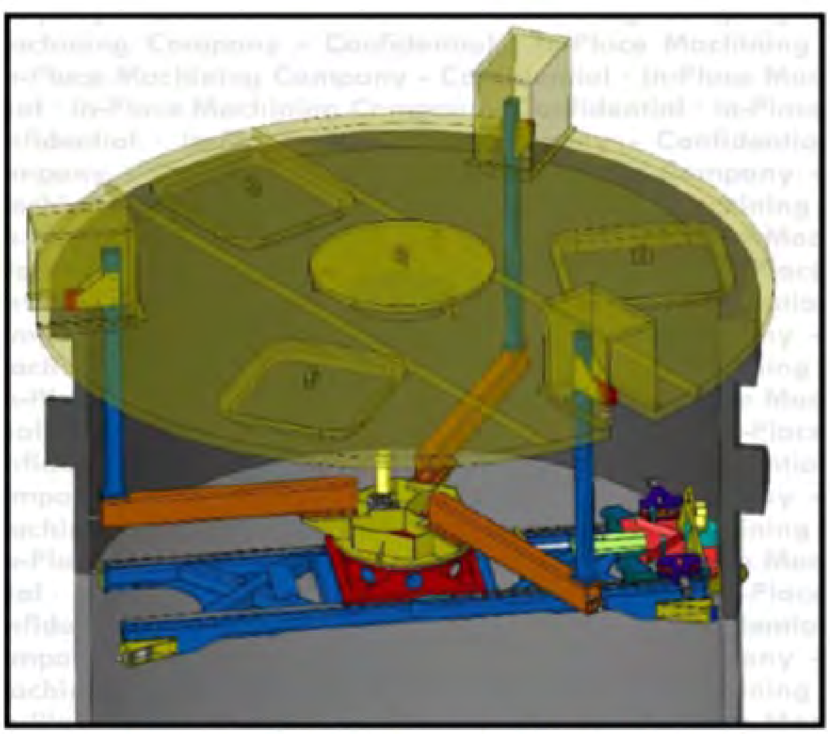


Figure 1- Section Through Reactor Vessel

Figure 3-11: Water Abrasive Cutting System

Figure 3-12: Underwater Bandsaw

Figure 3-13: Example Split Lathe

3.5 Primary and Secondary Radwaste

3.5.1 Greater than Class C LLRW

Low-level radioactive waste is defined in U.S. regulations as radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or uranium mill tailings. The NRC regulates disposal of LLRW and developed a classification system categorizing LLRW as Class A, Class B, or Class C. Wastes exceeding the LLRW classifications with radiological content greater than the limits of Class C waste are referred to as greater than Class C (GTCC) waste as defined in 10 CFR Part 61.

3.5.2 Commercial GTCC LLRW

GTCC waste from commercial sources regulated by the NRC, such as a nuclear power plant decommissioning, is not currently eligible for near surface disposal. Further, there are no commercially available licensed disposal facilities for NRC regulated commercial GTCC waste. GTCC waste types include:

- Activated metals – irradiated metal components as well as filters and resins from reactor operations and decommissioning.
    - o Common radionuclides include Ni-63, Ni-59, C-14, Tc-99, and Pu-239.

- Sealed sources – radioactive material that is sealed in a capsule ranging in size from a few millimeters to tens of centimeters
    - Common radionuclides include Cs-137, Am-241, Pu-238, and Pu-239.
- Other waste – wide range of physical forms and radionuclides from a wide range of sources (e.g., scrap metal, filters, rubble, sludges).
    - Can include Pu-239, Pu-240, Pu-238, Am-241, Cs-137, Sr-99.

Currently, GTCC waste from commercial sources is packaged and stored at NRC licensed Independent Spent Fuel Storage Installations (ISFSIs) co-located at each respective nuclear power plant site. The U.S. Government, specifically the DOE, is responsible for disposal of commercial GTCC waste, but only in a licensed geologic disposal cell that does not currently exist.

10 CFR 61.55(a)(2)(iv) states that GTCC waste is generally not acceptable for near-surface disposal and must be disposed of in a geologic repository unless a proposal for disposal is approved by the NRC after being evaluated on a case-by-case basis.

There may be some instances where GTCC waste would be acceptable for shallower than geologic disposal if the NRC found it to be safe and acceptable after a case-by-case technical evaluation. Shallower than deep geologic disposal could either be near-surface disposal (30 m below the earth's surface or less) or deeper than near-surface disposal (i.e., intermediate depth disposal).

In 2016, the DOE issued an Environmental Impact Statement (EIS-0375) to allow for disposal of GTCC waste. EIS-0375 can be accessed at the following link:

https://www.energy.gov/nepa/eis-0375-disposal-greater-class-c-low-level-radioactive-waste-and-department-energy-gtcc-waste

However, a Record of Decision (ROD) has yet to be issued, awaiting a decision from the U.S. Congress. Since the DOE sent the EIS report to Congress in 2017, the DOE issued an Environmental Assessment (EA) on disposal of GTCC-like material at WCS as one of the preferred alternatives in the 2016 EIS, but this too requires congressional approval. The EA can be accessed at the following link:

https://www.energy.gov/sites/prod/files/2018/11/f57/final-ea-2082-disposal-of-gtcc-llw-2018-10.pdf

3.5.3 DOE GTCC LLRW

DOE owns and/or generates non-commercial LLRW which have characteristics similar to those of commercial GTCC LLRW. This waste is referred to by the DOE and NRC as GTCC-like waste. The NRC does not have regulatory authority over the DOE's GTCC-like waste. The DOE GTCC-like waste is eligible for disposal at DOE disposal facilities.

DOE generated GTCC-like waste from DOE sources is eligible for disposal in accordance with DOE Order (O) 435.1, Radioactive Waste Management, as implemented by DOE Manual (M)

435.1, Radioactive Waste Manual. DOE facilities governed by DOE Order 435.1 use a performance assessment/composite analysis to set limits for disposal. Using the performance assessment/composite analysis process allows some wastes that would be considered NRC GTCC if disposed commercially are acceptable for disposal at the DOE's Nevada Nuclear Security Site.

Pending decision from U.S. Congress on the EIS and EA discussed in the previous section, there may be other sites that may be able to accommodate DOE facility generated GTCC waste. One of the preferred disposal alternatives in the 2016 EIS was the WCS Federal Waste Facility in Andrews, Texas.

3.5.4 Commercial GTCC LLRW Packaging

To date, commercial reactor GTCC waste has been packaged in storage systems based on 10 CFR Part 72 licensed spent fuel storage systems. These spent fuel storage systems typically consist of welded stainless steel canisters or liners which are placed into concrete storage modules. Specifically designed casks are used for onsite transfer of loaded canisters from wet storage (typically a spent fuel pool) to storage modules. Storage modules are located on an ISFSI facility designed in accordance with 10 CFR Part 72 [R-78] requirements.

GTCC storage systems utilize the same canisters used for spent fuel minus the grids used for placing spent fuel grids. Storage modules are identical to those used for spent fuel.

Use of a storage system essentially identical to a spent fuel system has a number of advantages. These advantages include:

1. Familiarity with the process of preparation for storage,
2. Use of a system that is designed and qualified for long term storage of high-level waste,
3. For certain systems, the canister is designed to meet 10 CFR Part 71 transport requirements,
4. Can be co-located with spent fuel on an ISFSI facility with minimal paperwork.

See Figure 3-14 for an example of the Holtec Inc. HI-SAFE GTCC storage system, which is commercially available.

Figure 3-14: Cut-Away View of the HI-SAFE 100 Storage System

3.5.5 GTCC LLRW Transportation

GTCC waste can be transported in systems that are licensed in accordance with 10 CFR Part 71 [R-79] for Type B shipments provided licensed content limits are met. There are a number of licensed Type B systems available which could be used to transport GTCC LLRW including the TN RAM, MP197HB, and CNS 8-120B. The quantity of GTCC waste that can be transported in a single shipment will be limited based on curie limitations imposed by the system license. See Figure 3-15 for a picture of the TN MP197HB shipping cask.

Figure 3-15: TN MP197HB

4.0 INFRASTRUCTURE ASSESSMENT

4.1 Introduction

This report provides an evaluation of the current conditions and potential reuse of existing PORTS infrastructure based on information collected as part of the PORTS site infrastructure assessment. The objective of this assessment is the availability and viability of the existing infrastructure including services, facilities, systems, and structures to support a future advanced reactor siting at a previously used site such as PORTS.

The SODI team has reviewed the PORTS D&D plans and evaluated potential infrastructure, structures, or building foundations that could be reused for a future reactor. Infrastructures such as connection to the electrical grid, rail spurs, and distribution yards were reviewed for reuse. This report identifies the potential infrastructure that could be reused for an advanced reactor demonstration and includes current conditions of the infrastructure, viability of the infrastructure to remain serviceable for a prolonged period to allow for reactor construction, potential buildings to reuse, foundations, or D&D material for reuse in a reactor suitable in siting of an advanced reactor, considering site excavation and construction.

Review of existing infrastructure for reuse has identified short-term actions with potential for immediate positive impact on the advanced reactor community's consideration of PORTS. Long-term considerations identified from the review would have positive impact for the development of the PORTS region for long-term sustainability of an advanced reactor and supporting related higher technology industries. Realizing short-term actions and long-term considerations for PORTS infrastructure improvements would be realized via Infrastructure Bill grant requests. Each grant request would consider social, economic, and environmental justifications and include impact for sustainable reindustrialization, regional growth, and independence from DOE programs as a driving force behind each grant request.

Examples of the considerations for infrastructure needs for future reuse scenarios, specifically Advanced Reactor Siting, are provided by "*Advanced Reactor Siting Policy Considerations,"* ORNL/TM-2019/1197, June 2019 [R-80]. This document is a very useful developmental document and readers are encouraged to reference it as well.

4.2 Services

4.2.1 Community Outreach

Awareness of community needs, concerns, and a pathway for community communications is necessary to advance a former nuclear processing site into a state of commercial reutilization. This section provides insights and considerations into the public outreach supporting overall site reuse.

4.2.1.1 Community Interface

The DOE supports the need for community outreach to facilitate constructive dialog with stakeholders and the public to ensure that information regarding current operations as well as future plans for sites such as PORTS is available, accurate, and accessible. Many communities in the geographic areas of DOE sites have been welcoming and supportive of DOE operations and activities. In many instances, the DOE facilities are the economic engine for an entire region. As such, balancing health and safety concerns with safe and reliable employment continues to be a focus for DOE and community outreach continues to be important for two-way communications with the public and all stakeholders.

Most communities neighboring DOE facilities are generally accepting of ongoing operations and new nuclear technologies. The long history of nuclear operations has produced an informed public and a well-trained workforce. Moreover, many of the facilities are home to continuing nuclear operations. For example, a Centrus nuclear fuel fabrication facility and a depleted uranium hexafluoride (DUF_6) processing facility are located on the PORTS site. Thus, coordination and cooperation are key ingredients to the siting of any advanced nuclear technology. In fact, public outreach and coordination is the cornerstone to community understanding and acceptance of any new project at a DOE site.

In most instances, the geographic footprint of a site encompasses all or part of various political subdivisions. Economic and health issues are not limited to one subdivision. Cooperation or competition between the subdivisions varies with the issue of the day. The shifting political landscape often strains relationships between the subdivisions and causes difficulties for DOE or private industry to reach consensus with the subdivisions relative to any project. Nevertheless, support from the affected communities is crucial to the success of any project. This is particularity true regarding nuclear projects. Fortunately, over the years, DOE has created an organizational structure to deal with these issues – Community Reuse Organizations.

4.2.1.2 Creation of Community Reuse Organizations

On September 27, 1991, President George H.W. Bush signed the first unilateral nuclear weapons agreement, signaling the end of the cold war. The decision would dramatically impact PORTS and numerous other communities where a majority of jobs and industry were related to national nuclear production efforts. The closure of many of the facilities would inalterably devastate the lives of workers and community residents while destroying the economy in the region.

Congress and DOE recognized the impact this national transition would have on the communities. Accordingly, Section 3161 of the Defense Authorization Act of 1993 provided grant funding to affected communities to limit the impact of the economic changes related to workforce restructuring – a restructuring that would affect numerous states, counties, townships, and municipalities. In order to provide a cohesive voice for the various political subdivisions and labor organizations within the new “community transition program,” Congress authorized the use of grant funding to establish “Community Reuse Organizations” (CROs) whose primary function was to act as the sole community voice and liaison to DOE for economic development issues. Although the various subdivisions have at times interjected their voices directly in the process, at the time Congress created the community transition program, most communities took advantage of the funding opportunities that came with the establishment of a CRO. Some of the CROs are:

- Southern Ohio Diversification Initiative at PORTS
- Community Reuse Organization of East Tennessee at Oak Ridge, Tennessee
- SRS Community Reuse Organization at Savannah River, South Carolina
- Paducah Area Community Reuse Organization at Paducah, Kentucky
- Mound Advanced Technology Center near Dayton, Ohio
- Regional Development Corporation at the seven counties surrounding Los Alamos, New Mexico
- Regional Development Alliance, Inc. at Idaho Falls, Idaho
- Tri-City Industrial Development Council at Kennewick, Washington

It is important to note that the structure, viability, and geographic reach of each of these CROs varies greatly. However, as a group, they have helped streamline and advance development at DOE sites where they are located.

4.2.1.3 Authority of a CRO

CROs are authorized to receive excess personal property and excess real property from DOE. Important to restructuring workforce opportunities at any DOE site is industry's ability to obtain real property through transfer, including sales or leases, or public private partnerships with DOE. Title 10, Chapter III, Part 770 of the Code of Federal Regulations outlines the process for the transfer of real property at defense nuclear facilities for economic development. Although transfers of real property are not limited to CROs, 10 CFR 770.4 specifically references and defines Community Reuse Organizations or CROs. That section reads, in pertinent part, as follows:

> *Community Reuse Organization or CRO means a governmental or non-governmental organization that is recognized by DOE and that represents a community adversely affected by DOE work force restructuring at a defense nuclear facility.*

Thus, DOE recognizes that the CRO can often assist in reducing the DOE footprint at a facility while coordinating the use of transferred property with local organizations and political subdivisions.

Two other portions of the transfer process are also noteworthy. DOE may transfer property at less than fair market value and DOE may indemnify the new owner or lessee of the property. The two relevant regulations are 10 CFR 770.8 and 10 CFR 770.9. 10 CFR 770.8 authorizes the transfer of real property at less than fair market value if (a) the real property requires considerable infrastructure improvements to make it economically viable, or (b) a conveyance at less than market value would, in DOE's judgment, further the public policy objectives of the laws governing the downsizing of defense nuclear facilities. Normally a CRO can demonstrate the existence of each of these requirements and receive property at less than fair market value. This in turn allows a CRO flexibility in pricing property and negotiating terms.

10 CFR 770.9 references the indemnification of claims by DOE. Perhaps the most important subsection is 10 CFR 770.9(e) which states:

> *Any indemnification provided will apply to any successor, assignee, transferee, lender or lessee of the original entity that acquires ownership or control.*

This provision provides any new owner or lessee with the confidence that DOE remains responsible for any contamination due to DOE activities that is later discovered. The advantages of working with an established CRO are obvious. Although every CRO places the health and safety of the community ahead of economic development, there is normally an established relationship with DOE that is often less adversarial than some political subdivisions. Likewise, there is normally a familiarity with the real property transfer process with a view toward regional projects. Finally, many of the statutory hurdles of working with political subdivisions are eliminated by working with a CRO.

4.2.1.4 SODI

SODI is the established CRO at the PORTS site. SODI is a 501(c)(3) nonprofit corporation pursuant to Ohio law and a Community Reuse Organization The original Articles of Incorporation can be viewed and downloaded from the Ohio Secretary of State website at the following link:

> https://bizimage.ohiosos.gov/api/image/pdf/5940_0708

Incorporated in 1997, SODI received Section 3161 grant funding and assisted various subdivisions throughout the area with a number of economic development projects. As a nonprofit corporation, SODI’s fourteen-member board consists of representatives of the four counties surrounding the site. Jackson, Pike, Ross, and Scioto Counties have at least one board member. The United Steelworkers that represent onsite workers, the security union, and the building trades have representatives on the board. Centrus, a tenant on the site, also has a representative on the board. Several board members are present or former elected officials of the political subdivisions in the counties. The representatives from Jackson, Ross, and Scioto counties are economic development professionals. This representation provides for a broad range of views regarding the future of PORTS as cleanup continues. It also provides a wealth of experience in dealing with local development issues.

In 2018, DOE transferred approximately 80 acres of land to SODI as the first real property transfer at PORTS. DOE is scheduled to transfer an additional 240 acres to SODI in the fall of calendar year 2022. Approximately one acre of SODI property has been leased to ARS Aleut Analytical LLC, where the company has placed a mobile laboratory to provide services to Fluor-BWXT Portsmouth, LLC (FBP), the current PORTS D&D contractor. In addition, a small portion of SODI property may be used to store railroad materials for reuse at the site, including: 3,700 linear feet of RE132 rail, 1,800 tie plates, and 378 joint bars.

SODI now owns property in the heart of the PORTS site. As a nonprofit corporation, SODI is not subject to the legal restrictions that might be applicable to a political subdivision. Obviously, SODI is subject to laws and regulations governing nonprofit corporations, however, it is not required to follow strict bidding or auction requirements. Thus, the delays and uncertainties of governmental rules and regulations can be avoided through the real property transfer provisions applicable to DOE and SODI.

Since its inception, SODI has worked with all stakeholders in the region to move toward reindustrialization at PORTS. Due to the makeup of the SODI Board of Directors and SODI activities over the years, it is uniquely positioned to bring together DOE, elected officials, the workforce, and community leaders to evaluate PORTS for advanced nuclear technology. The importance of SODI cannot be overstated. Community support is essential to the success of any project that involves deployment of advanced nuclear reactors. At PORTS, SODI has already established itself as a point of information and support with federal, state, and local elected officials as well as numerous community groups. The relationships and influence of SODI, or any CRO, would accelerate the ability of DOE and private industry to introduce an advanced nuclear technology project to the communities served by SODI.

4.2.1.5 Site-Specific Advisory Board

Within the DOE Office of Environmental Management (DOE EM), DOE has created the EM Site-Specific Advisory Board (SSAB). The EM SSAB was created to involve stakeholders more directly in EM cleanup decisions. The basic premise is that public input helps agencies make decisions that are cost effective, community specific, and environmentally sound, which leads to faster, safer cleanups. The current EM SSAB charter can be accessed at the following link:

> https://www.energy.gov/sites/default/files/2020/04/f74/EM-SSAB-Charter-2020-Renewal-signed.pdf.

In accordance with its charter, the EM SSAB exists to provide EM senior management with information, advice, and recommendations concerning issues affecting EM programs at various sites. Specifically, at the request of the assistant secretary or site managers, the board may provide advice and recommendations concerning the following EM site-specific issues: cleanup activities and environmental restoration; waste and nuclear materials management and disposition; excess facilities; future land use and long-term stewardship; risk assessment; and communications. These categories may directly affect decisions of private industry regarding the viability of any site for reindustrialization.

The EM SSAB's activities are governed by the Federal Advisory Committee Act (FACA), which was enacted to ensure that the general public has access to advisory board deliberations and recommendations. FACA has certain specific requirements regarding procedures for notification of the public, meetings, and submission of recommendations. While only one FACA-chartered EM SSAB exists, eight local boards have been organized under its umbrella charter. Among these is the PORTS SSAB. All local site board members are selected by DOE with a view toward membership that reflects a diversity of views, cultures, and demographics from affected communities and regions and is composed primarily of people who are directly affected by site cleanup activities. Members generally include stakeholders from local governments, tribal nations, environmental and civic groups, labor organizations, universities, industry, and other interested citizens. Much like CROs, the local SSABs have relationships with DOE and the communities.

PORTS SSAB has often supported SODI's vision for reindustrialization of the site. Together, SODI and PORTS SSAB have established relationships with DOE and the communities affected by the PORTS cleanup. Such established relationships would advance progress on any advanced technology project due to the communication avenues already created. Furthermore, SSAB acceptance of a project may assist EM in fashioning a cleanup that reduces time and costs for DOE.

The value by phase of a CRO such as SODI is presented in Appendix A, Portsmouth Site Specific Infrastructure Requirements by Phase, for PORTS and in Appendix B, Generic Site Infrastructure Requirements by Phase, for any previously used site. The Site-Specific Infrastructure priority by phase is represented as being high (H), medium (M), or low (L) priority.

4.2.2 Site Emergency Services

4.2.2.1 Emergency Response Assessment

Due to its ongoing nuclear mission, regulatory driven emergency response services are already at PORTS to support an advanced reactor developer. These services include emergency preparedness; emergency medical, fire, and hazardous material (HAZMAT) responders; an existing onsite fire station and supporting equipment; agreements with other area responders; onsite health services building; and emergency response centers.

This section provides information on emergency response requirements, emergency preparedness at PORTS, and emergency response assets of PORTS, all of which are available to support an incoming advanced reactor developer.

4.2.2.2 General Emergency Response Requirements

The DOE and its contractors at PORTS provide emergency response management, preparedness, and services for the PORTS reservation and interfaces with its local community and the State of Ohio. However, to perform these services, emergency response requirements must be uniformly applied to PORTS contractors, leaseholders, and reindustrialization entities. Uniformity in emergency response is guided by uniformity in applied emergency requirements. General requirements are discussed below.

The Emergency Planning and Community Right-To-Know Act of 1986, also referred to as the Superfund Amendments and Reauthorization Act Title III, is an overall reporting requirement for hazardous chemical inventories, releases to the environment, and emergency planning and response information. For emergency planning purposes, facilities must submit information for onsite chemicals present above a threshold planning quantity to state and local authorities.

When a new chemical is brought on site or increased to exceed the threshold planning quantity, information about the new chemical must be submitted to state and local authorities. The Hazardous Chemical Inventory Report includes the identity, location, storage information, and hazards of the chemicals present onsite in amounts above the threshold planning quantities specified by the U.S. EPA. In Section 304 of the Emergency Planning and Community Right-To-Know Act, reporting requirements of offsite releases must be made known to state and local authorities including emergency response authorities. These Emergency Planning and Community Right-To-Know Act reports are submitted to federal, state, and local authorities, including the cognizant PORTS Emergency Response Coordinator. [R-31]

Under the Ohio Environmental Protection Agency and DOE (aka Respondent) agreement for D&D of PORTS titled Director's Final Findings and Orders – Second Modification [R-32], Respondent must supply and maintain a health and safety plan (HASP) (U.S. EPA RI/FS Guidance Section 2.3.3). This plan also incorporates emergency response requirements. As a result of the agreement, the DOE is to flow down requirements to any current or potential contractor, leaseholder, and reutilization entity (defined as owner of adjacent former DOE property). A leaseholder and reutilization entity shall submit for review and comment a HASP that includes monitoring, procedures, and protocols needed to protect the health and safety of those persons conducting site activities, visiting the site, and residing or working in the surrounding community. The HASP will, at a minimum, address the following:

- Facility or site description including availability of resources such as roads, water supply, electricity, and telephone service;
- Description of known hazards and an evaluation of the risks;
- Listing of key personnel (including the site safety and health officer) and alternates responsible for site safety, response operations, and protection of public health;
- Delineation of the remedial action project work area, including a map;
- Description of levels of protection to be worn by personnel in work area(s), including a description of personal protective equipment to be used for each remedial action project task and operations being conducted;
- Description of the medical monitoring program;
- Description of standard operating procedures established to assure proper use and maintenance of personal protective equipment;
- Establishment of procedures to control access to the remedial action project area;
- Description of decontamination procedures for personnel and personal protective equipment;
- Establishment of site emergency procedures, including a contingency plan;
- Availability of emergency medical care for injuries and toxicological problems;

- Description of requirements for an environmental monitoring program (this should include descriptions of the frequency and type of any air and personnel monitoring, environmental sampling techniques, and calibration and maintenance of instrumentation used as it pertains to each remedial action project);
- Specification of any routine and special training required for site personnel;
- Entry procedures for confined spaces;
- Establishment of procedures for protecting workers from weather-related problems.

The HASP shall be consistent with applicable regulatory requirements and guidance.

DOE contractors and leaseholders must meet DOE Order 151.1D [R-33] to respond effectively and efficiently to all operational and energy emergencies and provide emergency assistance so that appropriate response measures are taken to protect the worker, the public, the environment, and national security. As either a leaseholder or fence-line property holder, an advanced reactor developer also would need to meet the requirements of DOE Order 151.1D to secure emergency response services from and provide support service to PORTS and its agreement agencies.

Emergencies are to be:

- Recognized, categorized, and classified promptly, as necessary, and parameters associated with the emergency are to be monitored to detect changed and degraded conditions;
- Reported and notifications are to be made in a timely manner;
- Concluded with reentry activities properly and safely accomplished in accordance with approved guidance and recovery and post-emergency activities commenced in a timely and efficient manner.

As PORTS already meets DOE Order 151.1D and has the above response process in place, an advanced reactor developer needs to implement plans, actions, equipment, and training for its specific facility and then communicate and coordinate with PORTS emergency response resources when needed.

Ohio Revised Code, Chapter 3750, Emergency Planning [R-34] establishes a state-wide emergency response commission, designates emergency planning districts, and requires facilities that generate an extremely hazardous substance above a specified threshold to submit a chemical emergency response preparedness plan for review and approval. Emergency coordinators and local exercises for each district are required along with provisions for mutual aid from other districts. Emergency response planning requirements for facilities in possession of hazardous substances are also detailed. The law requires that emergency response plans are updated annually, defines hazardous substances, and contains reporting requirements for hazardous chemicals.

PORTS, including the DOE and its leaseholders, operates under a uniform emergency management process as described in the Emergency Management Program [R-35]. The procedure incorporates DOE Order 151.1D, D&D, and leaseholder operational requirements into a single integrated and comprehensive program to ensure that:

- Emergencies are promptly recognized and categorized or classified;
- Emergencies are reported immediately;
- Appropriate response measures are taken to protect workers, the public, the environment, and national security;
- Reentry activities are properly and safely accomplished;
- Recovery and post-emergency activities commence promptly.

An advanced reactor developer will add to this procedure the specifics of its facilities, operations, emergency plan, and hazardous material inventory.

A complete listing of documents pertaining to environmental cleanup of PORTS – documents that also influence the emergency response requirements for a reutilization entity at PORTS – are listed at the following link:

> https://www.energy.gov/pppo/portsmouth-site/portsmouth-community-outreach/portsmouth-public-documents [R-36].

Finally, PORTS has in place eleven emergency response mutual aid memorandums of agreement or understanding with PORTS regional firefighting services and agencies, law enforcement agencies including radio repeater services, 911 dispatch operations, and emergency medical and healthcare services including ground and air ambulatory services. The use of these agencies and services are requested and guided under the procedure titled Mutual Aid [R-37], which also includes a listing of mutual aid providers in its Appendix A. This procedure provides guidance on roles, direction, and responsibilities of PORTS emergency response leadership during a PORTS emergency response including its emergency operations centers and other related procedures. The mutual aid memorandums of agreement or understanding provide guidance for roles, responsibilities, and responses by the mutual aid organizations to PORTS, and for PORTS emergency response capabilities to provide mutual aid to regional agencies and services.

4.2.2.3 General Site Reuse Considerations

Emergency response considerations for other potential reuse sites can be summarized by:

a. Having an understanding of overall federal emergency response requirements as stated in the Emergency Planning and Community Right-To-Know Act of 1986;
b. Having an understanding of state emergency response requirements;
c. Having an understanding of any reuse site's mutual agreement requirements;
d. Development by the reuse entity of a specific HASP, reporting requirements of hazardous substances as required by the various federal and state requirements, and participation in any local mutual support agreements for emergency response.

4.2.2.4 PORTS Area Emergency Response Capabilities

As described above, the PORTS site has an extensive agreement for mutual aid with several surrounding communities including Pike and Scioto Counties [R-37]. As a result of this agreement, regional firefighting support, law enforcement, and health facilities are available to support an emergency response as a single emergency response unit.

<u>Firefighting Services</u>

According to the U.S. Fire Administration National Fire Department Census Database, there are 46 career and volunteer fire departments in PORTS's region of interest. The career fire departments include:

- The PORTS Fire Department, which has three engine houses containing four engines, two ladder vehicles, and one rescue vehicle;
- The Chillicothe Fire Department, which consists of three units with a total authorized staff of 49 people;
- The PORTS onsite fire department with firefighting vehicles and associated equipment to contain most fires that would occur at PORTS.

Mutual aid agreements with local offsite fire departments are in place for events that are beyond the capability of the PORTS onsite fire department [R-38].

During an emergency that would require support of other regional career and volunteer fire departments, the PORTS Emergency Operations Center would coordinate responses of the multiple fire departments. All firefighting mutual aid support responders are HAZMAT Fire Responder trained and participate routinely with PORTS site personnel in emergency response drills [R-39].

<u>Law Enforcement Services</u>

Several state, county, and local police departments provide law enforcement in the ROI. Pike County, where PORTS is located, has 16 officers and provides law enforcement services to the PORTS site. The other counties in the ROI have a total of approximately 101 full-time officers: 14 in Jackson County, 44 in Ross County, and 43 in Scioto County [R-39].

<u>Health Care Facilities</u>

Adena Pike Medical Center, the hospital closest to PORTS, is located on Dawn Lane northwest of State Route 104, approximately 7.5 miles north of PORTS and just south of Waverly. The Adena Urgent Care facility is located on State Route 104 near the Adena Pike Medical Facility. PORTS has an onsite medical center, and the X-1007 Fire Station maintains a first aid room and provides ambulance service for emergency conditions. Adena Pike Medical Center has 25 licensed beds (ODSA 2016a). No other acute care facilities are located in Pike County. Adena Health Center and Southern Ohio Medical Center both operate an urgent care facility in Waverly, approximately 8 miles north of PORTS. Piketon and Waverly Family Health Centers, both located north of PORTS, are also available during working hours for minor emergencies [R-39].

PORTS Emergency Preparedness

Three principal entities are responsible for the development and execution of PORTS emergency responses. The Portsmouth/Paducah Project Office is responsible for Federal oversight of all activities at PORTS. Currently, D&D contractor FBP is responsible for developing and implementing the site-level HAZMAT management program. As operator of the DUF_6 conversion project, which includes the uranium hexafluoride (UF_6) cylinder storage yards and DUF_6 conversion facility, Mid-America Conversion Services, LLC (MCS) operates and implements the facility-level emergency response at the DUF_6 facility [R-40].

Routine assessments of the PORTS emergency management program occur to ensure its performance. The DOE Office of Emergency Management Assessments, within the independent Office of Enterprise Assessments, assesses the emergency management program at PORTS during postulated drills. These assessments evaluate the effectiveness of the PORTS emergency management program in responding to emergencies. In the most recent assessment in October 2019, the assessment team used the full-scale exercise to determine the effectiveness of the PORTS Emergency Response Organization's response to an emergency at key decision-making venues. This assessment is part of a series of assessments of emergency management exercise programs at sites throughout the DOE complex and was conducted in accordance with the Plan for the Office of Enterprise Assessments Assessment of the Emergency Management Program at PORTS, August–October 2019. Mutual aid organizations also take part in the drills and are subject to participation in the assessments [R-40].

4.2.2.5 PORTS Emergency Response Assets

This section details the inventory of equipment, facilities, and systems that supports an emergency response activity at PORTS and in the surrounding area via the mutual aid agreement.

Fire Department

The Fire Station, Building X-1007, was built in 1981 and is constructed of concrete block and brick (see Figure 4-1). It has served as the site Fire Station since 1984. The facility houses the fire department's six fire engines and two ambulances, emergency equipment, alarm room, first aid room, kitchen area, equipment storage, and fire station offices in a 13,500 ft^2 facility. The station's mobile emergency equipment includes pumpers, emergency trucks, and ambulances. The facility is staffed around the clock with emergency medical technicians and trained firemen. All emergency medical technicians and firemen are trained in HAZMAT response and participate in regular drills at the site. The site has an extensive agreement for mutual aid with several surrounding communities including Pike and Scioto Counties. All mutual aid support responders are also HAZMAT Fire Responder trained and participate with site personnel in regular drills [R-39].

Specific mobile firefighting equipment includes:

- 2015 Smeal 1500 GPM Pumper with 1000-gallon water tank;
- 2006 American La France-Freightliner 1500 GPM Pumper with 1000-gallon water tank;
- 2010 Spartan/Marion HAZMAT/Heavy Rescue Truck with walk-in quarters equipped with light plant, PTO generator, and rescue equipment;
- Two 2016 Ford/Wheeled Coach F450 Ambulances with Advanced Cardiovascular Life Support (ACLS) equipment;
- 2013 Chevrolet Silverado 3500HD 4-Wheel Drive Brush Truck equipped with a 2017 drop-in pump unit with 225-gallon water tank and 8-gallon foam tank for wildfire response;
- 2019 Ford Transit Van equipped with the TALON Robot (a lightweight, unmanned, tracked robot designed and built by Foster-Miller for security and firefighting missions).

There are two fire water systems at PORTS [R-41]:

1. The potable domestic water system supplies hydrants and fixed suppression sprinklers.
2. A dedicated high pressure firewater (HPFW) system at 125 psig, which includes a 300,000-gallon elevated storage tank 300 feet in height (see Figure 4-2 and Figure 4-3).

Except for connections to current Centrus and Mid-America Conversion leaseholder operations, much of the HPFW system has been or will be capped at a feed point into the edge of designated D&D areas and SODI reuse property. However, a reuse entity or advanced reactor developer simply needs to ask for the nearest firewater feed point to be identified and then connect its high pressure fire water system to the PORTS HPFW system.

<u>Health Services Building</u>

The X-101 Health Services Building, built in 1954, is a single-story building with an area of 10,300 ft^2 (see Figure 4-4). The building is currently used as the site hospital and has five treatment rooms, four doctor's offices with examination rooms, a laboratory, an X-ray room, a ward, an emergency room, a decontamination area, a lobby waiting room, an office area, medical records storage area, a physical therapy room, an audio booth with audiometer, and vision and pulmonary function test equipment. The facility is currently staffed with a full-time doctor, two nurses, and several administrative staff to support health services [R-39].

<u>Emergency Operations Centers</u>

The X-1020 Emergency Operations Center is a 7,180 ft^2 building built in the early 1980s (see Figure 4-5). It provides offices for emergency management personnel and serves as the main communications center during any plant emergency. It is manned 24 hours per day and also acts as backup for the site security facility. Approximately 10 personnel routinely work in the building, but during an emergency or drill the facility can hold upwards of 60 or more personnel. The Joint Information Center located at Miracle City Academy, a private school just north of the PORTS site, is designed to inform nearby communities and accommodate news media during an emergency to ensure timely information is provided to the public [R-39].

Both facilities were recently upgraded with new ceilings, lighting, flooring, heating, ventilation, air conditioning, furniture, computers, and state-of-the-art technology (see Figure 4-6 and Figure 4-7). WebEOC incident-management and other software were installed at both facilities, which streamlines the information sharing process. WebEOC is used by local governments, the state of Ohio, and the DOE Headquarters Watch Office in Washington, DC. Such tools are being incorporated into the site's continuity of operations plan, which outlines continuation of functions in times of emergency [R-42].

Plant Public Address System

To support site-wide communications including emergency response announcements, PORTS has a plant-wide public address system that provides a voice communications network to most site facilities. While the system has local paging capabilities in many facilities, the primary purpose is providing informational and emergency messages to the overall plant population. All messaging provided via the public address system originates in either the X-300 Plant Control Facility or the X-1020 Emergency Operations Center. There is also a public warning siren system consisting of a network of six pole-mounted siren assemblies in the vicinity of the PORTS plant, a siren repeater located at McCorkle Road, and three control stations. The primary purpose of this system is to notify the local population and site personnel of potential plant emergent and weather-related conditions. The public warning siren system can be activated from the X-300 Plant Control Facility, the X-1020 Emergency Operations Center, or the Pike County Sheriff's Office in Waverly, Ohio [R-43].

Telecom/Fiber Connections

Key to adequate emergency response actions is information flow, and key to information flow is adequate telephone and internet connections. At PORTS, there are two 48-strand backbone fiber bundles supplying the site, which are referred to as the west bundle and the south bundle. The west bundle is owned by Frontier Communications, enters the site along the west access road, and presents at the X-540 telephone exchange. The South bundle in owned by Columbus-based Horizon Corporation, enters the site along the southwest access road, and splits on site into 36 and 12 fiber bundles. The 12-fiber bundle presents to the X-152J computer center where all 12 fibers are fully utilized. The 36-fiber bundle presents in the X-1000 administration building where 4 of 36 fibers are being utilized. This is also the most likely location for connection by a reuse entity utilizing SODI property. Fiber would need to be extended a short distance to the SODI parcels with the DOE providing fiber extensions or easements to ensure future service can be provided to the SODI parcels slated for conveyance. PORTS is also adjacent to ultra-high capacity OARnet backbone, which is the most robust state-owned fiber backbone in the U.S. [R-44].

The value by phase of site emergency services is presented in Appendix A, Portsmouth Site Specific Infrastructure Requirements by Phase, for the Portsmouth site and in Appendix B, Generic Site Infrastructure Requirements by Phase, for any previously used site.

Figure 4-1: PORTS Fire Station

Figure 4-2: HPFW System Water Storage Tower

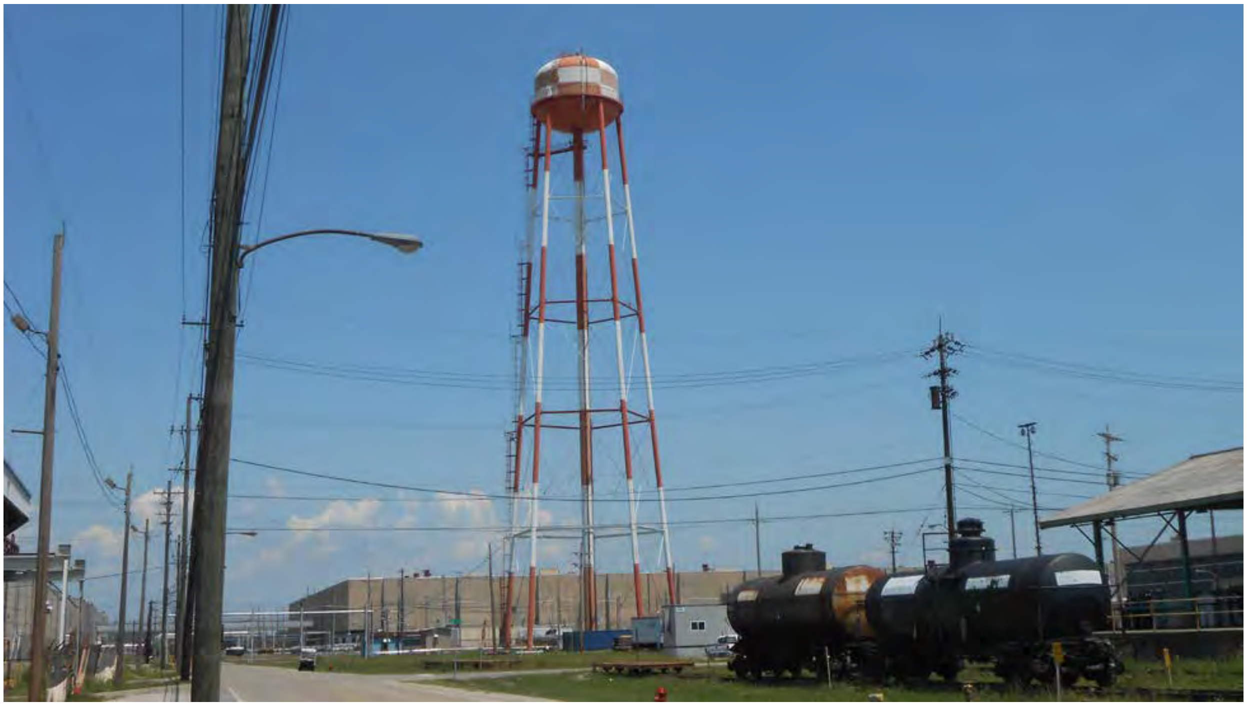


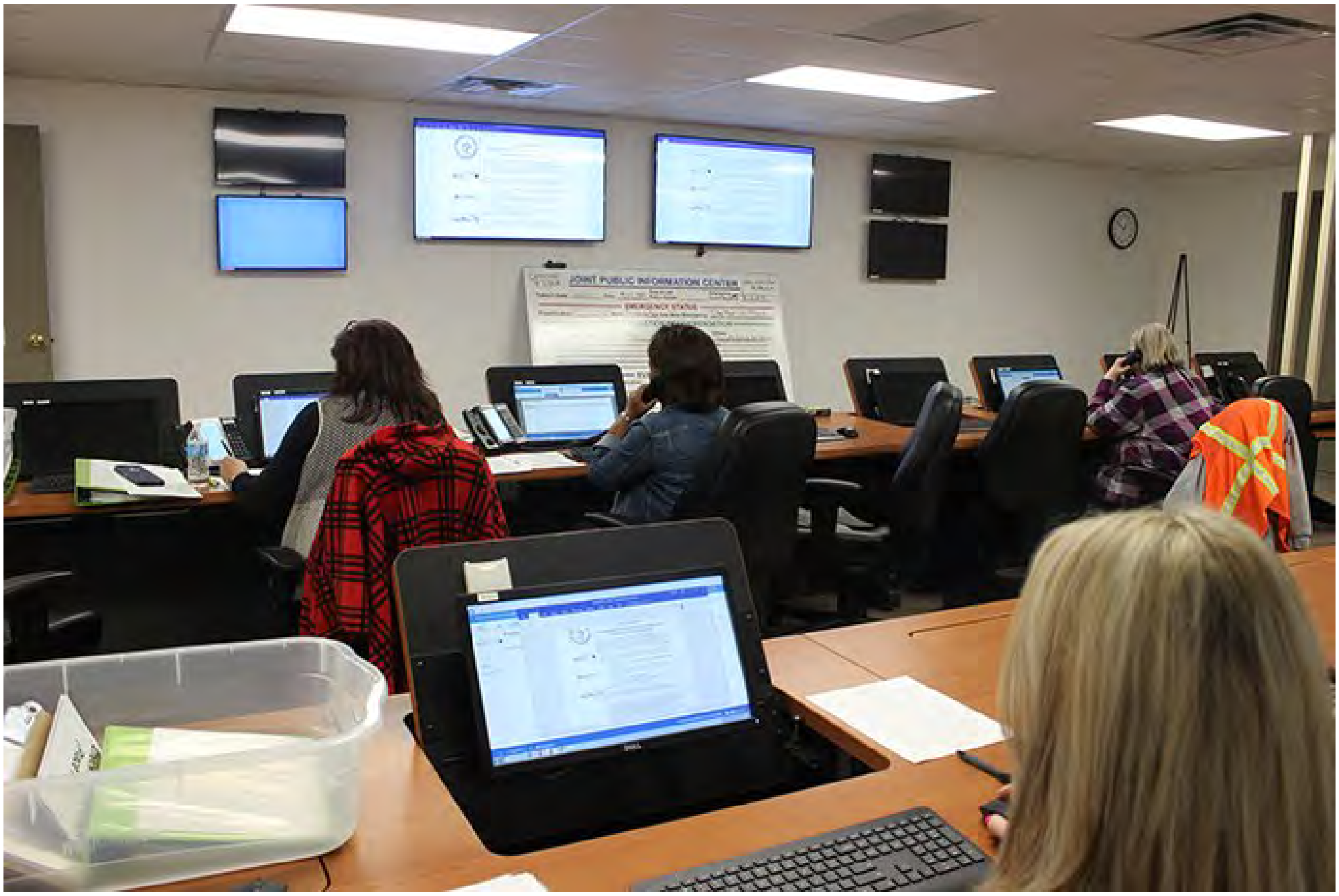
Figure 4-3: HPFW System Pump House

Figure 4-4: X101 Health Services Building

Figure 4-5: X-1020 Emergency Operations Center

Figure 4-6: Emergency Operations Center located at PORTS

Figure 4-7: Joint Information Center located at Miracle City Academy, a private school located just north of the PORTS site



4.2.3 Meteorological Tower Data Collection

Generic: Regulations and Guidance – Regulatory Guide 1.23

Real time, accurate site meteorological data serves as a very important aspect of the site's infrastructure throughout all phases. During the D&D phase, collection of specific data including wind speed, direction, temperatures, and precipitation totals can be useful in assessing impact of any planned or unplanned release of airborne or liquid effluents. Data collected during the operational and decommissioning phases can be archived and subsequently used as part of the pre-operational environmental monitoring data needed to support reactor licensing efforts.

Technical requirements and functional capabilities needed to support pre-operations and operations of a nuclear facility are provided in Regulatory Guide 1.23, Meteorological Monitoring Programs for Nuclear Power Plants. Below are the key points from the NRC's regulatory guidance that are relevant to the goals of this report.

For stationary power reactor site applications submitted on or after January 10, 1997, 10 CFR 100.20(c)(2) requires consideration of the meteorological characteristics of the site that are necessary for safety analysis or that may have an impact upon plant design in determining the acceptability of a site for a nuclear power plant. In addition, 10 CFR 100.21(c) requires evaluation of site atmospheric dispersion characteristics and establishment of dispersion parameters such that (1) radiological effluent release limits associated with normal operation from the type of facility proposed to be located at the site can be met for any individual located off site, and (2) radiological dose consequences of postulated accidents meet the prescribed dose limits at the exclusion area and low population zone distances set forth in 10 CFR 50.34(a)(1).

An onsite meteorological measurements program at a nuclear power plant site should be capable of providing the meteorological information needed to make the following assessments:

- A conservative assessment by both the applicant and NRC staff of the potential dispersion of radioactive material from, and the radiological consequences of, design-basis accidents to aid in evaluating the acceptability of a site and the adequacy of engineered safety features for a nuclear power plant in accordance with 10 CFR 100.3.
- An assessment by both the applicant and NRC staff of the maximum potential annual radiation dose to the public resulting from the routine release of radioactive materials in gaseous effluents to assist in demonstrating that operations will be or are being conducted within the limits of 10 CFR Part 20 and Appendix I to 10 CFR Part 50, and to ensure that effluent control equipment design objectives and proposed operating procedures meet NRC requirements for keeping levels of radioactive material in effluents to unrestricted areas as low as practicable.
- A conservative assessment by both the applicant and NRC staff of the habitability of the control room during postulated design-basis radiological accidents and hazardous chemical releases to demonstrate that the control room can remain occupied under accident conditions in accordance with GDC 195.
- A near-real-time ongoing assessment by the licensee of atmospheric transport and diffusion immediately following an accidental release of airborne radioactive materials to provide input to the evaluation of the consequences of radioactive releases to the atmosphere and to aid in implementation of emergency response decisions in accordance with the requirements in Appendix E to 10 CFR Part 50.
- An assessment by the licensee of natural phenomena being experienced or projected beyond usual levels (e.g., high winds) for the purposes of emergency classification in accordance with 10 CFR 50.47(b)(4) and Section IV.B of Appendix E to 10 CFR Part 50.
- A realistic assessment by both the applicant and NRC staff of the potential dispersion of radioactive materials from, and the radiological consequences of, a spectrum of

accidents to aid in evaluating the environmental risk posed by a nuclear power plant in accordance with Subpart A of 10 CFR Part 51.

- A realistic assessment by both the applicant and NRC staff of non-radiological environmental effects, such as fogging, icing, and salt drift from cooling towers or ponds, to aid in evaluating the environmental impact of a nuclear power plant in accordance with Subpart A of 10 CFR Part 51.

While the specific types of meteorological information needed differ for each of the above assessments, a single set of instruments can generally be used to obtain the basic data needed for all of them. For this reason, when establishing a meteorological program for an initial site survey, careful consideration should be given to the operational needs for meteorological information. In particular, care should be taken to locate the instrumentation where the measurements will accurately represent overall site meteorology and, if possible, where singular topographic features and vegetation or the construction of additional structures at a later date will not significantly influence wind patterns. For cases where a meteorological monitoring system is being “upgraded” due to age or when any change to the system is warranted, a review of appropriate new technologies should be undertaken to consider whether the meteorological monitoring system should utilize up-to-date technologies that may provide improved data sources. The minimum amount of onsite meteorological data to be provided at the time of application is: (1) for a construction permit, a representative consecutive 12-month period; (2) for an operating license, a representative consecutive 24-month period, including the most recent 1-year period; and (3) for an early site permit (ESP) or a combined license that does not reference an early site permit, a consecutive 24-month period of data that is defendable, representative, and complete but not older than 10 years from the date of the application. However, three or more years of data are preferable and, if available, should be submitted with the application.

PORTS Specific

The program also uses meteorological data collected at PORTS such as wind direction, wind speed, atmospheric stability, rainfall, and average air temperature.

Under the existing system, hourly averages of all measured parameters are calculated and recorded automatically onto a dedicated personal computer. This computer accumulates, records, summarizes, and archives an entire year’s data. This computer also provides direct real-time meteorological data to the release modeling system used for emergency management. At the end of each year, the accumulated information is backed up or copied onto a compact disc. These data are used to generate an annual joint frequency distribution of wind direction, speed, stability, average temperature, and total precipitation.

Records are compiled by FBP Environmental Protection personnel. The joint frequency distribution and averaged meteorological parameters are used in dispersion modeling and annual dose assessment using U.S. EPA-approved models such as CAP-88 or equivalent.

Extent and Frequency of Monitoring

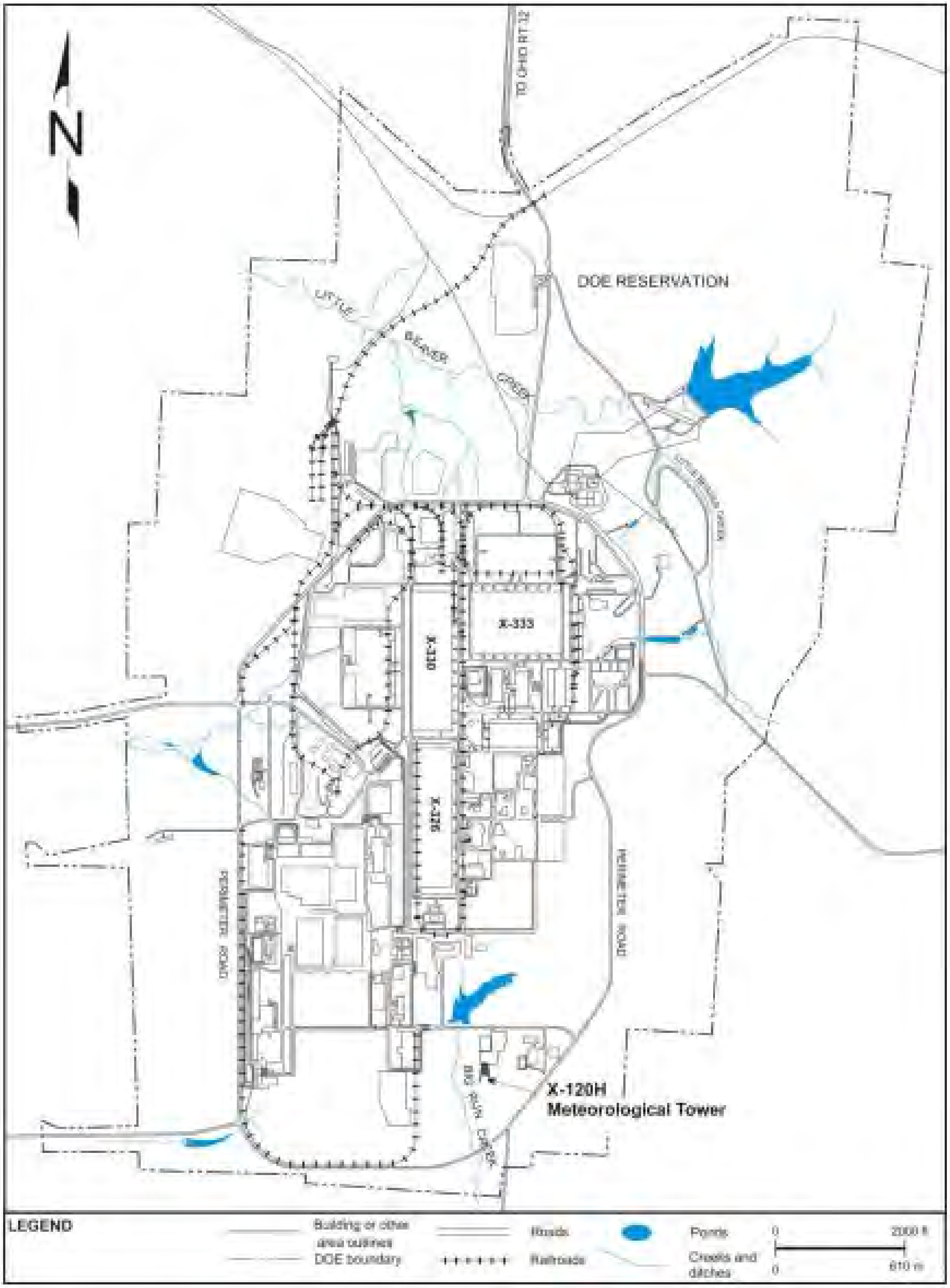
Tower instrument packages at heights of 10 m, 30 m, and 60 m measure air temperature, relative humidity, and wind speed and direction. These instrument packages are mounted on booms that are between three and four tower diameters from the tower. The temperature and relative humidity instruments are shielded instruments with forced ventilation to minimize the effects of direct and reflected radiation.

Ground-level instruments measure solar radiation, barometric pressure, and precipitation. Soil temperature is measured at 0.30 m and 0.61 m depths. Data from the National Weather Service or other local sources may be used in lieu of onsite data.

A microprocessor located at the foot of the tower receives analog data from each of the instruments.

Data recovery is at least 90% on an annual basis for those meteorological elements required to make dose assessments. Digital summaries are transmitted to the Emergency Operations Center or equivalent designee. The summaries consist of average and maximum wind speed, average and standard deviation of wind direction, averages of all temperatures, solar radiation, and precipitation over last interval. One summary is sent directly to a computer terminal, which also serves as the control terminal of the microprocessor. Another summary is sent to a portable computer that operates independently of the rest of the system. Fifteen-minute data summaries are also displayed on video terminals at several locations on site including the X-300 Plant Control

Figure 4-8: Location of meteorological tower at PORTS



The weighted value by phase of Meteorological Tower Data Collection is presented in Appendix A, Portsmouth Site Specific Infrastructure Requirements by Phase, for the PORTS site and in Appendix B, Generic Site Infrastructure Requirements by Phase, for any previously used site.

4.2.4 Environmental Monitoring

4.2.4.1 NRC Guidance

The NRC provides comprehensive guidance for planning and implementation of preoperational and operational environmental monitoring programs at nuclear facilities in Regulatory Guide 4.1, Radiological Environmental Monitoring for Nuclear Power Plants. The key points from that guidance document are summarized and presented below.

4.2.4.2 Objectives of the Radiological Environmental Monitoring Program (REMP)

The regulatory positions described in this document provide guidance on the establishment of the REMP. The REMP has the following basic objectives:

1. Survey radiological conditions in the vicinity of the facility before initial reactor operation to establish baseline radiological conditions in the local environment.
2. Measure levels of radiation and radioactive materials in the local environment during the lifetime of the facility.
3. Determine if any measurable levels of radiation or radioactive materials in the local environment are attributable to plant operation.
4. Determine if measurable levels of plant-related radiation and radioactive materials in the local environment are commensurate with radioactive effluents and plant design objectives (e.g., ALARA).
5. Report measurement results, summaries, and trends regarding radiation and radioactive materials in the local environment.
6. Maintain the REMP by identifying changes in land use (e.g., agricultural land use in unrestricted areas) that may impact the measurements or measurement results associated with exposure pathways identified in the REMP.

4.2.4.3 Preoperational Radiological Environmental Monitoring Program

A REMP should be established and implemented at least two years before initial facility operation. The program will contain the routine surveillances necessary to adequately characterize the radiological conditions in the vicinity of the reactor site. Once initiated, the collection of samples and analysis of data should follow the sampling and analyses schedule and should continue for the first three years of commercial operation. For new reactor sites that are collocated with currently operating nuclear power plants (or previously operating nuclear power plants with a currently operating REMP program), the existing operational

REMP associated with the operating (or previously operating) facility will normally meet the requirements for a preoperational REMP, given that the monitoring data is relevant to the time period. The preoperational REMP should be conducted so that the preoperational radiological conditions are understood in sufficient detail to allow future reasonable, direct comparison with data collected after power operation of the facility. The preoperational REMP should be updated when the land use census identifies new exposure pathways or receptor locations.

4.2.4.4 Operational Radiological Environmental Monitoring Program

Although all operating facilities will have a REMP associated with the operating reactors, some licensees may have other REMPs to satisfy other needs. An operational radiological environmental monitoring program may consist of several different parts. For example, a licensee may have: (1) a REMP associated with the 10 CFR Part 50 licensed facility; (2) a REMP associated with the 10 CFR Part 72 specific-licensed facility; and (3) a REMP not explicitly required by NRC regulations (e.g., environmental samples of local community interest or samples deemed important for continuity with the preoperational REMP). This regulatory guide addresses only those REMPs required by NRC regulations, but licensees may, at their discretion, apply this information to any aspect of a REMP conducted for purposes of local community interest. If a licensee has a REMP as part of a 10 CFR Part 50 license and another REMP as part of a 10 CFR Part 72 specific license, the licensee may choose to establish totally separate REMPs, or it may choose to collocate surveillance equipment where practical. In all cases, the licensee shall conduct the REMPs in accordance with applicable regulations and licensing bases at the site. The REMP is sometimes conceptualized as an offsite monitoring program. However, some portions of the REMP may be conducted on site. For example, NUREG-1301/1302 states that the inner ring of thermoluminescent dosimeters may be located "in the general area of the site boundary." The same is true for radioiodine and particulate sampling. NUREG-1301/1302 also describes ground water monitoring if ground water is "likely to be affected" and describes monitoring of drinking water supplies if they "could be affected." Licensees should consider this when implementing a REMP, especially if the facility obtains drinking water from wells located down gradient from the site.

4.2.4.5 Site-Specific Assessment for PORTS

The information provided in this section is based upon data provided in the "U.S. Department of Energy Portsmouth Gaseous Diffusion Plant Annual Site Environmental Report – 2017 Piketon, Ohio." Environmental monitoring at PORTS measures both radiological and chemical parameters in air, water, soil, sediment, and biota (animals, vegetation, and crops).

Environmental monitoring programs are required by state and federal regulations, permits, and DOE Orders. These programs may also be developed to address public concerns about plant operations.

Environmental monitoring data collected at PORTS are used to assess potential impacts to human health and the environment from radionuclides released by current and historical PORTS operations. This impact, called a dose, can be caused by radionuclides released to air and/or water, or radiation emanating directly from buildings or other objects at PORTS. The

U.S. EPA sets a 10 mrem/year limit for the dose from radionuclides released to the air in the NESHAP (40 CFR Part 61, Subpart H). DOE sets a dose limit ALARA, but no more than 100 mrem/year for the dose from radionuclides from all potential pathways in DOE Order 458.1.

On an annual basis, a site environmental report is prepared to summarize environmental monitoring and compliance activities conducted at PORTS for each calendar year. Environmental monitoring is conducted to assess the impact, if any, that site operations may have on public health and the environment. The annual Site Environmental Report fulfills a requirement of DOE Order 231.1B, Environment, Safety and Health Reporting, for preparation of an annual summary of environmental data to characterize environmental management performance. The annual site environmental report also provides the means by which DOE demonstrates compliance with the radiation protection requirements of DOE Order 458.1, Radiation Protection of the Public and the Environment.

- Figure 4-9: DOE ambient air and radiation monitoring locations
- Figure 4-10: PORTS NPDES outfalls/monitoring points and cylinder storage yards sampling locations
- Figure 4-11: Local surface water and sediment monitoring locations

Figure 4-9: DOE ambient air and radiation monitoring locations

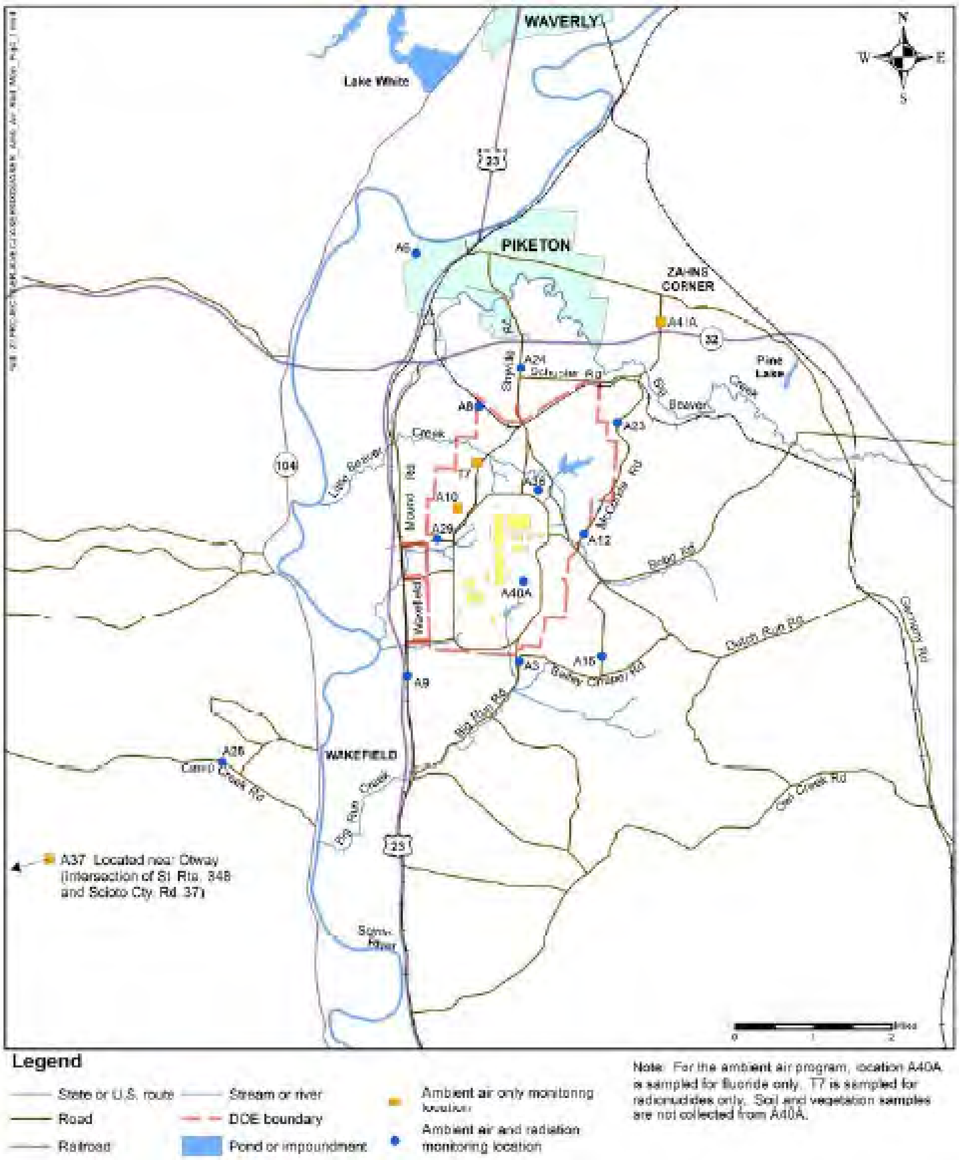


Figure 4-10: PORTS NPDES outfalls/monitoring points and cylinder storage yards sampling locations

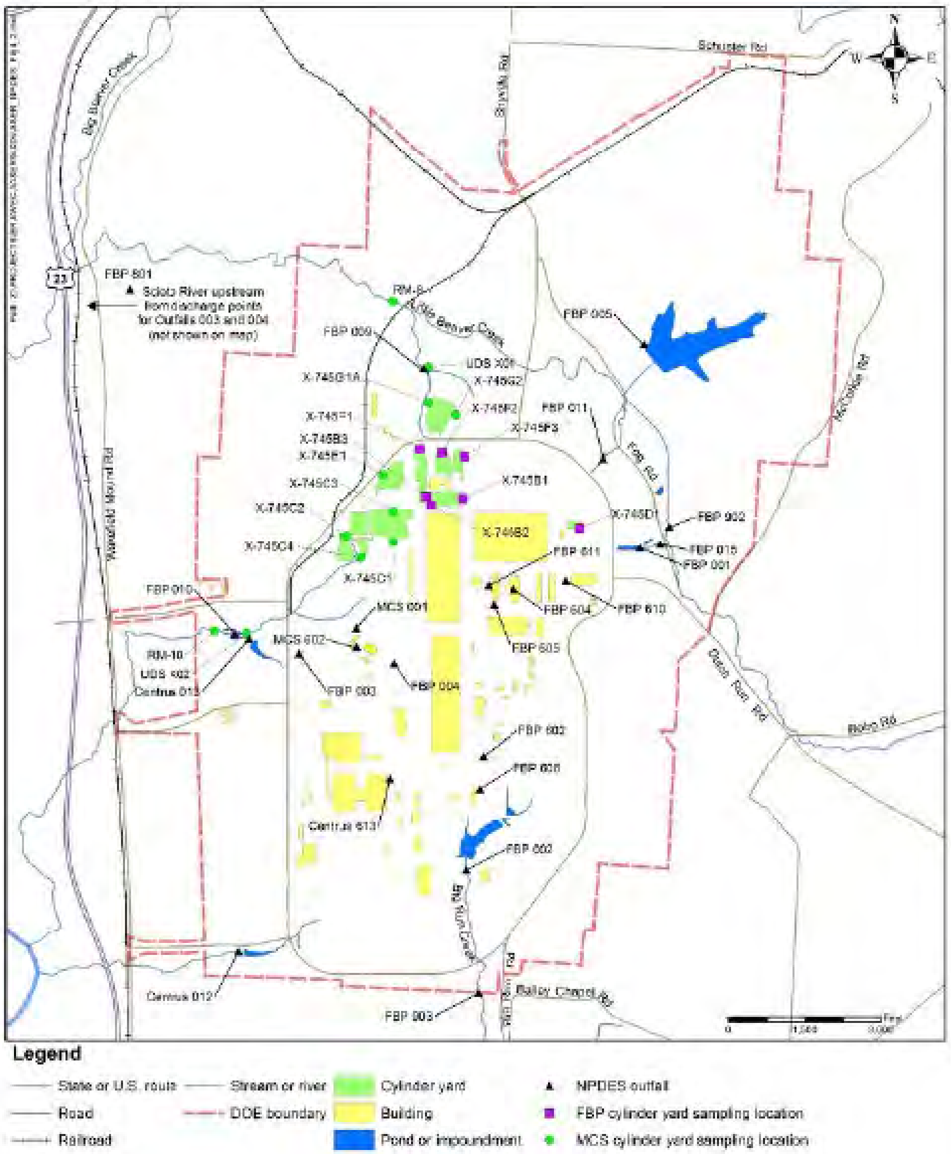
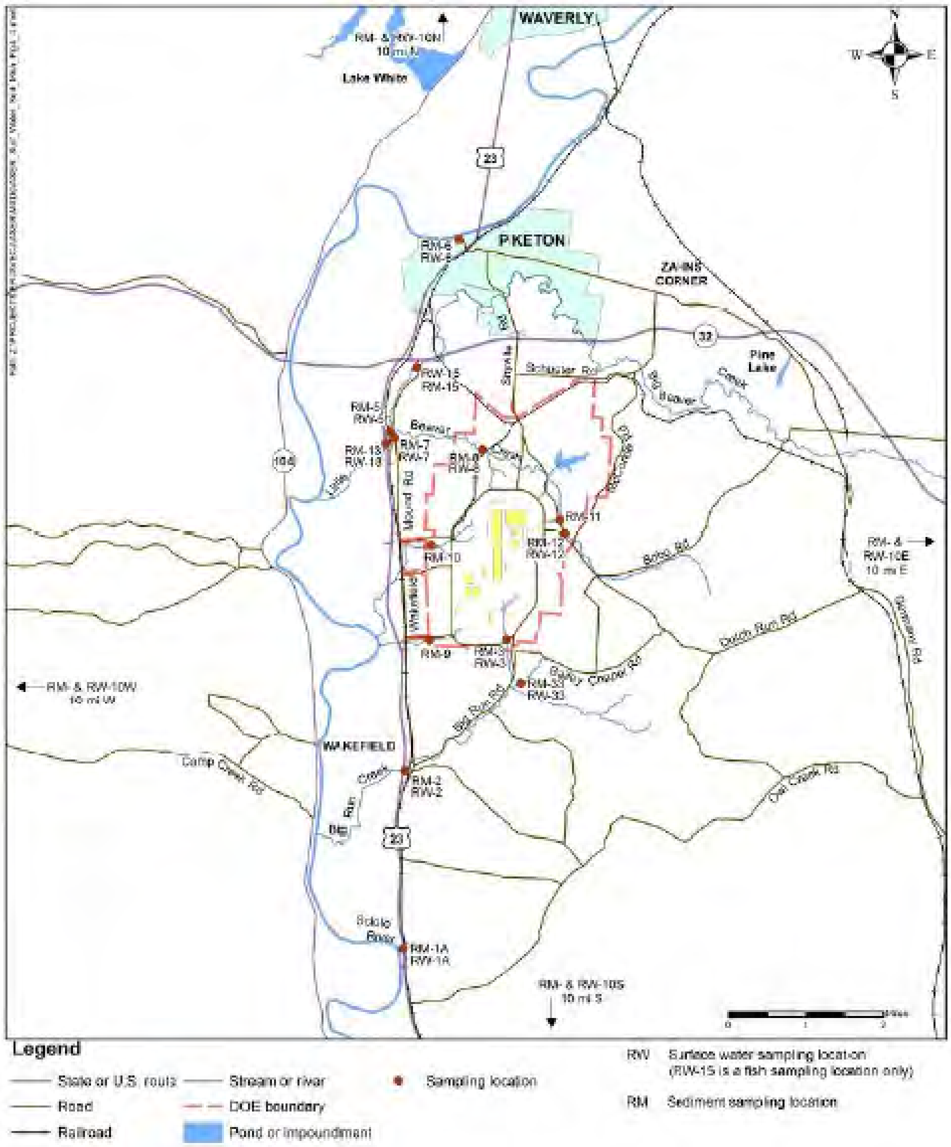


Figure 4-11: Local surface water and sediment monitoring locations



The weighted value by phase of environmental monitoring is presented in Appendix A, Portsmouth Site Specific Infrastructure Requirements by Phase, for the PORTS site and in Appendix B, Generic Site Infrastructure Requirements by Phase, for any previously used site.

4.2.5 Analytical Laboratories

Onsite analytical laboratories can provide essential services to all phases at a reuse site. The convenience of an onsite lab would result in quick turnaround of sample results, which improves the efficiency of all site operations. Subject to limitations inherent to all buildings (age, safe storage maintenance, and aesthetics), it is likely that any standalone buildings housing chemistry laboratories could have good reuse potential. Of particular value may be laboratories for environmental chemistry and for monitoring cooling water chemistry, as these types of facilities are generally located away from the power block. While required analyses may differ between plant designs, the basic laboratory design would be expected to be similar irrespective of plant type (fume hoods, bench space, demineralized water and instrument air lines, chemical storage, dedicated drainage system, etc.).

An onsite analytical laboratory at the PORTS site is currently undergoing certifications and should be placed into service in the near future.

The weighted value by phase of an onsite analytical laboratory is presented in Appendix A, Portsmouth Site Specific Infrastructure Requirements by Phase, for the PORTS site and in Appendix B, Generic Site Infrastructure Requirements by Phase, for any previously used site.

4.3 Facilities

4.3.1 Site Access Roads – PORTS Site

According to Transport Ohio Statewide Freight Plan [R-46], published by the Ohio Department of Transportation (ODOT), Ohio's roadway system is its most used freight infrastructure asset. This is supported by Ohio having the nation's fourth largest interstate system, which allows trucks to dominate freight movements and reach every commercial destination within the state.

Considerations for road access of a reuse site such as PORTS are separately described in the below sections as:

- General road access and capability considerations for any potential site reuse;
- General road access considerations for the State of Ohio;
- Specific road access considerations for PORTS.

4.3.1.1 General Road Access Considerations for Site Reuse

Road access is a major consideration in the selection of a reuse site for placement of an advanced reactor due to the shipment of building components and equipment and workers who need to access the potential reuse site. Available roadways will need to allow for routine standard weight and size truck shipments, but also need to accommodate transportation of overweight and oversized materials including fabricated hardware, bulk liquids and gases, and, in the near future, transportation of fresh and spent nuclear fuel to and from a selected advanced reactor reuse site.

General considerations for serviceable road access as an advantage for the potential reuse of a former reuse site include:

- What is the distance of major highway access to the actual site?
- Do the potential site's roads allow access for truck unloading in a site warehouse or laydown yard?

- If warehouse and laydown yard storage access is not directly on the reuse site, what is the feasible method of transportation between the storage location(s) and the site?
- If heavy-haul truck transportation is utilized to the potential reuse site, is there a clear path to the site related to bridge load weight limits, overpass clearance, utility line and traffic light clearance, turn radius, transport hours of service, etc.?
- Does the incoming road access location have a suitable crane unloading location that is level and meets the crane's load-bearing requirements?
- Do other industries, retail centers, school campuses, office complexes, hospitals, etc., on the same road pathway as a reuse site's accessible site entrances limit its intended use for the reuse operator?
- What is the condition of the reuse site's current road assets such as bridges, culverts, drainage ditches, traffic lights, signage, railroad crossings, and indicators?
- Does a specific loading/unloading facility or warehouse need to be built at the reuse site and, if so, when in the timeframe of the site's planned reuse – needed for reuse site contraction or only after site is in full production – and if to be built, is supporting road access already available or will it also need to be planned, state and county approved, budgeted, and constructed?
- Are truck fueling locations nearby or will the reuse site owner need to also plan for fueling of trucks, and what are the site implications for hazardous fuel storage and equipment filling?
- If an advanced reactor is supporting other manufacturing or service entities in an industrial park setting, will road use requirements of other industrial park entities impact advanced reactor operations, or will advanced reactor operations impact other industrial park entities; examples could be shift changes of large manufacturing or distribution centers, manufacturers of hazardous chemicals, etc.?

Keeping in mind that advanced reactors are targeted at being modular in design, fabrication, and final assembly, access to highways and local roads suitable for freight transportation can be of great benefit, allowing for large component and cargo shipments as oversized or overweight shipments, standard shipments, and bulk commodity shipments.

4.3.1.2 General Road Access Considerations for the State of Ohio

Road access to PORTS is only as good as road access throughout the State of Ohio. That said, the State of Ohio provides considerable federal, state, and local roads leading to PORTS. Ohio has more major interstates than most states and include I-70, I-71, I-75, I-76, I-77, and I-80/90.

Under Public Law 112-141, the Moving Ahead for Progress in the 21st Century Act (MAP-21) [R-47], the Federal Highway Administration designated 1,425 miles of Ohio highways as part of the Primary Highway Freight System (PHFS). This was greater than two percent of the national network and gave Ohio the fifth highest number of miles on the PHFS. Figure 4-12 reflects Ohio's PHFS highway corridors system [R-48].

Trucks make up about 13 percent of traffic on the state highway system, which includes all state, U.S., and interstate routes and 18 percent of traffic on the subset of Ohio's interstate highways. Average daily truck traffic on each Ohio interstate route is about 10,500; nearly 15,000 trucks a day travel each of the heaviest truck routes (I-75 and I-70). Five-axle, semi-tractor trailers comprise 80 percent of truck traffic on rural interstate roadways, while urban truck traffic has a higher percentage of two- and three-axle panel and dump trucks [R-49].

Traffic flows external or through the state generally favor interstates and other large capacity routes, most notably the east-west corridors of I-70 and the Ohio Turnpike. I-75 is a major north-south corridor that carries significant through traffic as well. Truck flows that originate and terminate inside Ohio primarily utilize I-75 and I-71, connecting Ohio's largest cities of Cincinnati, Columbus, and Cleveland. This also shows that Ohio's U.S. and state routes are considered a primary system for Ohio-based truck freight [R-49].

As shown in Figure 4-13, FAF5 data for 2017 (the program's most recent year of available data) show that truck tonnage shipped for Ohio totaled nearly 600,000 tons of freight with intra-Ohio shipping accounting for nearly 80 percent of the total. The remaining 20 percent was freight traveling through Ohio [R-50].

Additional freight data, maps, infrastructure conditions analyses, and proposed improvements in addition to research and forecast services can be found at the ODOT Office of Statewide Planning and Research at:

> https://www.transportation.ohio.gov/wps/portal/gov/odot/programs/statewide-planning-research/statewide-planning-research#page=1 [R-51].

The State of Ohio also has above average access to heavy-haul roads, which include almost all federal and state highways including State Routes 23 and 32, leading to PORTS. These roads may allow up to 300-ton heavy-haul loads dependent upon transport equipment used; specific heavy-haul information and permit applications for Ohio roads can be found at:

> https://www.transportation.ohio.gov/wps/portal/gov/odot/working/permits/special-hauling-permits/ [R-52].

4.3.1.3 Specific PORTS Road Access Considerations

PORTS is located within three miles of two of Ohio's PHFS highways – Route 23 going north-south and Route 32 going east-west across the state of Ohio. These are multi-lane divided highways with limited bridge and overpass interferences and capable of supporting heavy-haul truck shipments [R-52]. There is also a lack of road interference from local infrastructure such as shopping centers, other large industrial users, school campuses, etc. These traits allow the PORTS site to be favorably considered as a desirable reuse site due to its unimpeded traffic flow, access for freight and workers, and heavy-haul access to the site.

Area Pike County roads are shown in Figure 4-14 [R-53] and roads immediate to PORTS are shown in Figure 4-15 [R-53]. Access to the PORTS site is relatively easy with direct western access from State Route 23 via a dedicated exit ramp directly to the site's Perimeter Road. Perimeter Road is open to public traffic and not controlled by the DOE from the exit ramp intersection south around to the northeast side of the plant site at Dutch Run Road. Current and near-term SODI property available for reuse is along this section of Perimeter Road. However, should there be a national emergency, or the Homeland Security Advisory System or the National Terrorism Advisory System go to a state of high alert, access to PORTS could conceivably be controlled for an undefined period of time. Having an alternate route plan or a documented evaluation process in place between the DOE and the reuse developer should allow access to the reuse site during states of DOE controlled access.

PORTS roads are currently DOE maintained to state standards and codes for 80,000 lbs GVW and, with specialized equipment, are suitable for heavy-haul transport with wide utility easements minimizing potential interference. Currently, direct access to the north side of PORTS via Shyville Road from SR 32 is blocked due to construction and the planned use of Shyville Road as part of the haul road to the onsite landfill. This effectively blocks use to the north side of PORTS, including Perimeter Road, until completion of onsite D&D activities.

Current PORTS road access within Perimeter Road is DOE-controlled for Centrus and Mid-America Conversion leased property and currently DOE-controlled during D&D of the former plant's process areas within Perimeter Road. Also, D&D activities will remove most roads within Perimeter Road that are not under lease. As such, a potential reuse developer should intend to put into place its own direct road access to Perimeter Road, whether located inside or outside of Perimeter Road.

4.3.1.4 Road Assets of SODI

SODI has no direct control or ownership of PORTS roads as none have been released yet. Also, future roads that are released by the DOE will become state or county owned and maintained public roads.

4.3.1.5 Summary

As reflected in the above sections, the PORTS road infrastructure and central Ohio and U.S. location with access to major highway systems allows PORTS to be highly suitable for consideration as an advanced reactor reuse site. These traits are also positive examples of road access considerations for any potential reuse site.

Figure 4-12: PHFS Highway Corridors System

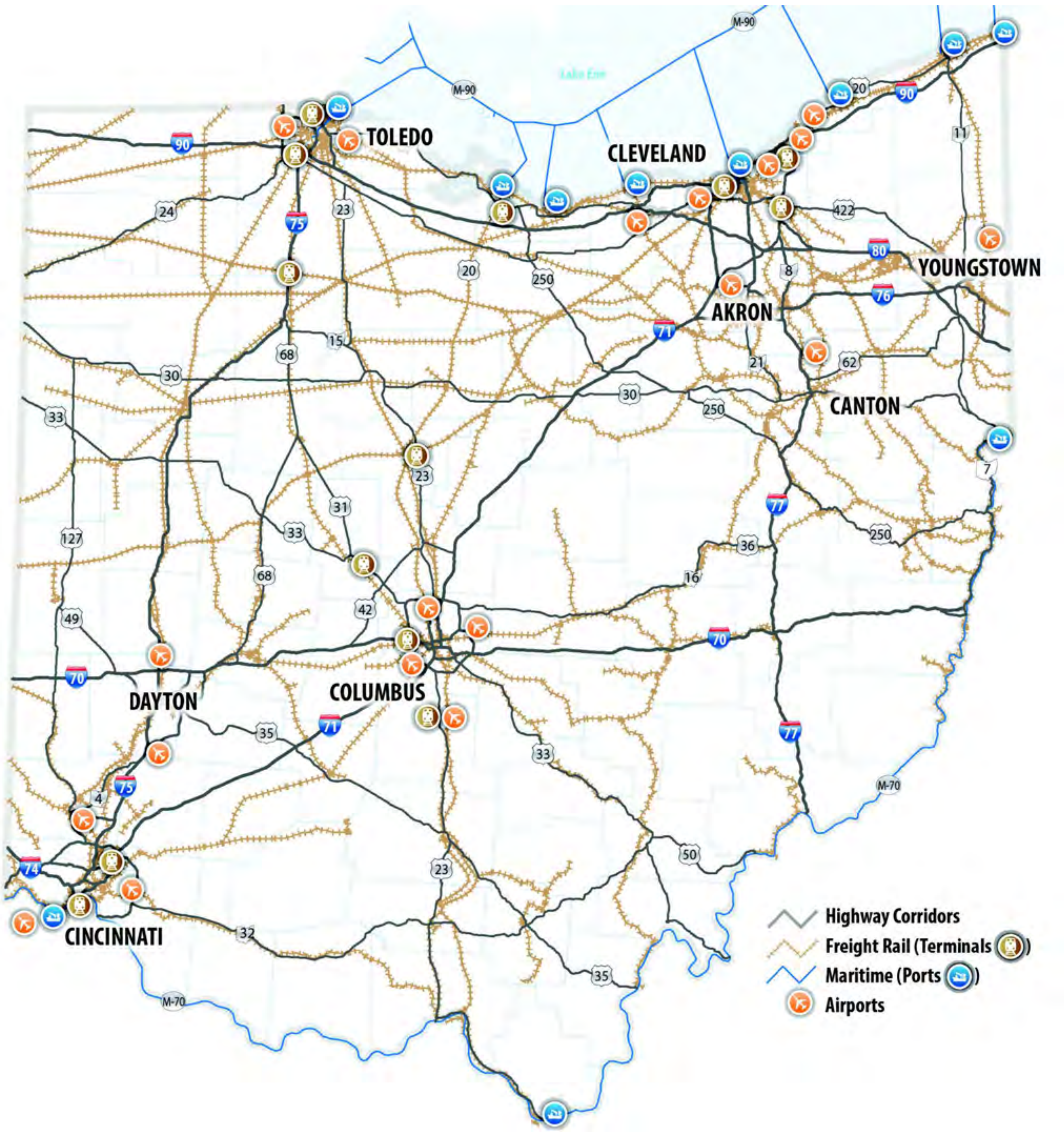


Figure 4-13: FAF5 data for Ohio shipments within, outbound, and inbound

Shipments Within, Outbound, and Inbound U.S. States - Tons by Trade Type & Transportation Mode: 2017
Data from the Freight Analysis Framework Version 5.1
Unit of measure is thousand tons
Outbound: Outbound flow from the given state to all other states (not including Within)
Inbound: Inbound flow all other states to the given state (not including Within)
* Click the drop-down arrow to select the origin you want to navigate.

			Within the given state (S to S)		Outbound from the given state (S to all other states)		Inbound to the given state (all other states to S)		Total Tons Truck Freight Shipped
State (S)	Trade Type	Domestic Mode	tons_within	tons_within_pctg	tons_out	tons_out_pctg	tons_in	tons_in_pctg	
Ohio	Total Flow		431,892.0	100.0%	252,667.4	100.0%	294,636.2	100.0%	
		Truck	350,436.2	81.1%	123,718.8	49.0%	125,131.2	42.5%	599,286.2
		Destination within S	350,436.2				125,131.2		475,567.3
		%-Total within S							79.36%

Figure 4-14: Area Pike County roads

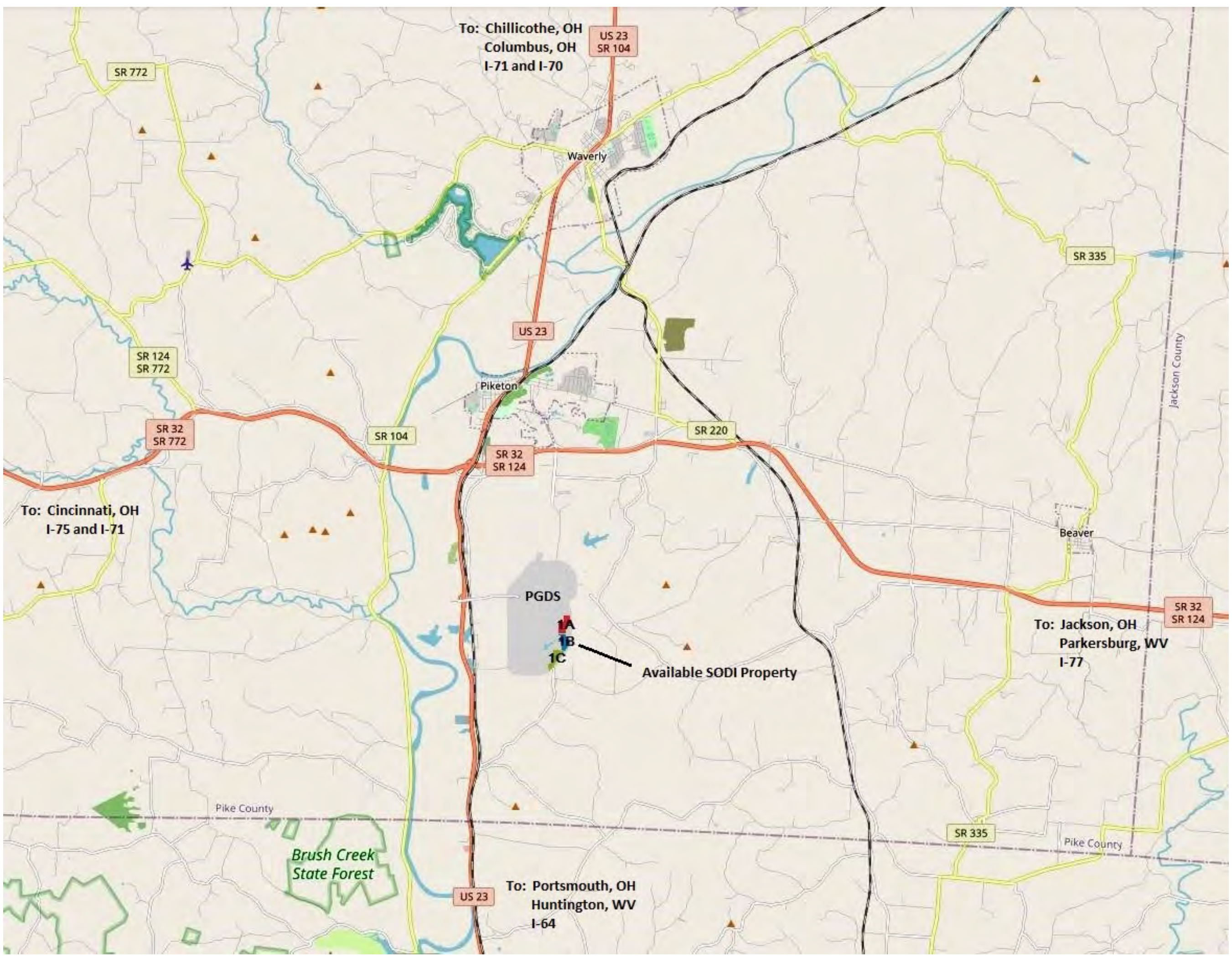
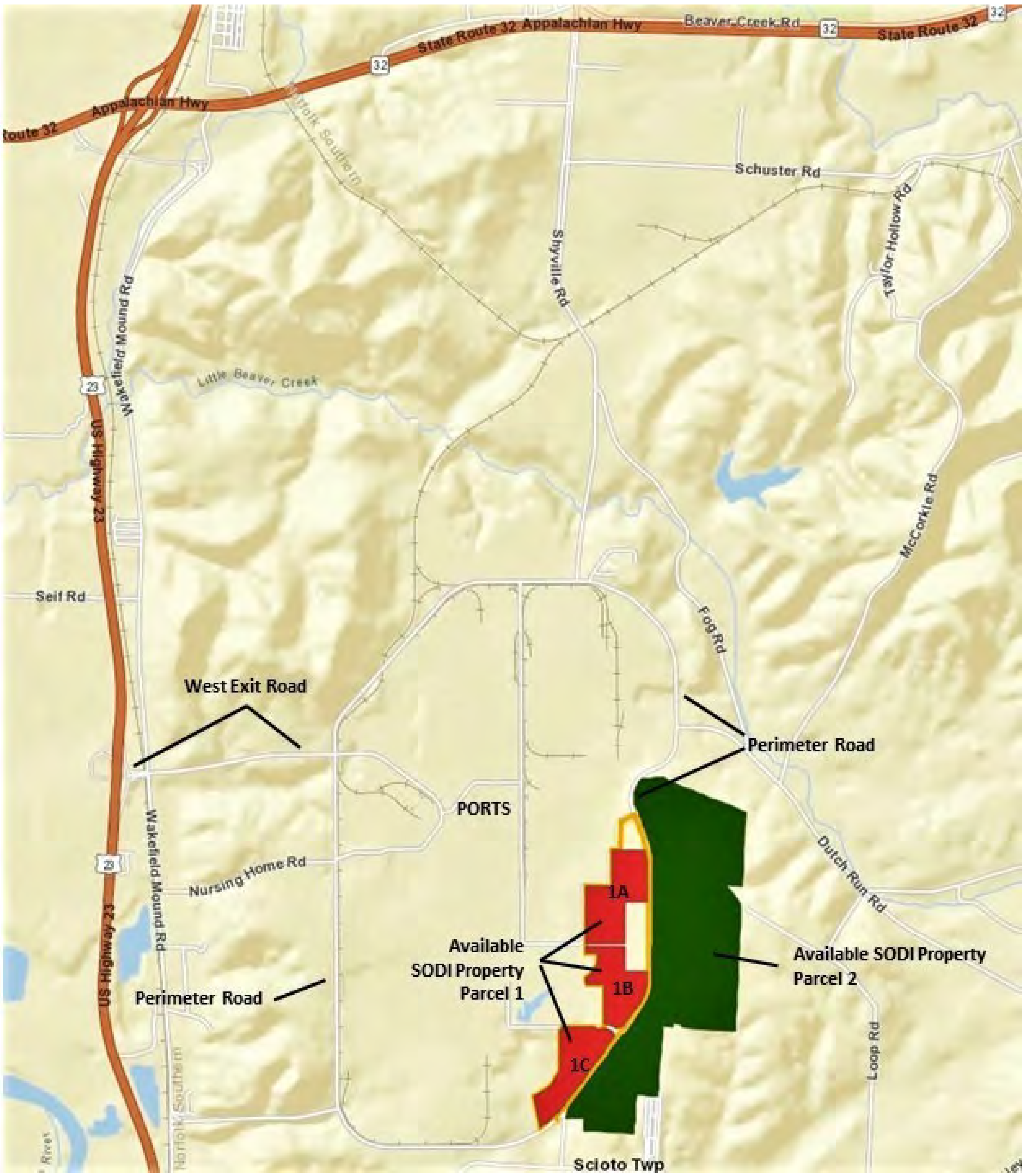


Figure 4-15: Immediate PORTS roads



Site access by roadway will be needed to support D&D of an existing facility, construction of a new facility on an existing site, and future D&D of the new facility. The degree of need for access by roads is directly tied to access to other modes of transportation (i.e., rail and barge). Access roads by definition include both onsite and offsite public roads.

4.3.1.6 Public Roads for Site Access – PORTS

D&D typically requires the removal from site of large, heavy components as well as bulk shipments of commodities such as concrete rubble and soil. Dependent on roadway weight capacities and clearances, for D&D, large components are often downsized from their original size to allow easier handling and transport, although it is more economical to transport a limited number of large packages rather than numerous small packages. A small number of larger packages also typically has less impact on the public.

Well-maintained public roads that meet state Department of Transportation standards are typically adequate for most D&D loads to be shipped over the road. As needed, standard overweight permits may be required. These types of roads can be used for limited numbers of super-heavy loads, steam generators and reactor heads for example, although this is very dependent on clearances and road grades. Payloads beyond about 300 tons become substantially more difficult (and expensive) to transport via road compared with rail and barge.

DOE/EA-1856 [R-1] discusses public roads in the PORTS site area as well as access to the site. The document, which assesses impacts from conveyance of PORTS property including future heavy industrial development, concludes:

> *"Materials and equipment associated with any construction activities to accomplish any proposed development would be transported over regional and local roadways to the site. Development would also likely be phased over time, and no adverse impacts are expected. The additional vehicle and truck traffic from operations associated with any new development would have a negligible impact on existing traffic since the affected roadways presently have sufficient design capacity."*

In addition, the DOE GNEP Detailed Site Study Report for the Portsmouth Reservation Piketon, Ohio [R-2] confirms that "The PORTS site possesses numerous physical attributes that would benefit the siting, construction, and operations of the GNEP facilities..." This includes site access roadways.

From the above, it can be concluded that local, public roadways would be adequate to support decommissioning and future uses of the PORTS facility.

4.3.1.7 On-Site Roadways – PORTS

Onsite roadways are described in a number of site documents, most particular DOE/EA-1856 [R-1], DOE/PPPO-03-3018616-15 [R-3], and the GNEP report [R-2]. In all cases, existing site roadways are shown acceptable for decommissioning of existing facilities and construction of new facilities. Also, DOE/EA-1856 and PPPO-03-3018616-15 provide for the construction of new haul paths if existing roads are not present.

From the above, it can be concluded that onsite roadways can be used to support decommissioning and future uses of the PORTS facility and additional roads can be built if required.

4.3.1.8 Site Access Roads – Other DOE Sites

4.3.1.9 Public Roads for Site Access – Other DOE Sites

As discussed above for PORTS, public roads in the vicinity of a site will be needed for both D&D and for reuse of the facility. The same is true for other DOE sites that will perform D&D and/or look at site reuse. The degree of road use will depend heavily on whether rail and barge access are available.

The GNEP Report for PORTS [R-2] used minimum criteria that the proposed site must be within 5 miles of a highway capable of supporting a load of 80,000 lbs GVW to be considered for use for siting a GNEP facility. This seems to be reasonable criteria.

It is likely that local roads were used to some degree for original construction and to support ongoing operations of the facility, including daily access for workers. Based on this, it is probable that local roads are maintained in good condition. Further, since the majority of DOE facilities can be considered large, industrial facilities similar to a commercial nuclear power plant, the conclusion can be that local roads can support D&D and new construction at the facility to a similar extent as during the original construction.

Removal from site of very large components (i.e., similar in size and weight to a commercial plant steam generator or reactor head) can be done using local roads. D&D at the Yankee Rowe plant and the recent shipment of the reactor vessel head from VC Summer are examples. In both cases, extensive surveys of the haul route were performed and some minor modifications were made before transport.

The choice to use local roads will be driven by two major considerations. The first is economic. Generally, movement of bulk shipments such as concrete rubble or soil and very large packages is less expensive by rail or barge, particularly over long distances.

The second is impact on the public. Shipments by rail and barge can have significantly less impact on the public.

4.3.1.10 Onsite Roadways – Other DOE Sites

As with PORTS, it is likely that site roads are adequate for use for D&D and reuse activities as long as they provide the needed access. Construction of new roads may also be required should the new facility be located such that existing roads do not provide adequate access. New roads may also be required if new facilities, such as onsite disposal, are developed for D&D.

Figure 4-16: PORTS – Local roads and highways

4.3.2 Barge Access

Barge access considerations are described separately below as general considerations for a potential site's reuse and specific barge access considerations for PORTS.

<u>Barge Access Considerations for Site Reuse</u>

Barge access can be of great benefit to the reuse of a site due to the large size of components and equipment that can be transported to and from a potential reuse site. However, additional logistics requirements can also negate any advantages of barge access.

Considerations of barge access as an advantage for a potential reuse site include:

- What is the distance from barge access to actual site placement or laydown yard at the potential reuse site?
- If barge access is not directly on the reuse site, what is a feasible method of transport between barge access and site placement or laydown yard; heavy haul truck and/or rail service?

- If heavy haul truck transport is utilized, is there a clear transport path to the site related to bridge load weight, overpass clearance, utility and traffic light clearance, turn radius, transport hours of service, etc.?
- Does the barge access location have access through a level system that may be present for heavy haul truck/trailer and a suitable sized mobile crane?
- Does the barge access allow large component cargo shipments or is it designed for dry bulk commodities only?
- Does the potential barge access have a stable platform for crane placement and loading and unloading on a heavy haul trailer or railcar?
- Does the barge access site and the potential cargo load allow for a balance of mobile crane size, crane reach, and lift weight, or does the site have suitable gantry cranes?
- What are the risk and insurance requirements for additional lifts and water transport of the cargo?

Keeping in mind that advanced reactors are targeted to be modular in design, fabrication, and final assembly, the need for large component transportation should be reduced as reactor and component size is reduced. Conceivably, advanced reactor transport needs should be met by transport services utilizing no larger than oversized truck and standard railcar shipments.

4.3.2.1 PORTS Barge Access

PORTS can be supported by river barge transportation from the Ohio River and with ocean going ship services from Ohio Lake Erie ports. However, barge access provides only limited accessibility to PORTS due to limited access through levees in the PORTS area and a significant distance to travel for Ohio Great Lake ports for final delivery to the PORTS site.

Water ports with barge and ship loading facilities are show in Figure 4-17 and include both Ohio River and Ohio Lake Erie locations [R-54]. The Ohio River Terminals Analysis, Ohio Statewide Freight Study [R-55] provides information on the Ohio River's barge access from Portsmouth to Wheelersburg, the closest barge access to PORTS and the Cincinnati area. These areas related to large component loading and unloading barge facilities are specifically detailed below.

4.3.2.2 Access from South of PORTS from the Ohio River

Due to limited bridge access on the Ohio River near the towns of Portsmouth and Wheelersburg, Ohio, unloading on the Ohio state side of the Ohio River will be required. Access from barge unloading sites through flood control levees on the Ohio state side of the Ohio River are limited to a single lane through levee walls. Additionally, heavy haul truck and mobile crane access from the barge unloading areas to Highway 23 North to PORTS can be difficult when passing through residential and commercial developments with standard elevation utilities and traffic control lights.

Descriptions of Southern Ohio barge access locations are described below.

- Town of Portsmouth, OH: The Town of Portsmouth Ohio has a single barge access location at McGovney Ready Mix, 55 River Avenue, Portsmouth, OH. This is a private location managed by Scioto Docking, Inc./McGovney River Terminal with access and barge unloading arranged independently with Scioto Docking, Inc. Although the site is listed in Section 3.3.2 of the Ohio River Terminals Analysis, Ohio Statewide Freight Study [R-56] as a bulk commodity facility, an earthen elevated barge unloading platform does exist on the site. Heavy haul truck and mobile crane access to and from the barge unloading area and Charles Street to State Route 52 is by a wide single lane stone roadbed through an earthen levee berm as seen in Figure 4-18. Access is approximately 16 miles north to State Route 23 North by State Route 52 (the Ohio River Scenic Byway), then east to State Route 823 and north until intersecting with State Route 23 north of Portsmouth. At this point, State Route 23 becomes a median-divided highway to the PORTS exits. Overpasses on State Route 823 will have to be considered but are no more limiting than the levee berm access itself.
- Village of New Boston, OH: An earthen elevated barge access platform is located by the northeast corner of the Norfolk-Southern rail yard in the village of New Boston located on the east side of Portsmouth, Ohio. This barge site is governed by the village and available for use by local industry. This site is not listed in Section 3.3.2 of the Ohio River Terminals Analysis, Ohio Statewide Freight Study [R-56]. Access to the site for oversized vehicles would need to be reviewed by the local Norfolk-Southern rail yard authority and site logistics for use would need to be coordinated with village authorities and the local industries of A&M Refractories, Inc., OSCI Industries, Inc., and Infra-Metals Co., all of which use and have materials staged at the barge access site. Heavy haul truck and mobile crane access to and from the barge unloading area and West Avenue to State Route 52 is limited by a single lane stone roadbed through a concrete levee wall as shown in Figure 4-19. Access approximately 14 miles north to State Route 23 North is by State Route 52 (the Ohio River Scenic Byway) east to State Route 823 and north until intersecting with State Route 23 north of Portsmouth. At this point, State Route 23 becomes a median-divided highway to the PORTS exits. Overpasses on State Route 823 will have to be considered but are no more limiting than the levee wall access itself.
- Town of Wheelersburg, OH: The village of Wheelersburg, OH is located in the Porter Township east of Portsmouth, OH on State Route 52. Although it has been acknowledged that Wheelersburg has barge services in other PORTS reuse publications, it has only bulk commodity transfer capability for barges through McGinnis, Inc. and Scioto Docking, Inc. Wheelersburg does not have a suitable unloading platform for lifting heavy loads, or suitable access to State Route 52 for heavy haul transport by truck/trailer to State Route 23 due to bridge weight limits and overpass heights.

4.3.2.3 Access from the Cincinnati Area by the Ohio River

Barge access on the Ohio River in the Cincinnati, Ohio, area can occur with final transportation to PORTS via heavy haul truck/trailer on State Route 32 or by Norfolk-Southern Corporation rail services to PORTS. However, barge ports in the Cincinnati area are primarily commodity transfer ports; specific off-loading platforms are available at Cincinnati Barge and Rail Terminal, LLC and at Kinder Morgan/Cincinnati Steel as identified in Section 3.3.1 titled "Cincinnati" in the Ohio River Terminals Analysis, Ohio Statewide Freight Study [R-57]. To unload at these sites, mobile cranes will need to be utilized and arranged through the subject port and terminal companies. These terminals are shown on Figure 4-20 [R-58]. All other ports and terminals in the Cincinnati area are commodity transfer terminals and not suitable for large component transfer.

4.3.2.4 Access from North of PORTS by Ohio's Lake Erie

Access from north of PORTS is by Ohio State Route 23 south through Waverly and Piketon, OH. Suitable ports with capable gantry cranes and road and rail access are available for heavy haul services from ports located in Cleveland, Sandusky, and Toledo, Ohio, for approximately a 250- to 280-mile trip to the northern access of PORTS. As available ports are typically dependent on commercial relationships with shipping services used, no specific ports are identified in this report; specific shipping services would need to identify specific available ports and the user would then need to identify specific heavy truck/trailer haul services for route identification or contact Norfolk-Southern Corporation for specific rail service to PORTS.

4.3.2.5 Summary

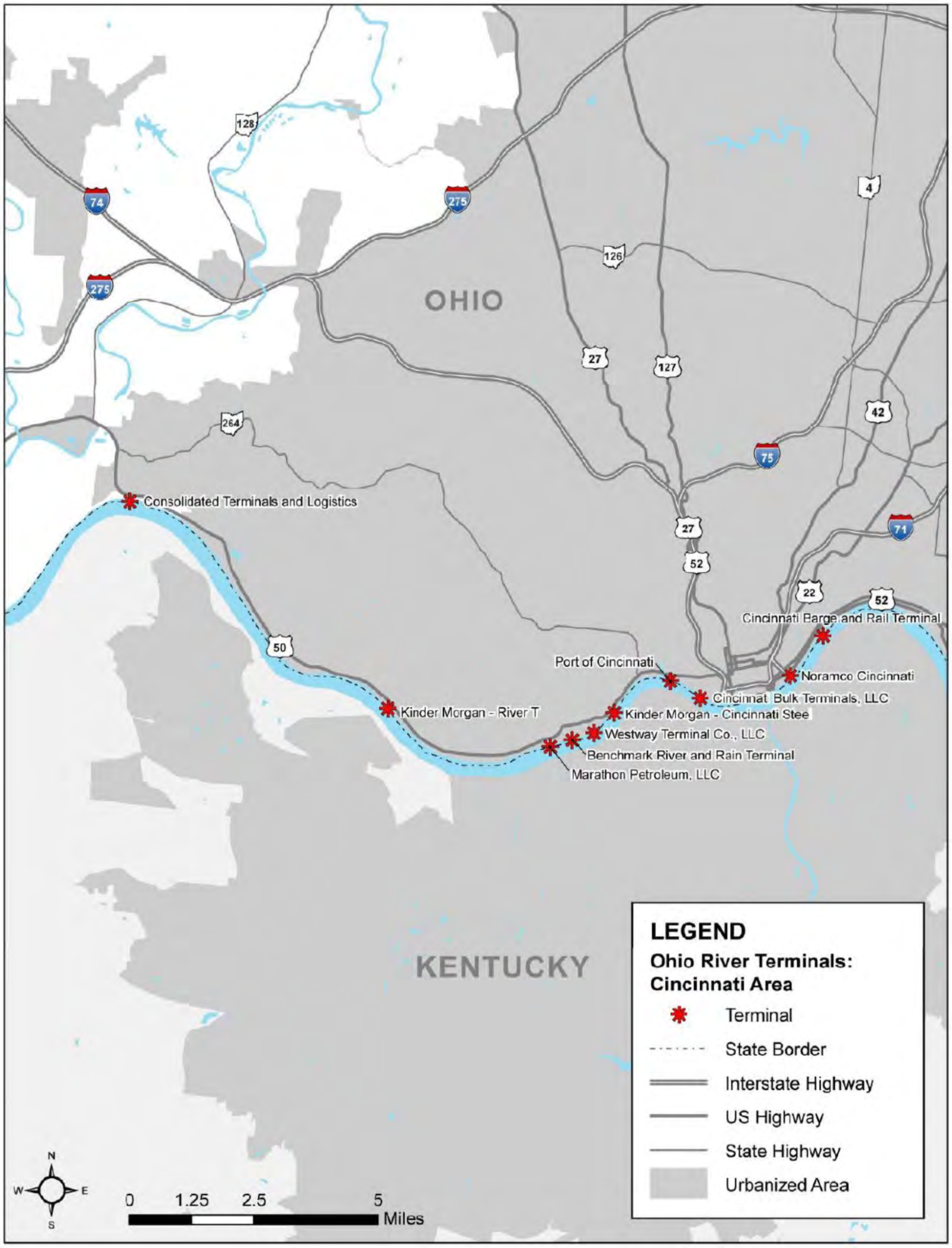
Barge access to PORTS is available only with connecting transport of heavy haul truck/trailer or rail services for final delivery to the plant site. This complicates logistics, transport services, and multiple handling and lifts and results in increased transport risk and cost. As advanced reactors are intended to be modular in design, which would yield smaller components to transport, it is feasible that all advanced reactor components, including suitable power transformers, can be oversize truck and/or rail cargo shipped directly from the fabricator to PORTS, reducing consideration of barge access to a minimum.

Figure 4-17: Ohio's Maritime Transportation System

Figure 4-18: Scioto Docking, Inc./ – McGovney River Terminal, Portsmouth, OH

Figure 4-19: Barge access for Village of New Boston, OH

Figure 4-20: Ohio River Barge Access in the Cincinnati Area



4.3.3 Railroad Service Access

PORTS has almost unlimited railroad service access from two major railroad services on Class 1 railroad tracks to and within PORTS for oversized, large, and standard freight cars, size templates, and weights. Adequate loading and unloading areas are limited only by the origination point selected by the reuse site user with a selection of several unloading and laydown yards available once freight is at PORTS. Considerations for railroad service access for PORTS are separately described in the sections below as:

- General rail service considerations for any potential site's reuse.
- Specific rail service access considerations for PORTS.

4.3.3.1 General Railroad Access Considerations for Site Reuse

Railroad access can be a determining factor in the selection of a reuse site for placement of an advanced reactor due to the large size of components and equipment that can be transported to and from a potential reuse site. Current railroad services allow for routine bulk transportation of materials including fabricated hardware, bulk debris and waste, liquids and gases, and, in the near future, transport of fresh and spent nuclear fuel to and from a selected advanced reactor reuse site utilizing Association of American Railroads approved S-2043 railcars [R-59].

General considerations for railroad access as an advantage for the potential reuse of a former reuse site include:

- What is the distance of railroad access to actual site unloading or laydown yard at the potential reuse site?
- If railroad access is not directly on the reuse site, what is a feasible method of transport between the railroad access point and site unloading or laydown yard: heavy haul truck, standard truck services, or other transport methods and arrangements?
- If heavy haul truck transport is utilized from the railroad access point to the reuse site, is there a clear transport path to the site related to bridge load weight limits, overpass clearance, utility line and traffic light clearance, turn radius, transport hours of service, etc.?
- Does the railroad access location have gantry crane services or a suitable level and load-bearing mobile crane loading and unloading site?
- Does a current facility on or near a reuse site's railroad tracks limit its intended use for the reuse operator?
- What is the condition of the reuse site's current railroad assets such as track, ties, roadbed, bridges, trestles, culverts, drainage ditches, switch units, gates, and crossing indicators?

- Does a specific loading/unloading facility need to be built at the reuse site and, if so, when in the timeframe of the site's planned reuse; needed for reuse site contraction or only after site is in full production?
- What is the speed in which shipments need to occur?
- How often will routine shipments need to switch rail service carriers before arriving at the reuse site or its unloading point?
- What are the additional or reduced cost, risk, and insurance requirements for the additional lifts of cargo, if any, during transport from the original loading and final unloading points for railroad transport of the cargo?
- What level of railroad service is available to and at the reuse site's railroad loading/unloading point?
  - Class 1 railroad service provider (denotes highest level of routine service and typically highest level of weight capacity on tracks, bridges/trestles, and allowable speed).
  - Class 2 or less railroad service provider (denotes a reduced level of routine service and, typically, a lower level of weight capacity on tracks, bridges/trestles, and allowable speed).
  - Dedicated railroad service providers' designated freight routes (as in Norfolk-Southern, CSX Transportation Corporation (CSX), Burlington-Northern, etc., commodity or container-type dedicated freight lines, switch yards, and intermodal terminals).
  - Third party rail service providers interfacing with dedicated railroad services on short-line tracks.
  - Short-line track services only.
  - Sideline track service only with switch-engine services available.
  - Sideline track service only with a user-owned dedicated switch-engine required.
  - Any combination of the above.
- If an advanced reactor is supporting other manufacturing or service entities in an industrial park setting, will the other entities also need and have access to the railroad services?

A railroad transportation logistics specialist or a railroad service provider's clearance manager will need to be contacted to fully quantify these areas of consideration.

Keeping in mind that advanced reactors are targeted at being modular in design, fabrication, and final assembly, access to railroad services for transportation can be of great benefit and allow for large component and cargo shipments as either oversized and standard railroad shipments or bulk commodity shipments. Conceivably, an advanced reactor's transport needs could be fully met by transport services utilizing only railroad shipments.

4.3.3.2 Specific PORTS Railroad Access Considerations

Two major railroad carriers, CSX and Norfolk Southern Corporation (NS), serve Pike County. Approximately 17 miles of railroad track and/or railroad beds exist on PORTS. Currently, the Norfolk Southern system has direct access to PORTS and provides access to other rail carriers. The subsections below provide information regarding railroad access to PORTS that would be available to an advanced reactor developer in reuse of the site.

4.3.3.3 Regional Overview of Railroad Service to PORTS

The Piketon area is a thoroughfare of major rail shipping lines connecting to nearby major rail hubs such as Columbus, Cincinnati, Cleveland, and Toledo and allowing access to all parts of the United States. As seen in Figure 4-21, the Ohio Rail Transportation Map published by the Ohio Rail Development Commission [R-60], the Pike County area is on a major north-south rail corridor connecting to major east-west rail corridors in Columbus, Cleveland, and Toledo. To obtain a more usable PDF version of Figure 4-21 or to request a printed copy, visit the following website:

https://rail.ohio.gov/wps/portal/gov/ordc/rail-in-ohio/resources/01-printed-rail-map-request

The PORTS onsite rail connects to the Norfolk Southern Heartland Corridor Main Line, which carries an average 35 or more trains per day through Pike County and can accommodate double-stacked intermodal trains throughout the entire corridor. This is a Surface Transportation Board (STB) [R-61] Class 1 rail line allowing maximum in-commerce weight loads and speeds, and also oversized/overweight heavy-duty railcar shipment of both in-commerce and specifically-cleared shipments. NS has major switchyards, freight transfer, and intermodal terminals at its major hubs in Columbus, Cincinnati, Cleveland, and Toledo along with other locations within the state.

CSX operates and maintains over 4,000 miles of track within Ohio and also has major switchyards, freight transfer, and intermodal terminals at its major hubs in Columbus, Cincinnati, Cleveland, and Toledo along with other locations within the state. CSX is a member of the National Gateway [R-62], an approximately $850 million, multi-state, public-private infrastructure project that improved the flow of double-stack freight cars between the Mid-Atlantic deep-water ports and major markets of the Midwest; these same improvements also allow for improved shipments of oversized freight loads. Area CSX tracks are STB Class 1 rail lines allowing maximum in-commerce weight loads and speeds, and also oversized/overweight heavy-duty railcar shipment of both in-commerce and specifically-cleared shipments. CSX had direct access to PORTS but the track itself has been removed; the railroad bed and right-of-way is still available for reuse through SODI.

Also serving a major portion of the Southern Ohio region is Genesee & Wyoming Inc. (G&W), an American short-line railroad holding company that owns or maintains an interest in multiple various short-line tracks serving smaller industrial sites within the Southern Ohio region from western West Virginia to the Cincinnati, OH areas, such as the operating Cincinnati Eastern

Railroad line, parented by the Homestead Rail Group, LLC, a sub-interest of G&W. G&W tracks are a combination of Class 2 and Class 3 short-lines and sidings.

Serving the entire state of Ohio, the Ohio Rail Development Commission (ORDC) is an independent commission within ODOT which represents the state of Ohio in non-regulatory interactions with the railroad industry [R-63]. It promotes the retention and development of Ohio companies through effective rail transportation, provides assistance to companies for new rail and rail-related infrastructure including safety improvement and rail-related economic development efforts, and coordinates railroad interactions with ODOT highway projects. Improvement grants are available for companies considering additions to existing business operations in the state and where significant job creation and retention are involved. The ORDC should be contacted directly for additional information at the following link:

https://rail.ohio.gov/wps/portal/gov/ordc/home.

4.3.3.4 Railroad Assets of PORTS

According to the U.S. DOE/EA 1856 [R-64], approximately 17 miles of railroad track exist on PORTS with approximately one-third currently in service and seldom used. All PORTS tracks including the NS northwest site entrance and the removed CSX northeast site entrance are shown in Figure 4-22 titled PORTS Regional Railroad Service [R-65]. However, due to D&D activities on the site, much of the track within Perimeter Road will be removed as the process buildings, foundations and substructures, and nearby supporting roads and utility pathways are remediated and then restored to near original elevations with sloped grading to maintain original water drainage flows outward towards Perimeter Road. Currently, functional PORTS tracks are rated as STB Class 1 tracks with no downgrading of roadbed or culverts (see Figure 4-23 [R-66]). Track will remain to service current DOE leaseholders, Centrus and Mid-America Conversion, which are shown in Figure 4-24 titled Railroad Tracks Proposed to Remain After D&D [R-67]. Functional tracks, track switchgear, and crossing indicators and gates are routinely inspected and maintained by the DOE operations contractor. Information for the Norfolk Southern rail spur into PORTS and for other area CSX and Norfolk Southern railroad tracks are presented in Figure 4-25, Figure 4-26, and Figure 4-27 [R-68].

PORTS has a small two-axle single car switch engine, but no railcar assets available to developers. Railcar switching services can be arranged with the DOE's services contractor at the site. Services for larger units coming onto or leaving the site can also be arranged directly with Norfolk Southern. These arrangements will need to be discussed and arranged directly with the services providers and will be based upon needed usage by the reuse developer; SODI representatives can arrange for direct contact.

4.3.3.5 Railroad Assets of SODI

Per U.S. DOE/EA 1856, the DOE has two real property leases with SODI [R-69]. The first lease was signed in April 1998 for seven acres of land on the north side of the DOE property. This tract is used as a right-of-way for a railroad spur that connects to the existing DOE north rail spur. SODI subleases a portion of this property to allow access to the rail line for a wood-grading operation. In October 2000, a second lease between DOE and SODI was signed to allow concurrent SODI access to and use of the existing north rail spur. Previously, CSX had direct rail service into the site via a bridge outside the PORTS east boundary. However, the bridge needed major repair, was seldom used, and therefore removed and the public side of the CSX right-of-way sold. The PORTS portion of the CSX railroad bed is still in place, although significant maintenance would be required to place it into operating condition and re-install track ties. Approximately five miles of track rails from the removed CSX track within the plant boundary are currently owned by SODI and available for reuse.

4.3.3.6 Suggested Additional Track to Remain

In order to provide adequate railroad access to SODI properties on the east-to-southeast side of PORTS, it is recommended that current sections of track on the west side of PORTS be retained with additional track added once D&D of the process areas on the north side of PORTS is completed. All retained areas are within Perimeter Road and the fence boundaries of PORTS.

Figure 4-28 shows both current track to be retained and additional track to be added [R-70]; retained track units are shown as black lines. The track spur from the northwest entrance to the Centrus plant and its sidings are already included in the plans for tracks to be retained after D&D is completed. These are track units designated as L3 through L13 coming into PORTS, plus track units L61, L65, and L74 to the Contractor's Access Road on the west side of the plant, and Mid-America/Centrus' sidings L73, L73A, L73A1, L73A2, L73B, L73B1, and L73B2.

Additional track to be retained includes track unit L74 from the Contractor's Access Road on the west side of the plant to the southern end of the plant site and track unit L72; these track units are shown as orange lines on the west and south end of PORTS within and parallel to Perimeter Road. This allows for industrial users of the SODI property tracks to have access to the site's rail services with the addition of track around the southeast side of the plant site running parallel to Perimeter Road.

For uniformity with PORTS, added railroad track should be STB Class 1 track to allow for staging and movement of overweight and oversized rail loads without clearance requirements for the short trip off PORTS. Once added, the additional track within the southeast side of Perimeter Road would allow future reuse developers to have direct access if inside Perimeter Road, or to add its own siding if located on SODI property outside of Perimeter Road. Allowing the reuse developer to design and build its own siding connection to current and/or added track provides flexibility for the developer to meet its specific loading/unloading needs within its property boundary.

Finally, after D&D is completed, track units L28 through L31 and unit L34 need to be replaced to allow track for train turnaround and for reuse developers to connect sidings from the center to north side of the plant. This added track is shown on Figure 4-28 as an orange line at the north side of PORTS. This will allow access to adequate loading/unloading areas, current and potential laydown yards available during reuse construction, and flexibility for routine-to-continuous receipt and shipping of freight for future reuse developers.

4.3.3.7 Summary

As reflected in the above sections, a valued asset of PORTS is its railroad infrastructure, central US location with access to major railroad transportation service providers, STB Class 1 railroad tracks both within and adjacent to the plant site allowing oversized, large, and standard freight loads, and flexibility in design of future unloading/loading facilities by reuse developers at PORTS.

Figure 4-21: Ohio Rail Transportation Map

(Also see website https://rail.ohio.gov/wps/portal/gov/ordc/rail-in-ohio/resources/01-printed-rail-map-request.)

Figure 4-22: PORTS Regional Railroad Service

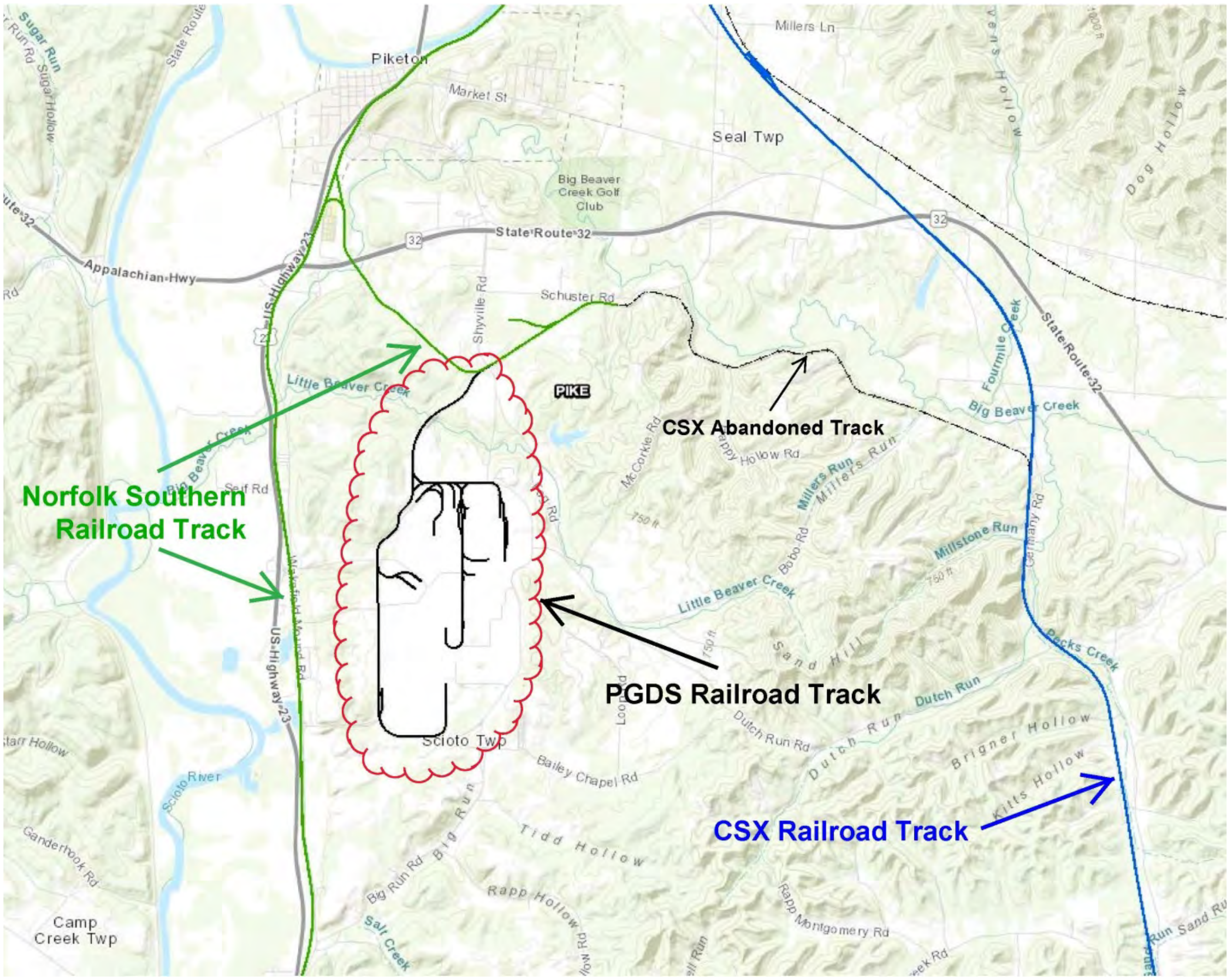


Figure 4-23: PORTS onsite railroad tracks

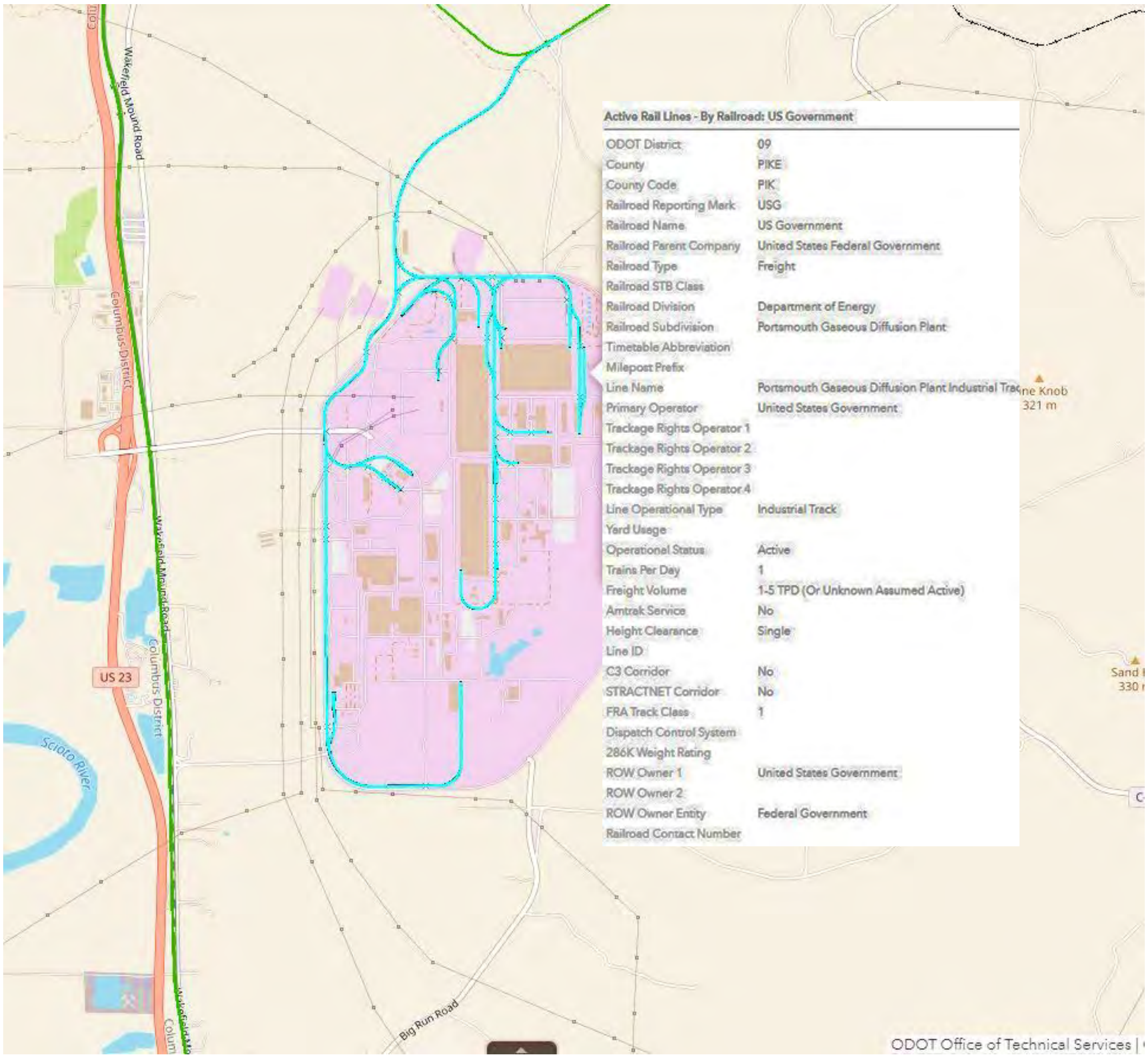


Figure 4-24: Railroad tracks proposed to remain after D&D

Figure 4-25: Norfolk Southern spur into PORTS track information

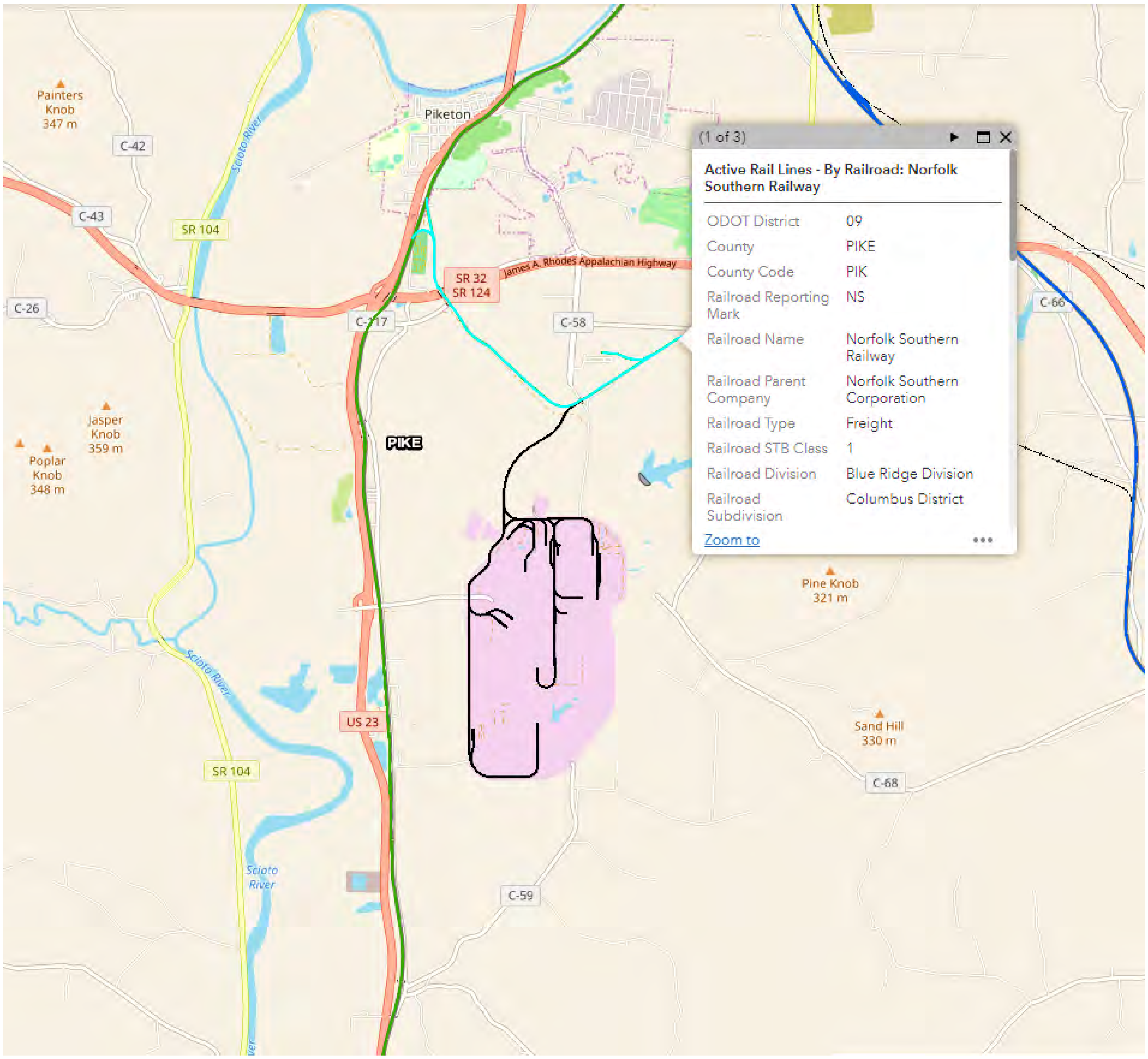
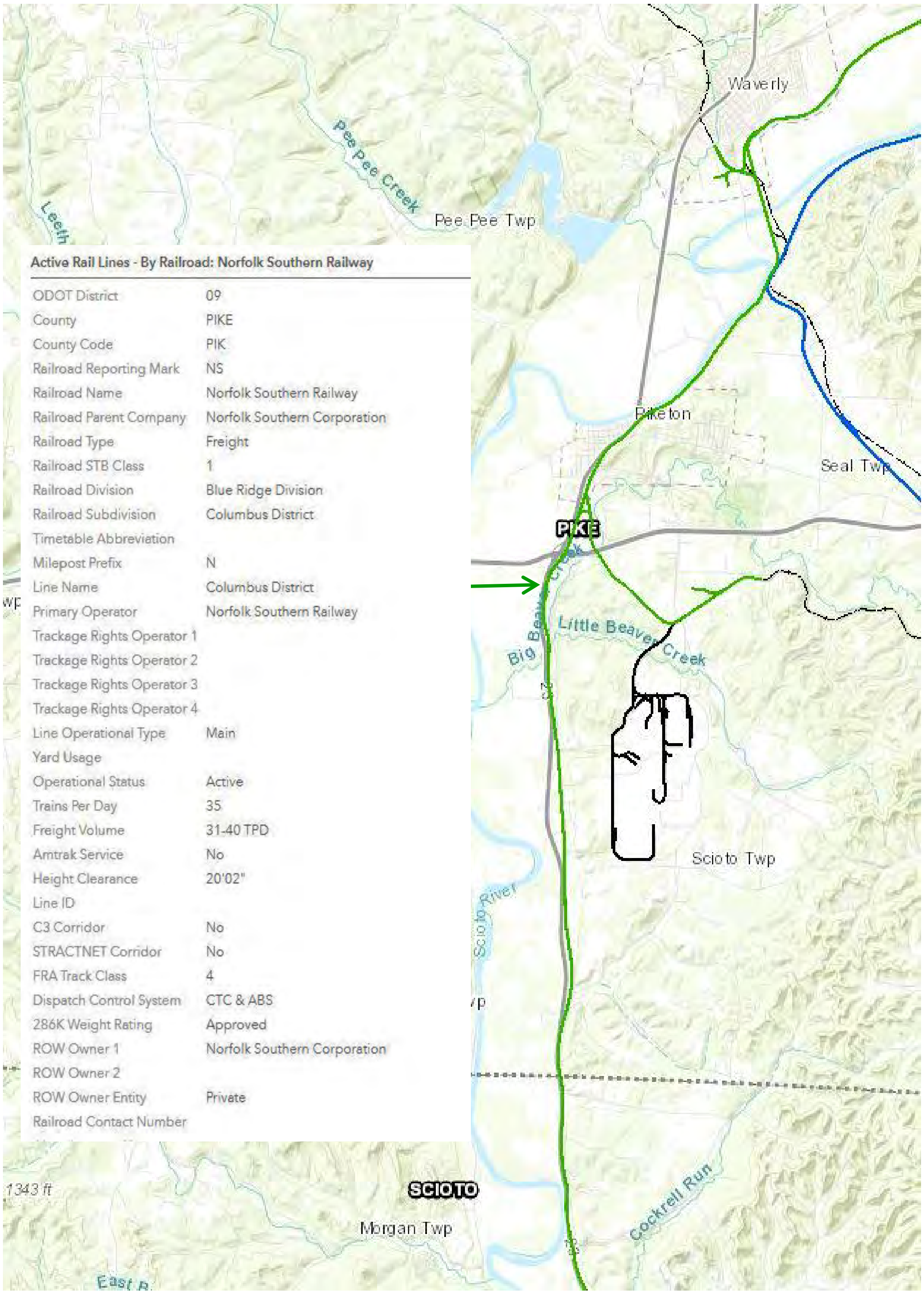


Figure 4-26: Norfolk Southern Railroad track information



ODOT District	09
County	PIKE
County Code	PIK
Railroad Reporting Mark	NS
Railroad Name	Norfolk Southern Railway
Railroad Parent Company	Norfolk Southern Corporation
Railroad Type	Freight
Railroad STB Class	1
Railroad Division	Blue Ridge Division
Railroad Subdivision	Columbus District
Timetable Abbreviation	
Milepost Prefix	N
Line Name	Columbus District
Primary Operator	Norfolk Southern Railway
Trackage Rights Operator 1	
Trackage Rights Operator 2	
Trackage Rights Operator 3	
Trackage Rights Operator 4	
Line Operational Type	Main
Yard Usage	
Operational Status	Active
Trains Per Day	35
Freight Volume	31-40 TPD
Amtrak Service	No
Height Clearance	20'02"
Line ID	
C3 Corridor	No
STRACTNET Corridor	No
FRA Track Class	4
Dispatch Control System	CTC & ABS
286K Weight Rating	Approved
ROW Owner 1	Norfolk Southern Corporation
ROW Owner 2	
ROW Owner Entity	Private
Railroad Contact Number	

Figure 4-27: CSX Railroad track information

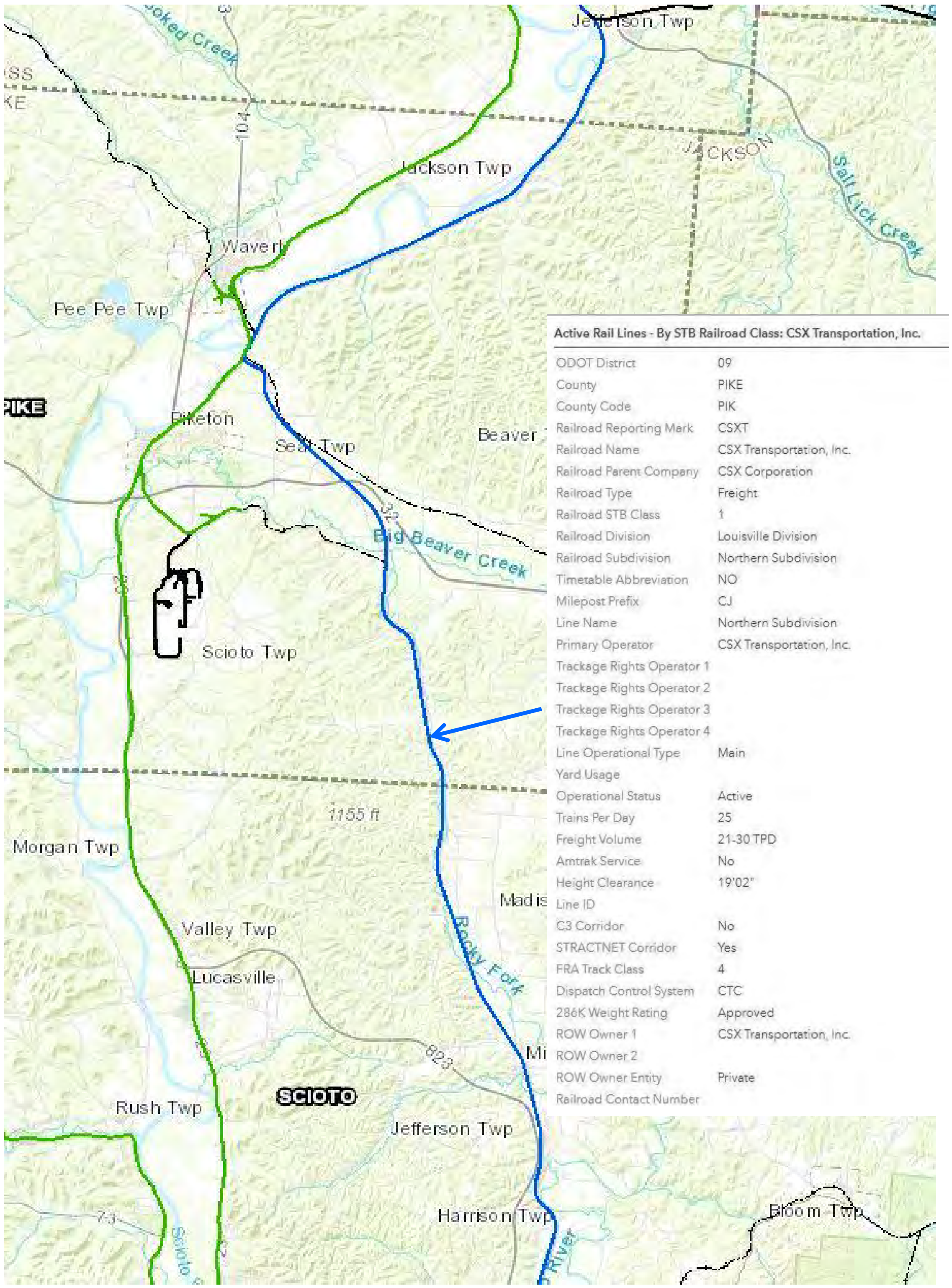
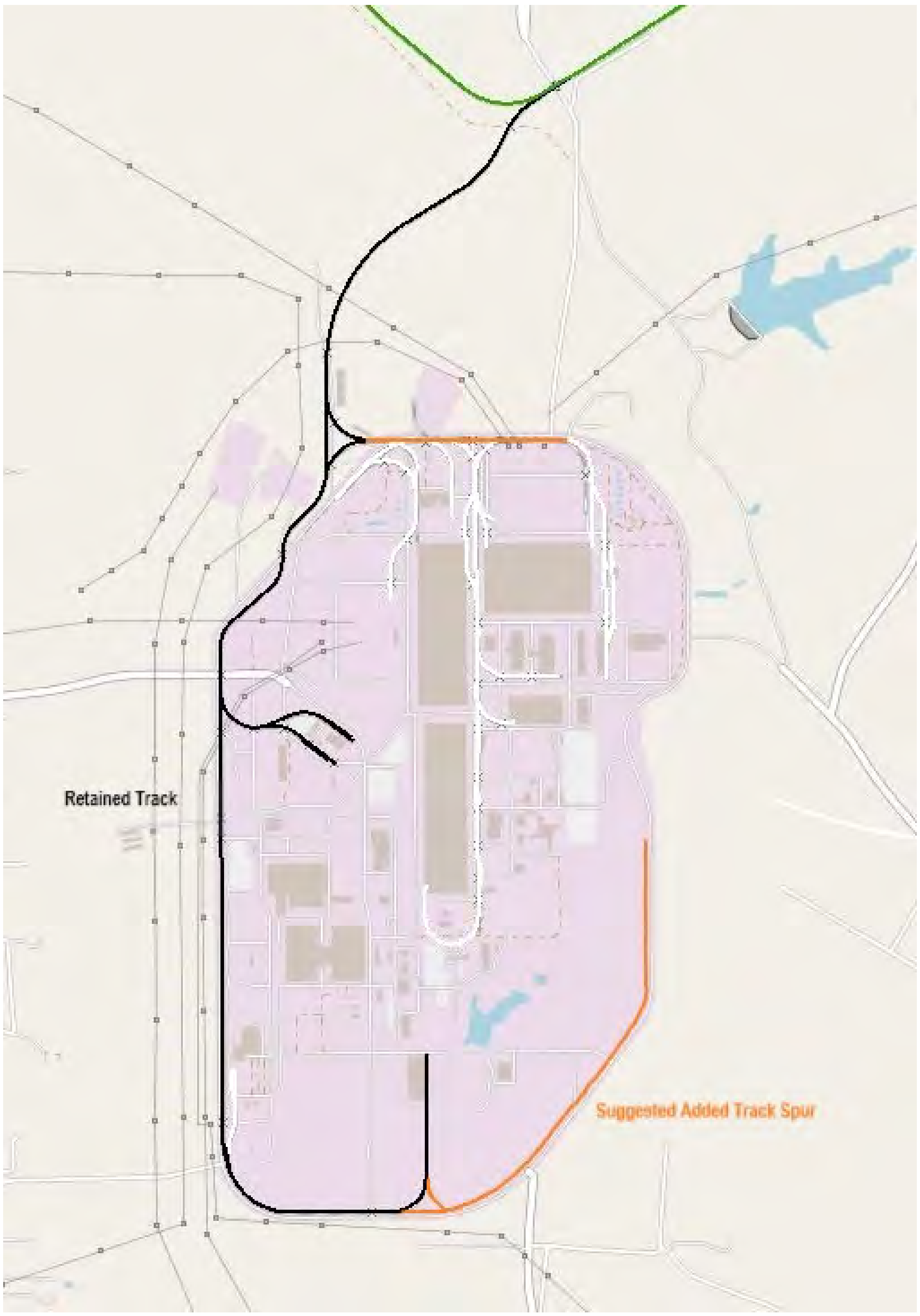


Figure 4-28: Suggested added track for PORTS



4.4 Systems

4.4.1 Electrical Grid and Water System Decommissioning, SODI

4.4.1.1 PORTS Electrical Grid

The PORTS electrical grid supported the distribution of large industrial electrical power to fully support the PORTS enrichment mission. The system was designed to bring in very large amounts of power when the Gaseous Diffusion Plant (GDP) system was in operation. The electrical grid continues to support the now shutdown GDP area, the American Centrifuge Project (ACP), the Depleted Uranium Hexafluoride Conversion Facility, and other sites. Both 345 kV and 13.8 kV lines run through the X-530A and X-530B switchyard and across the site on power poles and buried cables. Substations across the site allow local distribution of power (Portsmouth Gaseous Diffusion Plant Utilities Infrastructure Plan (PGDPUIP), FBP-DD-UT-PL-0001 Rev. 7, 2020, Section 17.1 [R-45]).

The closed GDP system draws a small fraction of the power formerly used when the plant was in operation. The ACP is also planned to draw down its power requirements going forward. The ACP draws 345 kV, and the DUF_6 plant uses the 13.8 kV lines (PGDPUIP, FBP-DD-UT-PL-0001 Rev. 7, 2020, Section 17.1 [R-45]). The greatly reduced power demand allows the system to remain functional despite the obsolescence of existing systems and minimal maintenance. The age and large original power capacity still demand significantly high levels of maintenance for the current low-power demand. The significant capacity of the electrical system and its potential effects on the electrical grid also bring it under North American Electric Reliability Corporation (NERC) requirements (PGDPUIP, FBP-DD-UT-PL-0001 Rev. 7, 2020, Section 17.2 [R-45]). NERC is the Electric Reliability Organization overseen by the Federal Energy Regulatory Commission (FERC) and other North American power grids according to the available information at the following link:

https://www.nerc.com/AboutNERC/Pages/default.aspx, visited 6/11/2021.

This adds to required reporting and reliability maintenance. NERC requirements are expected to be removed as part of the high-voltage system's lower-power reconfiguration described to the Public Utilities Commission of Ohio. NERC requirements may return if significant electrical power production is added to the site by a nuclear power plant.

Reconfiguration and ultimate removal of the high-voltage equipment is planned with the DOE, Ohio Valley Electric Corporation, and American Electric Power (PGDPUIP, FBP-DD-UT-PL-0001 Rev. 7, 2020, Section 17.4 [R-45]). Reconfiguration will reduce the risk of failure and create a sustainable system for the projected site loads. Further upgrades may be needed to ensure adequate operation for the needed life of the high-voltage equipment. Eventually, the 13.8 kV system will be optimized for the future site and creating space for potentially needed equipment and environmental planning would be useful.

Ongoing electrical support for the site will undergo significant changes so the cost of power is reduced and total power is delivered more efficiently. This will reduce operational and maintenance time and costs. An optimized system will reduce failure risk and better fit local demand. American Electric Power is set to take responsibility for power to the site in 2023 (PGDPUIP, FBP-DD-UT-PL-0001 Rev. 7, 2020, Section 17.4 [R-45]). Switchyard reconfiguration will provide an opportunity to account for a new advanced reactor to be deployed. Planning for the advanced reactor creates installed infrastructure.

Modern nuclear plants can have very different electrical-service requirements as provided in Advances in Small Modular Reactor Technology Developments, a supplement to IAEA Advanced Reactors Information System (ARIS) 2020 Edition [R-71]. Ultrasafe designs often do not require safety-related power delivery for post-accident operation. Obviating the need for safety-related electrical supply can allow an advanced reactor to operate with typical commercial power delivered to the site. Some advanced-reactor designs will conversely expect reliable offsite power as part of their safety-basis application with the NRC, making new electrical-supply equipment with a controlled design basis a requirement. The design of an advanced reactor will also influence the required house-load power. The coolant, pump design, and final heat sink requirements all influence house-load level ratio to output power. Air cooling, as the ultimate heat sink, increases house loads to drive fans for the cooling system.

The electrical system is currently unsuited for a new build of nuclear power without optimization. The 13.8 kV system was recently upgraded and could be used to provide house-load power to an advanced reactor. The 345 kV system has aged to the point where its use in a nuclear system is unlikely.

Powering the grid from a nuclear power plant would require high-capacity power lines sufficiently reliable for commercial operation. Total power from an advanced reactor ranges from a handful of megawatts to gigawatts. The extreme variance in potential power-production levels would require plans for an electrical switchyard to match the intended reactor.

In a regulated electrical market like Ohio Valley Electric Corporation, it would also be advantageous for a new nuclear power plant to have an agreement to take power with a local power company. Access to the grid can be made separate from the grid operator but planning for open access into the regulated grid can be costly and time consuming. AEC and FirstEnergy Corp. currently do not appear to include new nuclear in their power production planning according to the available information at:

https://www.aep.com/about/ourstory/cleanenergy, visited 6/15/2021, and

https://www.firstenergycorp.com/content/dam/investor/files/FEstrategicplan.pdf, visited 6/15/2021.

Public Utilities Commission of Ohio documents such as Understanding Electricity Markets in Ohio, Andrew R. Thomas, Iryna Lendel, and Sunjoo Park, July 2014 [R-74], discuss the difficulty of getting new-generation investments.

4.4.1.2 PORTS Electrical Grid Conclusions

The electrical grid at PORTS will shrink to match future power needs. The current system was created to support a much larger power use and is not suited to projected future demand. The high-voltage system will be made obsolete and removed, and the lower-voltage system would be optimized for future use.

The lower-voltage system has a potential to provide power to an advanced nuclear power plant. Details of the equipment needed would depend on whether the nuclear power plant design requires offsite electrical power as part of its safety basis.

Planning for power delivery to the grid as the system is reconfigured will provide benefits to deploying an advanced nuclear power plant. Given the extensive changes planned, some optimization can make the local electrical grid suitable for an advanced nuclear power plant. Using new, well-documented equipment would further benefit nuclear power plant deployment. Should the deployed plant be made smaller, demands on the electrical system would be reduced. Discussions with the local grid operator and electrical companies on how power is to be delivered to the larger commercial grid should be started to avoid delays and costs.

4.4.1.3 Potential Actions

Actions that could be undertaken in the near term would be to:

1. Select a potential plant design and establish a proposed power level, operating conditions, and likely house loads.
2. Start power purchase or delivery discussions with the Public Utilities Commission and power companies. Establish grid-connection plan for delivered power.
3. Establish an initial plan for incoming power from the best 13.8 kV lines. Include any needed changes into a 13.8 kV reconfiguration plan. For a low-power reactor, establish a plan to deliver 13.8 kV power to the grid. Include any changes into the 13.8 kV reconfiguration plan. For a plant delivering higher powers, identify a 345 kV grid-access point and plan to deliver power to the grid.
4. Review the choice of advanced nuclear power plant and iterate the technology choice to optimize overall siting selection.

4.4.1.4 Integrated Energy System

The likely future of nuclear power will include non-electric applications to provide the operator better economic performance. Producing hydrogen, ammonia, and other heat-enabled products can provide higher income to the plant when electrical prices are low. Integrated energy systems necessitate many additional decisions for site development. Including flexibility to the local electrical grid, particularly the 13.8 kV system, would enable the creation of industrial processes made possible by the nuclear power plant. Specific integrated energy systems can be evaluated with advanced nuclear power plant selection.

4.4.1.5 General Reuse Site Electrical Grid Evaluation

The electrical grid that supports a nuclear power plant needs to supply necessary power to that plant for operations and send electrical power produced back to the grid. Given the larger range in size for advanced reactors (1–1000 MWe), the demands on the electrical grid can be highly variable. Modern plants generate power at 5–34.5 kV and transmit between 13.8 and 765 kV, with higher voltages associated with higher power levels. The change in voltage, from generation to transmission voltages, requires switchyards with adequately sized transformers. Capital costs of the equipment and transmission lines, as well as maintenance and operational costs, can be on par with the cost of the nuclear equipment (2016 edition of the World Nuclear Association's World Nuclear Supply Chain).

The electrical grid typically has complex rules for access and adding infrastructure and operation (Commissioner M. Beth Trombold, History of Electric Regulation in Ohio, presented by 7th Partnership Activity of NARUC and NERC, June 2013 [{R-83}]). Given the potential complexities, starting necessary discussions early in a project to both take and deliver power would be very useful.

Given a potential site and reactor design, evaluation of the local electrical grid can be made. The need for both lower and voltage-supplied power and infrastructure and costs needed by higher-voltage produced power can be evaluated. Infrastructure cost should include the cost of establishing needed design-basis information. Upgrades and reconfiguration of existing equipment can play a central role in the preparation of a site for a new nuclear power plant. Safety-related incoming power supplies will require a high-quality design basis. Many industrial sites might lack documentation and maintenance; these will need to be upgraded. Stepping up to NERC/FERC grid-reliability requirements and reporting is also likely necessary for a nuclear power plant contributing to a larger grid.

Selection of nuclear power plant technology can create and relieve electrical grid requirements. Advanced reactors do not necessarily depend on external water and electric sources to remain safe. These advanced reactors will have reduced requirements that can enable economic siting at a particular location without the capital investment typical of current nuclear power plants. The ultimate heat sink also affects needed house loads. Fans to drive a closed-loop air-cooled system would reduce the plant's water requirement but increase the needed power. Each deployment would benefit from iterated siting studies.

Powering the grid from the nuclear power plant would require power lines reliable enough for commercial operation and maintenance.

Placing generated power into the electrical market is a complex, cooperative, and long-term activity. Working with local power companies to plan access and potential purchase of power is beneficial. Power companies have developed future, typically carbon-free production plans. Establishing interest in nuclear power and being credited as a green-energy source by the public is a goal in power-production planning.

4.4.1.6 General Reuse Electrical Grid Conclusions

The electrical grid that could support an advanced nuclear power plant needs to be optimized to the reactor technology and existing electrical-grid infrastructure. Planning for long-term nuclear operations would establish what level of investment in the electrical grid is required. Details of the equipment needed would depend on the nuclear power plant design. If the nuclear power plant requires offsite electrical power as part of its safety basis, the system will operate at higher reliability and cost.

Given the extensive changes typically required, optimization can make the local electrical grid suitable for an advanced nuclear power plant. Using new, well-documented equipment would further benefit nuclear power plant deployment. As the deployed nuclear power plant is made smaller, demands on the electrical system are reduced.

4.4.1.7 Actions

1. Select potential design and establish a proposed power level, operating conditions, and likely house loads of an advanced nuclear power plant.
2. Start power purchase or delivery discussions with the Public Utilities Commission and power companies. Establish grid-connection plan for delivered power.
3. Establish initial plan for incoming power through the best available lines. Identify electrical grid access points and plan to deliver power into the grid.
4. Review the choice of advanced nuclear power plant and iterate the technology choice to optimize overall siting selection.

4.4.1.8 Integrated Energy System

The likely future of nuclear power will include non-electric applications to provide the operator better economic performance. Producing hydrogen, ammonia, and other heat-enabled products can provide higher income when electrical prices are low. Integrated energy systems offer many additional decisions for site development. Including flexibility for the electrical grid would enable the creation of industrial processes enabled by the nuclear power plant. Specific integrated energy systems can be evaluated upon selection of an advanced nuclear power plant.

4.4.2 PORTS Water System

The PORTS water system, like the electrical system, was scaled for heavy industrial use and could handle the site's need for various water sources, uses, and volumes. The PORTS site is characterized by multiple water sources to meet site demand. This is analogous to the multiple water sources needed by a commercial nuclear reactor.

The raw-water system is the bulk source of water to the site. Two well fields, X 608B and X 6609, provided water for the site. Each well field included multiple electrically driven pumps. The well fields could produce 500-million-gal flow per year (PGDPUIP, FBP-DD-UT-PL-0001 Rev. 7, 2020, Table 3.1 [R-45]). This is still below the water required to cool a current gigawatt-type PWR, which would use approximately 5 billion gal per year according to available information at the following link:

> http://neinuclearnotes.blogspot.com/2008/03/nei-fact-sheet-on-water-consumption-at.html, visited 18 June 2021.

Plans call for reduced use of raw water as the population of the site declines. Significant growth in demand is possible as the on-site Waste Disposal Facility is built and water for dust suppression is required. Overall, the plan is that raw water demand will drop and be supported by a resized raw-water system. Eventually, the raw-water system will be replaced by an external commercial supply (PGDPUIP, FBP-DD-UT-PL-0001 Rev. 7, 2020, Section 3.4 [R-45]). The drawdown in delivery matches fading capabilities of the old system as currently maintained. The overall raw-water system includes buildings and pipelines that interface with other water systems. The future water supply plan accounts for these interactions.

The water treatment plant is the natural interface from the raw water system to other PORTS water systems including cooling, fire, and potable water. These systems received treated, potable water from the treatment house. General drawdown in site water use is expected to reduce demand at the treatment plant. The system would need improvements to be a reliable source of potable, non-safety water for a nuclear power plant. A plan to provide water from an outside company can replace the need for the water treatment system.

The recirculating cooling-water (RCW) system removed the heat created in compressing UF_6 for the gaseous-diffusion enrichment system. RCW used evaporative systems, including cooling towers, pumps, and a complex intra- and extra-building recirculating piping system (PGDPUIP, FBP-DD-UT-PL-0001 Rev. 7, 2020, Section 5.3 [R-45]). The RCW exists in part but no longer has a function. It is unlikely that a mission would be available for the RCW in a new nuclear power plant.

The make-up water system supplied additional water for the RCW system when it operated. The system provides water to the high-pressure fire system. Multiple component issues exist in the system. The system is not currently capable of supporting a nuclear power plant (PGDPUIP, FBP-DD-UT-PL-0001 Rev. 7, 2020, Section 6.3 [R-45]).

The HPFW and sanitary fire-water systems supply the sprinkler system in the gas-diffusion buildings and various fire hydrants. The pumps, motors, backup diesel power supplies, and supporting systems are in good shape. After leak repair and maintenance, the system could provide non-nuclear fire-safety requirements (PGDPUIP, FBP-DD-UT-PL-0001 Rev. 7, 2020, Sections 7 and 8 [R-45]).

Recirculating heating water was disconnected and does not have a current function (PGDPUIP, FBP-DD-UT-PL-0001 Rev. 7, 2020, Section 9.1 [R-45]).

4.4.2.1 PORTS Water-Supply Conclusions

Overall, the water system at PORTS is of little direct use to an advanced nuclear power plant. The PORTS site has demonstrated that it can support a large nuclear plant and substantial water use and demand. The existing systems would not practically support safety-related requirements. The system condition and design basis would not be suitable to safety-related nuclear applications. The condition of the water system should be considered when evaluating an advanced-reactor design for siting at PORTS. A reactor that has no safety-related water requirement and is potentially air-cooled would greatly simplify needed water systems. This would also make getting commercial water rights easier given the much-lower use of water.

(DOE water rights would not typically transfer to the new owner unless the mission was the same as the original DOE application: enrichment of UF_6, in this case.) Greatly reduced water rights also simplify the avoidance of any CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) or contamination issues that exist in the subsurface of the PORTS site.

The PORTS system may be able to supply non-safety-related water supplies. Potable water and non-safety-related fire suppression would be low volume but important capabilities to provide to a new nuclear power plant.

4.4.2.2 Actions

1. Select potential design and establish a proposed power level, operating conditions, and likely water requirements of an advanced nuclear power plant.
2. Plan to establish needed safety- and non-safety-related water supplies.
3. Review need for commercial water rights separate from DOE rights.
4. Review the choice of advanced nuclear power plant and iterate the technology choice to optimize overall siting selection.

4.4.2.3 General Reuse Site Water Evaluation

The water requirements for an advanced nuclear power plant can significantly depend on the technology employed. The largest likely use of water is to create the ultimate heat sink for the reactor. Current plants use up to 5 billion gal/yr to provide the ultimate heat-rejection source in once-through or closed-loop cycles to reject approximately 65% of the reactor's heat to the environment. Newer reactor designs can directly use air cooling as the heat-rejection sink. Reactors that use water to transfer heat can still use forced-air cooling to reject heat as needed. Less-significant water demand – for make-up water in closed loops, potable water, and fire suppression – are easier to establish and likely to be non-safety related, making commercial water sources capable of providing adequate supply.

Understanding total water requirements and whether the water is safety related allows planning for water sources. Central to using water is having an adequate water right for the water used. Water rights are of growing importance and are potentially a local community issue. Water rights are a specialized legal subtopic that engages local and state attention. Additional information can be accessed at the following link:

https://www.ncsl.org/Portals/1/Documents/energy/Energy_Water_Nexus_v04_33640.pdf.

It is recommended that a strategy be established early to avoid having a critical issue that may limit deployment options or economics.

Water use also has a direct connection to environmental evaluations. The more water used, the more important both withdrawal and return of the water becomes. Historic once-through water cycles are no longer authorized as provided by the EPA, refer to the following link for additional information at:

https://www.epa.gov/cooling-water-intakes, visited 18 June 2021.

Water has effects across the environment and is subject to multiple laws and regulations at both federal and state levels as provided by the EPA; refer to the following links for additional information:

https://www.epa.gov/laws-regulations/summary-clean-water-act, and

https://www.epa.gov/aboutepa/about-office-water, visited 6/18/2021.

National Environmental Policy Act (NEPA) compliance also requires integrating the effects of using water. The NEPA process begins when a federal agency develops a proposal to take a major federal action as defined in 40 CFR 1508.1. Refer to the following link for additional information:

https://www.epa.gov/nepa/national-environmental-policy-act-review-process.

It can be expected that new water infrastructure, pumps, wells, controls, treatment systems, and piping will be needed to ensure nuclear power quality is met. Even non-safety-related systems require high reliability to avoid imposing limits on power production. External commercial water supplies may be sufficient for non-safety-related water systems.

Advanced reactors do not necessarily depend on external water to remain safe. These advanced reactors will have reduced requirements that can enable economic siting at a particular site without the capital investment typical of current, water-intensive nuclear power plants. Fans to drive a closed-loop air-cooled system would reduce a plant's water requirement but increase the needed power and reduce total power available to the grid. The reduction in water use can change the need for electrical power. Each reactor deployment will benefit from iterated siting studies.

4.4.2.4 General Reuse Site Water Evaluation

The water supply for an advanced nuclear power plant will need to work efficiently with available water sources, regulations, and community needs. Starting with a new water-supply design allows optimization of the broad water needs of a nuclear power plant. Using new well-documented equipment would further benefit nuclear power plant deployment. As the deployed nuclear power plant is made smaller, demands on the water supply are reduced. Optimized advanced reactor designs can ease water requirements in new builds.

4.4.2.5 Actions

1. Select potential design and establish a proposed power level, operating conditions, and likely water requirements for an advanced nuclear power plant.
2. Plan to establish needed safety- and non-safety-related water supplies.
3. Review the need for commercial water rights separate from DOE rights.

4. Review the choice of advanced nuclear power plant and iterate the technology choice, including all water-use effects to optimize overall siting selection.

4.4.3 Site Drawings and Configuration Control

4.4.3.1 Site Drawing Availability

The availability of accurate, well maintained site drawings, including general site arrangement drawings, overhead lines, buried utilities, etc., is essential for efficient planning and, more importantly, worker safety. As various facility needs evolve, design changes are made to support the mission of the facility. Those changes are captured and maintained on numerous facility drawings under a configuration control program to ensure the locations and descriptions of systems, services, and related utilities are known at all times. When the decision is made to discontinue operations of a facility, the need to maintain those drawings remains until such time as they are no longer needed. Below are typical systems/facilities that are reflected on site arrangement drawings that should be maintained throughout the lifecycle of the facility to ensure safety, access, and optimized usage of the existing infrastructure.

- Electrical power distribution
- Fire protection system headers
- Service air and breathing systems
- Communication lines above ground and buried
- Potable water supply lines
- Storm water and sanitary drain lines
- Cathodic protection system
- Security systems, video surveillance, motion sensors, etc.
- Raw water
- Water treatment plant
- Recirculating cooling water
- High pressure fire water
- Recirculating heating water
- Storm drains
- Sanitary sewer
- Steam and condensate
- Nitrogen
- Fluorine

- Natural gas
- Communications, specifically:
  - Telephone system
  - Emergency telephone system
  - Plant public address system
  - Public warning siren system

4.4.3.2 Initial D&D Phase

During initial D&D of a facility, it is very important that staff have access to current drawings to support planning and implementation of a safe and effective D&D project. Locations, capacities, and conditions of site services and utilities are used to determine an approach to utilize the existing infrastructure to the greatest extent practical while also ensuring worker safety from inadvertent contact with energized systems including electrical, water, steam, communications, etc. Availability of current, well maintained site plans and drawings can lower overall costs of the D&D process by eliminating the need for temporary services and using the existing infrastructure. This translates into improved schedule efficiency and lower equipment costs.

4.4.3.3 Advanced Reactor Construction and Operations

When siting a new facility such as an advanced reactor, it is very convenient for planning staff to have access to current drawings that support the detailed planning required to repurpose a former use site. Locations, capacities, and conditions of site services and utilities would be used to support the evaluation process and determine the best location for the reactor building and support facilities. Understanding the locations of below and above ground systems and utilities would inform decisions on haul paths, staging areas, excavations, and all subsequent construction and plant operations while also ensuring worker safety from inadvertent contact with energized systems including electrical, water, steam, communications, etc. As stated previously, the availability of current, well maintained site plans and drawings can lower overall costs of the new construction and operating costs by eliminating or reducing the need for temporary services and using existing infrastructure. This translates into improved schedule efficiency and lower equipment costs.

4.4.3.4 Final D&D Phase

As previously stated in the initial D&D phase, access to accurate, well maintained site arrangement maps and drawings helps ensure the safety of workers performing final D&D activities. In addition, considerable schedule and cost efficiencies are provided by continued maintenance of accurate drawings throughout all phases of the site/facility's lifecycle. Whether the systems are active, removed, or abandoned in place, accurate drawings are a key factor in protecting workers and optimizing the value of existing infrastructure.

4.4.3.5 Site Specific Assessment:

Drawings of PORTS systems, services, and utilities appear to be well maintained and under configuration control that ensures accuracy of the current conditions.

Figure 4-29: PORTS GDP Recirculating Cooling Water Map

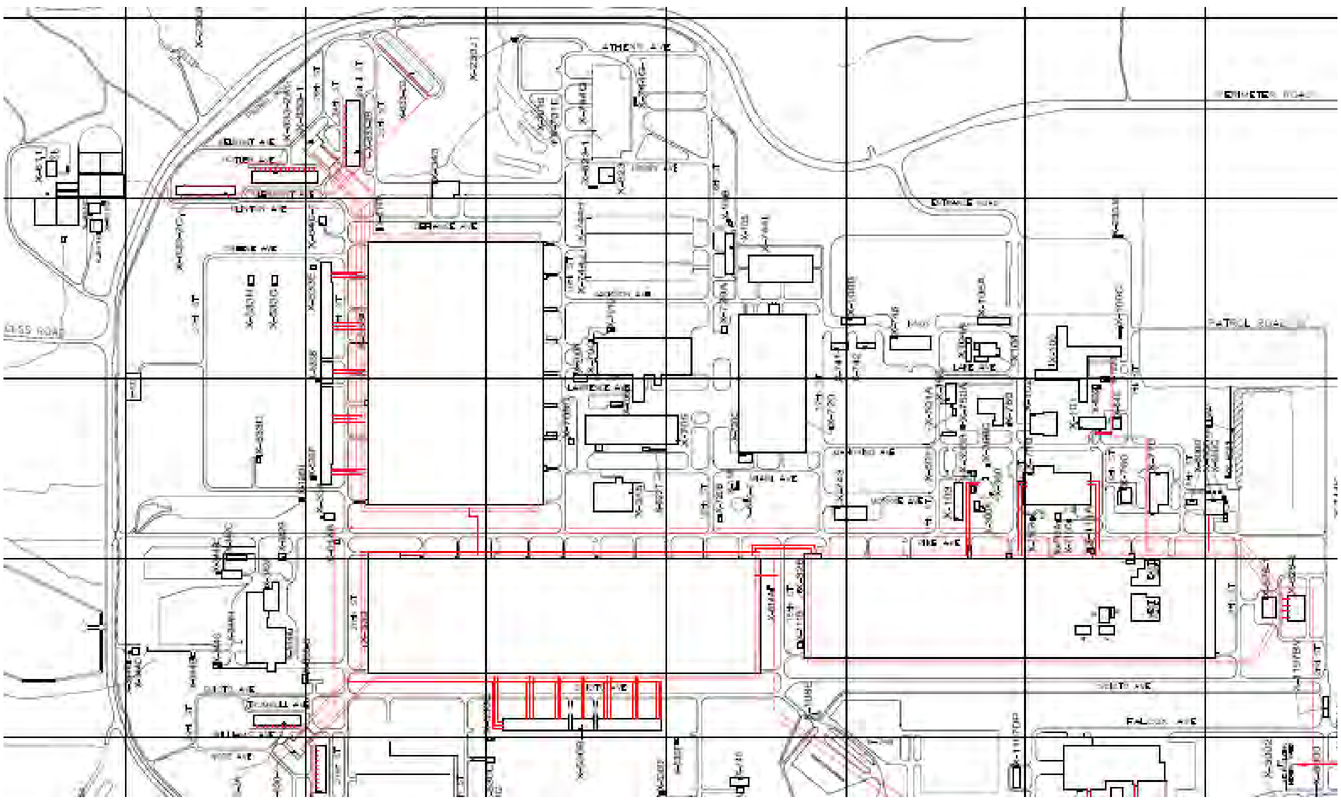


Figure 4-30: PORTS Sanitary/Fire Water System Map

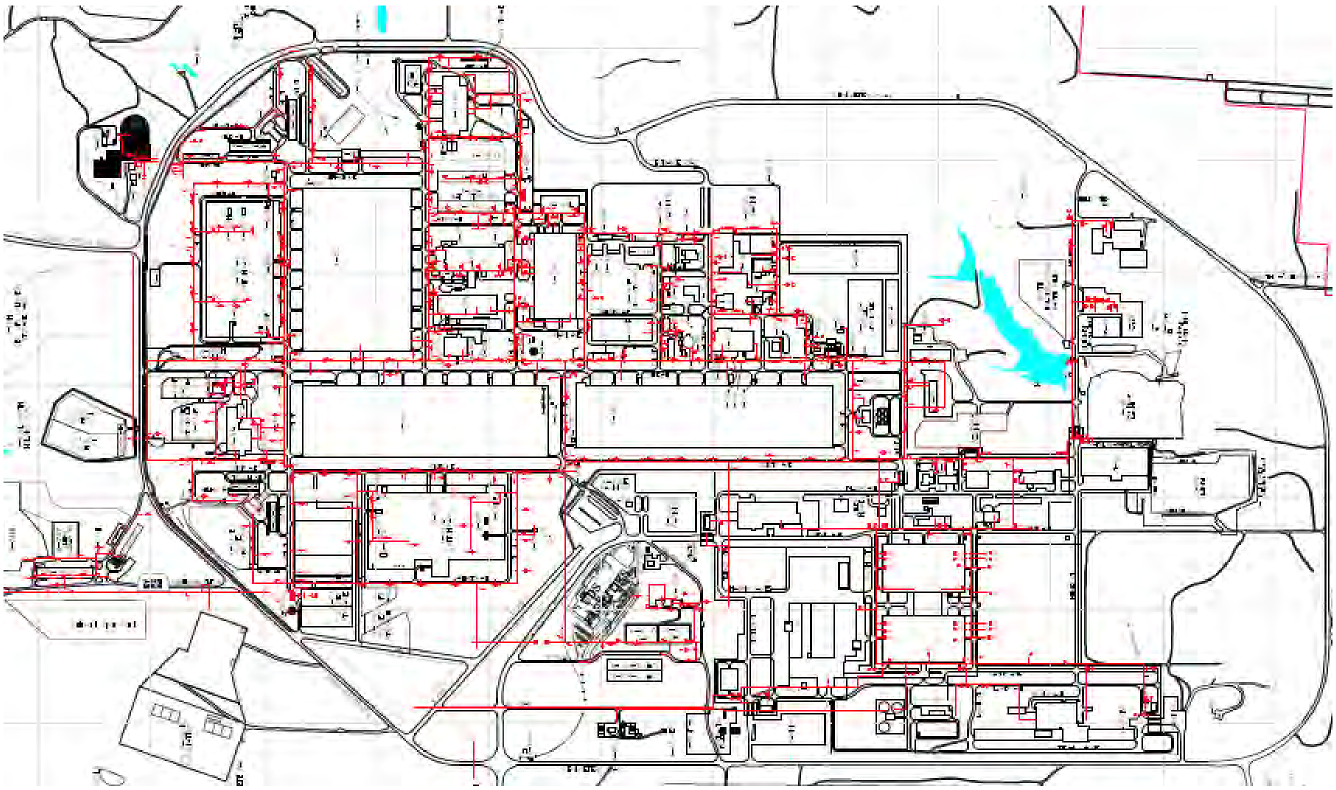
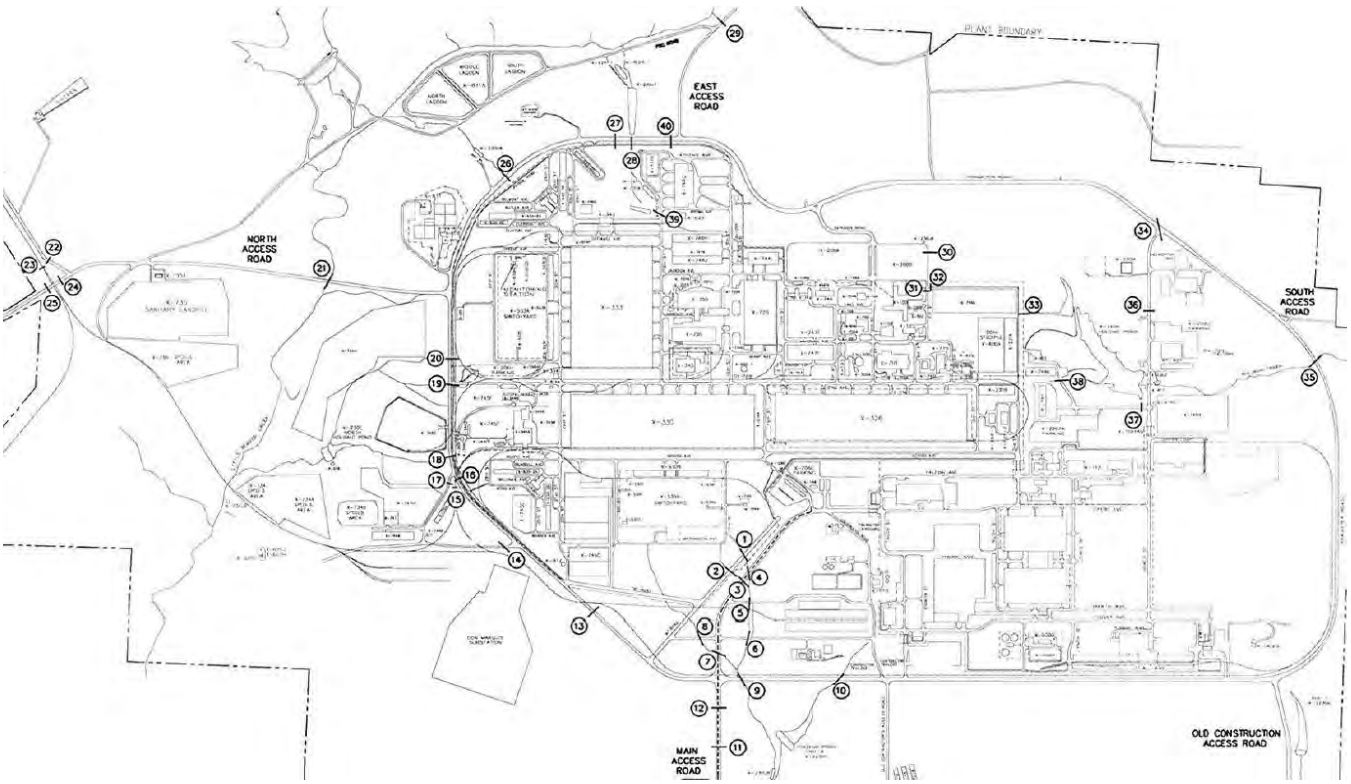


Figure 4-31: PORTS Storm Drain Culverts – Culvert Map



4.4.4 Below Grade Structures

During decommissioning of nuclear power plants, building basements, buried piping, and other commodities at depths greater than 1 to 2 meters are routinely left in place. This is also a common practice during dismantlement of non-nuclear facilities, as the approach offers both worker safety and economic benefits.

Many plants have successfully used what is termed the Basement Fill Model (see [R-71] for example). The general steps of the Basement Fill Model are:

- All components and commodities are removed.
- Remaining concrete is decontaminated as required to meet site radiological release limits.
- Holes are drilled through the walls to allow natural groundwater flow.
- The basement is filled with radiologically clean material (typically concrete rubble from demolished site structures).
- Finally, radiologically clean soil is overlaid to grade.

Under the Basement Fill Model, permissible levels of residual radioactivity are higher than those that would correspond to an intact structure left in place since the space would no longer have the ability to be occupied. Thus, the potential direct dose from building occupancy would not need to be included in calculation of release limits for the basement concrete.

Buried piping (for example, effluent discharge lines) and other commodities (air and water lines, electrical conduit, etc.) are also decontaminated as required to meet site release limits and otherwise remediated (de-energized, cleared of any hazardous material, etc.) as required if they are intended to remain in place. The effort to decontaminate and remediate buried piping and commodities is compared to the effort for removal to determine whether to leave in place.

It is understood that plans for management of below grade structures at PORTS have not been fully developed. However, it is also understood through written and verbal communications and review of site construction photos on the PORTSMAP website that substantial underground structures exist at the facility. Thus, this is an important topic relative to potential site reuse.

Leaving buried structures in place is often sensible during facility decommissioning. However, the practice may have implications for future reuse of the site, particularly if the site is intended for placement of new nuclear facilities. The primary challenges are:

- Many advanced reactor designs include placing all or a substantial portion of the reactor block below grade. This is a critical feature in the safety design of several of the plants and offers advantages in lowering construction costs. For example, the NuScale, BWR X-300, Holtec SMR160, Westinghouse SMR, and BWXT (mPower) plants all plan for substantial portions of the plants to be installed below grade. Thus, construction of these types of plants on the reused site would either require partial or full removal of the below grade structures previously left in place, or limitations on areas of the site where the power block may be built.
- Irrespective of plant design, any below grade construction activities have the potential to disturb the radiological material (RAD) left in place. While the radioactivity levels are low, any disturbed material would need to be properly handled and dispositioned.
- Aside from potential radiological impacts, the physical presence of below grade material simply has the potential to impact construction activities.

For sites intended for reuse, careful consideration should be given to leaving below grade structures in place and to permissible residual radioactivity levels for any structures left in place. In any event, a complete inventory of below grade structures left in place should be developed and conveyed to future site owners. The inventory should include, as a minimum, the location, physical dimensions, depth relative to grade, maximum depth, material(s) of construction, and average and maximum levels of residual radioactivity (recorded for all relevant radionuclides).

4.5 Infrastructure Needs for Advanced Plant Designs

The list of basic infrastructure needs for larger scale advanced nuclear reactors will be substantially the same as for the currently operating fleet. This includes items such as potable water; fire water; natural gas; compressed, service, and instrument air; heavy haul paths (for construction and large component replacement); storm drain system; electrical distribution systems; security system; meteorology systems; and others. Although the same types of infrastructure may be needed, the nature of specific infrastructure may be substantially different, as discussed below.

In contrast, the needs for microreactor designs may be dramatically different, as some designs (for example, the Westinghouse eVinci reactor) are intended to be essentially self-sufficient and thus have minimal infrastructure needs. These designs will not be addressed here on the basis that, if the site can accommodate a larger reactor type, it will be suitable for a microreactor.

Note that infrastructure needs unique to specific plant designs are typically included in the design (for example, components for handling molten salts) and are unlikely to be available for reuse on a repurposed site.

Cooling Water: Most larger, advanced plant designs produce electric power through a gas-driven turbine (typically steam) and thus will require a source of cooling water and heat sink to cool the working fluid for reuse (typically water). Some components of an existing cooling water system on site may be suitable for reuse, particularly intake and discharge piping and associated structures used for open cooling water systems. Although possible, it is unlikely that existing cooling towers or other components of closed cooling water systems would be compatible with a new plant design.

Office/Administration Buildings: Existing office buildings may be useful for a future new plant. However, some important factors may limit their value for reuse:

- Condition and age of digital infrastructure such as fiber optic cabling, wireless internet network, building security systems, etc. It is assumed that a potential new operator would need state-of-the-art systems for staff in the buildings. Given the rapid rate of advancement of technology year-to-year, it is unlikely that existing digital infrastructure would be suitable, even in the near future (that is, within the next ten years).
- Although staffing needs for advanced reactors have not been fully determined, a key characteristic of all designs is reduced staffing needs. It is conservatively estimated that staffing for an advanced plant will be at least 32% lower than for a comparably sized reactor in the current fleet, and likely much lower [R-72], [R-73]. Thus, needs for office space will be much less.
- Aesthetics must also be considered. It is assumed that a potential new operator would want all onsite buildings to look similar (or be visually compatible).
- Cost of care and maintenance between site release and reuse. The material condition of the building must be maintained to allow reuse.

Since the cost to construct an office building is low compared to overall plant cost, the factors above likely favor new construction rather than reuse.

Warehouse Buildings and Laydown Areas: Advanced plant designs generally include plans for modular construction of the power block. In many cases, such as the NuScale integrated PWR, nuclear steam supply system components will be factory assembled and delivered as a module. Additionally, advanced plant designs are intentionally much simpler, with a substantive reduction in the number of parts requiring periodic maintenance or replacements (valves, pump components, etc.). Moreover, the current practice of using offsite laydown areas and just-in-time delivery of components during construction is very likely to be employed for advanced plan construction as well. Thus, while some warehouse and laydown capacity will be needed during plant construction and operation, it is likely to be much less than required for current generation plants. As with office buildings, it may be undesirable to use any existing warehouse facilities for a new plant during operations due to aesthetics and digital infrastructure needs. However, warehouse buildings and designated laydown areas would have potential value during construction.

Chemistry Laboratories: Subject to limitations inherent to all buildings (age, safe storage maintenance, and aesthetics), it is likely that any standalone buildings housing chemistry laboratories could have good reuse potential. Of particular value may be laboratories for environmental chemistry and for monitoring cooling water chemistry, as these types of facilities are generally located away from the power block. While required analyses may differ between plant designs, basic laboratory design would be expected to be similar irrespective of plant type (fume hoods, bench space, demineralized water and instrument air lines, chemical storage, dedicated drainage system, etc.).

4.6 Short-term Infrastructure Improvements

The review of existing infrastructure for reuse identified short-term actions that would have the potential for immediate positive impact on the advanced reactor community's consideration of PORTS. The short-term actions that follow could be achieved via simple grant requests as these are short term in development, execution, and relatively low-cost improvements that would show advanced reactor developers the advantages of selecting the PORTS site and the SODI property for placement of an advanced reactor facility.

These grant requests would be based on the phases listed below, each as a single grant or the phases combined under a single grant. Phases include:

a. Study for justification including current needs, potential growth of site and community, cost and cost recovery/payback/long-term operational expense/revenue, and viable operator;

b. Conceptual design, siting, and construction plans;

c. Final design and construction;

d. Plant commissioning and turnover to operator.

Short-term infrastructure improvements are described in the subsections that follow.

4.6.1 Natural Gas Line Relocation

Relocation of current natural gas lines from the center of SODI property to the property perimeter would increase available options for suitable reactor site property and demonstrate usability of SODI property to an advanced reactor developer. Justification for relocating current natural gas lines is that leaving the current gas line easement in place through the center of the SODI property greatly reduces available property, access, and sites suitable for a reactor facility.

4.6.2 Power Transmission

Site easements for near-term power transmission from the current SODI property to the PORTS switchyard would show PORTS site suitability to an advanced reactor developer. SODI and DOE are now allowed to plan for power transmission easements. The easement plans would show future advanced reactor developers options for low-cost connection of the reactor facility to the PORTS switchyard, demonstrate usability of the SODI property, and add to the PORTS site suitability for a reactor facility placement.

4.6.3 Interconnect Study

Performing and publishing an interconnect study by SODI would support a decision basis for potential incoming advanced reactor developers. The interconnect study would show future advanced reactor developer usability of the SODI property and show the PORTS site as a suitable location for placement of an advanced reactor facility.

4.6.4 Rail Lines

Extension of current rail access to lower the part of PORTS site and SODI property would show PORTS site suitability to an advanced reactor developer. The plan would include retaining and maintaining rail line sections L74 and L72 and extending section L72 alongside Perimeter Road to the SODI property. As shown in Figure 4-32, extending current rail access would illustrate future usability of the SODI property to an advanced reactor developer and add to the PORTS site suitability for a reactor facility placement in the near-term future. A request was started by Kevin Shoemaker of SODI in late August 2021.

4.6.5 PORTS Water Treatment Plant

Replacement of the PORTS water treatment plant would show usability of the SODI property to an advanced reactor developer as well as make the site more desirable for serving the reactor facility, current leaseholders/DOE owners, and the community as a whole. Replacement of the PORTS water treatment plant would illustrate future usability of the SODI property to an advanced reactor developer and add to the PORTS site suitability for a reactor facility placement in the near-term future.

4.6.6 PORTS Sewage Treatment Plant

Replacement of the PORTS sewage treatment plant would show usability of SODI property to an advanced reactor developer as well as make the site more desirable for serving the reactor facility, current leaseholders/DOE owners, and the community as a whole. Replacement of the PORTS sewage treatment plant would illustrate future usability of the SODI property to an advanced reactor developer and add to the PORTS site suitability for a reactor facility placement in the near-term future.

4.6.7 Consent Based Siting Process

Entering a Consent Based Siting process for an advanced reactor with a generated ESP for the PORTS/SODI property would show an advanced reactor developer that the groundwork for the siting process has been performed to accelerate the advanced reactor licensing and construction process. Performance of this process would provide real potential to improve advanced reactor industry, public power availability, and community development. Independent grant considerations and/or phases to be as follows:

a. Characterize available PORTS and SODI site property;

b. Perform Geographic Information System/Light Detection and Ranging mapping of PORTS/SODI property and other potential property to support characterization data;

c. Perform seismic and flooding analysis of characterization/site application area;

d. Perform demographic data study to support site advanced reactor and related new support industries for worker supply and commute, housing, equipment supply, consumer retail sales, medical and healthcare services, education/school development parameters for current and future workers, etc.;

e. Determine other potential property needed outside of the PORTS/SODI property immediately available to support long-term site/region/industry growth.

4.6.8 Unrestricted Use of SODI Office Space

Create and execute a program to characterize, prioritize, free-release, D&D if necessary, then transfer office building property to SODI for future rental purposes to incoming re-industrialization stakeholders of the PORTS site. This effort would also evaluate incoming property for upgrades against operation cost/revenue to determine upgrade potential of the property. Planning and execution of this program would show usability of the SODI property to an advanced reactor developer as well as make the site more desirable for serving the reactor facility, current leaseholders/DOE owners, and the community as a whole. This program would show future usability of SODI office space to an advanced reactor developer and incoming re-industrialization stakeholders of the PORTS site.

Figure 4-32: SODI requested retained and additional railroad track at PORTS

4.7 Long-term Considerations

Long-term considerations identified from the review would have positive impact for development of the PORTS region for long-term sustainability of an advanced reactor and supporting related higher technology industries. Realizing short-term actions and long-term considerations for PORTS infrastructure improvements would be realized via Infrastructure Bill grant requests. Each grant request would consider social, economic, and environmental justifications and include impact for sustainable reindustrialization, regional growth, and independence from DOE programs as a driving force behind each grant request.

4.7.1 Human Resource Development

Develop a program for long-term human resource development that includes university and vocational training administered and executed jointly by local higher education units and unions (Steel, Building Trades (electrical, plumbing, masonry). The program would show human resource development with consideration for the PORTS community as well as regional growth. The program would include industries other than just advanced reactor deployment and its supporting industries and show it to be self-sustaining and supported by outside funding mechanisms. The program would include evaluation to determine specific skill and education needs for both short-term and long-term growth including location mapping, education funding and participant scholarships, and specific education and/or vocational skill development tracks.

4.7.2 Clean Energy Industrial Demonstration Project

Based on stakeholder input, plans need to be developed for a carbon free clean energy industrial park as a demonstration project for hydrogen generation and utilization standalone project or as a regional hydrogen generation and distribution industrial hub and integrated energy system. Benefits of an advanced reactor in an integrated energy system are described in the Nuclear Innovation: Clean Energy Future (NICE Future) publication titled Integrated Energy Systems: Maximizing Clean Energy for Industry, Transportation and the Grid [R-84] at the following link:

https://www.nice-future.org/assets/pdfs/21-50289-integrated-energy-systems.pdf

The NICE Future publication provides information regarding industries that can benefit from carbon-free nuclear heat, as follows:

- Bioenergy and bioproducts: Heat can dry and process biomass into more useable forms for making biofuels, biopower and bioproducts, or for upgrading biofuels into higher value products.
- Hydrogen: Heat and electricity can be used to make clean hydrogen, avoiding the carbon dioxide generated by today's techniques (steam methane reforming). Carbon-free hydrogen can be stored and turned back into electricity, burned as a clean transportation fuel or converted to valuable chemicals such as ammonia, a key ingredient in fertilizer.

- Water: Heat and electricity can power desalination plants that convert salty or brackish water to potable water for drinking or agriculture, or to clean industrial wastewater.
- Agriculture: Heat can be used for greenhouses, soil warming or to help dry and process crops. Nuclear energy can also support production of fertilizer, herbicides, and pesticides, all of which require significant process heat to produce.
- CO_2 capture: Heat and electricity can power chemical reactions that convert CO_2 from fossil fuels or biofuels into useful chemicals, such as carbon monoxide and methane. These chemicals can then be used to produce any number of products including plastics, polymers, other chemicals and carbon-based fuels, especially syngas. When that CO_2 is captured from a nearby fossil fuel plant, it can be combined with hydrogen to produce "synfuels" that can be burned in a standard gasoline engine.

The demonstration project planning would include all short-term items listed in Section 4.6 and Long-Term Considerations in Section 4.7.1 as these are necessary to support advanced reactor siting, construction, commissioning, and long-term operation. The planning would also include evaluations for additional available land and land use needed as well as supporting industries and their product generation, and additional infrastructure that may be needed. The approach to advanced reactor and hydrogen generation applications would be singular for each supporting facility or supporting industry with evaluation of which comes first and where, or for a combined SMR ESP Application.

4.7.3 Additional SODI Operational Programs

Additional SODI operational programs will need to be considered, developed, and funded to support transfer, upgrades, and maintenance of a DOE building transfer program. Because DOE will not fund upgrades and maintenance in future if SODI/Community owns buildings, SODI would need to include additional operational programs in concert with Section 4.6.8, Unrestricted Use of SODI Office Space in the Short-Term Actions.

4.8 PORTS Property End State and Reuse Scenarios

This report section provides information regarding PORTS property available for reuse and reindustrialization, requirements for title transfer from the DOE to the private and public sectors, and discussion of various end state scenarios with relative factors such as cost, schedule, and reuse restrictions. Although this study is focused on PORTS, the process and guidance are applicable to all DOE D&D sites. The ROD under the regulatory authority of the Ohio EPA defines the conditions required to allow transfer of PORTS property to new ownership. The ROD binds the DOE with responsibility to clean up PORTS property impacted by known site contaminants (i.e., RAD and/or non-radiological HAZMAT that occurred from past PORTS operations and defines the conditions that must be met before DOE can transfer PORTS property to a new owner.

There is a sizable amount of PORTS property that falls into a category of non-impacted from past PORTS operations with ownership of two small parcels already transferred to SODI, the designated CRO for PORTS site reuse and reindustrialization. However, there exists large centrally located parcels of PORTS property that have been impacted by contaminants from past PORTS operations. Most of the impacted property will undergo decommissioning, dismantlement, and other remedial actions to meet ROD criteria for title transfer. For property intended for title transfer, DOE has the mission to leave the property in as close to preexisting and usable condition as possible in accordance with the ROD. However, there is some property that will remain under DOE management and will not be transferred as provided in the DOE's Environmental Assessment, DOE/EA-1856.

4.8.1 DOE PORTS Environmental Assessment

The DOE completed an EA, DOE/EA-1856, for conveyance (title transfer) of DOE real properly located at PORTS for mixed use economic development. The EA was conducted to meet NEPA requirements and resulted in findings of no significant impact in assessing consequences of the transfer of PORTS real property for reuse and reindustrialization. The purpose and need for DOE's Proposed Action (i.e., title transfer) is to support local economic development, reduce the footprint of the site, and reduce the cost to maintain the site. Because the EA resulted in findings of no significant impact, the DOE was not required to perform a NEPA EIS. The EIS process takes many years to complete and would require DOE to suspend PORTS site D&D activities until completed.

Under the Proposed Action, DOE evaluated the transfer of up to 3,677 acres of real property. However, significant portions of land within the 1,200-acre centrally developed area would not be transferred until after D&D and remedial actions are completed, and property used for waste disposal locations will not be transferred. In an effort to classify PORTS site property including buildings, systems, and environmental soils areas, the DOE conducted numerous historical site assessments (HSAs), site characterization surveys, and other investigations. Results of the site characterization efforts were evaluated and used to classify the PORTS properties as impacted or non-impacted to determine what, if any, remedial actions were necessary to meet the ROD criteria for property transfer.

4.8.2 SODI and PORTS Property Reuse

Potential developers, including advanced reactor developers, must address many steps in the licensing process for application of permits and ultimately their license application to site and build an advanced reactor. In this process, advanced reactor developers are required to develop and present their advanced reactor design in the license application and are also required to present the location and/or siting of where the reactor will be built as required in 10 CFR 52 Subpart A – Early Site Permits. Because the effort to design an advanced reactor can take as much time as the advanced reactor siting and licensing process, it is prudent for advanced reactor developers to develop an ESP in parallel with the process to obtain the advanced reactor design certification.

At the PORTS site, the DOE has designated SODI as the CRO for future reindustrialization of the former PORTS site. As the designated CRO, SODI can take clear title to land and surplus property from DOE for lease, resale, and reindustrialization. The SODI team was awarded contract DE-NE0008934, Site Reuse Deployment Guidance Project, to evaluate and plan for reuse of SODI property on the former PORTS site. One project specific objective is for the SODI team to review existing data from the former PORTS site that could aid in applying for and obtaining an ESP from the NRC for the purpose of siting, constructing, and operating an advanced reactor on the SODI property.

Since its inception, SODI has worked with all stakeholders in the region to move toward reindustrialization at PORTS. The SODI effort will reduce the time required for advanced reactor constructors to develop and obtain an ESP by several years and millions of dollars in cost while presenting the PORTS site as a desirable location for advanced reactor siting.

4.8.3 PORTS Property Area Classifications

Much of the information and terms used in this section is based on guidance documents, including:

- DOE, EPA, and NRC consensus guidance provided in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), DOE/EH-0624, Rev. 1, EPA 402-R-97-016, Rev. 1, and NUREG-1575, Rev. 1, and
- NUREG-1757, Consolidated Decommissioning Guidance Volume 2, Characterization, Survey, and Determination of Radiological Criteria (Revision 1).

Using this guidance, PORTS property buildings, systems, and environmental soils areas can be classified as either impacted or non-impacted by PORTS operations. The terms “impacted” and “non-impacted” are area classifications from the guidance documents as they apply to PORTS structures, systems, and components (SSCs) and environs.

4.8.3.1 Non-impacted Property for Title Transfer

Non-impacted property includes areas with no reasonable potential for residual RAD and/or HAZMAT in excess of natural background or fallout levels for RAD. Areas with no reasonable potential of residual RAD or HAZMAT include those without a history of storage or use of RAD and/or HAZMAT and/or shown to be free of contaminants from PORTS operations based on characterization data. Upon agreement between Ohio EPA and the DOE, PORTS property (i.e., SSCs or environs) meeting the non-impacted classification could undergo a title transfer from the DOE to the CRO for future private or public venture on an “unrestricted use” basis provided conditions of the ROD are satisfied.

For example, 80 acres of PORTS property known as Parcel 1 and 240 acres known as Parcel 2 met non-impacted environ criteria, have agreement of Ohio EPA and the DOE, and have already completed title transfer to SODI. The Parcel 1 and Parcel 2 properties are currently being considered for reuse for construction of an advanced reactor following the NRC process for development of an ESP application (see Figure 4-15 for PORTS location). NRC requirements and process for siting a reactor facility is beyond the scope of this section but is presented in the ESP Application Template Report. According to the DOE EA, up to two-thirds of the PORTS property has potential for obtaining a non-impacted classification and being suitable for reuse and reindustrialization.

4.8.3.2 Impacted Property for Title Transfer

Impacted SSCs or environs are areas with some reasonable potential for residual RAD contaminants and/or HAZMAT contaminants in excess of natural background or fallout levels for RAD. Areas with a reasonable potential of residual RAD or HAZMAT include those with a history of storage or use of RAD and/or HAZMAT or are shown to be contaminated with detectible levels of RAD and/or HAZMAT from PORTS operations based on characterization survey data. An area can be a structure, system, or component (SSC) or environ and have an impacted classification. Depending on the degree of contamination or potential for contamination, these areas or survey units are further separated into one of three designated classes; Impacted Class 1 area, Impacted Class 2 area, or Impacted Class 3 area, as follows:

1. Impacted Class 1 SSC or environ area is the most contaminated area; an Impacted Class 1 environ may also include subsurface RAD and/or HAZMAT contamination.
2. Impacted Class 2 SSC or environ area has residual contamination at or above cleanup criteria but without subsurface RAD and/or HAZMAT contamination.
3. Impacted Class 3 SSC or environ area has detectable RAD and/or HAZMAT residual contamination at or below cleanup criteria.

An Impacted Class 3 SSC or environ area may require some remediation to meet ROD conditions and/or performance of an EA before title of the property could be transferred. In contrast, an Impacted Class 1 area can require remedial actions that may include decontamination, demolition, excavation (for an environ), and removal to meet ROD cleanup criteria before title of the property could be transferred. There is considerable planning, scheduling, and resource utilization required in efforts to remediate an Impacted Class 1 area. An Impacted Class 2 area would require some remedial actions, but to a lesser degree than an Impacted Class 1 area.

The cost associated with cleanup of an Impacted Class 1 area is the most expensive and is dependent upon many factors. The primary factors to determine cost for a remedial action include the type of area (i.e., SSC or environ), the RAD and/or HAZMAT contaminants, and the lateral and vertical extent of the contamination. This information is obtained from following DOE, EPA, and NRC guidance provided in the MARSSIM and performing an HSA and a comprehensive site characterization of the area. Data from a proper HSA and characterization form the basis for all downstream planning, scheduling, and estimating the cost of a remedial action.

The HSA and characterization data provide information on what materials are contaminated above cleanup criteria and also allow planners to determine the most appropriate technology, methodology, and resources needed to achieve cleanup goals. From this, waste types and waste volumes generated by the remedial action can be estimated to provide further planning for waste packaging, transportation, and disposal. Each of these process elements are input to resource loaded schedules and are ultimately used to determine the cost and budget needed to successfully perform the remedial action. First and foremost with all such planning is with safety of the public, workers, and the environment in mind.

4.8.4 PORTS Property Release for Title Transfer

Cleanup of PORTS impacted property to meet criteria for title transfer will require a range of methods as discussed in Section 3.0 of this report. Methods may range from performing an EA for Class 3 SSC or environs, a focused decontamination on Class 2 SSC or environ, to major decommissioning, dismantlement, decontamination, and other removal actions to allow for release of Class 1 property. The goal for each of the cleanup methods is to obtain release for "unrestricted use" of the property that would allow property transfer in accordance with the ROD. However, in cases where release for unrestricted use is unattainable, title transfer on a "restricted use" basis is possible.

According to the DOE EA, obtaining property outside of the EA stated assumptions would require a prospective property buyer to develop a proposal for DOE and Ohio EPA review and approval. The proposal would also include an EA specific to the property that includes a reuse scenario and the conditions for restricted use of the property. If approved by the DOE and Ohio EPA, the property title could be transferred on a limited or restricted use basis.

A hypothetical example for a restricted use of property could be reuse of a concrete pad that meets criteria for unrestricted use, but because of subsurface contamination from a plume extending over a large site area, there is a restriction against disturbing surface and subsurface soils or other media such as asphalt walks and roadways. A reuse scenario for the concrete pad, walks, and roadway to the pad could include construction of a warehouse for storage of materials and supplies. A restriction would be that all services required for warehouse operations would enter and exit above ground. This is one of many possible reuse and/or reindustrialization possibilities for PORTS property title transfers.

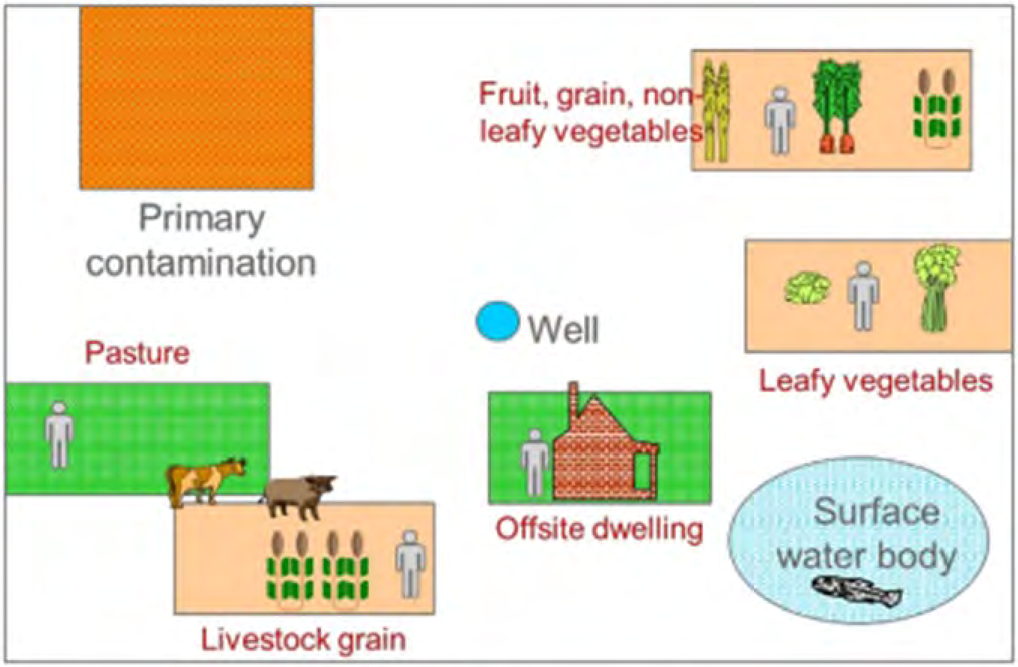
4.8.5 Defining PORTS Property End State and Reuse Scenarios

An essential element of defining the "end state" of any decommissioning project is development of the final use scenario. By clearly defining the reuse scenario, one can create realistic models that estimate potential exposure pathways to hypothetical individuals that would occupy the land or structures to be released. The residual contaminants, if any, are evaluated to predict theoretical exposures that may result for the various reuse scenarios. They range from "industrial reuse" as depicted in Figure 4-33, with very limited occupancy and restrictions on the types of activities permitted, all the way to a "resident farmer" scenario as depicted in Figure 4-34, which is the most conservative in nature.

4.8.5.1 Brownfield End State and Reuse Scenario

Shown as the "Primary contamination" in Figure 4-33, "industrial reuse" would be considered a "brownfield" end state site. A brownfield site has residual contaminants that would typically prohibit occupancy for an individual member of the critical group for greater than 40 to 60 hours per week. Other prohibitions can include no surface disturbing activities or excavations would be allowed, for example.

Figure 4-33: Industrial Reuse Scenario



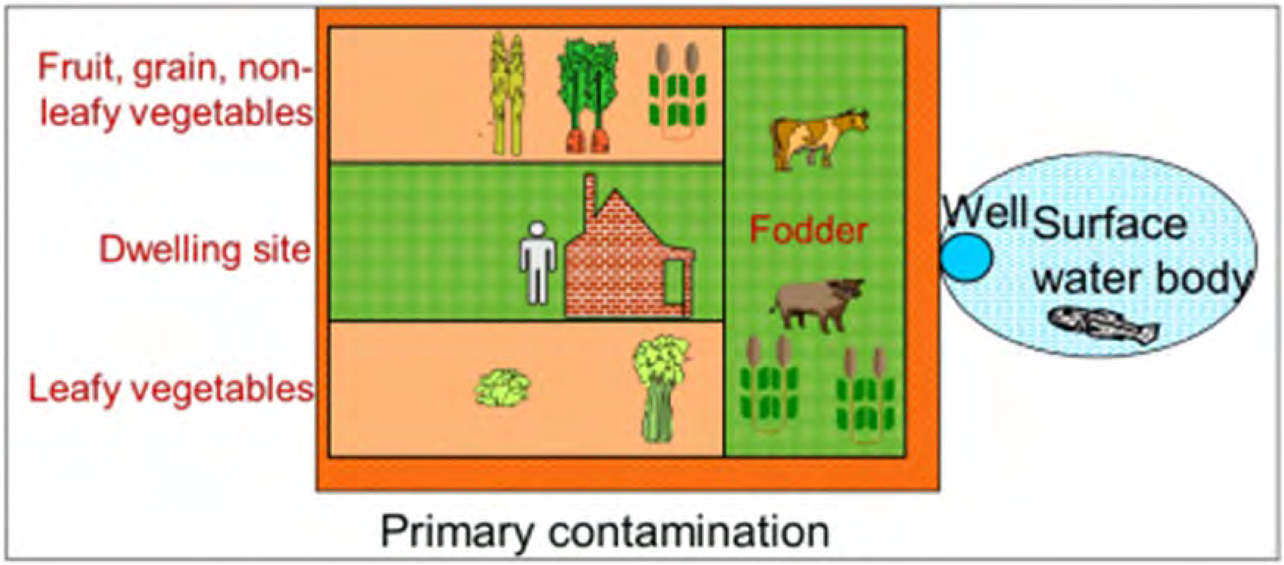
Exposure Locations for an Offsite Exposure Scenario

Other regulator prohibitions placed on a brownfield industrial reuse area include that emissions from site contaminants must limit exposure to the public and environmental areas within a defined proximity of approved site activities. Regulations require emissions from the brownfield site be monitored to ensure no offsite release of contaminants in air and water could present exposure risk to the public. The monitoring program, referred to as the Radiological Environmental Monitoring Program (REMP), is required to ensure exposure through the air, in drinking water, crops, livestock, and fish consumed by the public is kept ALARA.

4.8.5.2 Resident Farmer End State and Reuse Scenario

The “resident farmer” or more commonly known as “greenfield” scenario assumes continuous occupancy, farming, drinking of ground water, and many other conservative assumptions on a formerly impacted site as depicted in Figure 4-34. D&D and cleanup of an impacted site to greenfield levels greatly limits the amount of residual RAD and/or HAZMAT that would be permitted to remain onsite. A greenfield site may have previously been an Impacted Class 1 area, Impacted Class 2 area, or Impacted Class 3 area that has been remediated to contaminant levels to meet a resident farmer reuse scenario. The process known as a final status survey is planned and implemented following site decommissioning and/or remediation of a site to show that derived concentration guideline levels (DCGLs) have been met and the site can be released for unrestricted use by a responsible regulatory authority such as the EPA and/or the NRC.

Figure 4-34: Resident Farmer Scenario



Exposure Locations for an Onsite Exposure Scenario

The use of advanced modeling codes such as ResRad will allow the landowner and the regulator to agree upon an acceptable end state and the corresponding clean up levels expressed as DCGLs.

4.8.6 Evaluation of Scenarios

As described above, the industrial reuse or brownfield scenario limits possible reuses of a facility to those that have been evaluated and are bounded by the model. For example, low levels of activated or volumetrically contaminated concrete or soils may be left in place but there would be restrictions on cutting, digging, or excavating the areas of concern to prevent unintentional release and exposure to individuals from the very low levels of contamination. Reuse of any impacted structures, systems or land areas that have not met unrestricted release criteria would be governed by the regulatory authority for the site. For PORTS the reuse would be governed by the Ohio EPA and DOE according to the conditions stated in the ROD.

The benefit of allowing low levels of residual activity to remain is cost and schedule savings as well as potential reduction of risk and exposure to workers performing D&D activities. Allowing radioactive materials to remain in place in a stable condition while shorter-lived nuclides continue to decay is known as beneficial decay. While this option does result in many near term benefits, there are also tradeoffs down the road to consider. Depending on the nature and extent of the residual contamination, certain activities like new construction, excavation, and other surface disturbing activities may be restricted. This greatly reduces the options for reuse scenarios and must be considered during planning of the site's decommissioning. A summary of the pros and cons of the end states are provided in Table 4-1.

Table 4-1: Reuse Pros and Cons

	SSC or Environ PROPERTY CLASSIFICATION	DESCRIPTION	RESTRICTIONS	REUSE
1	Non-impacted	No history of contamination of any type	None - Greenfield	Unlimited
2	Impacted Class 3	May have been impacted but EA or remediation completed successfully and release/confirmatory surveys allow unrestricted use	None - Greenfield, free release complete	Unlimited
3	Impacted Class 2	May have been impacted but remediation completed successfully and release/confirmatory surveys allow unrestricted use	None - Greenfield, free release complete	Unlimited
3	Impacted Class 1	Brownfield, industrial reuse, institutional controls	Various, including limitations on excavations, demo of existing structures, etc.	Limited to reuse scenario approved by DOE and Ohio EPA

The opposite end of the spectrum is the “greenfield” scenario. This approach involves removal of all detectable residual RAD and/or HAZMAT materials to acceptable cleanup levels above background from the site such that there are no restrictions in reuse of the facility. Clearly the benefit of this option is attractiveness of the increased value of the property and options allowed for reuse of the property. However, there are considerations for this option as well.

Costs for complete removal of RAD and/or HAZMAT material and subsequent release surveys can be considerable. Typically, removal of the majority of the source term present on a D&D site is usually limited to a small portion of the systems, structures, and components as well as limited land areas (i.e., environs). In the Greenfield scenario, the additional impacted areas that contain very little radioactivity require considerable time and effort to remediate to the very low DCGLs.

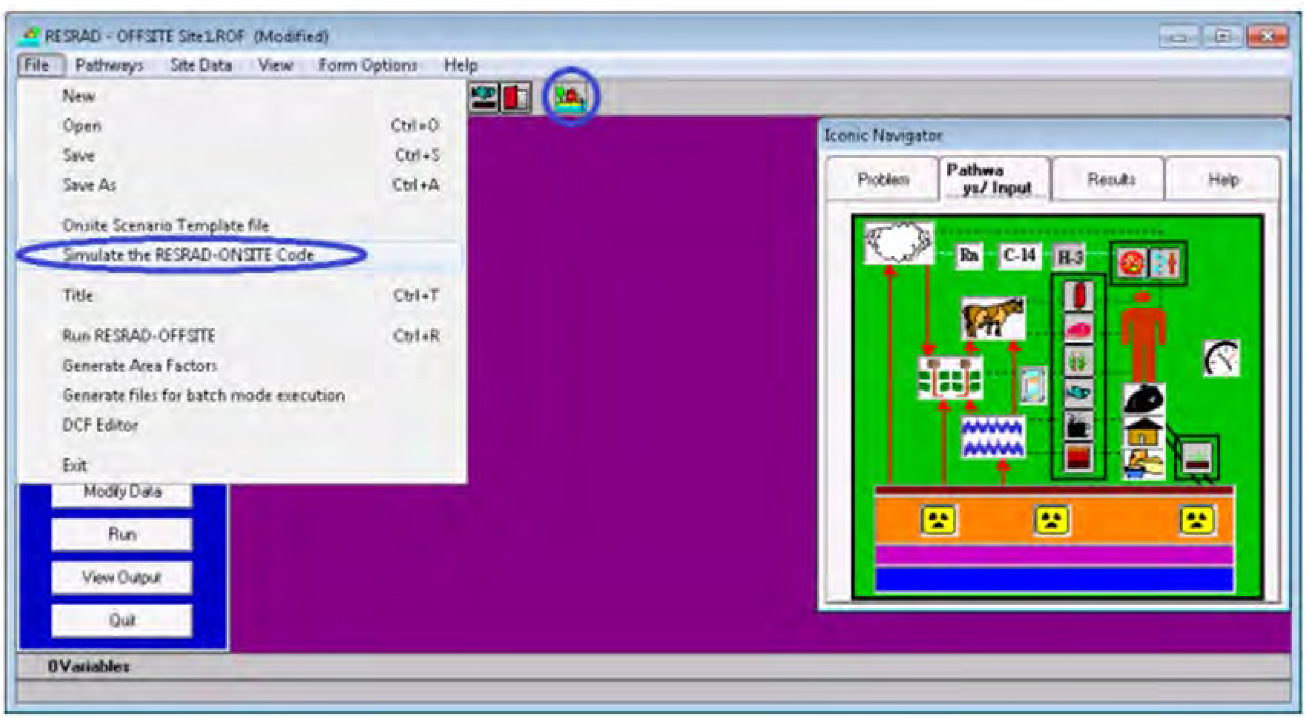
Limited release under an industrial reuse scenario may preclude new construction for an advanced reactor due to soil DCGLs being above background. An unrestricted release under the resident farmer scenario using the most restrictive EPA and possibly state limits will cost more but will not restrict future reuse options.

4.8.6.1 RAD Cleanup Criteria Development

As previously discussed, many considerations go into determining the reuse of impacted property and the reuse scenario. For cleanup of RAD impacted property, the NRC in NUREG-1757 has provided “screening levels” for common radionuclides associated with nuclear power plant D&D for SSCs and environs. NRC screening levels can also be used as DCGLs that would serve to release a site for unrestricted use if the cleanup achieved was below these levels as shown with final status survey data.

For sites other than a nuclear power plant with radionuclides not provided in NUREG-1757, computer programs such as the RESRAD family of codes was developed at Argonne National Laboratory to analyze potential human and biota radiation exposures from the environmental contamination of RESidual RADioactive materials. Using site characterization data and the desired reuse scenario (i.e., greenfield or brownfield) the RESRAD for environs and RESRAD-BUILD for SSCs can be used to calculate DCGLs and cleanup criteria. The codes use pathway analysis to evaluate radiation exposure and associated risks, and to derive cleanup criteria or authorized limits for radionuclide concentrations in the contaminated source medium. The RESRAD family of codes is widely used by regulatory agencies, the risk assessment community, and universities in more than 100 countries around the world. Figure 4-35 is a screenshot of the RESRAD program start/control screen.

Figure 4-35: RESRAD Computer Code



4.8.6.2 HAZMAT Cleanup Criteria

The EPA provides Regional Screening Levels (RSLs) for cleanup of HAZMAT contaminated sites. Downloadable from the EPA website, these RSLs can be used as HAZMAT cleanup criteria for greenfield reuse scenarios similar to NRC screening levels or DCGLs. The EPA also provides an RSL calculator for sites with a brownfield reuse scenario. The RSL calculator is used to determine HAZMAT cleanup criteria and acceptable levels of residual HAZMAT that can remain on a site for a brownfield reuse scenario similar to the RESRAD code used to determine acceptable levels of residual RAD that can remain on a site.

EPA conducts and supervises investigation and cleanup actions at sites where oil or hazardous chemicals have been or may be released into the environment. Cleanup activities take place at active and abandoned waste sites, federal facilities and properties, and where any storage tanks have leaked. EPA, other federal agencies, states or municipalities, or the company or party responsible for the contamination may perform cleanups. Cleanup can also include site reuse and redevelopment. There are several programs under which EPA and its partners conduct cleanup related activities.

4.8.7 Process Steps for Requesting PORTS or Other DOE EM Property

The process that follows could be used by private or public entities to obtain PORTS property from the DOE for reuse and reindustrialization. Each item may need more explanation.

1. Contact SODI (or other responsible CRO) to describe property desired and plan for the property's reuse.
2. Work with SODI to determine what PORTS property is available and the property's current state.
3. Develop the planned state of desired property detailing transition from current planned state to new desired state and its reutilized end use.
4. Provide detail such as an encompassing business plan on why desired property is needed for new desired state, the business entity including partners desiring the property, facility(ies) desired, operational processes including introduced and produced hazardous materials, a summary of funding mechanisms, and any supporting State of OH, regional, local, union, etc., programs that will be put in place to support the transition and reutilization concept.
5. Provide details on the local, regional, and State of OH economic savings/costs/benefits and demographic improvements.
6. Review with SODI for possible conflicts.
7. Using SODI as intermediary, present new concept to DOE PPPO and, if successful,
8. Work with DOE to provide detailed provisions for items 3, 4, and 5 to ensure success of transition.

4.9 Infrastructure Conclusion

Early engagement, collaboration, and cooperation by key stakeholders of a facility undergoing the D&D process at a DOE or similar site can be very beneficial to all parties involved. By incorporating future needs into "end state" planning, viable reuse of the former facility can provide excellent opportunities for repurposing a site to a new mission that utilizes many of the site's attributes such as electrical grid, roads, and other types of infrastructure. Repurposing a site can result in substantial cost savings as well as accelerate construction schedules for a new facility. Early engagement as well as maintaining a continuous dialogue with the DOE or property owner can help ensure a former site can be reused to the greatest extent practical. Scenarios range from simply dedicating and preserving non-impacted land to ensure early release for transfer to a developer, to preserving critical infrastructure undergoing D&D to ensure beneficial reuse in the future.

4.10 Infrastructure Recommendations

In cases where a formerly active DOE site is undergoing the D&D process, it is recommended that a CRO approach the DOE with a clear plan for site reuse as soon as practical and as stated in Section 4.7. This proposed plan should clearly define the future use of the site or portion of the site as well as relevant factors that the DOE can act upon. By providing the DOE with well-defined objectives for beneficial reuse of DOE properties, both parties may be able to negotiate a mutually satisfactory outcome that best uses DOE resources and provides the community with economic opportunities that otherwise would go unrealized. It is also important to emphasize the importance of the CRO to maintain an ongoing dialogue with the DOE.

4.10.1 Communicating with the DOE or Property Owner

Section 4.6.7 is the suggested methodology for initiating a productive dialogue with the site CRO and/or directly with the DOE. For the purposes of the PORTS site, SODI is the CRO, but the principle is the same at other sites.

4.10.2 Preoperational Radiological Environmental Monitoring Program

To implement 10 CFR Part 20 regulatory requirements, the NRC in Regulatory Guide 4.1, Radiological Environmental Monitoring for Nuclear Power Plants, provides that a Radiological Environmental Monitoring Program should be established and implemented at least two years before initial facility operation. The program will contain the routine surveillances necessary to adequately characterize the radiological conditions in the vicinity of the reactor site.

Regulatory Guide 4.15 provides the basic principles of quality assurance in all types of radiological monitoring programs for effluent streams and the environment. The guide does not specifically address nuclear power plants but covers all types of licenses and licensees. It provides the guidance for structuring organizational lines of communication and responsibility, using qualified personnel, implementing standard operating procedures, defining data quality objectives, performing quality control checking for sampling and analysis, auditing the process, and taking corrective actions.

5.0 CONCLUSION

The former gaseous diffusion plant at PORTS has an extensive amount of infrastructure that could be reused for a future advanced reactor facility and a nuclear trained workforce. A rail spur exists, wells on the site can supply water, and connection to the electrical grid can save an estimated $1B of cost [R-8]. Identification and reuse of these items can significantly reduce the overall cost to a future commercial venture. It may be possible to reuse some of the non-process related buildings, foundations, or slabs that exist at the main gaseous diffusion plant if decommissioning is carried out in such a way that the integrity of the structure is not compromised or called into doubt. This has significant cost savings and schedule savings to an advanced reactor entity and to DOE EM. Reuse of material at the site for a future reactor will also reduce the size of the onsite disposal cell, which will have a significant positive effect with the local community.

For some formerly utilized nuclear sites, the ability to reuse existing site characterization data and/or previously granted NRC licenses can present the possibility to reduce schedule and associated cost for future NRC licensing of an advanced reactor. An example of a formerly utilized nuclear site with usable existing data would be one where all D&D activities had been completed, NRC license terminated, and the site released for unrestricted use. In any case, the NRC should be consulted prior to using existing data for new licensing purposes. In discussion with the NRC, reuse of existing data for the PORTS site was disallowed though the USEC NRC license, DOE EM characterization data, and data available from previous industry studies that looked at building a reactor on the site as it would not be considered representative of site conditions after disturbance from D&D activities. In this and similar cases, site characterization would need to be performed according to applicable NRC requirements and guidance.

The documents presented in Section 3.1 of this report provide a reasonable view of the scope of the PORTS Site decommissioning as well as the general approach. Based on review of these documents, the SODI team concluded that the PORTS D&D is progressing in a logical manner using lessons learned from both PORTS and commercial decommissionings.

6.0 RECOMMENDATIONS

Based on the evaluation of existing site infrastructure at the PORTS facility and its potential reuse in support of an advanced reactor site, the following recommendations have been developed to support a future mission.

Federal infrastructure support requests (federal support dollars) for replacement and/or support for infrastructure projects for PORTS:

a. Replace water treatment plant.
b. Replace sewage treatment plant.
c. Relocate natural gas lines from center of SODI property.
d. Retain and maintain L74 and L72 sections and extend L72 alongside Perimeter Road to SODI.

SODI has initiated a request for south Perimeter Road railroad tracks to SODI property. In addition, Parcel 2, a 240-acre transfer is expected to occur in CY2022.

Advanced reactor designs vary greatly and, as such, their respective needs for infrastructure vary as well. Once specific advanced assessments for each of the leading designs are performed, it is recommended to closely match infrastructure needs to both the PORTS site and generic reuse sites to determine needs and ensure availability and preservation of existing infrastructure.

Consult with the NRC to determine if existing site characterization data can be used for new reactor licensing purposes.

There are no specific recommendations for the application of modern decommissioning techniques to the PORTS site. However, modern D&D methods presented in Section 3.0 of this report can be evaluated for PORTS and other potential D&D activities and projects.

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APPENDIX A: PORTSMOUTH SITE SPECIFIC INFRASTRUCTURE REQUIREMENTS BY PHASE

Portsmouth Site Specific Infrastructure Requirements by Phase (1)

Description	OPS	Initial D&D	Adv Rx Const.	Adv Rx Ops.	Final D&D	comments
Services						
Community Outreach (SODI)	L	M	H	L	H	
Met Tower Data Collection	H	M	H	H	M	
Analytical Laboratories	H	M	L	M	L	
Site Emergency Services	H	M	H	H	M	
Environmental Monitoring	H	M	H	H	M	Limited need in Final D&D
Facilities						
Heavy Haul Road(s)	L	M	H	L	M	
Rail Spurs	L	M	H	L	M	
Barge Slips	L	M	M	L	M	Possible need only dependent upon advanced reactor design and fabrication location
Cranes (installed; i.e., polar, gantry)	H	M	H	L	M	
Systems						
Fire protection system headers	H			H	M	
Service air and breathing systems	H	H	H	H	M	
Communication lines above ground and buried	H	H	H	H	M	
Potable water supply lines	H	H	H	H	M	
Storm water and sanitary drain lines	H	H	H	H	M	
Cathodic protection system	H	H	H	H	M	
Electric power supply lines	H	H	H	H	M	
Transformers, control centers	H	H	H	H	M	
Security systems video surveillance, motion sensors, etc.	H	M	M	H	L	
Raw Water	H	H	H	H	M	
Water Treatment Plant (X-611)	H	H	H	H	M	
Recirculating Cooling Water	H	H	H	H	M	
Make-Up Water for the Cooling Towers	H	H	H	H	M	
High Pressure Fire Water	H	H	H	H	M	
Sanitary and Fire Water	H	H	H	H	M	
Recirculating Heating Water	H	H	H	H	M	
Storm Drains	H	H	H	H	M	
Sanitary Sewer	H	H	H	H	M	

Description	OPS	Initial D&D	Adv Rx Const.	Adv Rx Ops.	Final D&D	comments
Steam and Condensate	H	H	H	H	M	
Dry Air	H	H	H	H	M	
Nitrogen	H	H	H	H	M	
Fluorine	H	H	H	H	M	
Natural Gas	H	H	H	H	M	
Electrical Power	H	H	H	H	M	
Communications, specifically:	H	H	H	H	M	
Administrative Telephone System	H	H	H	H	M	
Emergency (Red) Telephone System	H	H	H	H	M	
Plant Public Address System	H	H	H	H	M	
Public Warning Siren System	H	H	H	H	M	
Fiber Optics	M	M	M	L	L	
Wireless Computer Network (WiMAX)	H	L	L	L	L	
Criticality Accident Alarm System	L	L	L	L	L	

Note:

1. The Site-Specific Infrastructure priority by phase is represented as being high (H), medium (M), or low (L) priority.

APPENDIX B: GENERIC SITE INFRASTRUCTURE REQUIREMENTS BY PHASE

Generic Site Infrastructure Requirements by Phase [(1)]

Description	OPS	Initial D&D	Adv Rx Const.	Adv Rx Ops.	Final D&D	comments
Services						
Community Outreach	L	M	L	L	H	
Met Tower Data Collection	H	M	H	H	M	
Site Emergency Services	H	M	L	M	L	
Analytical Laboratories	H	M	H	H	M	
Environmental Monitoring	H	M	H	H	M	Limited need in Final D&D
Facilities						
Heavy Haul Road(s)	L	M	H	L	M	
Rail Spurs	L	M	H	L	M	
Barge Slips	L	M	M	L	M	Possible need only dependent upon D&D activities and disposal location, and advanced reactor design and fabrication location
Cranes (installed; i.e., polar, gantry)	H	M	H	L	M	
Systems						
Fire protection system headers	H			H	M	
Service air and breathing systems	H	H	H	H	M	
Communication lines above ground and buried	H	H	H	H	M	
Potable water supply lines	H	H	H	H	M	
Storm water and sanitary drain lines	H	H	H	H	M	
Cathodic protection system	H	H	H	H	M	
Electric power supply lines	H	H	H	H	M	
Transformers, control centers	H	H	H	H	M	
Security systems video surveillance, motion sensors, etc.	H	M	M	H	L	
Raw Water	H	H	H	H	M	
Water Treatment Plant	H	H	H	H	M	
Recirculating Cooling Water	H	H	H	H	M	
Make-Up Water for the Cooling Towers	H	H	H	H	M	
High Pressure Fire Water	H	H	H	H	M	
Sanitary and Fire Water	H	H	H	H	M	
Recirculating Heating Water	H	H	H	H	M	

Description	OPS	Initial D&D	Adv Rx Const.	Adv Rx Ops.	Final D&D	comments
Storm Drains	H	H	H	H	M	
Sanitary Sewer	H	L	H	H	M	
Steam and Condensate	H	L	H	H	M	
Dry Air	H	L	H	H	M	
Nitrogen	H	L	H	H	M	
Fluorine	H	L	H	H	M	
Natural Gas	H	L	H	H	M	
Electrical Power	H	H	H	H	M	
Communications:	H		H	H	M	
Administrative Telephone System	H	M	H	H	M	
Emergency (Red) Telephone System	H	M	H	H	M	
Plant Public Address System	H	M	H	H	M	
Public Warning Siren System	H	M	H	H	M	
Fiber Optics	M	L	M	L	L	
Wireless Computer Network (WiMAX)	H	M	L	L	L	
Criticality Accident Alarm System	L	L	L	L	L	

Note:

1. The Site-Specific Infrastructure priority by phase is represented as being high (H), medium (M), or low (L) priority.

APPENDIX C: CONCRETE DECONTAMINATION

As the primary material of construction for nuclear facilities, concrete naturally represents the largest fraction of contaminated material in decommissioning plants by surface area. Particularly challenging in the decontamination of concrete is the variable depth of contamination resulting from the porosity of the material, presence of cracks and penetrations, and history of the various concrete structures in a typical nuclear power plant. This typically translates to the need for iterative labor-intensive survey work during the planning and execution of concrete decontamination projects. Moreover, currently-used techniques for decontamination of contaminated concrete are generally slow and labor-intensive to apply and changes and advancements in these techniques have been limited in the past 20 years. Where performed, decontamination of concrete thus remains a major activity during decommissioning projects.

In this section, currently available and developing concrete decontamination techniques are reviewed to assess (1) the state of readiness of these techniques for deployment at commercial nuclear power plants and (2) the ease of use and effectiveness of these concrete decontamination techniques.

Table C-1: Descriptions of Technology Readiness Levels

Technology Readiness Level (TRL)	Description
TRL1: Exploratory Research	Exploratory research transitioning basic science into laboratory application
TRL2: Concepts Formulated	Technology concepts and/or application formulated
TRL3: Proof of Concept Validated	Proof of concept validation
TRL4: Subsystem Validation	Subsystem or component validation in laboratory environment to simulate service conditions
TRL5: System Validated	Early system validation demonstrated in laboratory or limited field application
TRL6: Early Demonstration	Early field demonstration and system refinements completed
TRL7: Demonstration	Complete system demonstrated in an operational environment
TRL8: Early Commercial Deployment	Early commercial deployment (Serial Nos. 1, 2, etc.)
TRL9: Commercialization	Wide-scale commercial deployment

A summary of the reported productivities of these techniques during specific plant applications is presented in Table C-2.

Table C-2: Summary of Commercially Available Concrete Decontamination Techniques: Advantages and Disadvantages

Technique	Relative Removal Rate [a]	Relative Availability [a]	TRL	Advantages	Disadvantages
Hand-Held Needle Scaling, Scabbling, Shaving	Low	Medium to High	9	• Suitable for hard to reach areas • Light-to-medium-weight tool • No secondary waste	• Physically taxing technique • Removal depth typically not adjustable • High vibration
Hand-Held Roto-Peening	Medium	High	9	• Suitable for hard to reach areas • Light-to-medium-weight tool • No secondary waste	• Physically taxing technique • Removal depth typically low • High vibration
Mechanized Scabbling	Floor: Medium to High Wall/Ceiling: Low to Medium	Floor: Medium Wall/Ceiling: Low	9	• No secondary waste • Low consumable cost	• Only suitable for planar surfaces • Very heavy equipment; Req. fork-lift, etc. for wall/ceiling decontamination • High dust generation • Rough finishing • Sensitive to presence of metal inserts • High vibration level
Shaving	High to Very High	Floor: Medium Wall/Ceiling: Low	9	• No secondary waste • Insensitive to presence of metal inserts • Low consumable cost • Smooth finishing • Removal depth adjustable	• Only suitable for planar surfaces • Very heavy equipment; Req. fork-lift, etc. for wall/ceiling decontamination • High dust generation
Shot or Grit Blasting	Medium to High	Medium to High	9	• Suitable for irregular surfaces • Insensitive to presence of metal inserts • Removal depth adjustable • Dry method	• Generates secondary waste (which can be reduced via recycling) • Risk of cross-contamination (with recycling) • High personal safety requirements • High dust generation

Technique	Relative Removal Rate [a]	Relative Availability [a]	TRL	Advantages	Disadvantages
Ultra High Pressure Washing	Low	High	9	• Suitable for irregular surfaces • Insensitive to presence of metal inserts • Removal depth adjustable	• Effluent water generally contaminated and/or hazardous and requires treatment • High personal safety requirements • Risk of cross-contamination • Although the technique is wet, airborne contamination typically still generated • Difficult to monitor airborne dose (wet tech.)

a) The relative removal rate does not account for periods of non-operation (e.g., setup, maintenance, movement from room to room, etc.). Anticipated periods of non-operation are accounted for in the relative availability. The relative removal rates given in this table are defined as: Low < 1 m2/hr < Medium < 5 m2/hr < High < 10 m2/hr < Very High. The relative availability given in this table are based on engineering judgement based on a review of the literature.

Table C-3: Summary of Commercially Available Concrete Decontamination Techniques: Productivity Experiences

Tech	Surface Type	Equipment Setup	Removal Depth (mm)	Removal Rate (m^2/hr) [a]	Availability (%) [a]	Experience	Ref.
Needle Scaling	All	Hand-Held	3 - 50	1.3	Unknown	DOE Hanford	
Scabbling	All	Hand-Held	3	1	Unknown	BR3	
	Floor	Human Driven; Motor Powered	5	4 - 6	Unknown	Unknown	
	Floor	Moose® System; Remote Controlled	3	12	Unknown	ANL CP-5	
Shaving	All	Hand-Held; Underwater w/ divers	3	0.8 [b, c]	N/A [c]	Humboldt Bay	
	Floor	Human Driven; Motor Powered	3	5-13	20% (ATUE only)	CEA (ATUE) CEA (Brennilis)	
	Floor/Wall	Automated; Suction-Clamped to Surface	10	0.5 [c]	N/A [c]	Hinkley Point A	
	Wall	Milling Head(s) Mounted on Industrial Carriers (Fork Lift, Gantry, Brokk, etc.)	25	1.2 - 1.5	20-50%	CEA (EL4 & AT1)	
			10	10		CEA (ATUE)	
			3	8 - 25		BP (Eurochemic) CEA (EL4) Kahl & Karlsruhe	
Shot or Grit Blasting	Unknown	Unknown	4 - 5	2	77%	CEA – AT1	
	Floor/Wall	En-Vac Robotic Wall Scabbler	3	14	Unknown	INL Eng Lab TAN	
Roto-Peening	All	Hand-Held Pentek Roto-Peen Scaler	3	3.7	Unknown	ANL CP-5	[9]
	Floor	3M™ Heavy Duty Roto-Peen	3	6.5	Unknown	ANL CP-5	[9]
Ultra High Pressure Washing	All	Hand-Held	2 - 5	0.3 [c]	N/A [c]	Bradwell Hunterston A	[1]

a) With three exceptions (see Footnote c), the removal rate reported in this table does not account for periods of non-operation (e.g., setup, maintenance, movement from room to room, etc.). Periods of non-operation are accounted for in the availability. The availability is calculated as the active decontamination time/total time spent generally supporting the decontamination activity.

c) These removal rates do account for periods of non-operation (e.g., setup, maintenance, movement from room to room, etc.).

Techniques that have been demonstrated in a laboratory setting but do not have significant operating experience during nuclear plant decommissioning are considered developing concrete decontamination techniques. A summary of the advantages and disadvantages of these developing concrete decontamination techniques and their technology readiness levels is presented in C-12, along with the equivalent data from commercially available techniques to facilitate their comparison. A summary of the reported productivities of these developing techniques during specific laboratory evaluations is presented in C-13, along with productivity data for commercially available techniques to facilitate their comparison.

C.1 Liquid Nitrogen Blasting (NitroJet®)

C.1.1 Overview

Liquid nitrogen blasting (NitroJet®) is a concrete decontamination technique wherein a jet of high-pressure liquid nitrogen is sprayed from a nozzle to remove concrete via a combination of the following three effects:

- The high velocity of the jet mechanically removes surface material (like other jet blasting techniques).
- The liquid nitrogen evaporates as it impacts the surface of the concrete, which results in a rapid volumetric expansion (650-700X in volume) and associated impact on the concrete.
- The low temperature (-150°C) of the jet embrittles the surface of the concrete and results in a substantial temperature difference between the surface and the bulk of the concrete, which may cause delamination of the surface.

The liquid nitrogen jet temperature and velocity can be modified as needed to adjust the aggressiveness of the technique. For example, the liquid nitrogen jet can be controlled to remove coatings (e.g., paint), scabble concrete to various depths, or to cut materials. The equipment required to implement the NitroJet® technique is summarized in Table C-4. To collect removed materials, the NitroJet® nozzle is covered by a shroud that is connected to vacuum collector equipment. Since the liquid nitrogen used with this technique evaporates, the collected waste is dry (solids only). Depending on the level of contamination, the NitroJet® technique may be implemented manually by workers wearing appropriate PPE or may be implemented robotically.[11, 16] The NitroJet® decontamination technique was developed by the US DOE/INL and improved and commercialized by NitroCision, LLC.

Table C-4: NitroJet® Equipment Requirements [1, 17]

Equipment	Description/Function
Power Utility (fuel)	250 kVA - Power supply
Liquid Nitrogen Tank	16,000 L - Nitrogen storage
NitroJet® Skid	480V, 3 phase, 150kVA - Core of the technology
Heat Exchanger (HE)	Final cooling of the nitrogen jet
Air Compressor and Drier	Rotation of the nozzle, valves powering
Insulated LP Pipes	Transportation of LP nitrogen from the tank to the skid and from the skid to the HE
HP Pipes	Transportation of HP nitrogen from the skid to the HE and from the HE to the Gun
Gun Mounted with Rotary Nozzle	Distribution of the nitrogen
Two Axis Bearer (Carrier)	Motorized axis for automatic operations
Shroud System	Collection of the nitrogen and of the concrete dusts
Cyclonic Vacuum System, HEPA Filter	Separation of dusts; aspiration of the nitrogen, purification of the gas

C.1.2 Experience

The concrete removal performance during recent (~2016) NitroJet® testing is summarized in Table C-5. This testing was conducted on 20 cm x 30 cm x 5 cm concrete specimens that had been fabricated with the same specification as that generally used in Japanese nuclear power plants. As shown in this table, the performance of the NitroJet® technique for concrete removal was not significantly affected by the presence of paint on the concrete. The DFs achieved by this technique was evaluated during this testing using a non-radioactive tracer (a fluorescent coating). For removal depths of ~8 mm and ~16 mm, the DFs achieved were ~200-400 and ~1000, respectively [11].

While details of the demonstration results were not available to support this report, the NitroJet® process was also successfully demonstrated in the decontamination of concrete on the roof of a building at the Fukushima Daiichi nuclear site in 2018. This most recent experience supports the TRL ≥ 7 rating of the NitroJet® process in Table C-12.

Table C-5: NitroJet® Decontamination Rate at Various Scabble Depths [11]

Approx. Surface Removal Rate (m^2/hr) [a]	Approx. Scabbled Depth (mm)			
	Bare Concrete (220 MPa) [b]	Bare Concrete (315 MPa) [b]	Painted Concrete (220 MPa) [b]	Painted Concrete (315 MPa) [b]
0.15		42		
1.5	13	20	13	21
4.2	8	12		
5.1				10
6.6	6	9		8
9.6	4	8	4	7

a) The jet width is not specified in the reference. The surface removal rate is calculated based on an assumed jet width of 5 cm, which is consistent with the pictures in the reference and with the jet width listed in other NitroJet® documentation.

b) The pressure listed is the NitroJet® application pressure.

Other experience with the NitroJet® technique is summarized below [1]:

- Two pictures of the concrete surface after decontamination via this technique are shown in Figure C-1 [1]. It is clear from these images that the process can be very precisely controlled.
- In some cases [1], the NitroJet® technique only removes the cement from the concrete, leaving the aggregate behind. Aggregate is typically not contaminated, and thus does not necessarily need to be removed. However, it is reported to be "easily removed" if required.
- Some concrete decontamination trials were conducted for Magnox sites on concrete coupons. In the trials, ~12 mm (0.5 inches) of concrete was removed in a single pass, resulting in a single pass DF of 220. The technique was then repeated, resulting in a cumulative DF of 770 (in two passes total).[1]
- In 2010, the NitroJet® technique was applied remotely at the West Valley Demonstration Project (WVES) site, a high-level waste (HLW) solidification and radiological cleanup site in New York [18], to remove a polymeric fixative from metal surfaces of two hot cells. Although this application did not include concrete decontamination, the equipment would be similar during a concrete decontamination application. Information on the equipment performance is briefly summarized below:
    - Deployment of the technology was generally considered a success. Due to successful decontamination of the two hot cells at WVES, the site opted to deploy the technology for decontamination of other facilities at WVES.
    - ~30 m2 could be decontaminated in a 10-hour shift.
    - The availability of the equipment during the first month of operation was only 18%. However, after resolving a number of issues (see discussion in Reference [18]), the

availability increased to 67% in the second month of deployment and then to 80% in the fourth month of deployment.

- In 2009, industrial scale testing of the technology was conducted at AREVA's SICN facility in Veurey, France [1]. This testing included implementation of the technology manually, semi-manually (i.e., a manual tool was mounted on a stand), and automatically. During this testing, the equipment was operated ~5 hrs/day for several weeks with no major maintenance problems. Based on the results of this study, AREVA concluded that the NitroJet® technique would be cost effective for the decontamination of concrete walls and ceilings when ≥5 mm scabbling depth is required for a surface that is ≥500 m2. However, AREVA concluded that conventional scabbling techniques would be more cost effective for the decontamination of concrete floors.

Figure C-1: Concrete Scabbled via NitroJet®: (Top) without Aggregate Removed and (Bottom) with Aggregate Removed [1]

C.1.3 Advantages/Positive Attributes

The main advantages of the NitroJet® technique are listed below:

- Based on the testing results, very high material removal rates can be achieved. As shown in Table C-5, the testing demonstrated surface area removal rates of ~9.6 m2/hr and ~4.2 m2/hr could be achieved for removal depths of ~4-7 mm and ~8-12 mm, respectively (not including time for setup, etc., of the equipment).
- With one set of equipment, the material removal depth can be adjusted as needed depending on the expected contamination depth (by adjusting the scanning speed of the NitroJet® or by conducting multiple passes). Material removal depths up to about 42 mm have been achieved in the laboratory testing.
- The equipment that would need to be mounted to implement this technique autonomously or remotely is relatively light (compared to traditional mechanical concrete removal techniques).
- No secondary wastes are produced with this technique.
- The risk of cross-contamination (i.e., recontamination of previously cleaned regions) is generally higher for techniques involving liquid that can act as a carrier. Being a dry technique, the risk of cross-contamination associated with the NitroJet® process is considered minimal.
- Performance of the technique is not significantly affected by the presence of paint on the concrete.

C.1.4 Disadvantages/Negative Attributes

The main disadvantages of the NitroJet® technique are listed below:

- Relatively complicated process equipment is needed to implement this technique.
- This technique likely needs to be paired with robotics for automation or remote operation to be most effective and to achieve consistent results.
- The required liquid nitrogen supply rate is 5 gpm [17]. At this supply rate, the 16 m^3 liquid nitrogen tank would last only ~14 hours during continuous use. Further, this liquid flow rate corresponds to a gas flow rate of ~740 m^3/hr. Therefore, the ventilation system utilized to capture concrete removed via this technique would be required to have a higher capacity than 740 m^3/hr.
- The liquid nitrogen would most likely be supplied from a liquid nitrogen tank located outside of the building being decontaminated. Therefore, the liquid nitrogen supply lines would be significant in length (likely 100 meters or more). These nitrogen supply lines would require very good thermal insulation.
- There is non-negligible risk of asphyxiation with the use of this technique.

- Although the tooling incorporates features to control it, this technique may produce airborne contamination considering the high jet velocities and rapid volumetric expansion rate associated with the process.
- Generally, this technique leaves a rough surface finish, which increases the difficulty of subsequent characterization.

C.1.5 Gaps for Commercial Readiness/Development Opportunities

This technique is considered to be TRL ≥ 7.

Gaps for commercial readiness and development opportunities for this technique are listed below:

- Engineering work is required to integrate the NitroJet® equipment into a field hardened system suitable for deployment in a decommissioning nuclear power plant (e.g., equipment that enables automation or remote control of the technique for a large-scale project).
- While the system was successfully demonstrated for external concrete decontamination at Fukushima in 2018, a large-scale field demonstration within a decommissioning site is considered necessary to demonstrate/assess (1) the reliability of the field equipment, (2) prototypic concrete decontamination rates (i.e., accounting for equipment setup, maintenance, movement from room to room, etc.), (3) the countermeasures required to mitigate the asphyxiation risk associated with this technique, and (4) the cost per square meter to implement the technique.
- Several of the disadvantages listed in the prior section relate to the high usage of liquid nitrogen. Optimization of the technique to reduce the rate of liquid nitrogen usage would increase the commercial viability of this technique.

C.2 Laser Scabbling

C.2.1 Overview

Laser scabbling is a concrete decontamination technique wherein a high-power diverging laser beam (generally >4 kW) is directed at the surface of concrete to result in its surface fracture/removal. The mechanism by which laser scabbling occurs is not known with certainty but is generally believed to be a combination of the following [19, 20]:

- Rapid expansion of water in the concrete, resulting in high pressure generation in the concrete pores.
- Significant heating of the surface layer of the concrete, resulting in significant thermal-stress gradients.
- Decarbonation of calcite in the concrete, resulting in the generation of gases in the concrete and high pressure levels in the concrete pores.

Historically, industrial high-power lasers (CO_2 lasers) were not considered reliable for nuclear plant decommissioning environments. However, more recently developed fiber lasers exhibit considerable promise for nuclear plant decommissioning applications. These types of lasers are more efficient and much more robust than CO_2 lasers. The equipment required to implement this decontamination technique is listed below (note that equipment generally required for all concrete decontamination techniques (e.g., a vacuum system to collect the debris) is not listed):

- A laser generating system
- A chiller to cool the laser generating system and the optics
- A beam switching unit to isolate the laser itself from the delivery fiber optic cable, which protects the laser in the event the delivery fiber optic cable is damaged
- Fiber-optic cable to transmit the laser
- A small process head to direct the diverging laser beam at the concrete surface
- An air compressor to provide a cross jet of air to protect to the process head optics.

Since the laser energy can be efficiently transmitted up to several hundreds of meters via fiber-optic cable, in most cases, the bulk of laser scabbling equipment can be installed in a non-contaminated, more industrially safe area than the area of active concrete decontamination [19].

C.2.2 Experience

A significant amount of laser scabbling research was found in the open literature. The results of the two major studies are presented in Sections C.2.2.1 and C.2.2.2. Both of these studies were conducted within the last ten years (i.e., since 2009). Note that Reference [20] provides a brief literature review of other laser scabbling research conducted up to early 2015.

Experience with laser scabbling in nuclear facilities is summarized in Section C.2.2.3.

C.2.2.1 TWI Ltd. Testing (~2009)

Reference [19] describes laser scabbling testing conducted by TWI Ltd. for the UK Nuclear Decommissioning Authority. Concrete specimens with three different types of aggregate were used in this testing: limestone aggregate, basalt aggregate, and siliceous aggregate. A continuous wave Nd:YAG laser with a capacity of 4 kW was used during testing. The laser incident diameter on the concrete slabs ranged from 23-65 mm. Therefore, the laser scabbling power density ranged from 120-960 W/cm^2. During testing, the laser was translated across the concrete surfaces at speeds ranging from 100 mm/min to 1400 mm/min. Testing was conducted on both dry and wet concrete. A picture of the laser scabbling head used during testing is shown in Figure C-2. The major results of the testing are summarized below:

- The full laser scabbling testing matrix is not reported in Reference [19]. However, known information on the testing matrix and testing results is summarized Table C-6.
    - o Significant material removal was only achieved for the limestone aggregate concrete specimens.

  - For the siliceous aggregate concrete specimens, only minor surface scabbling was observed, with minimal material removal. For the basalt aggregate concrete specimens, no scabbling was observed. Under certain conditions, the surfaces of these two types of concrete vitrified (i.e., the surface melted and formed a glass layer). Note that surface vitrification of concrete is also sometimes referred to as glazing.

- For the limestone aggregate concrete, material removal rates of 55-65 cm^3/min were observed. For a laser incident diameter of 65 mm, a single pass of the laser at 100 mm/min resulted in an average removal depth of 11 mm and a scabbling track width of ~80 mm. This corresponds to a concrete surface removal rate of ~0.5 m^2/hr.

- A picture of limestone aggregate concrete after laser scabbling is shown in Figure C-3. A picture of the debris resulting from the laser scabbling is shown in Figure C-4. As shown in this figure, the debris was mostly large pieces.

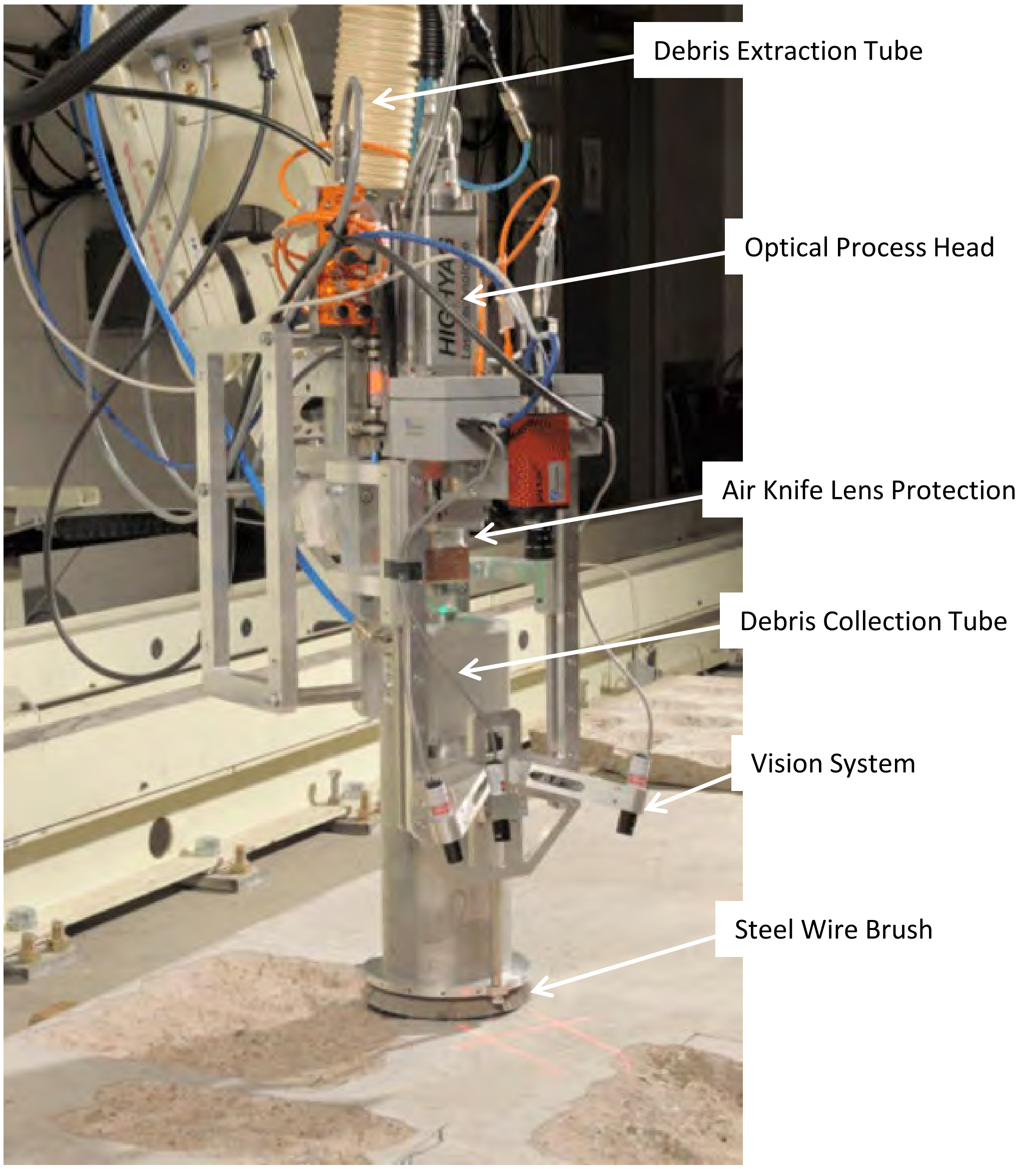

Figure C-2: Laser Scabbling Head Used during TWI Ltd. Testing (reproduced courtesy of TWI Ltd) [21]

Figure C-3: Example Results of Laser Scabbling of Limestone Aggregate Concrete [1]

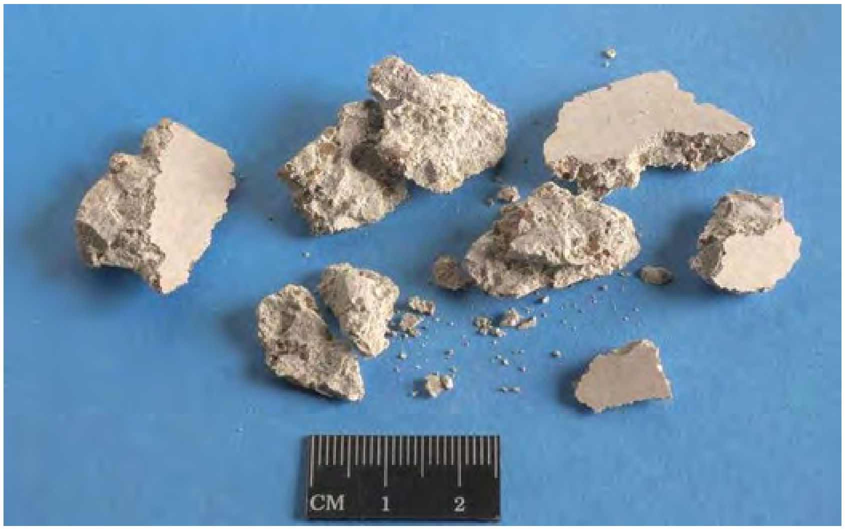

Figure C-4: Typical Debris Resulting from Laser Scabbling of Limestone Aggregate Concrete [1]

Table C-6: Summary of Laser Scabbling Testing Conducted by TWI Ltd. [19]

Parameter	Siliceous Aggregate Concrete							Limestone Aggregate Concrete			Basalt Aggregate Concrete			
Power (kW)	4							4			4			
Incident Diameter (cm)	6.5	4.3					2.3	6.5	4.3	2.3	4.3			
Power Density (W/cm^2)	120	280					960	120	280	960	280			
Scanning Speed (cm/min)	10	100	50	30-50	25	10	10-140	10	10	10	30	20	10	5
Surface Coverage Rate (m^2/hr)	0.4	2.6	1.3	0.8-1.3	0.6	0.3	0.1-1.9	0.4	0.3	0.1	0.8	0.5	0.3	0.1
Concrete Surface Dry or Wet	Dry & Wet	Dry	Dry	Wet	Dry	Dry	Dry	Dry & Wet			Dry	Dry	Dry & Wet	Dry
Surface Vitrification Observed?	No	No	No	No	No	Yes	Yes	No			Slight	Slight	Yes	Yes
Scabbling Observed?	Slight	Slight	Slight	Some	Slight	None	None	Very Good Scabbling			None	None	None	None

C.2.2.2 University of Sheffield, TWI Ltd., and University of Manchester Testing (~2014-2018)

More recent laser scabbling testing conducted by a collaboration of researchers from the University of Sheffield, TWI Ltd., and the University of Manchester is described in References [12, 20, 22, 23]. This testing was conducted on several compositions of concrete and its constituents (e.g., mortars and cements), including limestone aggregate concrete and basalt aggregate concrete. The concrete compositions tested in this research were based on the composition of the pre-stressed concrete pressure vessel of the advanced gas cooled reactor Heysham Unit 2.

A continuous wave fiber laser with a capacity of 5 kW and operated at 100% capacity was used during testing. The laser incident diameter on the concrete was 60 mm, resulting in laser scabbling power density of ~177 W/cm^2. The laser head was stationary during this testing (i.e., the laser was focused on a single spot) and was operated for durations ranging from 5 – 40 seconds. The major conclusions of this testing are summarized below:

- In contrast to the results of the testing described in Section C.2.2.1, the basalt aggregate concrete was successfully scabbled in the studies described in this section. The difference in the test results is expected to be due to the differences in power densities used. Specifically, the power densities used on the basalt aggregate concrete in the two studies were ~177 W/cm^2 and 280 W/cm^2. The power density of 280 W/cm^2 used in the earlier research resulted in vitrification of the basalt aggregate concrete which inhibited the scabbling. However, in a similar trend to the testing described in Section C.2.2.1, material removal rates for the basalt aggregate concrete remained generally lower than those for the limestone aggregate concrete. The authors of the 2014-2018 studies concluded that the laser scabbling mechanisms (pore pressure spalling and thermal stress spalling) occurred in the cement and mortar of the concrete, not in the aggregate. This suggests that laser scabbling of concrete should be feasible in all types of concrete, regardless of aggregate type.
- The approximate material removal rates during one of the studies [12] are summarized in Table C-7. As shown in this table, after 20 seconds of laser exposure, no further scabbling of the basalt aggregate concrete occurred. Further, after 30 seconds of laser exposure, no further scabbling of the limestone aggregate concrete occurred. Such apparent limits in the depth of scabbling were at least partially attributed to the presence of the aggregate in the concrete specimens (relative to specimens made entirely of mortar). Specifically, replacement of mortar with coarse aggregate reduces the amount of free water in the material and the chemically combined water (due to a reduction in cement paste content). This reduces the potential for spalling to take place from vaporization of this water content. It was moreover suggested that the higher compressive strength of the concretes (compared to mortars) results in higher tensile strength of the concretes as compared to mortars, which thereby increases the resistance to scabbling. Thus, once the initial scabbling of the surface layer is completed, a significant reduction in performance was thought to be attributable to the now exposed aggregate. This sudden reduction in the rate of scabbling was observed

to result in rapid increase in surface temperatures, which, especially in the case of the basalt concrete with its lower melting point aggregate, led to vitrification of the concrete and scabbling arrest.

- Laser scabbling testing was conducted on concrete specimens aged for 4-30 months under different storage conditions to determine the effect of aging expected to be relevant during plant applications [12, 20, 23]. The results of this testing are summarized in Table C-8. As shown in this table, when the specimens were stored in very humid conditions (~95% relative humidity), aging did not significantly affect laser scabbling performance. However, when the specimens were stored in less humid conditions (~40% relative humidity), aging did reduce laser scabbling performance, particularly for the limestone aggregate concrete.
    - Since laser scabbling performance was not significantly affected by age when the specimens were stored in very humid conditions, but was affected when stored in dryer conditions, the authors concluded that the reduction in scabbling performance was predominantly caused by reduction in the moisture content of the specimens resulting from aging in dry conditions. The free water content of the specimens (prior to laser scabbling) is given in Table C-8.
- Testing was conducted on mortar specimens with free moisture contents ranging from 0% up to 9.3%. Mortar contains all of the constituents of concrete except for the aggregate. Over the range of 0% to 6.2% moisture content, higher moisture content exhibited higher material removal via laser scabbling. However, at 9.3% moisture content, laser scabbling removal was somewhat reduced relative to the scabbling rate achieved on specimens with 6.2% moisture content.[22]
    - This testing also included specimens that had been oven dried to remove all free water and then resaturated with water. The resaturation process is reported to have occurred over two days, but the mechanism of resaturation is not reported. Good laser scabbling of the resaturated specimens was observed down to the depth of resaturation (about 5-10 mm). This result suggests that, if the moisture content of concrete in nuclear plants is too low to result in satisfactory laser scabbling performance, it may be possible to precondition (i.e., resaturate) the concrete to improve laser scabbling effectiveness. Of course, the added complexity and added waste management issues that would likely result from this evolution would need to be balanced against the increases in laser scabbling effectiveness before undertaking such an evolution.
- Testing was conducted on concrete specimens with ~10 mm sized limestone/basalt aggregate and ~20 mm sized limestone/basalt aggregate. Similar scabbling performance was observed for these different aggregate sizes.[12]
- Testing was conducted on two different compositions of limestone/basalt concrete: concrete made with Ordinary Portland Cement, and concrete made with both Ordinary Portland Cement and Pulverized Fuel Ash. Similar scabbling performance was observed for both concrete compositions.[12]

- In general, the laser scabbling testing results were found to be repeatable (i.e., similar concrete removal rates were achieved under identical testing conditions). This was particularly true for tests involving concrete specimens that were less than 30 months old.

Table C-7: Approximate Average Material Removal Rates during Static Concrete Laser Scabbling Testing [a] [12]

Testing Results			Calculated Material Removal Rates for a Scanning Laser Beam		
Exposure Duration (sec)	Total Material Removal (cm^3)		Surface Removal Rate (m^2/hr) [b]	Removal Depth (mm) [c]	
	Limestone Agg. Concrete	Basalt Agg. Concrete		Limestone Agg. Concrete	Basalt Agg. Concrete
5	4	2	2.0	1.4	0.7
10	12	9	1.0	4.2	3.2
20	28	20	0.5	9.9	6.7
30	37	22	0.3	13	6.7
40	39	21	0.3	14	7.1

a) Common Testing Conditions: 5 kW Laser; 6 cm Incident Diameter; ~177 w/cm^2 Power Density; Specimens aged ~7 Months; Specimens stored at ~95% relative humidity during aging.

b) The approximate surface removal rates were calculated based on reported volumetric removals, exposure durations, and calculated average removal depth.

c) The average removal depths were calculated based on reported volumetric removals and laser incident diameter on the concrete surface (60 mm).

Table C-8: Approximate Average Material Removals Resulting from 40 Seconds of Laser Exposure for Specimens of Various Ages [a] [12, 20, 23]

Specimen Age (Months)	Specimen Storage Conditions	Total Material Removal (cm^3)		Specimen Free Water Content (Prior to Laser Scabbling)	
		Limestone Agg. Concrete	Basalt Agg. Concrete	Limestone Agg. Concrete	Basalt Agg. Concrete
4	Stored in a mist room at ~20°C and ~95% relative humidity	48	28	4.6%	4.5%
7		39	21	Not measured. Expected to be similar to the above values due to storage conditions.	
22		47	30		
30		45	26		
4	~20°C and ~40% relative humidity	48	42	3.0%	3.2%
30		20	16	2.3%	2.6%

a) Common Testing Conditions: 5 kW Laser; 6 cm Incident Diameter; ~177 w/cm^2 Power Density; 40 Second Static Laser Exposure.

C.2.2.3 Nuclear Facility Experience

The only known experience with the use of a laser for concrete decontamination at a nuclear facility was at JAERI's Reprocessing Test Facility (JRTF) in ~1998 [24, 25]. At this facility, a laser was used to glaze (i.e., vitrify) the surface of concrete[1], after which the glazed concrete surface was reported to be "easy" to remove. The method that was used to remove the glazed concrete layer was not found in the publicly available literature. The laser power was 600 W and the laser incident diameter on the concrete was 13 mm, resulting in a power density of 452 W/cm^2. The scanning speed of the laser was 8.0 cm/min. These parameters correspond to a surface removal rate of ~0.06 m^2/hr.

This experience suggests that if some concrete surface vitrification does occur during laser scabbling, the vitrified surface can be easily removed by a supplemental mechanical technique.

C.2.3 Advantages/Positive Attributes

The main advantages of laser scabbling are listed below:

- Based on the testing results, it is anticipated that high surface area removal rates could be achieved for a full-scale application of laser scabbling. As shown in Table C-7, the testing demonstrated surface area removal rates of 1.0 m^2/hr and 0.5 m^2/hr could be achieved for removal depths of ~3-4 mm and ~7-10 mm, respectively, with a 5 kW laser (not including time for setup, etc., of the equipment). It is anticipated that these removal rates would scale linearly with the laser capacity (by increasing laser incident diameter

[1] This facility had a surface area of ~3600 m^2 of contaminated concrete with contamination depth of ~5-10 mm. It is not known how much of this surface area was decontaminated by laser glazing.

to maintain a constant power density). For example, for a 15 kW laser, it is anticipated that surface area removal rates of 3.0 m^2/hr and 1.5 m^2/hr could be achieved for removal depths of ~3-4 mm and ~7-10 mm, respectively (not including time for setup, etc., of the equipment). Further, since this technique is still developing, it is anticipated that the material removal rates can be increased by additional optimization of the process (e.g., optimal power density, scanning speed, incident angle, etc.).

- With one set of equipment, the material removal depth can be adjusted depending on the expected contamination depth (by adjusting the scanning speed of the laser or by conducting multiple passes). Material removal depths up to about 14-17 mm have been achieved in laboratory testing [20].
- The equipment that would need to be mounted to implement this technique autonomously or remotely is relatively light (compared to traditional mechanical concrete removal techniques). Further, this technique does not produce a reaction force when applied (i.e., a force pushing backward from the concrete surface), which significantly reduces the requirements to brace/stabilize the equipment, fasten the equipment to the surface, etc.
- No secondary waste is produced from this technique and thus the risk of cross-contamination is expected to be minimal.
- This technique can be applied to irregular surfaces such as rounded surfaces, corners, etc.
- This technique likely produces much less noise than most other techniques (i.e., conventional methods).
- Minimal concrete dust was generated during testing, suggesting that this technique will not result in significant airborne contamination/hazardous material concerns.

C.2.4 Disadvantages/Negative Attributes

The main disadvantages of laser scabbling are listed below:

- This technique is expected to require pairing with robotics for automation or remote operation to be most effective and to achieve consistent results.
- The process parameters (power density, scanning speed, etc.) likely need to be optimized for different types of concrete.
- If the laser scabbling is implemented with non-optimized parameters (power density, scanning speed, etc.), the concrete surface may vitrify and/or dry out. This may prevent or hinder further laser scabbling of that surface. In such an event, a secondary mechanical removal step may be required, reducing the net application speed of the process.
- Appropriate means of protecting against stray laser energy that could damage nearby structures and/or injure personnel working in the vicinity of laser scabbling needs to be

provided (in research to date, this appears to have been effectively achieved through design of the debris collection nozzle/shroud surrounding the laser head).

- Generally, this technique leaves a rough surface finish, which increases the difficulty of subsequent characterization.

C.2.5 Gaps for Commercial Readiness/Development Opportunities

This technique is considered to be TRL 3.

Gaps for commercial readiness and development opportunities for this technique are listed below:

- Additional testing is required prior to a full-scale application of the technique. Specifically, testing is required to (1) optimize laser operational parameters such as power density and scanning speed for different types of concrete and (2) determine whether this technique would be effective on representative nuclear plant concrete surfaces (i.e., concrete up to 60+ years old, where the moisture content is unknown). Prior to such testing, it would be beneficial to conduct a review on the different types of concrete used in nuclear plants worldwide and the effect of age, operational conditions, and environmental conditions on the moisture content of the various types of concrete.
- Additional analysis and engineering work is needed to determine the optimal equipment size (e.g., laser capacity) that would result in the lowest cost per area of concrete decontaminated. Then, engineering work is required to design and fabricate a full-scale laser scabbling system that is integrated with a suitable robotic platform to enable automation or remote control of the technique in a decommissioning nuclear power plant.
- A large-scale field demonstration is required to demonstrate/determine (1) the reliability of the field equipment, (2) the real-world concrete decontamination rate (i.e., accounting for equipment setup, maintenance, movement from room to room, etc.), and (3) the cost per square meter to implement the technique.

C.3 Microwave Scabbling

C.3.1 Overview

Microwave scabbling is a concrete decontamination technique wherein a high-frequency microwave (generally ≥2.45 GHz) is directed at the surface of concrete to result in its surface fracture/removal. The mechanism by which microwave scabbling occurs is not known with certainty but is generally believed to be a combination of the following [14, 26]:

- Non-uniform heating of the concrete, resulting in significant thermal-stress gradients in the concrete.
- Rapid expansion of water in the concrete, resulting in high pressure generation in the concrete pores.

The major equipment required to implement this technique is listed below (note that equipment generally required for all concrete decontamination techniques (e.g., a vacuum system to collect the debris) is not listed below):

- A microwave generator
- A waveguide transmission system to transmit the microwaves from the generator to the applicator
- A waveguide applicator to direct the microwaves at the concrete surface.

C.3.2 Experience

Microwave scabbling of concrete for decontamination was first tested in the late 1980s and early 1990s by JAERI [27], the UK Harwell laboratory, and ORNL [13, 15]. More recently (in 2015), testing of this technique was conducted at the University of Nottingham in the UK [14]. Brief summaries of the ORNL and University of Nottingham test programs are presented below:

- A summary of the ORNL and University of Nottingham testing results is presented in Table C-9. As shown, concrete surface removal rates up to about 3.7 m^2/hr were observed for removal depths of about 5 mm and removal rates of up to about 1.0 m^2/hr were observed for removal depths of >25 mm.
    - o Microwave power levels from ~3.6 to 15 kW were tested. The volumetric rate of material removal increased with increasing microwave power in the testing.
    - o Microwave frequencies from 2.45 GHz to 18 GHz were tested. As the microwave frequency is increased in this range, the penetration depth of the microwave energy decreases substantially. This typically resulted in lower depths of removal, but higher overall material removal rates.[2] This testing result is supported by numerical analysis studies [14, 26] of microwave concrete decontamination.
- Pictures of the concrete removal via microwave decontamination from the University of Nottingham testing are shown in Figure C-5. As shown, concrete with three different types of aggregate were tested: whinstone, gravel, and limestone. The relative rates of material removal for the three types of concrete were limestone > gravel > whinstone. However, differences in material removal rates were not substantial. Specifically, the rate of material removal for the limestone aggregate concrete was only about 30% higher than that for concrete with whinstone aggregate.
- During the University of Nottingham testing, particle sizing was conducted on concrete removed from one of the specimens (limestone aggregate concrete). The particle sizing indicated 80% of the material was greater than 1 mm in size and only ~1.6% of the

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[2] It is noted that, while not stated explicitly in Reference [14], the factor of 5 difference in the removal depth for conditions that are nominally the same, as listed in Table C-9, is expected to be due to a difference in scanning speed between the two tests.

material was <0.1 mm. A technique that results in larger particulate waste is preferable from a filtration system design/implementation standpoint.

- In one of the ORNL studies [13], testing was conducted on concrete without steel reinforcement, concrete with ~1.3 cm diameter steel reinforcing rods, and concrete with 5.6 mm diameter steel wire mesh. For the concrete with metal reinforcement, the metal was located 5 cm below the surface of the concrete. The presence of the metal reinforcement was only found to have a minor effect on the effectiveness of the technique for concrete removal. This was thought to be at least partially due to the fact that the removal depths were relatively modest (< 1 cm) and significantly shallower than the depth of the reinforcement.
    - The type of concrete used during the ORNL testing was not reported.
- Testing with painted and unpainted concrete was conducted in both the ORNL [15] and University of Nottingham [14] programs. In both programs, the material removal rate of painted concrete was slightly lower than that of unpainted concrete. However, in the University of Nottingham testing, the difference was not considered statistically significant.
- The ORNL testing [15] included testing of concrete soaked in oil prior to exposure to the microwave scabbling process. The testing results suggested that the presence of the oil did not affect the effectiveness of the microwave decontamination.
- In contrast to the laser scabbling results described previously, no vitrification of the concrete surfaces was observed in the microwave scabbling testing.

Table C-9: Summary of Microwave Concrete Decontamination Testing

Testing	ORNL 1992 [13]	ORNL 1992 [13]	ORNL 1995 [15]	ORNL 1995 [15]	Univ. of Nottingham 2015 [14]	Univ. of Nottingham 2015 [14]
Concrete Painted?	No	No	No	Yes	No	No
Microwave Power (kW)	5.2	3.6	15	15	15	15
Microwave Frequency (GHz)	2.45	10.6	18	18	2.45	2.45
Avg. Material Removal Rate (cm^3/min)	64	127	270-294	147-160	291-416	416-583
Avg. Removal Depth (mm)	5.6	5.2	4-5	4-5	>25	>5
Avg. Surface Removal Rate (m^2/hr) [a]	0.7	1.5	3.7	2.0	0.7-1.0	1.0-1.4

a) The average surface removal rate was calculated based on the reported material removal rate and the reported average material removal depth.

Figure C-5: Microwave Decontamination of Concrete with Basalt (Whinstone) Aggregate (Top), Gravel Aggregate (Middle), and Limestone Aggregate (Bottom) [14]

C.3.3 Advantages/Positive Attributes

The main advantages of microwave scabbling are listed below:

- Based on the testing results, it is anticipated that high material removal rates could be achieved for a full-scale application of the technique. As shown in Table C-9, the testing demonstrated surface area removal rates of up to 3.7 m^2/hr could be achieved for a removal depth of ~4-5 mm with a 15 kW microwave generator (not including time for setup, etc., of the equipment). On a per kW basis, these rates are similar to those achieved by laser scabbling. Like laser scabbling, it is anticipated that these removal rates could be increased by increasing the capacity of the microwave generator (and the incident area of the microwaves). Further, since this technique is still developing, it is anticipated that the material removal rates can be increased by additional optimization of the process (e.g., optimal power density, frequency, laser head travel speed, incident angle, etc.).
- With one set of equipment, the material removal depth can be adjusted as needed depending on the expected contamination depth (by adjusting the scanning speed of the equipment or by conducting multiple passes).
- The equipment that would need to be mounted to implement this technique autonomously or remotely is relatively light (compared to traditional mechanical concrete removal techniques). Further, this technique does not produce a reaction force when applied (i.e., a force pushing backward from the concrete surface), which significantly reduces the requirements to brace/stabilize the equipment, fasten the equipment to the surface, etc.
- This concrete decontamination technique has similar advantages and disadvantages to laser scabbling. However, relative to laser scabbling, microwave scabbling has a lower risk of vitrifying the concrete.
- No secondary waste is produced from this technique and thus the risk of cross-contamination is expected to be minimal.
- This technique can be applied to irregular surfaces such as rounded surfaces, corners, etc.
- This technique likely produces much less noise than most other techniques (i.e., conventional methods).
- Minimal concrete dust was generated during testing, suggesting that this technique will not result in significant airborne contamination/hazardous material concerns.

C.3.4 Disadvantages/Negative Attributes

The main disadvantages of microwave scabbling are listed below:

- This technique is expected to require pairing with robotics for automation or remote operation to be most effective and to achieve consistent results.

- The process parameters (power density, scanning speed, etc.) may need to be optimized for different types of concrete.
- Generally, this technique leaves a rough surface finish, which increases the difficulty of subsequent characterization.
- The equipment required to transmit the microwaves, the waveguide, is large and expensive. For 18 GHz, the waveguide would have cross-sectional dimensions of approximately 12.5 mm x 6 mm. The equivalent dimensions for 10.6 GHz waveguide would be approximately 22 mm x 10 mm. For practical implementation during decontamination, a flexible waveguide would be required; these have worse energy propagation properties than rigid waveguides and thus could hamper the efficiency of the technique.
- Appropriate means of protecting personnel and other plant structures against stray through-wall microwave energy, especially in applications involving relatively thin concrete structures, needs to be provided.

C.3.5 Gaps for Commercial Readiness/Development Opportunities

This technique is considered to be TRL 3.

Gaps for commercial readiness and development opportunities for this technique are listed below:

- Additional testing is required prior to a full-scale application of the technique. Specifically, testing is required to (1) optimize operational parameters such as microwave power density, microwave frequency, applicator exposure area, scanning speed, standoff distance, etc., for different types of concrete and (2) determine whether this technique would be effective on representative nuclear plant concrete surfaces (i.e., concrete up to 60+ years old, where the moisture content is unknown). Prior to such testing, it would be beneficial to conduct a review on the different types of concrete used in nuclear plants worldwide and the effect of age, operational conditions, and environmental conditions on the moisture content of the various types of concrete.
- Additional analysis and engineering work is needed to determine the optimal equipment size (e.g., microwave capacity) that would result in the lowest cost per area of concrete decontaminated. Then, engineering work is required to design and fabricate a full-scale microwave scabbling system that is integrated with a suitable robotic platform to enable automation or remote control of the technique in a decommissioning nuclear power plant.
- Engineering work is required to develop an applicator that allows the unhindered propagation of microwave energy, but that also prevents concrete fragment ingress into the waveguide system [14].
- A large-scale field demonstration is required to demonstrate/determine (1) the reliability of the field equipment, (2) the real-world concrete decontamination rate (i.e., accounting

for equipment setup, maintenance, movement from room to room, etc.), and (3) the cost per square meter to implement the technique.

C.4 Sprays, Foams, and Gels

C.4.1 Overview

There are a number of spray and gel products that may be used to chemically decontaminate concrete. Generally, these decontamination techniques involve the following:

- A spray, foam, or gel is applied to the concrete surface. For small-scale applications, the sprays, foams, or gels can be applied manually (e.g., spatula for surface application of gel). For a large-scale application, the spray, foam, or gel would likely be sprayed onto the concrete surface of interest.
- The spray, foam, or gel then reacts with the surface for a period of several minutes up to a few days to physically and/or chemically bind contaminants.
- The spray, foam, or gel is then removed from the concrete surface. Generally, the spray, foam, or gel is either peeled off of the surface (e.g., for a strippable coating) or rinsed and vacuumed off the surface (e.g., for a spray or foam).
- The removed spray, foam, or gel is then either (1) disposed of or (2) treated to reduce the volume of the waste and then disposed of.

The equipment required to implement these techniques is relatively simple and generally consists of standard spraying and vacuuming technologies.

C.4.2 Experience

Significant testing of sprays, foams, and gels for surface decontamination has been conducted by the US EPA. Generally, this testing has been performed to evaluate decontamination techniques that could be rapidly deployed for decontamination of building materials after terrorist activities, not for decontamination of nuclear plant concrete. The majority of the EPA testing was conducted from 2010 – 2013. The testing was conducted on 15 cm by 15 cm concrete coupons that had been dosed with various radionuclides. For all the testing involving Cs-137, the initial Cs-137 surface activity was 44 $\mu Ci/m^2$ (1 µCi total per coupon). A summary of this testing is presented in Table C-10 [28].

In 2015, additional EPA testing was conducted on CBI's DeconGel™ 1120 and EAI's Supergel [29]. This testing was conducted on 1.5 – 3.0 m^2 concrete coupons that had been dosed with various radionuclides. Test parameters and results for Cs-137 are summarized in Table C-11.

Rad-Release II was used to decontaminate concrete pedestals at the East Tennessee Technology Park in Oak Ridge, Tennessee. The concrete pedestals were decontaminated from 2,000,000 dpm/100 cm^2 to non-detectable levels. Further, this product was used at Maine Yankee to decontaminate the floor of the Primary Auxiliary Building. Additional details on these experiences are presented in EPRI 3002005412 [1].

C.4.3 Advantages/Positive Attributes

The main advantage of these techniques is that they can be applied at much lower capital and labor costs than alternative techniques. Specifically, it is anticipated that these techniques could be applied relatively quickly to nuclear plant concrete surfaces using relatively low-cost equipment (e.g., standard spraying technology). The use of complicated and expensive automated systems is not expected to be required.

Other advantages of these techniques are listed below:

- These techniques do not cause structural damage to the concrete.
- These techniques generally leave the concrete surface smooth, which eases subsequent characterization efforts.
- These techniques would require lower worker safety controls than most physical concrete decontamination techniques discussed in this report.
- Sprays, foams, and gels may penetrate into and decontaminate cracks in concrete. Some products have been demonstrated to penetrate 2 inches in a near perfect concrete surface [1]. Many alternative techniques are poorly suited for such focused decontamination scenarios as cracks in concrete.
- These techniques can very easily be applied to irregular surfaces such as rounded surfaces, corners, etc.
- This technique would produce much less noise than most other techniques.

C.4.4 Disadvantages/Negative Attributes

The main disadvantage of the spray, foam, and gel concrete decontamination techniques is that the DFs achievable with these techniques are much lower than other concrete decontamination techniques. Specifically, DFs only up to about 5.0 were achieved in the EPA laboratory testing. Further, as summarized below, the achievable DF during a field application may be lower than this value:

- The effectiveness of these decontamination techniques appears to decrease with the amount of time that a contaminant has been present on the concrete.
- The EPA testing of these decontamination techniques has generally been on unpainted concrete surfaces. If contamination is present under the concrete paint (e.g., if a concrete surface was repainted, etc.), it is anticipated that the effectiveness of these techniques would be reduced.

Other disadvantages and anticipated challenges with these techniques are listed below:

- The consumable material cost (i.e., variable cost) to implement these techniques are likely higher than alternative decontamination methods.

- These techniques result in the generation of secondary waste. To minimize waste disposal costs, waste treatment of the foam, spray, or gel may be required after completion of the decontamination.

C.4.5 Gaps for Commercial Readiness/Development Opportunities

This class of techniques is considered to be TRL 5.

Gaps for commercial readiness and development opportunities for these techniques are listed below:

- The DFs achievable with these techniques are generally much lower than other concrete decontamination techniques. It is not currently clear whether these techniques would be sufficient for nuclear plant concrete decontamination. Analysis is required to determine if the DFs achievable with these techniques would be sufficient for any of the following applications in the immediate dismantling scenario (i.e., DECON) or the deferred dismantling scenario (i.e., SAFSTOR):
  - Decontamination for concrete clearance (e.g., per regulations in various European countries)
  - Decontamination for site release (e.g., in the US)
  - Decontamination to facilitate disposal of concrete in a lower cost facility (e.g., for US plants, disposal in a non-NRC licensed waste disposal facility)
  - Decontamination to facilitate open-air demolition of contaminated concrete structures.
- Additional testing of one or more of these techniques on real nuclear plant concrete (e.g., during a small-scale plant trial) is required for the following reasons:
  - As noted previously, the effectiveness of these decontamination techniques appears to decrease with the amount of time that a contaminant has been present on the concrete. Testing of these techniques on real nuclear plant concrete would help determine how effective these techniques would be on contamination that has been present on the concrete for many (i.e., 10+) years.
  - Most testing with these techniques has been on only a few radionuclides (e.g., Cs-137, Co-60, Sr-85, and Am-243). Since many of these techniques remove contamination by chemically binding the radionuclide (rather than physically removing it), it is not clear how effective these techniques would be on other radionuclides (in particular, non-metal radionuclides). Testing of these techniques on real nuclear plant concrete would help determine DFs for other radionuclides.
- The relative effectiveness of several of these techniques after repeated applications is not well known. Additional testing would be useful to determine if multiple consecutive applications of these products would result in higher DFs.
- Some of these techniques require the development of a waste treatment method.

Table C-10: Summary of EPA Testing of Sprays, Foams, Gels, and Strippable Coatings for Concrete Decontamination [28, 30, 31]

Product Name	Product Form	Testing Application Mechanism	Testing Removal Mechanism	# Apps	Soak Duration (each app)	Material Cost ($/m^2) [b]	Waste Generated	Age of Contami-nation	Average DF			
									Cs 137	Co 60	Sr 85	Am 243
EAI Rad-Release I	Liquid	Sprayed	Rinse and Vacuum	1	30 min	[c]	3-8 L/m^2	<2 weeks	3.9			
EAI Rad-Release II				1	60 min (2-steps)			<2 weeks	4.1	4.8	3.3	8.3
								1 year	2.1			
EAI SuperGel	Gel	Paint Scraper	Vacuum	1	1-2 hrs	1.5-3.0	5-10 L/ m^2	<2 weeks	3.7	2.6	1.7	3.0
								1 year	1.9			
CBI DeconGel 1101	Strippable Coating	Paint Brush	Strippable Coating	1	12-48 hrs	50-125	200 g/m^2	<2 weeks	1.8			
CBI DeconGel 1108								<2 weeks	3.0	6.7	2.8	6.3
INTEK ND-75	Liquid	Spray	Rinse and Vacuum	3	15 min	1	3-5 L/m^2	<2 weeks	1.9			
INTEK ND-600				3	30 min	2		<2 weeks	2.1			
INTEK LH-21				6	10 min	4		<2 weeks	1.8			7.7
Allen-Vanguard's SDF	Foam	Foamer	Rinse and Vacuum	2	30 min	8.25	25 L/m^2 (foam) 15 L/m^2 (rinse water)	<2 weeks	2.0			
								1 year	1.4			
Environment Canada's UDF				3	30 min	12		<2 weeks	2.6			
								1 year	1.6			
RDS Liquid	Liquid	Spray/Foam Bottles	Wiped off	6	3-6 min	250	5 L/m^2	<2 weeks	2.1			
RDS Foam								<2 weeks	2.0			

RDS 2000	Liquid	Sprayed	Rinse and Vacuum	3	5 min	75	10 L/m^2	<2 weeks	1.1	2.0	1.8	3.2
Bartlett Stripcoat	Strippable Coating	Paint Brush	Strippable Coating	2	4-12 hrs	33 [d]	400 g/m^2	<2 weeks				1.9

a) Grey cells indicate that this was not tested.

b) The costs listed here are as reported in EPA/600/S-15/155. These costs are generally based on documentation from 2011.

c) With the exception of the Rad-Release solutions, all listed costs are material costs only and do not include labor or waste treatment costs. In contrast, the Rad-Release solutions are not sold as a stand-alone product. EAI, Inc. offers decontamination services which employ the Rad-Release products for which the cost varies greatly from project to project. Typical project costs have been approximately \$33-\$55/m^2.

d) Costs for two applications of the coating.

Table C-11: Summary of Larger-Scale EPA Testing of Gels for Concrete Decontamination [29]

Product Name	Applied with	Time to Apply (min/m^2)	Removal Method	Removal Time (min/m^2)	Waste (L/m^2)	Int. Cs-137 Activity (µCi/m^2)	DF after 1st App	DF after 2nd App
CBI DeconGel™ 1120	Paint Sprayer	2 - 4	Peeled	5 - 43 [a]	1.4	6.7	1.3	1.4
EAI Supergel		1 - 4	Vacuumed	5 - 8	2-2.5		1.5	2.0

a) During two of the tests it took ~5 min/m^2 to remove but during one test it took 43 min/m^2.

C.5 Ice Blasting

C.5.1 Overview

Ice blasting can be performed as a blasting technique (i.e., similar to grit blasting) or as an abrasive water jet technique. In both cases, ice (i.e., H_2O) is used as the abrasive component instead of more traditional blasting medium such as sand, metal shot, dry ice (i.e., CO_2), etc. This process is similar in concept to dry ice blasting and liquid nitrogen blasting in that additional solid wastes are not introduced into the waste. The only secondary waste produced from this technique is water. Ice blasting is more aggressive than dry ice blasting since the hardness of water ice particles is higher than that of dry ice.

C.5.2 Experience

The only known experience with ice blasting for concrete decontamination is a testing program conducted by ORNL in 1993 at Oconee Nuclear Power Plant Unit 1 [32]. Details on the testing program are very limited. However, the conclusions of the testing program were that ice blasting would remove coatings and some fixed surface contamination, but that the technique would not remove concrete to a significant depth [32]. Since the details on this testing program are not known, it is unclear if a different design/implementation of ice blasting could be effective for concrete decontamination/removal.

C.5.3 Advantages/Positive Attributes

Advantages of the ice blasting technique are listed below:

- A lower amount of secondary waste would be produced from this technique than most other high pressure washing/abrasive waterjet techniques.
- This technique is anticipated to be more effective than dry ice blasting for concrete decontamination since ice is harder than dry ice [33, 34, 35].
    - The hardness of ice increases with decreasing temperature, starting at a hardness of ~1.5 Mohs at 0°C and increasing to about 6 at -80°C. The hardness of ice at temperatures below -80°C is not well known.

- The equipment that would need to be deployed onto a robotic platform to implement this technique autonomously or remotely would likely be relatively lightweight.
- This technique could likely be applied to irregular surfaces such as rounded surfaces, corners, etc.

C.5.4 Disadvantages/Negative Attributes

The main disadvantages of the ice blasting technique are listed below:

- This technique has many of the same advantages and disadvantages as ultra-high pressure washing/waterjet blasting. The main difference is that ice blasting may require lower volumes of water and thus would result in less secondary waste. However, the equipment required for this technique would be more complicated and expensive than ultra-high pressure washing/waterjet blasting. Therefore, to warrant use, this technique would likely have to be much more effective than ultra-high pressure washing/waterjet blasting.
- The effectiveness of this technique for concrete decontamination is not known.
- The contaminated water resulting from the use of this technique would need to be processed/separated from the contaminated concrete and/or paint.
  - The waste resulting from ultra-high pressure washing of Magnox plants in the UK was a sludge that was difficult to process. Due to the presence of concrete constituents in the sludge, the waste was hazardous and had to be disposed of as a special waste [1].
- Like other wet techniques, this technique may result in cross contamination.
- This technique may produce airborne contamination. Since the technique is wet, airborne dose from alpha contamination, which is the most limiting constraint in airborne activity, would be difficult to accurately measure (due to shielding from moisture in the air) [1].

C.5.5 Gaps for Commercial Readiness/Development Opportunities

This technique is considered to be TRL 2.

Laboratory testing of this technique is required to demonstrate the effectiveness of this technique for concrete decontamination and to optimize the design and operational parameters prior to justifying significant additional expense in the development of dedicated equipment supporting a demonstration.

Table C-12: Summary of Available and Emerging Concrete Decontamination Techniques: Advantages and Disadvantages

	Technique	Relative Removal Rate [a]	Relative Availability [a]	TRL	Advantages	Disadvantages
Commercially Available Techniques	**Hand-Held Needle Scaling, Scabbling, Shaving**	Low	Medium to High	9	• Suitable for hard to reach areas • Light-to-medium-weight tool • No secondary waste	• Physically taxing technique • Removal depth typically not adjustable • High vibration
Commercially Available Techniques	**Hand-Held Roto-Peening**	Medium	High	9	• Suitable for hard to reach areas • Light-to-medium-weight tool • No secondary waste	• Physically taxing technique • Removal depth typically low • High vibration
Commercially Available Techniques	**Mechanized Scabbling**	<u>Floor:</u> Medium to High <u>Wall/Ceiling:</u> Low to Medium	<u>Floor:</u> Medium <u>Wall/Ceiling:</u> Low	9	• No secondary waste • Low consumable cost	• Only suitable for planar surfaces • Very heavy equipment; Req. fork-lift, etc. for wall/ceiling decontamination • High dust generation • Rough finishing • Sensitive to presence of metal inserts • High vibration level
Commercially Available Techniques	**Shaving**	High to Very High	<u>Floor:</u> Medium <u>Wall/Ceiling:</u> Low	9	• No secondary waste • Insensitive to presence of metal inserts • Low consumable cost • Smooth finishing • Removal depth adjustable	• Only suitable for planar surfaces • Very heavy equipment; Req. fork-lift, etc. for wall/ceiling decontamination • High dust generation

	Technique	Relative Removal Rate [a]	Relative Availability [a]	TRL	Advantages	Disadvantages
Commercially Available Techniques	**Shot or Grit Blasting**	Medium to High	Medium to High	9	• Suitable for irregular surfaces • Insensitive to presence of metal inserts • Removal depth adjustable • Dry method	• Generates secondary waste (which can be reduced via recycling) • Risk of cross-contamination (with recycling) • High personal safety requirements • High dust generation
	Ultra High Pressure Washing	Low	High	9	• Suitable for irregular surfaces • Insensitive to presence of metal inserts • Removal depth adjustable	• Effluent water generally contaminated and/or hazardous and requires treatment • High personal safety requirements • Risk of cross-contamination • Although the technique is wet, airborne contamination typically still generated • Difficult to monitor airborne dose (wet tech.)

Technique		Relative Removal Rate [a]	Relative Availability [a]	TRL	Advantages	Disadvantages
Emerging Techniques	**NitroJet (see Section C.1)**	High	Medium	≥ 7	• High removal rates • Relatively lightweight; Suitable for automation • Suitable for irregular surfaces • No secondary waste • Removal depth adjustable • Insensitive to presence of metal inserts	• High personal and facility safety requirements • Asphyxiation Risk • Very high ventilation requirements • Complex technology • High liquid nitrogen consumption • Rough finishing
	Laser Scabbling (see Section C.2)	Medium	Medium	3	• Lightweight; suitable for automation • Does not impart a force on the concrete • Suitable for irregular surfaces • No secondary waste • Removal depth adjustable • Insensitive to presence of metal inserts • Minimal dust generation • Low noise • Low risk of cross-contamination	• Developing Technique • Potential to vitrify concrete, hindering further laser scabbling • Rough finishing • Equipment costs unknown • Potential concerns with laser diffraction
	Microwave (see Section C.3)	Medium	Medium	3	• Relatively Lightweight; Suitable for automation • Does not impart a force on the concrete • Suitable for irregular surfaces • No secondary waste • Removal depth adjustable • Insensitive to presence of metal inserts • Minimal dust generation • Low noise • Low risk of cross-contamination	• Developing Technique • Rough finishing • Equipment costs unknown • Equipment required to transmit microwave energy is relatively large and expensive

	Technique	Relative Removal Rate [a]	Relative Availability [a]	TRL	Advantages	Disadvantages
Emerging Techniques	**Sprays, Foams, & Gels (see Section C.4)**	No Material Removal Application Speed is High	High	5	• Low capital and labor costs • Can be applied to surfaces quickly • Suitable for irregular surfaces • Low safety requirements • Smooth finish • Low noise • Insensitive to presence of metal inserts • No structural damage to concrete • No dust generation	• Achievable DF may not be sufficient • Developing Technique • Higher consumable costs than other techniques • Secondary waste generated • Waste treatment may be required • Risk of cross-contamination
Emerging Techniques	**Ice Blasting (see Section C.5)**	Unknown	Medium to High	2	• Suitable for irregular surfaces • Insensitive to presence of metal inserts • Removal depth adjustable	• Developing Technique • Effluent water generally contaminated and/or hazardous and requires treatment • High personal & facility safety requirements • Risk of cross-contamination • Although the technique is wet, airborne contamination typically still generated • Difficult to monitor airborne dose (wet tech.)

a) The relative removal rate does not account for periods of non-operation (e.g., setup, maintenance, movement of from room to room, etc.). Anticipated periods of non-operation are accounted for in the relative availability. The relative removal rates given in this table are defined as: Low < 1 m^2/hr < Medium < 5 m^2/hr < High < 10 m^2/hr < Very High. The relative availability given in this table are based on engineering judgement based on a review of the literature.

Table C-13: Summary of Commercially Available and Emerging Concrete Decontamination Techniques: Productivity Experiences

	Technique	Surface Type	Equipment Setup	Removal Depth (mm)	Removal Rate (m²/hr) [a]	Availability (%) [a]	Experience	Ref.
Commercially Available Techniques	**Needle Scaling**	All	Hand-Held	3 - 50	1.3	Unknown	DOE Hanford	[9]
	Scabbling	All	Hand-Held	3	1	Unknown	BR3	[8]
		Floor	Human Driven; Motor Powered	5	4 - 6	Unknown	Unknown	[8]
		Floor	Moose® System; Remote Controlled	3	12	Unknown	ANL CP-5	[9]
	Shaving	All	Hand-Held; Underwater with divers	3	0.8 [b, c]	N/A [c]	Humboldt Bay	[1]
		Floor	Human Driven; Motor Powered	3	5-13	20% (ATUE only)	CEA (ATUE) CEA (Brennilis)	[8]
		Floor/Wall	Automated; Suction-Clamped to Surface	10	0.5 [c]	N/A [c]	Hinkley Point A	[1, 10]
		Wall	Milling Head(s) Mounted on Industrial Carriers (Fork Lift, Gantry, Brokk, etc.)	25	1.2 - 1.5	20-50%	CEA (EL4 & AT1)	[8]
				10	10		CEA (ATUE)	[8]
				3	8 - 25		BP (Eurochemic) CEA (EL4) Kahl & Karlsruhe	[1, 8]
	Shot or Grit Blasting	Unknown	Unknown	4 - 5	2	77%	CEA – AT1	[8]
		Floor/Wall	En-Vac Robotic Wall Scabbler	3	14	Unknown	INL Eng Lab TAN	[9]
	Roto-Peening	All	Hand-Held Pentek Roto-Peen Scaler	3	3.7	Unknown	ANL CP-5	[9]
		Floor	3M™ Heavy Duty Roto-Peen	3	6.5	Unknown	ANL CP-5	[9]
	Ultra High Pressure Washing	All	Hand-Held	2 - 5	0.3 [c]	N/A [c]	Bradwell Hunterston A	[1]

Emerging Techniques	**NitroJet®**	All	See Section C.1	8 - 12	4.2	Unknown	Laboratory Testing	[11]
				6 - 9	6.6			[11]
				4 - 8	9.6			[11]
	Laser Scabbling	All	5 kW; See Section C.2	7 - 10	0.5	Unknown	Laboratory Testing	[12]
				3 - 5	1.0			[12]
	Microwave Scabbling	All	3.6 kW; 10.6 GHz; See Section C.3	5	1.5	Unknown	Laboratory Testing	[13]
			15 kW; 2.45 GHz; See Section C.3	>25	0.7 - 1.0			[14]
			15 kW; 18 GHz; See Section C.3	4-5	3.7			[15]
	Sprays, Foams, and Gels	All	See Section C.4	Insignificant material removal; Application speed >10 m^2/hr		Unknown	Laboratory Testing	-
	Ice Blasting		Unknown – Very limited testing experience					-

a) With three exceptions (see Footnote c), the removal rate reported in this table does not account for periods of non-operation (e.g., setup, maintenance, movement of from room to room, etc.). Periods of non-operation are accounted for in the availability. The availability is calculated as the active decontamination time/total time spent generally supporting the decontamination activity.

b) Target shaving rate at Humboldt Bay.

c) These removal rates do account for periods of non-operation (e.g., setup, maintenance, movement of from room to room, etc.).

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