Environmental Topical Report for Potential Commercial Spent Nuclear Fuel Reprocessing Facilities in the United States

Final Report

U.S. Nuclear Regulatory Commission

Office of Federal and State Materials and Environmental Management Programs

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<u>DISCLAIMER</u>

The U.S. Nuclear Regulatory Commission staff views expressed in this Environmental Topical Report are preliminary and do not constitute a final determination of the matters addressed or of the acceptability of a license application for a spent nuclear fuel reprocessing facility.

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ENVIRONMENTAL TOPICAL REPORT FOR POTENTIAL COMMERCIAL SPENT NUCLEAR FUEL REPROCESSING FACILITIES IN THE UNITED STATES

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EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) staff has prepared this Environmental Topical Report (ETR) to identify potential technical- and environmental-related considerations and issues that may be associated with the preconstruction (e.g., site preparation)[1], construction, operation, and decommissioning of potential commercial facilities in the United States for reprocessing spent nuclear fuel (SNF) from commercial nuclear power plant reactors. Reprocessing refers generally to the methods necessary to separate spent nuclear reactor fuel into material that may be recycled for use in new nuclear fuel (i.e., uranium and plutonium) and material that would be disposed of as waste. This ETR is intended and has been prepared to serve as a high-level, generic, internal resource document for use by the NRC staff that would prepare a future environmental assessment (EA), or environmental impact statement (EIS) if necessary, for the NRC's proposed rulemaking for licensing and regulating commercial SNF reprocessing facilities. There are no reprocessing facilities currently operating in the United States.

BACKGROUND

The NRC staff is in the process of developing a regulatory framework for licensing and regulating potential commercial SNF reprocessing facilities. This activity originated as a result of nuclear initiatives in the U.S. Department of Energy's (DOE's) Global Nuclear Energy Partnership (GNEP) Program, initially announced as a comprehensive international strategy to enable the worldwide expansion of nuclear energy by demonstrating and deploying technologies to recycle nuclear fuel, minimize waste, and reduce the risk of nuclear proliferation.[2] In August 2006, DOE announced that its approach to the GNEP would involve industry development and deployment of advanced recycling technologies, including commercial-scale SNF reprocessing, fuel fabrication, and advanced burner reactor (ABR) facilities ("GNEP facilities"). Such commercial facilities would come under the purview of the NRC in its authority to regulate civilian uses of nuclear materials and facilities under the Atomic Energy Act of 1954, as amended (AEA).

Subsequently, the NRC staff prepared a paper to the Commission, SECY-07-0081, *"Regulatory Options for Licensing Facilities Associated with the Global Nuclear Energy Partnership,"* May 15, 2007, which addressed options for developing a regulatory framework for licensing major GNEP facilities and associated special nuclear material. On June 28, 2007, the Commission directed the staff in SRM-SECY-07-0081, *"Staff Requirements - SECY-07-0081 - Regulatory*

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[1] Certain construction-related activities (such as certain site preparation activities), referred to as "preconstruction" activities in this Environmental Topical Report, are activities that are explicitly excluded from the U.S. Nuclear Regulatory Commission's (NRC's) definition of "construction" in Title 10 of the *Code of Federal Regulations* (10 CFR) 51.4.

[2] "Nuclear proliferation" is a term used to describe the spread of nuclear weapons, fissile material, and weapons-applicable nuclear technology and information, to nations that are not recognized as "Nuclear Weapon States" by the *Treaty on the Nonproliferation of Nuclear Weapons*.

Options for Licensing Facilities Associated with the Global Nuclear Energy Partnership (GNEP)," to conduct a regulatory gap analysis to identify changes to existing NRC regulatory requirements that would be necessary to license and regulate a reprocessing facility and ABR and develop a regulatory framework to support rulemaking for licensing GNEP facilities.

In 2008, three commercial entities informed the Commission of their interest in moving forward with SNF reprocessing outside the GNEP framework. Also at the time, the NRC staff noted that DOE's progress on GNEP initiatives had waned, and it appeared appropriate to shift the focus of the staff's efforts from specific GNEP facility regulations to a more broadly applicable regulatory framework for commercial reprocessing facilities. Consequently, the staff began to concentrate on conducting a gap analysis and developing a regulatory basis to support rulemaking for potential commercial SNF reprocessing facilities in response to industry needs, as discussed in SECY-08-0134, *"Regulatory Structure for Spent Fuel Reprocessing,"* September 12, 2008*; "Annual Update on Reprocessing Activities—Timeline for Completion of Regulatory Framework"* (Memorandum to the Commission, May 14, 2010); and SECY-11-0163, *"Reprocessing Rulemaking: Draft Regulatory Basis and Path Forward,"* November 18, 2011. In SECY-08-0134, the staff also described three alternative approaches to rulemaking for licensing and regulating a reprocessing facility: (1) revision of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities;" (2) revision of 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material;" or (3) the development of a new "10 CFR Part 7X".

In the absence of any new regulatory framework, reprocessing facilities would currently be regulated under 10 CFR Part 50 because they are considered production facilities as defined in the Atomic Energy Act of 1954, as amended. However, the staff noted that 10 CFR Part 50, and the related 10 CFR Part 52, have evolved to focus primarily on light water reactors. Reprocessing facilities are also fuel cycle facilities; and non-reprocessing fuel cycle facilities that handle isotopes of plutonium and special nuclear material are regulated in 10 CFR Part 70. However, the staff has concluded that the existing requirements of 10 CFR Part 70 do not adequately address SNF reprocessing facilities since, as compared to other types of existing fuel cycle facilities, SNF reprocessing facilities process much larger quantities of highly radioactive material thereby introducing significant onsite and offsite hazards that need to be adequately controlled. Thus, the staff envisioned that integrating applicable requirements from 10 CFR Parts 50, 52, and 70, and other regulations, into a new regulation--i.e., 10 CFR Part 7X--might best address the unique safety and design issues for commercial SNF reprocessing facilities.

If it is determined by the Commission as a matter of discretion (pursuant to 10 CFR 51.20(a)(2)), or based on an EA (pursuant 10 CFR 51.31(a)), that the future SNF reprocessing rulemaking could be considered a major federal action with the potential to significantly affect the quality of the human environment, then pursuant to 10 CFR 51.20(a)(1), it is likely that the staff would be required to prepare an EIS for the rulemaking. An EA or EIS would be prepared in accordance with the requirements of the National Environmental Policy Act of 1969, as amended (NEPA), and the NRC's NEPA-implementing regulations in 10 CFR Part 51. An EIS, if required, would be prepared in parallel with the rulemaking, which in SECY-11-0163 was anticipated to begin in Fiscal Year (FY) 2015, with completion of the rulemaking and Final EIS estimated in FY2019.

ETR PURPOSE, SCOPE, AND GENERAL APPROACH

Because the potential rulemaking may not begin until FY2015, the staff prepared an environmental informational report, in the form of this ETR, as a prelude to developing a future EA or EIS. More specifically, this ETR is intended and has been prepared to serve as a high-level, internal resource document for use by the NRC staff that would prepare a future EA or EIS for the rulemaking and thereby support NEPA document development by:

- Providing pertinent preliminary generic information, analyses, and bibliographic references regarding technical- and environmental-related considerations and issues for commercial SNF reprocessing facilities; and

- Assisting the staff in scoping a future EA, or EIS (if needed), by identifying important issues that may potentially be addressed in those documents.

Thus, this ETR provides a review and preliminary, high-level discussion and analysis of technical and environmental information and considerations associated with SNF reprocessing, based largely on publicly available information and current understanding of relevant issues associated with existing commercial reprocessing facilities in other countries. Also considered is information on past reprocessing operations in the U.S., as well as on other types of nuclear materials facilities with some apparent similarities to potential reprocessing facilities (such as uranium enrichment and fuel fabrication facilities), for which relevant documentation is also publicly available.

Note, however, that because this ETR is for potential U.S. commercial SNF reprocessing facilities, and since no commercial reprocessing facilities are currently operating in the United States, and only limited information on commercial reprocessing facilities in other countries is in the public record, there is no detailed plant- and site-specific information is available upon which to base the discussions and analyses in this report. Furthermore, the exact nature and scope of the proposed rulemaking has not yet been finalized and, therefore, specific design and siting requirements for any future reprocessing facilities in the U.S. have not been established. Thus, the potential reprocessing-related technical and environmental information and considerations presented in this report are neither project- nor location-specific. Instead, this ETR identifies and describes in generic terms some potential technical- and environmental-related considerations roughly based on the Plutonium-Uranium Extraction (PUREX) reprocessing technology, at potential generic reprocessing facilities that could be located at each of three generalized types, or categories, of sites, i.e., rural site, industrial site, and DOE site. Any updates or modifications to information presented in this ETR would be made in the future EA or EIS.

PUREX is an aqueous chemical extraction process that separates uranium and plutonium from the fission products in SNF and from one another, and currently is the only commercial reprocessing technology in use worldwide. It is the only demonstrated technology with operational technical and environmental information available in the public domain. Consequently, the PUREX process serves in this report as a “proxy” for other chemical separation processes currently in development. The generalized rural, industrial, and DOE site types represent a non-specific range of potential environments for commercial reprocessing facilities.

Consequently, consistent with generic, non-location-specific SNF reprocessing facilities as described above, the discussions and analyses presented in this report are preliminary, generic, and largely qualitative; and the ETR cannot provide exhaustive information or be all inclusive. To the extent possible, this ETR concentrates on a broad range of potentially important, anticipated technical- and environmental-related considerations and issues on which a future EA or EIS for the proposed reprocessing rulemaking might be focused, but does not speculate on their significance or provide any conclusions or recommendations.

It is important to note that this ETR is not a NEPA document; i.e., it is neither an EA nor an EIS. This is because the purpose of the ETR is not to assess the potential environmental impacts of a proposed Federal (i.e., NRC) action and alternatives to a proposed action, and it includes no staff findings, conclusions or recommendations regarding a preferred alternative. Simply stated, the potential environmental-related considerations and issues identified in this ETR are factors that could be taken into account by the NRC staff in preparing an EA or EIS for the future rulemaking.

THE NUCLEAR FUEL CYCLE AND SPENT NUCLEAR FUEL REPROCESSING

To provide background and context for the technical- and environmental-related considerations and issues associated with the potential implementation of commercial SNF reprocessing in the United States, the ETR initially presents an overview of the nuclear fuel cycle, a brief history of national and international experience with SNF reprocessing, brief descriptions of SNF reprocessing technologies, and a more detailed description of the PUREX reprocessing technology.

The NRC defines “nuclear fuel cycle” as the series of steps listed below involved in supplying fuel for nuclear power reactors. In the United States, all commercial nuclear reactors use uranium (U), specifically the fissionable U-235 isotope, as fuel; therefore, the nuclear fuel cycle is sometimes referred to as the uranium fuel cycle. The fuel cycle includes the “front end” steps that culminate in the preparation of uranium fuel elements for reactor operation, and the “back end” steps that occur after the fuel is removed from the reactors as SNF. As shown below, SNF reprocessing is a step in the nuclear fuel cycle, although as mentioned earlier, there are no SNF reprocessing facilities currently operating in the United States. Thus, SNF generated at commercial nuclear power reactors in the U.S. currently is in interim storage as high-level radioactive waste (HLW)[3] awaiting a final disposition (disposal) option as no Federal HLW repository is currently approved (licensed) in the United States.

Steps in the Nuclear Fuel Cycle

- Uranium recovery, to extract (or *mine*) uranium ore and concentrate (or *mill*) the ore to produce "yellowcake," a mixture of uranium oxides.[4]
- Conversion of yellowcake into uranium hexafluoride (UF_6).
- Enrichment to increase the concentration of U-235 in the UF_6.
- Deconversion of the depleted uranium hexafluoride (DUF_6), or "tailings", produced in the uranium enrichment process back to uranium oxides, to reduce the hazards associated with the DUF_6.
- Fuel fabrication to convert enriched UF_6 into fuel for nuclear reactors.
- Use of the fuel in the nuclear reactors.
- Interim storage of spent fuel (or SNF), a HLW.
- Reprocessing (or recycling) of SNF to recover the fissionable material (uranium and plutonium).
- Nuclear fuel fabrication from reprocessed SNF.
- Final disposition (disposal) of HLW.

The NRC regulates these processes (except for conventional mining of uranium ore), as well as the fabrication of mixed oxide (MOX) nuclear fuel, which is a combination of uranium and plutonium oxides that may be derived from SNF reprocessing.

POTENTIAL ENVIRONMENTAL SETTINGS FOR U.S. REPROCESSING FACILITIES

Generalized Environmental Settings (Site Types)

Since no specific locations for potential commercial SNF reprocessing facilities in the United States have been identified, for the purposes of this ETR generalized descriptions of the characteristics of hypothetical environmental settings, or “affected environments,” for such

[3] The NRC defines high-level radioactive waste (HLW) as the highly radioactive materials produced as byproducts of the reactions that occur inside nuclear reactors or of fuel reprocessing. HLW includes irradiated spent nuclear fuel (SNF) discharged from commercial nuclear power reactors; the highly radioactive liquid and solid materials resulting from the reprocessing of SNF, which contain fission products in concentration; and other highly radioactive materials that the Commission may determine require permanent isolation. See 10 CFR §§ 60.2 and 63.2.

[4] Uranium recovery may also be accomplished by in situ recovery, in which the uranium ore is chemically altered underground before being pumped to the surface for further processing.

facilities—in the contexts of rural, industrial, and DOE site types, or categories—are used to establish a basis, or baseline, for defining and evaluating environmental-related considerations and issues.

The three types, or categories, of potential SNF reprocessing facility "hosting sites" were originally proposed by DOE in its "Draft Global Nuclear Energy Partnership Programmatic Environmental Impact Statement," October 2008 (DOE/EIS-0396) (Draft PEIS), which was prepared to assess the potential environmental impacts of expanding nuclear power in the United States, including SNF reprocessing. DOE solicited potential hosting sites for an SNF reprocessing facility location. Eleven potential locations spanning the continental U.S. were identified, which embody a broad set of site characteristics based on reported conditions at the sites of actual, current and former nuclear and non-nuclear facilities in rural, industrial, and DOE site environments. In this ETR, the characteristics of these sites are aggregated to establish generalized, hypothetical characteristics of the three site types, to serve as representative settings for potential SNF reprocessing facilities.

Of course, there are many uncertainties involved in generically describing site characteristics in broad classifications such as rural, industrial, and DOE sites. Generalizations may not fully depict the conditions at a given location. However, for this ETR, it is reasonably assumed that companies developing reprocessing facilities would select suitable sites with environmental conditions favorable to such facilities.

Brief descriptions of the three generalized sites types are presented below. Additional descriptive information is provided in the report.

Rural Site
The rural environment is generally free from prior industrial or heavy commercial activity. Consequently, it is assumed that electrical power lines, water and sewer, and roadways, railways, or barge access necessary to support industrial activity would need to be constructed. Radiological and non-radiological discharges or effluents associated with industrial or heavy commercial activity have not affected the air quality, water quality, and soil in this environment.

Industrial Site
The industrial environment has been previously developed for non-nuclear industrial or heavy commercial activity. Electrical power lines, water and sewer, and roadways, railways, or barge access necessary to support industrial activity already exist. Non-radiological discharges or effluents associated with industrial or heavy commercial activity may have affected air quality, water quality, and soil. There have been no radiological discharges or effluents that would have affected this environment, although there may have been releases of hazardous materials to the environment.

DOE Site
A "DOE site" is one at which past and present DOE operations have occurred, and at which a potential SNF reprocessing facility might be co-located. Such sites may also

accommodate other privately owned and operated facilities co-located with DOE operations, which may exist or are planned. The DOE site environment has been previously developed for nuclear and non-nuclear research, industrial, or testing activities. Thus, environmental conditions may be somewhat similar those at industrial sites, except that it is likely that radioactive materials were handled, used, and possibly disposed of at DOE nuclear sites. Electrical power lines, water and sewer, and roadways, railways, or barge access necessary to support industrial activity already exist. Radiological and non-radiological discharges or effluents associated with DOE site activities may have affected air quality, water quality, and soil in this environment. Note, however, that some DOE sites are very large and may include significantly sized undeveloped areas with environmental conditions and characteristics similar to rural site types.

Potential Co-location with Other Nuclear Facilities

The NRC staff acknowledges that for reasons such as efficiency and to minimize costs and risks associated with the transport of high activity nuclear materials, SNF reprocessing facilities could be co-located with other nuclear facilities with purposes or operations directly related to SNF reprocessing. Such related nuclear facilities may include:

- Commercial nuclear power plants
- Independent spent fuel storage installations or monitored retrievable storage installations for storage of SNF or HLW
- Reprocessed uranium enrichment facilities
- Enriched uranium or MOX nuclear fuel fabrication facilities.

Such co-located facilities may already exist at potential reprocessing facility sites or may be constructed concurrent with or following reprocessing facility construction. If regulated by the NRC, these facilities may be licensed by the NRC under a single license, or each of these facilities may be licensed separately and at different times. Such co-location could occur at DOE sites with both existing and future nuclear facilities (with both related and unrelated functions), although it could also occur at rural and non-DOE industrial sites (although more likely with related nuclear facilities at such locations).

At this time, it would be difficult to predict in what forms and at what locations, if any, the co-location of SNF reprocessing facilities with other types of nuclear facilities, both related and unrelated, may occur. Many facility combinations and potential locations are possible, resulting in a multitude of factors that would need to be considered. Further, the timing and interrelationships of potential co-located facilities would be a significant factor relating to how the potential environmental effects of such projects would be evaluated. Consequently, in consideration of the above issues and complications, potential environmental-related considerations associated with the possible co-location of SNF reprocessing facilities with other nuclear facilities is not addressed in any detail within the limited scope of this high-level, generic, qualitative report.

POTENTIAL ENVIRONMENTAL-RELATED CONSIDERATIONS

Potential environmental-related considerations associated with preconstruction, construction, operation, and decommissioning of potential commercial SNF reprocessing facilities are discussed in this report for the following resource areas: land use and site infrastructure, transportation, geology and soils, water resources (water use and water quality), air quality, noise, ecological resources, waste management, historic and cultural resources, visual and scenic resources, public and occupational health (radiological and non-radiological), socioeconomics, and environmental justice. Preliminary environmental-related considerations associated with cumulative environmental effects, greenhouse gas emissions, and postulated accidents potentially associated with commercial reprocessing facilities are also addressed.

For the most part, management or mitigation of potential adverse environmental effects is not considered in the generic discussions in this report as such measures would be highly site-, project-, and design-specific. However, for future reference, examples of such measures are identified and described in general terms.

As mentioned earlier, to the extent possible this ETR concentrates on a broad range of potentially important, anticipated technical- and environmental-related considerations and issues, within the contexts of generalized, potential environmental settings, on which a future EA or EIS for the proposed reprocessing rulemaking might be focused, but does not speculate on their significance or provide any conclusions or recommendations.

ETR ORGANIZATION AND CONTENT

The ETR is organized as follows:

- Chapter 1, the report introduction, presents background information regarding the NRC's proposed rulemaking for licensing and regulating commercial SNF reprocessing facilities and the ETR purpose scope, and general approach.

- Chapter 2 presents an overview of the nuclear fuel cycle, a brief history of national and international experience with SNF reprocessing, brief descriptions of reprocessing technologies, and a more detailed description of the PUREX reprocessing technology.

- Chapter 3 provides preliminary, generic descriptions of, and related information regarding, characteristics of potential environmental settings for potential commercial SNF reprocessing facilities, presented in the contexts of the generalized rural, industrial, and DOE site types where applicable.

- Chapter 4 discusses potential environmental-related considerations, or factors, associated with preconstruction, construction, operation, and decommissioning of potential commercial reprocessing facilities.

- Chapter 5 provides examples of possible measures to manage or mitigate potential adverse environmental effects from preconstruction, construction, and operation of potential commercial SNF reprocessing facilities.
- Chapter 6 discusses environmental-related considerations that could be associated with postulated accidents that could occur at potential SNF reprocessing facilities that would use the PUREX process.

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ACRONYMS

ABR	advanced burner reactor
ACHP	Advisory Council on Historic Preservation
ACP	American Centrifuge Plant
ACRS	Advisory Committee on Reactor Safeguards
ADT	average daily traffic
ADU	ammonium diuranate
AEA	Atomic Energy Act of 1954, as amended
AEC	active engineered control
AEGL	Acute Exposure Guideline Level
AFCI	Advanced Fuel Cycle Initiative
AIHA	American Industrial Health Association
ALARA	as low as reasonably achievable
ALARP	as low as reasonably practicable
AP	aqueous polishing
APE	area of potential effect
ASLB	Atomic Safety and Licensing Board
ASME	American Society of Mechanical Engineers
BEA	Bureau for Economic Analysis
BLM	Bureau of Land Management
BLS	Bureau of Labor Statistics
BMP	best management practice
BNFP	Barnwell Nuclear Fuel Plant
BRC	Blue Ribbon Commission on America's Nuclear Future

BTP	bis-triazinyl-pyridine
BWR	boiling water reactor
CAB	controlled area boundary
CEDE	Committed Effective Dose Equivalent
CEQ	Council of Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMPO	octyl-phenyl-di-isobutyl-carbamoylmethyl- phosphine-oxide
COEX	Co-Extraction
CWA	Clean Water Act
DBA	design basis accident
DIAMEX	Diamide Extraction
DOE	U.S. Department of Energy
DP	decommissioning plan
DU	depleted uranium
DWPF	Defense Waste Processing Facility
EA	environmental assessment
EAB	exclusion area boundary
EIS	environmental impact statement
EJ	environmental justice
EPA	U.S. Environmental Protection Agency
EREF	Eagle Rock Enrichment Facility
ERPG	Emergency Response Planning Guideline
ESA	Endangered Species Act

ETR	Environmental Topical Report
FR	Federal Register
FWPCA	Federal Water Pollution Control Act
FY	fiscal year
GANEX	Grouped Extraction of Actinides
GDC	General Design Criteria
GESMO	Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide
GHG	greenhouse gas
GNEP	Global Nuclear Energy Partnership
GTCC	Greater-Than-Class C
GWP	Global Warming Potential
HA	highly active
HAN	hydroxylamine nitrate
HAP	hazardous air pollutant, or High Activity Product
HCE	high consequence event
HCP	Habitat Conservation Plan
HEPA	high-efficiency particulate air
HEU	highly enriched uranium
HFC	hydrofluorocarbon
HLLW	high level liquid waste
HLW	high-level radioactive waste
HVAC	heating, ventilation, and air conditioning
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection

IDLH	Immediately Dangerous to Life and Health
ILW	intermediate-level radioactive waste
INL	Idaho National Laboratory
IOC	individuals (or individual) outside the controlled area
IPCC	Intergovernmental Panel on Climate Change
IROFS	Item(s) Relied On For Safety
ISA	Integrated Safety Analysis
ISFSI	independent spent fuel storage installation
ISR	in situ recovery
ISS	Items Supporting Safety
LCF	latent cancer fatality
LEL	Lower Explosive Limit
LEU	low enriched uranium
LFL	Lower Flammability Limit
LLW	low-level radioactive waste
LNT	linear, no-threshold theory
LOS	level of service
LPZ	low population zone
LWR	light water reactor
MEI	maximally exposed individual
MFFF	Mixed Oxide Fuel Fabrication Facility
MOA	Memorandum of Agreement
MOX	mixed oxide
MP	mixed oxide process

MRS	monitored retrievable storage
MTHM	metric tons of heavy metal
MTIHM	metric tons of initial heavy metal
MTU	metric tons of uranium
MWD	megawatt days
NAAQS	National Ambient Air Quality Standards
NAGPRA	Native American Graves Protection and Repatriation Act
NAS	National Academy of Sciences
NCRP	National Council for Radiation Protection
NEF	National Enrichment Facility
NEPA	National Environmental Policy Act of 1969, as amended
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NHPA	National Historic Preservation Act of 1966, as amended
NMFS	National Marine Fisheries Service
NMVOC	nonmethane volatile organic compound
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NSR	New Source Review
NWPA	Nuclear Waste Policy Act of 1982, as amended
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Health and Safety Administration
PA	Programmatic Agreement

PAC	Protective Action Criterion
PAG	Protective Action Guideline
PEC	passive engineered control
PEIS	Programmatic Environmental Impact Statement
PFC	perfluorocarbon
PRA	Probabilistic Risk Analysis
PSD	Prevention of Significant Deterioration
PSM	Process Safety Management
PSSCs	principal systems, structures, and components
PTFE	polytetrafluorethylene
PUREX	Plutonium-Uranium Extraction
PWR	pressurized water reactor
QA	quality assurance
QC	quality control
QHG	quantitative health guideline
RB	Regulatory Basis
RCRA	Resource Conservation and Recovery Act
REDOX	Reduction-Oxidation
RFFA	reasonably foreseeable future action
RG	Regulatory Guide
RIMS	Regional Input-Output Modeling System
RMP	Risk Management Program
ROI	region of influence
SANEX	Selective Actinide Extraction

SHPO	State Historic Preservation Officer
SNF	spent nuclear fuel
SNM	special nuclear material
SOP	standard operating procedure
SPCC	Spill Prevention, Control and Countermeasures
SPPP	Stormwater Pollution Prevention Plan
SRS	Savannah River Site
SSCs	structures, systems, or components
SWMP	Stormwater Management Plan
T&E	threatened and endangered
TALSPEAK	Trivalent Actinide Lanthanide Separation by Phosphorus Extractants and Aqueous Komplexes
TBP	tributyl phosphate
TCP	traditional cultural property
TEDE	Total Effective Dose Equivalent
TEEL	Temporary Emergency Exposure Limit
tHM	tons of heavy metal
THORP	Thermal Oxide Reprocessing Plant
THPO	Tribal Historic Preservation Officer
TPH	hydrogenated tetrapropene
TRAGIS	TRAnsportation Geographic Information System
TRPO	Tri-alkyl Phosphine Oxides
TRU	transuranic
TRUEX	Transuranic Extraction
TVA	Tennessee Valley Authority

UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
UREX	Uranium Extraction
USACE	U.S. Army Corps of Engineers
USCB	U.S. Census Bureau
USDOT	U.S. Department of Transportation
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VHCE	very high consequence event
VOC	volatile organic compound
VOG	vessel offgas
VRM	visual resource management
WTP	Waste Treatment Plant
WV	West Valley

1 INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) staff has prepared this Environmental Topical Report (ETR) to identify potential technical- and environmental-related considerations and issues that may be associated with the preconstruction (e.g., site preparation)[1], construction, operation, and decommissioning of potential commercial facilities in the United States for reprocessing spent nuclear fuel (SNF) from commercial nuclear power plant reactors. Reprocessing refers generally to the methods necessary to separate spent nuclear reactor fuel into material that may be recycled for use in new nuclear fuel (i.e., uranium and plutonium) and material that would be disposed of as waste. This ETR is intended and has been prepared to serve as a high-level, generic, internal resource document for use by the NRC staff that would prepare a future environmental assessment (EA), or environmental impact statement (EIS) if necessary, for the NRC's proposed rulemaking for licensing and regulating commercial SNF reprocessing facilities. There are no reprocessing facilities currently operating in the United States.

1.1 Background

The NRC staff is in the process of developing a regulatory framework for licensing and regulating potential commercial SNF reprocessing facilities. This activity originated as a result of nuclear initiatives in the U.S. Department of Energy's (DOE's) Global Nuclear Energy Partnership (GNEP) Program. DOE initially announced the GNEP Program on February 6, 2006, as a comprehensive international strategy to enable the worldwide expansion of nuclear energy by demonstrating and deploying technologies to recycle nuclear fuel, minimize waste, and reduce the risk of nuclear proliferation[2] (DOE, 2006). On August 7, 2006, DOE announced that its approach to the GNEP would involve industry development and deployment of advanced recycling technologies, including commercial-scale SNF reprocessing, fuel fabrication, and advanced burner reactor (ABR) facilities ("GNEP facilities") (see *Federal Register*, Vol. 71, pages 44673-44676 and 44676-44679 (71 FR 44673 and 71 FR 44676, respectively). Such commercial facilities would come under the purview of the NRC in its authority to regulate civilian uses of nuclear materials and facilities under the Atomic Energy Act of 1954, as amended (AEA).

Subsequent to DOE's August 2006 announcements, the NRC staff prepared a paper to the Commission, SECY-07-0081, *"Regulatory Options for Licensing Facilities Associated with the Global Nuclear Energy Partnership,"* May 15, 2007 (NRC, 2007a), which addressed options for developing a regulatory framework for licensing major GNEP facilities and associated special

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[2] "Nuclear proliferation" is a term used to describe the spread of nuclear weapons, fissile material, and weapons-applicable nuclear technology and information, to nations that are not recognized as "Nuclear Weapon States" by the *Treaty on the Nonproliferation of Nuclear Weapons* (Wikipedia, 2012).

nuclear material (SNM). On June 28, 2007, the Commission directed the staff in SRM-SECY-07-0081, *"Staff Requirements - SECY-07-0081 - Regulatory Options for Licensing Facilities Associated with the Global Nuclear Energy Partnership (GNEP)"* (NRC, 2007b), to conduct a regulatory gap analysis to identify changes to existing NRC regulatory requirements that would be necessary to license and regulate a reprocessing facility and ABR and develop a regulatory framework to support rulemaking for licensing GNEP facilities.

In 2008, three commercial entities informed the Commission of their interest in moving forward with SNF reprocessing outside the GNEP framework. Also at the time, the NRC staff noted that DOE's progress on GNEP initiatives had waned, and it appeared appropriate to shift the focus of the staff's efforts from specific GNEP facility regulations to a more broadly applicable regulatory framework for commercial reprocessing facilities. Consequently, the staff began to concentrate on conducting a gap analysis and developing a regulatory basis providing technical concepts and requirements necessary to support rulemaking for potential commercial SNF reprocessing facilities in response to industry needs, as discussed in SECY-08-0134, *"Regulatory Structure for Spent Fuel Reprocessing,"* September 12, 2008 (NRC, 2008)*; "Annual Update on Reprocessing Activities—Timeline for Completion of Regulatory Framework"* (Memorandum to the Commission, May 14, 2010) (NRC, 2010); and SECY-11-0163, *"Reprocessing Rulemaking: Draft Regulatory Basis and Path Forward,"* November 18, 2011 (NRC, 2011). In SECY-08-0134 (NRC, 2008), the staff also described three alternative approaches to rulemaking for licensing and regulating a reprocessing facility: (1) revision of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities;" (2) revision of 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material;" or (3) the development of a new "10 CFR Part 7X".

The staff finalized the regulatory gap analysis for licensing and regulating commercial SNF reprocessing facilities in SECY-09-0082, *"Update on Reprocessing Regulatory Framework-Summary of Gap Analysis,"* May 28, 2009 (NRC, 2009), identifying 23 gaps. The staff categorized each of the regulatory gaps into one of four of the following types: (1) lack of regulations; (2) existing regulations pose a significant hindrance or regulatory burden to effective and efficient licensing; (3) gap resulting from potentially licensing a production facility under 10 CFR Part 70 (versus 10 CFR Part 50); and, (4) requirements exist, but modifications may be needed for clarity. Additionally, the staff assigned the 23 gaps qualitative priorities for resolution (i.e., low, moderate, or high priority). See SECY-09-0082 (NRC, 2009) for more information on the 23 regulatory gaps and their categorization.

Based on language in the AEA, SNF reprocessing facilities are considered production facilities, as they are designed and used for the separation of the isotopes of plutonium and for the processing of irradiated materials containing SNM. Thus, in the absence of any new regulatory framework, reprocessing facilities would currently be regulated under 10 CFR Part 50. The regulations within this part contain some specific requirements pertaining to fuel reprocessing facilities, such as Appendix F, "Policy Relating to the Siting of Fuel Reprocessing Plants and Related Waste Management Facilities." However, 10 CFR Part 50, and the related 10 CFR Part 52, have evolved to focus primarily on light water reactors (LWRs).

Reprocessing facilities are also fuel cycle facilities. Non-reprocessing fuel cycle facilities that handle isotopes of plutonium and SNM are regulated in 10 CFR Part 70. However, the staff has concluded that the existing requirements of 10 CFR Part 70 do not adequately address SNF reprocessing facilities since, as compared to other types of existing fuel cycle facilities, SNF reprocessing facilities process much larger quantities of highly radioactive material thereby introducing significant onsite and offsite hazards that need to be adequately controlled.

The staff recognized that because 10 CFR Part 50 had evolved into a regulation focused primarily on LWRs, it may be difficult to modify this part into an effective and efficient regulation for a production facility that reprocessed SNF. Additionally, the materials utilization requirements in 10 CFR Part 70 do not address potential fission product hazards associated with SNF reprocessing. Thus, the staff envisioned that integrating applicable requirements from 10 CFR Parts 50, 52, and 70, and other regulations, into a new regulation--i.e., 10 CFR Part 7X--might best address the unique safety and design issues for commercial SNF reprocessing facilities (NRC, 2009).

If it is determined by the Commission as a matter of discretion (pursuant to 10 CFR 51.20(a)(2)), or based on an EA (pursuant to 10 CFR 51.31(a)), that the future SNF reprocessing rulemaking of the type currently anticipated by the staff could be considered a major federal action with the potential to significantly affect the quality of the human environment, then pursuant to 10 CFR 51.20(a)(1), it is likely that the staff would be required to prepare an EIS for the rulemaking. An EA or EIS would be prepared in accordance with the requirements of the National Environmental Policy Act of 1969, as amended (NEPA), and the NRC's NEPA-implementing regulations in 10 CFR Part 51. An EIS, if required, would be prepared in parallel with the rulemaking, which in SECY-11-0163 was anticipated to begin in Fiscal Year (FY) 2015, with completion of the rulemaking and Final EIS estimated in FY2019 (NRC, 2011).

1.2 ETR Purpose, Scope, and General Approach

As discussed above, the NRC staff would be required to prepare an EA or EIS in support of an NRC action to conduct rulemaking for the licensing and regulation of potential commercial SNF reprocessing facilities. Because the potential rulemaking may not begin until FY2015, the staff prepared an environmental informational report, in the form of this ETR, as a prelude to developing a future EA or EIS. More specifically, this ETR is intended and has been prepared to serve as a high-level, internal resource document for use by the NRC staff that would prepare a future EA or EIS for the rulemaking and thereby support NEPA document development by:

- Providing pertinent preliminary generic information, analyses, and bibliographic references regarding technical- and environmental-related considerations and issues for commercial SNF reprocessing facilities; and

- Assisting the staff in scoping a future EA, or EIS (if needed), by identifying important issues that may potentially be addressed in those documents.

Thus, this ETR provides a review and preliminary, high-level discussion and analysis of technical and environmental information and considerations associated with SNF reprocessing, based largely on publicly available information and current understanding of relevant issues associated with existing commercial reprocessing facilities in other countries. Also considered in this report is information on past reprocessing operations in the U.S., as well as on other types of nuclear materials facilities with some apparent similarities to potential reprocessing facilities (such as uranium enrichment and fuel fabrication facilities), for which relevant documentation is also publicly available. Potential environmental-related considerations for preconstruction, construction, operation, and decommissioning of potential commercial SNF reprocessing facilities are included in this report for the following resource areas: land use and site infrastructure, transportation, geology and soils, water resources (water use and water quality), air quality, noise, ecological resources, waste management, historic and cultural resources, visual and scenic resources, public and occupational health (radiological and non-radiological), socioeconomics, and environmental justice. Greenhouse gas emissions and postulated accidents potentially associated with a commercial reprocessing facility are also addressed.

Note, however, that because this ETR is for potential U.S. commercial SNF reprocessing facilities, and since no commercial reprocessing facilities are currently operating in the United States, and only limited information on commercial reprocessing facilities in other countries is in the public record, there is no detailed plant- and site-specific information is available upon which to base the discussions and analyses in this report. Furthermore, the exact nature and scope of the proposed rulemaking has not yet been finalized and, therefore, specific design and siting requirements for any future reprocessing facilities in the U.S. have not been established. Thus, the potential reprocessing-related technical and environmental information and considerations presented in this report are neither project- nor location-specific. Instead, this ETR identifies and describes in generic terms some potential technical- and environmental-related considerations roughly based on the Plutonium-Uranium Extraction (PUREX) reprocessing technology (described in Section 2.3 of this report), at potential generic PUREX reprocessing facilities that could be located at each of three generalized types, or categories, of sites, i.e., rural site, industrial site, and DOE site. Any updates or modifications to information presented in this ETR would be made in the future EA or EIS.

PUREX is an aqueous chemical extraction process that separates uranium and plutonium from the fission products in SNF and from one another, and currently is the only commercial reprocessing technology in use worldwide. Therefore, it is the only demonstrated technology with operational technical and environmental information available in the public domain. Consequently, the PUREX process serves in this report as a “proxy” for other chemical separation processes currently in development (see Section 2.2.2.2). Further, the generalized rural, industrial, and DOE site types represent a range of potential environments for commercial reprocessing facilities.

Consequently, consistent with generic, non-location-specific SNF reprocessing facilities as described above, the discussions and analyses presented in this report are preliminary, generic, and largely qualitative; and the ETR cannot provide exhaustive information or be all inclusive.

To the extent possible, this ETR concentrates on a broad range of potentially important, anticipated technical- and environmental-related considerations and issues within the contexts of generalized, potential environmental settings, on which a future EA or EIS for the proposed reprocessing rulemaking might be focused, but does not speculate on their significance or provide any conclusions or recommendations.

It is important to note that this ETR is not a NEPA document; i.e., it is neither an EA nor an EIS. This is because the purpose of the ETR is not to assess the potential environmental impacts of a proposed federal (i.e., NRC) action and alternatives to a proposed action, and it includes no staff findings, conclusions or recommendations regarding a preferred alternative. Simply stated, the potential environmental-related considerations and issues identified in this ETR are factors that could be taken into account by the NRC staff in preparing an EA or EIS for the future rulemaking.

1.3 ETR Organization and Content

The remainder of the ETR is organized as follows:

- Chapter 2 presents an overview of the nuclear fuel cycle, a brief history of national and international experience with SNF reprocessing, brief descriptions of reprocessing technologies, and a more detailed description of the PUREX reprocessing technology.

- Chapter 3 provides preliminary, generic descriptions of, and related information regarding, characteristics of potential environmental settings for potential commercial SNF reprocessing facilities, presented in the contexts of the generalized rural, industrial, and DOE site types where applicable.

- Chapter 4 discusses potential environmental-related considerations, or factors, associated with preconstruction, construction, operation, and decommissioning of potential commercial reprocessing facilities.

- Chapter 5 provides examples of possible measures to manage or mitigate potential adverse environmental effects from preconstruction, construction, and operation of potential commercial SNF reprocessing facilities.

- Chapter 6 discusses environmental-related considerations that could be associated with postulated accidents that could occur at potential SNF reprocessing facilities that would use the PUREX process.

1.4 References

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2 THE NUCLEAR FUEL CYCLE AND SPENT NUCLEAR FUEL REPROCESSING

This chapter presents an overview of the nuclear fuel cycle, a brief history of national and international experience with spent nuclear fuel (SNF) reprocessing, brief descriptions of SNF reprocessing technologies, and a more detailed description of the Plutonium-Uranium Extraction (PUREX) reprocessing technology--to provide background and context for the technical- and environmental-related considerations and issues associated with potential development of commercial SNF reprocessing in the United States.

2.1 Overview of the Nuclear Fuel Cycle

The U.S. Nuclear Regulatory Commission (NRC) defines "nuclear fuel cycle" as the series of steps listed below involved in supplying fuel for nuclear power reactors. The nuclear fuel cycle is illustrated in Figure 2-1. In the United States, all commercial nuclear reactors use uranium (U), specifically the fissionable U-235 isotope, as fuel; therefore, the nuclear fuel cycle is sometimes referred to as the uranium fuel cycle. The fuel cycle includes the "front end" steps that culminate in the preparation of uranium fuel elements for reactor operation, and the "back end" steps that occur after the fuel is removed from the reactors as SNF. As shown below, SNF reprocessing is a step in the nuclear fuel cycle, although as mentioned earlier, there are no SNF reprocessing facilities currently operating in the United States. Thus, SNF generated at commercial nuclear power reactors in the U.S. currently is in interim storage as high-level radioactive waste (HLW)[1] awaiting a final disposition (disposal) option as no Federal HLW repository is currently approved (licensed) in the United States.

<u>Steps in the Nuclear Fuel Cycle</u>

- Uranium recovery, to extract (or mine) uranium ore and concentrate (or mill) the ore to produce "yellowcake," a mixture of uranium oxides. Uranium recovery may also be accomplished by in situ recovery (ISR), formerly known as in situ leach recovery, in which the uranium ore is chemically altered underground before being pumped to the surface for further processing. (See Sections 2.1.1 and 2.1.2.)

- Conversion of yellowcake into uranium hexafluoride (UF_6) (see Section 2.1.3).

- Enrichment to increase the concentration of U-235 in the UF_6 (see Section 2.1.4).

- Deconversion of the depleted uranium hexafluoride (DUF_6), or "tailings", produced in the uranium enrichment process back to uranium oxides, to reduce the hazards associated with the DUF_6 (see Section 2.1.5).

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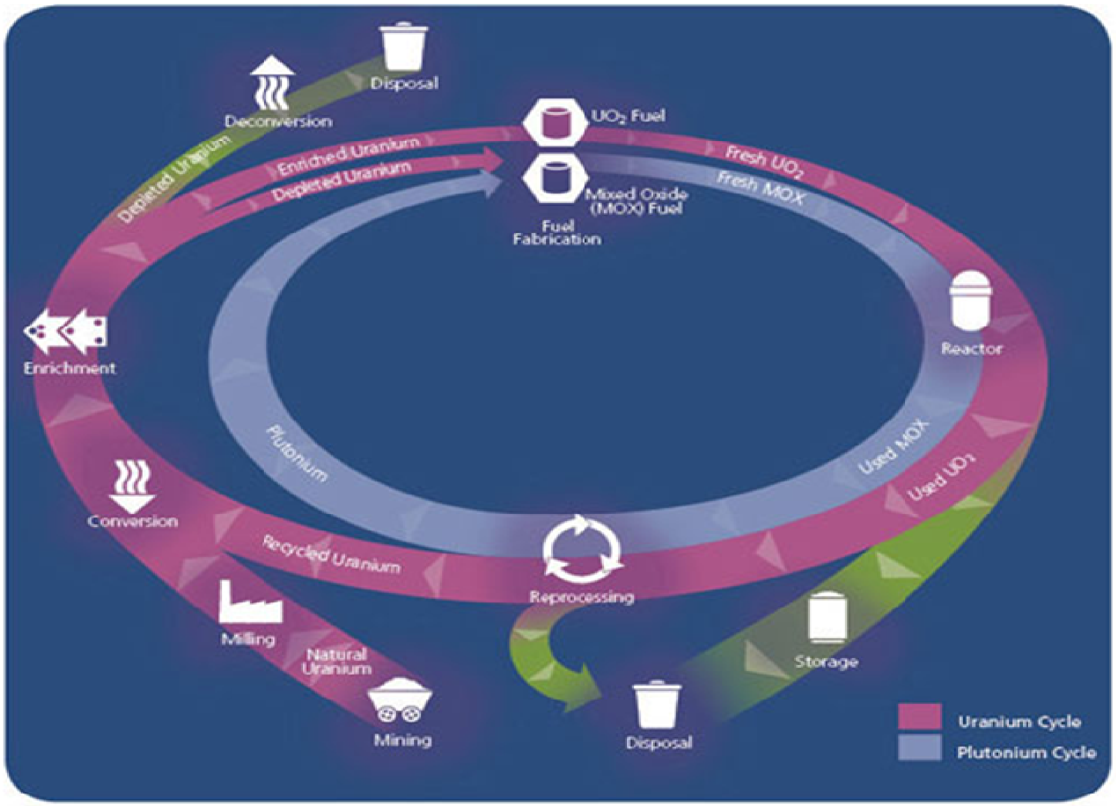
[1] The U.S. Nuclear Regulatory Commission (NRC) defines high-level radioactive waste (HLW) as the highly radioactive materials produced as byproducts of the reactions that occur inside nuclear reactors or of fuel reprocessing. HLW includes irradiated spent nuclear fuel (SNF) discharged from commercial nuclear power reactors; the highly radioactive liquid and solid materials resulting from the reprocessing of SNF, which contain fission products in concentration; and other highly radioactive materials that the Commission may determine require permanent isolation. See Title 10 of the *Code of Federal Regulations* (10 CFR) 60.2 and 63.2.



Source: U.S. Nuclear Regulatory Commission

Figure 2-1 Stages of the Nuclear Fuel Cycle
(Source: NRC, 2012a)

- Fuel fabrication to convert enriched UF_6 into fuel for nuclear reactors (see Section 2.1.6).
- Use of the fuel in the nuclear reactors (see Section 2.1.7).
- Interim storage of spent fuel (or SNF), a high-level radioactive waste (HLW) (see Section 2.1.8).
- Reprocessing (or recycling) of SNF to recover the fissionable material (uranium and plutonium (Pu)) (see Section 2.1.9).
- Nuclear fuel fabrication from reprocessed SNF (see Section 2.1.10).
- Final disposition (disposal) of HLW (see Section 2.1.11).

The NRC regulates these processes (except for conventional mining of uranium ore), as well as the fabrication of mixed oxide (MOX) nuclear fuel, which is a combination of uranium and plutonium oxides that may be derived from SNF reprocessing. The elements of the nuclear fuel cycle are briefly described in the sections that follow.

2.1.1 Mining of Naturally Occurring Uranium

The uranium fuel cycle starts with the mining of uranium ore. Uranium is a naturally-occurring element and is found at low levels in virtually all rock, soil, and water. Significant concentrations may be found in substances such as phosphate rock deposits, and minerals such as uraninite in uranium-rich ores. The most common naturally occurring isotope of uranium is U-238 (99.3 percent), while the isotope that is used to generate nuclear power, U-235, is only present in small amounts (about 0.7percent) (DOE, 2008). Uranium ore may be conventionally mined via open pit or from underground mines, or extracted using ISR techniques.

In open pit mining, the ore is recovered from near-surface deposits following the removal of overburden rock and soils. The dimensions of these pits may be several hundred feet across and in depth. For underground mining, several different mining techniques may be utilized. Selection of an appropriate underground mining method and equipment depends on the depth, geometry, and grade (uranium concentration above background) of the ore body. For example, for mining deep, highly enriched ore deposits, only mechanized and automated mining equipment might be used to limit potential worker exposure to excessive radon radiation. Ore is then transported up the shafts. In both open pit and underground mining, the ore is stockpiled before being sent offsite for further processing.

More recently, most uranium production in the United States has been undertaken using ISR methods. ISR facilities recover uranium from low-grade ores where other mining and milling methods may be too expensive or environmentally disruptive. In this process, a solution typically containing water mixed with oxygen or hydrogen peroxide, as well as sodium carbonate or carbon dioxide, is injected underground through a series of wells into the ore body to dissolve the uranium. The solution containing dissolved uranium is then collected in a series of recovery wells, through which it is pumped to a processing plant where the uranium is extracted from the solution through an ion exchange process. ISR facilities generally consist of wellfields, pipelines, a compact and simple uranium extraction plant (see Section 2.1.2), and drying facilities (Vattenfall, 2010).

2.1.2 Production of Yellowcake

Uranium ore obtained from open pits or underground shafts typically is hauled to a conventional uranium extraction plant or mill, which is usually located near the mine. In the mill, the ore is crushed, pulverized, and mixed with water to produce a feed slurry for further processing. The remaining slurry containing waste rock, or “tails”, is pumped from the mill to a lined tailings pond for disposal. Through a sequence of chemical extraction steps, the uranium ore is gradually enriched to produce a much more concentrated uranium oxide (mostly U_3O_8) known as yellowcake. The specific composition of yellowcake depends on the process employed, but it generally is a yellow or brown powder that contains about 90 percent uranium oxide (DOE, 2008). In the case of uranium obtained through solvent extraction in ISR facilities, the uranium extract is further purified and concentrated in a uranium extraction plant and then dried to produce yellowcake.

2.1.3 Conversion of Yellowcake to UF6

After the yellowcake is produced, it is transported to a facility that converts it to UF_6 gas. The conversion process includes the following major steps. The yellowcake (mostly U_3O_8) is converted to uranium trioxide (UO_3) powder, by addition of nitric acid to produce a uranyl nitrate solution, followed by evaporation, thermal decomposition, and pulverization of the UO_3 into a fine powder. The UO_3 is then reduced with hydrogen gas into uranium dioxide (UO_2), which is reacted with hydrogen fluoride (HF) to form uranium tetrafluoride (UF_4), followed by calcination to remove all water. The UF_4 powder is then reacted with fluorine gas to produce UF_6 gas. The UF_6 gas is pressurized and cooled to a liquid, after which it is drained into cylinders and then further cooled to solidify (NRC, 2012b).

2.1.4 Uranium Enrichment

Cylinders containing solid UF_6 are shipped to enrichment plants, at which the proportion of U-235 atoms to U-238 atoms is increased to make the mixture usable as nuclear fuel (DOE, 2008). As discussed earlier, natural uranium primarily contains two isotopes, U-238 (99.3 percent) and U-235 (0.7 percent). The concentration of U-235, which is the fissionable isotope in uranium, needs to be increased to 4 or 5 percent for practical use as a nuclear fuel in a light water reactor (LWR)[2]. Enrichment on a commercial scale can currently be achieved through gaseous diffusion or gas centrifuge processes. Laser separation is an emerging technology for the process. Both the gaseous diffusion and gas centrifuge technologies are currently in use, although the older gaseous diffusion process is being phased out of use and being replaced by the less energy intensive, more efficient gas centrifuge process (NRC, 2012c).

In the gaseous diffusion process, UF_6 gas is filtered through porous membranes in which the pores are so small that the UF_6 gas molecules can barely pass through. U-235 enrichment occurs when the lighter UF_6 gas molecules with U-235 diffuse faster through the barriers than the heavier UF_6 gas molecules with U-238. Many hundreds of barriers in sequence are needed before the UF_6 gas contains a suitable percentage of U-235 for use as reactor fuel. At the end of the process, the U-235 enriched UF_6 gas is condensed back into a liquid and allowed to cool and solidify before transport to fuel fabrication facilities (NRC, 2012c).

The gas centrifuge process uses a series of rotating cylinders in sequence (referred to as cascades) to enrich uranium. UF_6 gas is placed in a cylinder and rotated at a high speed. The heavier gas molecules containing U-238 tend to move toward the outside of the cylinder and the lighter gas molecules containing U-235 tend to collect closer to the center. The slightly enriched U-235 stream is withdrawn and conveyed into the next higher stage, while the slightly depleted stream is returned back to the next lower stage. The gas centrifuge process uses only about 5 percent as much electricity as is consumed by a gaseous diffusion plant (ORNL, 2004).

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[2] Light water reactors (LWRs) use ordinary water as coolant and include boiling water reactors (BWRs) and pressurized water reactors (PWRs). All commercial nuclear power reactors in the U.S. are LWRs.

The laser separation uranium enrichment process is based on photoexcitation principles that result in the isotopic separation of the various forms of uranium. These technologies include Atomic Vapor Laser Isotope Separation (AVLIS), Molecular Laser Isotope Separation (MLIS), and Separation of Isotopes by Laser Excitation (SILEX) (NRC, 2012d). AVLIS uses a uranium-iron metal alloy as its feed material, while MLIS and SILEX use UF_6 as feed material.

2.1.5 Deconversion of DUF_6

As U-235 is enriched in the enrichment process for use in fabricating fuel for nuclear reactors, large quantities of DUF_6, or tailings, are produced. These tailings are transferred into cylinders which are stored in large yards at the enrichment facilities. A process called "deconversion" is used to chemically extract the fluoride from the DUF_6 stored in the cylinders. This deconversion process produces stable uranium oxides, which are generally suitable for disposal as low-level radioactive waste (LLW).

For example, in a deconversion process proposed by International Isotopes Fluorine Products, Inc. (NRC, 2012e), DUF_6 would be deconverted to depleted uranium dioxide (DUO_2) with marketable byproducts. In this process, the DUF_6 would be reacted with hydrogen gas to produce depleted uranium tetrafluoride (DUF_4), along with HF as a marketable byproduct. The DUF_4 would then be processed to produce two other marketable byproducts: silicon tetrafluoride (SiF_4) and boron trifluoride (BF_3), by reaction of the DUF_4 with silicon dioxide (SiO_2) and boron oxide (B_2O_3), respectively, with DUO_2 produced in both processes.

2.1.6 Fuel Fabrication

Fuel fabrication involves the manufacture of the fuel components that are placed into the reactor core to generate heat that is converted to electricity in commercial nuclear power reactors. In the U.S., fuel fabrication begins with the receipt of U-235 enriched UF_6 in solid form from an enrichment plant. The UF_6 is heated to a gaseous form, and the UF_6 gas is chemically processed to form UO_2 powder. This powder is then pressed into pellets that are loaded into long tubes known as fuel rods. The fuel rods are made of a noncorrosive material called cladding that is usually constructed from a zirconium alloy. The fuel roads are grouped together into bundles to form fuel assemblies (NRC, 2012f).

2.1.7 Fuel Use in Nuclear Reactors

Commercial nuclear reactors located in the United States are all LWRs and utilize either a pressurized water reactor (PWR) or boiling water reactor (BWR) design. Fuel use in these designs consists of splitting the nuclei of U-235 atoms (fission) with low-energy thermal (slow) neutrons to release energy. The energy is used to heat water and turn it into steam which drives a turbine. The turbine is connected to an electricity-producing generator. In the reactor core, some of the U-238 is turned into plutonium. The main plutonium isotope, Pu-239, is also fissile material and yields about one third of the energy in a typical nuclear reactor (World Nuclear Association, 2011). The typical lifespan of a fuel assembly in a reactor is 36 to 48 months, after which the majority of the U-235 has fissioned and an inadequate amount remains to support the chain reaction. Operators then remove the fuel from the reactor as part of the refueling process (NEI, 2005).

2.1.8 Interim Storage of Spent Fuel

NRC regulations provide for two acceptable storage methods for SNF after it is removed from the reactor core: wet storage in pools (Title 10 of the *Code of Federal Regulations* (10 CFR) Parts 50 and 72) and dry storage in casks (10 CFR Part 72). Most SNF is safely stored in specially designed pools (wet storage) at individual reactor sites around the country. This involves storing spent fuel rods under at least 20 feet of water, which provides adequate shielding from the radiation for workers near the pool. About one-fourth to one-third of the total fuel load is removed from the reactors every 12 to 18 months and replaced with fresh fuel (NRC, 2012g). Pool capacity at some reactors has been extended in some cases by re-racking the SNF (i.e., placing the SNF in different, more space-efficient configurations within the pool) (NRC, 2012h).

If pool capacity is reached at a facility, even with re-racking, licensees may apply to the NRC for a license to use above-ground dry storage casks (dry storage). Using cask designs certified by the NRC, these storage casks can receive SNF that has cooled for at least five years in a fuel pool. The casks provide leak-tight containment of the spent fuel, and can be stored either vertically or horizontally at the reactor site. Additionally, some of the cask designs can be used for both storage and transportation (NRC, 2012i).

2.1.9 Reprocessing Spent Fuel

Both large-scale commercially-proven and laboratory-scale experimental processes exist for reprocessing SNF to recover the fissionable material (uranium and plutonium) for use in fabricating fuel for use in nuclear reactors. The most widely used commercially-proven process is the PUREX process. SNF reprocessing technologies are briefly described in Section 2.2.2. The PUREX process is described in greater detail in Section 2.3.

2.1.10 Reprocessed Fuel Fabrication

Uranium and plutonium derived from reprocessing are incorporated into new fuel assemblies. The plutonium can be combined with low-enriched or depleted uranium to produce a MOX fuel assembly. The uranium can be re-enriched for use in producing a reprocessed uranium fuel assembly. Currently, only MOX fuel assemblies are fabricated for use in commercial nuclear power generation, although other technologies exist. MOX fuel fabrication and other technologies are described below.

Fabrication of MOX fuel is similar in many ways to fabrication of fresh nuclear fuel. For example, the MOX fuel fabrication process used by AREVA NC at their MELOX facility in Marcoule, France is briefly described below (Simpson and Law, 2010):

- Reprocessed plutonium oxide powder is mixed with depleted uranium to achieve the desired concentration of plutonium.

- The mixture of depleted uranium and plutonium is ball milled to achieve the desired consistency necessary for fuel pellet production.
- Once the desired consistency is achieved, the powder is pressed into “green” pellets.
- The “green” pellets are then sintered in a high-temperature furnace to convert them into metallic form.
- The pellets are then subject to a grinding process to achieve the proper size and shape.
- The finished pellets are inserted into fuel rods.
- The loaded fuel rods are combined to produce assemblies for nuclear power production.

Another option is to re-enrich the small concentration of U-235 that is contained in SNF and produce a reprocessed uranium fuel assembly. After reactor operations, U-235 in SNF is reduced relative to fresh fuel, typically on the order of several tenths of a percent, which is about the same concentration that is found in natural uranium. This U-235 in SNF is re-enriched using the standard enrichment methodologies discussed in Section 2.1.4 which are currently available to yield additional uranium for use as LWR fuel (NRC, 2008).

Reprocessed uranium fuel assemblies require a higher level of enrichment relative to a new uranium fuel assembly. This is due to the increased concentration of U-236 in reprocessed uranium that acts as a "poison" in the nuclear fuel, requiring more U-235 to overcome it. Each kilogram (kg) (2.2 pounds (lb)) of U-236 that is present in the reprocessed fuel requires an additional 0.3 kg (0.7 lb) of U-235 to compensate for it (NRC, 1996).

Another source of reprocessed fuel is highly enriched uranium (HEU) from surplus nuclear weapons, which is downblended to create low enriched uranium (LEU) suitable for use as LWR fuel. HEU by definition has greater than 20 percent U-235, although HEU utilized for nuclear weapons typically contains greater than 85 percent uranium U-235 (NRC, 2011; IEER, 2012).

2.1.11 Final HLW Disposition

Without reprocessing, SNF would be an HLW destined for final disposition. Reprocessing of SNF results in the generation of other HLW. If SNF was to be reprocessed multiple times, there could be a decrease in the total amount of HLW generated.

Under the Nuclear Waste Policy Act of 1982, as amended (NWPA), SNF and other HLW are required to be disposed of underground in a deep geologic repository. Under the NWPA, the NRC is one of three Federal agencies with a role in the disposal of SNF. NRC regulations covering SNF and other HLW disposal include 10 CFR Part 63, "Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada" and 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories." At this time, the future of Yucca Mountain and the nation’s policy on the disposition of HLW remain indeterminate.

On June 3, 2008, the U.S. Department of Energy (DOE) submitted a license application to the NRC, seeking authorization to construct a deep geologic repository for disposal of HLW at Yucca Mountain. However, on March 3, 2010, DOE filed a motion with the Atomic Safety and Licensing Board (ASLB) seeking permission to withdraw its application. The ASLB denied that request on June 29, 2010, in LBP-10-11 (ADAMS Accession Number ML101800299), and the parties filed petitions asking the Commission to uphold or reverse this decision. On October 1, 2010, the NRC began orderly closure of its Yucca Mountain activities. As part of the orderly closure, the NRC staff prepared three technical evaluation reports.[3]

On September 9, 2011, the Commission issued a Memorandum and Order, CLI-11-07 (ADAMS Accession Number ML11252A532), stating that it found itself evenly divided on whether to take the affirmative action of overturning or upholding the ASLB's June 29, 2010, decision. Exercising its inherent supervisory authority, the Commission directed the ASLB to complete all necessary and appropriate case management activities by September 30, 2011. On September 30, 2011, the ASLB issued a Memorandum and Order, LBP-11-24 (ADAMS Accession Number ML11273A041), suspending the proceeding.

The NRC's non-sensitive Yucca Mountain-related documents are being preserved and made available to the public as part of the NRC staff's activities to retain the accumulated knowledge and experience gained as a result of its Yucca-mountain-related activities.

In 2010, the Blue Ribbon Commission on America's Nuclear Future (BRC) was formed to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle and to provide recommendations for developing a safe, long-term solution to managing the nation's spent nuclear fuel and nuclear waste (Carter, et al., 2010). The BRC submitted its final report to the Secretary of Energy on January 26, 2012 (BRC, 2012). The report recommended a strategy with the following eight key elements:

1. "A new, consent-based approach to siting future nuclear waste management facilities.

2. "A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed.

3. "Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management.

4. "Prompt efforts to develop one or more geologic disposal facilities.

5. "Prompt efforts to develop one or more consolidated storage facilities.

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[3] The three technical evaluation reports are:

- NUREG-2107, "Technical Evaluation Report on the Content of the U.S. Department of Energy's Yucca Mountain Repository License Application; Postclosure Volume: Repository Safety After Permanent Closure." ADAMS Accession Number ML11223A273.
- NUREG-2108, "Technical Evaluation Report on the Content of the U.S. Department of Energy's Yucca Mountain Repository License Application; Preclosure Volume: Repository Safety Before Permanent Closure." ADAMS Accession Number ML11250A093.
- NUREG-2109, "Technical Evaluation Report on the Content of the U.S. Department of Energy's Yucca Mountain Repository License Application; Administrative and Programmatic Volume." ADAMS Accession Number ML11255A002.

6. “Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste to consolidated storage and disposal facilities when such facilities become available.

7. “Support for continued U.S. innovation in nuclear energy technology and for workforce development.

8. “Active U.S. leadership in international efforts to address safety, waste management, non-proliferation, and security concerns.”

2.2 Overview of SNF Reprocessing

This section presents a brief history of SNF reprocessing in the U.S. and internationally (Section 2.2.1) and descriptions of commercial- and laboratory-scale reprocessing technologies (Section 2.2.2).

2.2.1 A Brief History of Reprocessing

Spent nuclear fuels were first reprocessed in the 1940s using the bismuth phosphate precipitation process, which was soon replaced by a solvent extraction process known as Reduction-Oxidation (REDOX) (Hylko, 2008). The latter process was better suited to continuous, large-scale, remote operation, allowing for the separation of three main streams of nuclides that include uranium, plutonium, and waste (i.e., fission products and minor actinides). A number of distinct solvent extraction systems were investigated before the more efficient PUREX system was developed. The PUREX process utilizes an extractant, tributyl phosphate (TBP), which is mixed in a largely inert hydrocarbon solvent. PUREX soon replaced all earlier solvent extraction processes because of its high performance in large-scale industrial plants. The PUREX process was also used for several decades in the production of separated plutonium for military purposes. The process has continued to be improved to optimize efficiency of recovery and purification (IAEA, 2008a).

In the United States, early reprocessing facilities were constructed under Federal programs in the 1940s and 1950s, in Hanford, Washington, and at the Savannah River Site (SRS) near Aiken, South Carolina, for use in the nuclear weapons program (i.e., not for commercial use purposes). The first plant to reprocess spent fuel from commercial nuclear power plants was located in Belgium in the 1960s. In the 1960s, the Atomic Energy Commission, the predecessor agency to the NRC and DOE, sought to develop a self-sufficient commercial nuclear power industry, and encouraged the transfer of SNF reprocessing from the Federal government to private industry. Three privately owned reprocessing plants were constructed--the Barnwell Nuclear Fuel Plant (BNFP), Barnwell, South Carolina; Western New York Nuclear Service Center, West Valley, New York; and Midwest Fuel Recovery Plant, Morris, Illinois (Hylko, 2008).

During the 1970s, it was assumed that the nuclear energy would undergo rapid expansion and there would be a corresponding increase in uranium demand. Therefore, industrial implementation of the PUREX process was further extended with the reprocessing of used fuel coming initially from gas-cooled reactors, and later from LWRs. The recycling of plutonium in the form of MOX fuel in fast breeder reactors was regarded as the best path forward. At the time, breeder reactors were projected to be deployed on a large scale (IAEA, 2008a).

Worldwide demand for nuclear energy during the 1980s was less than had been anticipated, and the development of fast breeder reactors for reprocessing purposes was delayed in a number of countries. Reaction to accidents at Three-Mile Island in Pennsylvania, and Chernobyl in the Ukraine further reduced the demand for commercial nuclear power. However, France, Japan, the United Kingdom (UK), Russia, and India continued to research and developed PUREX technology. Consequently, the volume and radiotoxicity of highly radioactive and long-lived waste was significantly reduced in these countries as compared to countries that employed a once-through fuel cycle strategy in which SNF was not reprocessed. Countries pursuing reprocessing found that their HLW inventories contained mostly fission products and minor actinides (which are conditioned in a stable glass matrix), and that only small amounts of plutonium were deposited in the waste streams (IAEA, 2008a). Examples of commercial reprocessing facilities outside the U.S. are the AREVA La Hague facility in La Hague, France; the Sellafield nuclear site in Cumbria, England; and the Rokkasho facility in Japan.

There are no reprocessing facilities currently operating in the United States. The following sections describe historic reprocessing facilities in the United States and historic and currently operational reprocessing facilities internationally.

2.2.1.1 U.S. Reprocessing Facilities

Following are descriptions of past SNF reprocessing operations in the U.S., including facilities that used the PUREX process and other reprocessing technologies.

2.2.1.1.1 Hanford

Federal programs at Hanford, Washington, maintained two facilities that reprocessed SNF for use in the nuclear weapons program. The REDOX process was developed at Hanford in the late 1940s. The REDOX plant (known as the S Plant) was in operation from 1952 through 1967 (NRC, 2008). The operations at the REDOX plant consolidated plutonium processing programs into one building and process, which had previously required multiple facilities and processes. The REDOX plant has been shut down for more than 40 years, but remains highly contaminated. Hanford also used a PUREX facility to extract plutonium from irradiated fuel rods. It was constructed in the early 1950s, went into operation in 1956, and operated from 1956 to 1972 and again from 1983 to 1990 (DOE, 2012).

2.2.1.1.2 Savannah River

The SRS near Aiken, South Carolina, has two areas that engaged in reprocessing operations, known as F Canyon and H Canyon. F Canyon, which was constructed in the early 1950s and began operation in 1954, chemically dissolved aluminum-clad materials that were irradiated at the SRS's nuclear reactors and other test and research reactors to recover Pu-239 and U-235. During separations operations, nuclear materials were directly fed to chemical dissolvers. Plutonium and uranium were then separated from each other and from fission products. Waste was transferred to the site's HLW storage tanks for eventual vitrification. The facility was shut down in 1992. Then, in February 1995, DOE decided to resume chemical separation operations in F Canyon to stabilize and manage most of the remaining inventory of plutonium-bearing materials at the SRS. Most of the stabilization actions utilized the same chemical dissolving process. However, DOE has committed that Pu-239 from stabilization actions will not be used for nuclear weapons purposes. F Canyon completed stabilization operations in March 2002 (SRNS, 2008).

H Canyon was constructed in the early 1950s and began operations in 1955. As part of the DOE Enriched Uranium and Plutonium Disposition Programs, the facility is currently used to downblend weapons-usable HEU to make LEU, which is being converted to commercial reactor fuel for use by the Tennessee Valley Authority (TVA) (SRNS, 2010).

In 2000, the United States and Russia signed a bilateral agreement stipulating that each country would commit to eliminating 34 metric tons (37 tons) of surplus military plutonium produced during the Cold War by recycling it as fuel for civilian nuclear applications. In 2008, DOE made an agreement with an AREVA and SHAW groups' joint venture for construction of the Mixed Oxide Fuel Fabrication Facility (MFFF) at SRS, where plutonium oxide will be mixed with uranium oxide to make MOX fuel assemblies (NRC, 2005; Shaw-AREVA, 2012).

2.2.1.1.3 Barnwell

Construction of the BNFP in Barnwell, South Carolina, began in 1970. It was the first domestic large-scale commercial reprocessing facility in the U.S. The plant design was based on the PUREX process. The BNFP separations and UF_6 facilities were completed and undergoing pre-operational testing when the NRC terminated all licensing actions on December 23, 1977, as part of U.S. policy initiated by President Carter to indefinitely defer the reprocessing of commercial SNF in response to proliferation concerns (Hylko, 2008). The BNFP was abandoned before operating with spent fuel; however, plant operating systems were tested extensively with natural uranium as a surrogate material. Cleanup of natural uranium and transuranic (TRU) contamination in tanks and piping was determined to be necessary to terminate the plant radioactive material license issued by the South Carolina Department of Health and Environmental Control and release the property for commercial and industrial uses (McNeil, 2000; NRC, 2008).

2.2.1.1.4 West Valley

The West Valley (WV) facility in West Valley, New York, started reprocessing commercial SNF assemblies in 1966 using the PUREX process. Other fuel reprocessed at WV was uranium oxide fuel and fuel containing thorium. Throughout 1973 and 1974, the Atomic Energy Commission adopted increasingly rigorous safety criteria for nuclear facilities, mainly related to seismic issues. In 1976, WV closed due to these seismic concerns, as well as the economics of complying with heightened regulatory requirements (Hylko, 2008). Cleanup of this facility is ongoing.

2.2.1.1.5 Morris

The Midwest Fuel Recovery Plant in Morris, Illinois, was completed in 1971. The facility was designed as a prototype for intermediate-size reprocessing plants to be built near existing nuclear power plants, in an effort to reduce transportation costs and public acceptance obstacles. Additionally, the designers attempted to minimize the generation of radioactive liquid effluents by minimizing the use of solvent extraction. The facility utilized an Aquafluor process that had only one stage of solvent extraction and used remotely operated equipment. The waste was to be calcined, placed into containers, and stored in a pool awaiting shipment for disposal. Numerous equipment failures and technical problems kept the plant from operating at full scale. Its longest sustained run was 26 hours. All operations were suspended in 1974. It was determined that a second solvent extraction cycle would be required and would take four years to complete. Projected costs and the regulatory scrutiny similar to that at WV resulted in termination of all operations that year. The facility is currently used for independent wet-pool storage of SNF (Hylko, 2008).

2.2.1.2 International Reprocessing Facilities

The focus of this section is on large-scale reprocessing facilities outside the U.S.

2.2.1.2.1 La Hague

The AREVA La Hague commercial reprocessing facility in La Hague, France, entered service in 1966. The site occupies 300 hectares (ha) (741 acres (ac)) and currently has two parallel reprocessing lines (UP2 800 and UP3) with a combined capacity of 1,700 metric tons (1,900 tons) of SNF per year, equivalent to annual SNF discharges from 90 to 100 LWRs. The site has reprocessing agreements with the French nuclear program, Japanese power companies, and 29 European power companies located in Germany, Belgium, Switzerland, and the Netherlands. The radioactive waste products from this plant are classified as low-, intermediate-, and high-activity. The low activity wastes are compacted, containerized, and then disposed in a near-surface facility. The intermediate-activity wastes are compacted solidified, containerized, and stored onsite until a permanent disposal site is available. The high-activity wastes are vitrified onsite and stored until a permanent disposal site is available. The volume of HLW requiring disposal is reduced by a factor of six compared with directly disposing of SNF (Hylko, 2008).

2.2.1.2.2 Sellafield

The Sellafield nuclear site in Cumbria, England, is owned by the Nuclear Decommissioning Authority. Two reprocessing facilities have been located at Sellafield. The Magnox (Magnesium non-oxidizing) reprocessing plant came into service in 1964 to reprocess SNF from the Magnox reactors using the PUREX process. Magnox fuel is reprocessed because it corrodes if stored under water, and routes for dry storage of this fuel have not yet been proven (Sellafield Ltd, 2012). The Thermal Oxide Reprocessing Plant (THORP) was in operation until 1994 to reprocess irradiated oxide nuclear fuel from both UK and foreign reactors (Sellafield Ltd, 2012).

2.2.1.2.3 Rokkasho

Japan's first commercial reprocessing plant is located at Rokkasho-mura, and testing for commercial startup is underway. It was scheduled to become fully operational in 2007, but has experienced numerous delays and, as of this writing, still has not been commissioned. The plant uses an improved PUREX process based on the French design. The plant's nominal reprocessing capacity is 800 metric tons of heavy metal (MTHM) (880 tons of heavy metal (tHM)) of uranium per year (NRC, 2008).

2.2.2 Reprocessing Technologies

Since World War II, a number of commercial- and laboratory-scale technologies have been developed for reprocessing SNF and are briefly described below.

2.2.2.1 Conventional Commercial Reprocessing (PUREX)

For industrial-scale applications, the only process currently being used commercially is the PUREX process (NEI, 2006). This process is well understood and has proven to be commercially viable (Laidler, 2007). PUREX was the primary method used in the United States before the Federal government halted commercial reprocessing of SNF. It currently is used in the UK, France, Japan, and Russia. A potential drawback to the PUREX process is that it results in a pure stream of plutonium, which could result in a concern for potential proliferation of nuclear weapons if the plutonium were stolen or diverted and used to make a nuclear device (NEI, 2006).

A PUREX process flow sheet is shown in Figure 2-2. In the process, spent fuel is first chopped into small pieces and then dissolved in nitric acid. It is then subjected to a solvent extraction process using TBP. Uranium and plutonium are selectively taken up in the TBP phase, resulting in separation from the rest of the fission products and minor actinides which are retained in the initial acid medium. The uranium and plutonium are then separated in multistage extraction cycles and purified. The present state-of-the-art in PUREX reprocessing provides a 99.9 percent separation of uranium and plutonium. In some variants of the process, the plutonium is co-precipitated with uranium to avoid the separation of pure plutonium. This is the case in the Japanese reprocessing plant at Rokkasho. The solid waste streams from the PUREX process are: liquid HLW that contains fission products, minor actinides and activation products; and metallic waste from the fuel rods and assemblies (IAEA, 2008b). The HLW is typically processed, vitrified, and encapsulated in a steel container.

Approximately 80,000 MTHM (90,000 tHM) have been reprocessed in civilian PUREX reprocessing facilities, with a current annual industrial reprocessing capacity of approximately 4,200 MTHM (4,600 tHM) globally. It is projected that an additional 1,800 MTHM (2000 tHM) might be added in the next 10 years (IAEA, 2008b).

A detailed description of a PUREX reprocessing facility is provided in Section 2.3.

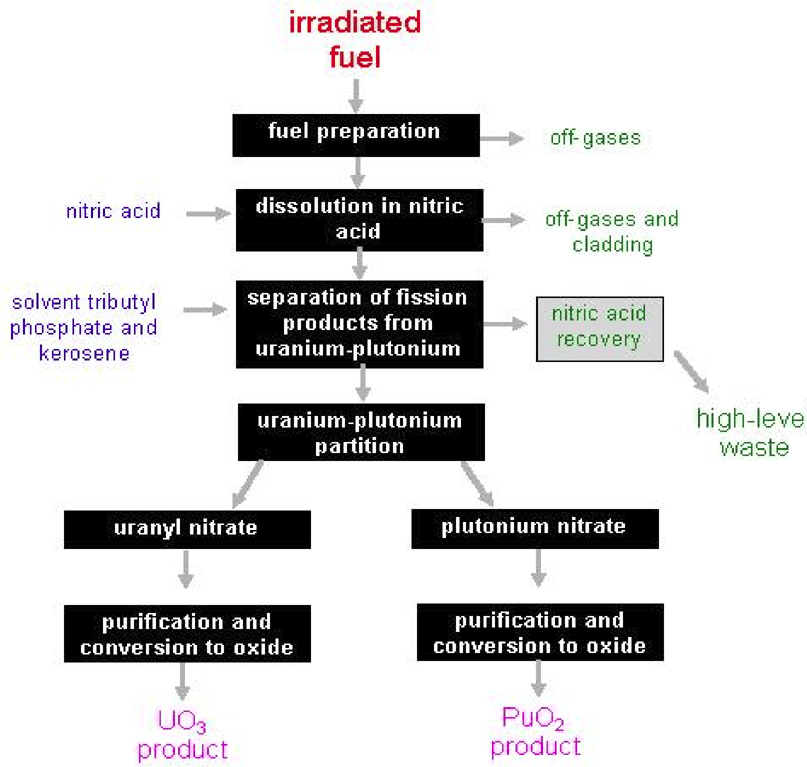

Figure 2-2 PUREX Process Flow Sheet
(Source: NRC, 2008)

2.2.2.2 Reprocessing Technologies under Development

A number of additional technologies have been devised which are attempting to address recognized limitations in or improve upon the PUREX and PUREX-derived processes. The International Atomic Energy Agency (IAEA) believes that new technologies need be flexible in that they can be readily adapted to allow for increased burnup (nuclear fuel utilization). They may demonstrate a reduction in environmental impacts, including decreased effluent discharges and decreased HLW and intermediate-level radioactive waste (ILW) volumes. Reductions in occupational exposure during reprocessing, simplification of reprocessing methodologies, and increased proliferation resistance are also desirable attributes. New reprocessing technologies will still have to grapple with issues associated with HLW due to the presence of minor actinides and long-lived fission products, as well as the processing of TRU-rich fuels being developed for future advanced nuclear reactors (IAEA, 2005; IAEA, 2008a).

New aqueous processes are being developed in which minor actinides and some long-lived fission products are removed to reduce radiotoxicity and high heat load in the final HLW. Minor actinides will be incorporated in reactor fuel for transmutation, while the separated fission products are conditioned for long-term storage or separated for use in fast reactors. Additional methods are under development in which plutonium is never separated in a pure form but is always combined with minor actinides for proliferation resistance. Several different lines of research are being developed and tested at the laboratory scale (IAEA, 2008b).

For reprocessing technologies involving solvent extraction, there are two different lines of approach. The first is the separation of different components in the high level liquid waste (HLLW) generated by the PUREX process (advanced separation). The second approach is changing the chemistry in the first separation step so that only uranium is separated, while keeping plutonium, minor actinides, and other fission products in the waste solution for later processing (e.g., UREX6).

Some examples of advanced processes are described in the sections that follow (IAEA, 2008b). The listing is intended to provide short descriptions of current areas of research that may be employed in future reprocessing activities. These technologies are still in the early stages of research and development, and none have been deployed at a commercial scale.

2.2.2.2.1 Chemical Separation Processes

Some chemical separation processes under development are described below. The list below is meant to be not all inclusive, and other technologies may also be available.

COEX and Other PUREX Derivatives

The primary focus of research in advanced PUREX processes is to prevent the separation of pure plutonium in order to reduce proliferation risk. Another research objective pertains to increased control of neptunium (Np) and technetium (Tc) chemistry to allow for the extraction of these materials. In France, the Co-Extraction (COEX) process is being developed by the *Commissariat à l'Energie Atomique et aux Energies Alternatives* (CEA) (English: Atomic Energy and Alternative Energies Commission) and AREVA. This process co-extracts the uranium and plutonium and produces a Pu-U product instead of a pure plutonium product. This is accomplished by modifying the PUREX chemistry to allow for some uranium to be added back into the solvent with the plutonium. The process also uses a co-conversion process to produce a Pu-U oxide product. Also, at the Idaho National Laboratory (INL), DOE is evaluating the co-extraction of neptunium using the COEX process to produce a Pu-U-Np oxide product. Because the COEX process essentially represents a modification of the PUREX process, it is possible that that this process could be implemented with a lesser need for additional research and development than other chemical separation technologies described below. (NRC, 2008; Simpson and Law, 2010)

DIAMEX

The Diamide Extraction (DIAMEX) process was developed in France, and is now being researched in France, Germany, Italy, India, Japan, and the U.S. It is based on the use of a malonamide extractant involving selective separation of long-lived radionuclides from short-lived fission products (with a focus on americium (Am) and californium (Cm) separation). This can be implemented with COEX, following separation of U-Pu-Np. U-Pu and minor actinides could be recycled separately in Generation IV fast neutron reactors. The process generates minimum organic waste as the solvent is totally combustible (IAEA, 2008b).

TRUEX

The Transuranic Extraction (TRUEX) process was developed in the United States in the 1980s, and is now being studied in India, Italy, Japan, the Russian Federation, and the U.S. It is based on the use of octyl-phenyl-di-isobutyl-carbamoylmethyl- phosphine-oxide (known as CMPO) as an extractant. The advantages of the TRUEX process include the fact that it can extract actinide and lanthanide salts from acidic feeds, and there is significant worldwide experience with this process. The main drawbacks include the necessity of using large concentrations of TBP as a solvent modifier, the stripping of metal ions (which is not efficient), and the challenging solvent cleanup (IAEA, 2008b).

GANEX

The Grouped Extraction of Actinides (GANEX) process co-precipitates some uranium with the plutonium (as with COEX). The process then separates minor actinides and some lanthanides from the short-lived fission products. The uranium, plutonium, and minor actinides would together become fuel in Generation IV fast neutron reactors and the lanthanides would become waste (World Nuclear Association, 2011).

TRPO

The Tri-alkyl Phosphine Oxides (TRPO) process was developed in China, and is currently being researched there and in India. It is based on the use of a mixture of tri-alkyl phosphine oxides as an extractant. Its main drawbacks concern the necessity to reduce the feed acidity and the use a concentrated nitric acid solution for stripping, which complicates the subsequent actinide and lanthanide partitioning steps (IAEA, 2004).

TALSPEAK

The Trivalent Actinide Lanthanide Separation by Phosphorus Extractants and Aqueous Komplexes (TALSPEAK) processes were developed in the United States in the 1960s and then adopted by Sweden. The process features good efficiency, but drawbacks include the necessity to adjust the pH of the feed, the limited solvent loading of metal ions, and difficult solvent cleanup (IAEA, 2004).

SANEX

The Selective Actinide Extraction (SANEX) process refers to two distinct technologies. The SANEX-S process utilizes S-bearing extractants (e.g., Cyanex 301 with 2, 2-bipyridul) to separate actinides from lanthanides (IAEA, 2008b). Efficient use of this process requires that the feed solution be adjusted to pH3 to pH5. It is used in China, Germany, and India (IAEA, 2004). The SANEX-N process uses neutral N-bearing extractants (e.g., bis-triazinyl-pyridines (BTPs)) for separating actinides and lanthanides from HLW (IAEA, 2008b). The drawbacks of this process are that the solvent cleanup process is not yet defined, and the process generates phosphorus-, sulfur-, and chlorine-bearing wastes (from the degraded extractants) that need to be managed. The process is being researched in France and Germany (IAEA, 2004).

UREX

The Uranium Extraction (UREX) process was developed as a replacement for PUREX. In this process, plutonium remains mixed with the fission products and minor actinides, resulting in pure uranium. This result was sought to avoid production of a pure plutonium stream and, therefore, offers increased proliferation resistance (NEI, 2006). The UREX+ suite of processes is being developed at Argonne National Laboratory and other national laboratories under the Advanced Fuel Cycle Initiative (AFCI) funded by the U.S. (Vandegrift, et al., 2004). Primary objectives of the UREX+ processes include proliferation-resistance and removal of the major sources of decay heat that would limit the spacing of waste packages in a disposal facility. This technological concept consists of a suite of UREX processes, each of which consists of a series of steps designed to remove specific groups of radionuclides to tailor the desired product compositions and waste streams (NRC, 2008). The solvent extraction steps include: (a) recovery of technetium and uranium (UREX); (b) recovery of cesium and strontium (CDC-PEG); (c) recovery of plutonium and neptunium (NPEX); (d) recovery of americium, californium, and rare-earth fission products (TRUEX); and (e) separation of americium and californium from the rare earths (Cyanex 301) (Vandegrift, et al., 2004).

While each of the solvent extraction separation steps has been separately researched and developed, little data exists on the efficiency and operability of the integrated separations. Furthermore, except for the UREX separation step for uranium and technetium, which is essentially a modified PUREX process, no large-scale operating experience is available with the various steps of the UREX processes (NRC, 2008).

2.2.2.2 2 Pyroprocessing

Pyroprocessing is an alternative reprocessing technology to PUREX and other aqueous methodologies described above. This technology achieves separation by way of high-temperature electrorefining. The process utilizes molten salt electrolytes as the separation media rather than acidic aqueous solutions and organic solvents. Ceramic and metal waste streams are produced by this process, which serves to immobilize fission products. It is expected that the plutonium and minor actinides produced through this process would be recycled and used for fast reactor fuel fabrication if this process is implemented at a commercial scale (IAEA, 2008b).

The basic principles behind pyroprocessing are well understood, yet there are technical challenges that remain. For example, pyroprocessing requires an oxygen- and moisture-free environment. There is also a need to develop materials that will not only withstand high radiation levels but have resistance to high-temperature corrosion in molten metals and molten halide salts (IAEA, 2008b).

2.3 PUREX Reprocessing Facility Description

As discussed in Section 1.2, the PUREX process is used in this ETR as a basis for identifying and evaluating technical- and environmental-related considerations and issues for potential commercial SNF reprocessing facility projects. Although the PUREX process ultimately may or may not be employed at new commercial reprocessing facilities in the U.S., this process is used in this report as a “proxy” for other aqueous chemical separation processes. This section describes the general characteristics of a PUREX reprocessing facility. The characteristics and general design features are based on existing commercial PUREX facilities. An average facility could have an 800- to 1,000-MTHM/year (880- to 1,100-tHM/year) capacity. The information presented in this section is taken largely from NUREG-1909, *“Background, Status, and Issues Related to the Regulation of Advanced Spent Nuclear Fuel Recycle Facilities,”* (NRC, 2008).

The NRC staff recognizes, however, that the PUREX separation process, in its basic form, may not be used by commercial reprocessing facilities in the U.S. because proliferation issues will not allow for the separation of plutonium from uranium, and possibly from other TRU nuclides. However, for the purposes of the high-level, generic, preliminary discussions in this report, the generalized PUREX process is used because, as indicated from the discussions in Section 2.2.2.2 above, other reprocessing technologies are not sufficiently developed and, therefore, little or no information on these technologies is available to adequately define characteristics of potential commercial reprocessing facilities.

2.3.1 External Appearance and Location

Commercial PUREX SNF reprocessing facilities are large-scale industrial complexes consisting of several buildings and other structures necessary to contain the numerous processing steps and support systems required for the chemical separation process. For example, the THORP facility at Sellafield, which has a nominal reprocessing capacity of 900 MTHM/year (990-tHM/year)) includes 15,000 process vessels and 300,000 meters of pipe (Phillips, 1999). Most of the processing steps take place in hot cells[4] or glove boxes[5] to provide shielding from radioactivity. Material is transferred between process areas via piping. In addition to the structures that contain the processing activities, there are additional structures that house various support functions including laboratory, reagent handling and storage, waste handling, security, and administration.

The overall size (footprint) of a reprocessing facility varies as a function of the design and reprocessing capacity. For example, the Rokkasho facility (nominal reprocessing capacity 800 MTHM/year (880-tHM/year)) occupies 380 hectares (940 acres) (NRC, 2008).

The siting of a reprocessing facility is limited by the infrastructure necessary to support its operation. For example, a reprocessing facility requires:

- Transportation of SNF and process materials to and products and wastes from the site (e.g., by road, rail, or barge access)

[4] A hot cell is a room where radioactive material can be handled safely. Hot cells are constructed with thick walls of dense material, such as lead or concrete, to shield workers and the public from potentially harmful effects of radiation.

[5] A glove box is a container where radioactive material can be handled safely. The container is typically constructed of glass or plastic, which provides shielding and allows workers to see inside. The contents can be accessed and manipulated from the outside via gloves built into the side of the box.

- Space adequate for the facility
- Electric power necessary for operations
- Workforce (both skilled and unskilled)
- Geologic stability
- Access to water

2.3.2 Plant Design and Process Descriptions

The following sections describe the major processes involved in reprocessing SNF using the PUREX process. The numbers and types of vessels, tanks, columns, and pipes used in each process vary as a function of the specific facility design. Because PUREX is a chemical process, the required separation efficiency and product purity can be achieved by varying chemical concentrations, temperature, and flow rates for a given design. Because of this high degree of variability that is dependent on specific facility design, the following descriptions are general and intended to identify the major elements of each process. A flow diagram of the PUREX process is shown in Figure 2-2.

2.3.2.1 Receiving and Storage of Spent Fuel

Reprocessing of SNF begins when a spent fuel assembly is transported to the reprocessing facility in an NRC-approved shipping cask. Upon arrival, the transportation cask must be moved from the conveyance (e.g., truck or rail car) into a heavily shielded receiving area where the cask can be opened and each assembly transferred to a storage area until it can be processed. The substantial size and weight of the shipping and storage casks require that the facility have high-capacity, high-reliability cranes for transfer among the different storage and fuel handling structures. At both the Rokkasho and La Hague facilities, the mechanical process of opening casks and transferring fuel assemblies into water-filled storage pools is highly automated and performed remotely.

2.3.2.2 Shearing and Dissolution

To initiate reprocessing, an SNF assembly is transferred from the storage area into the shearing operation. Here the bulky metal ends of the assembly are removed and disposed as waste. The metal tubes (cladding) that hold the SNF are cut or sheared into short sections to allow the SNF to dissolve efficiently. Figure 2-3 depicts the various parts of an LWR fuel assembly. The sections are transferred to a dissolver vessel containing hot nitric acid. At the end of the dissolution process, the nitric acid containing dissolved uranium, plutonium, minor actinides, and most of the fission products is transferred to an accountability vessel[6] where the composition of the liquid material is measured. The dissolution and accountability vessels are designed with geometries to prevent criticality, and are made of a material that can tolerate the highly corrosive nitric acid used for SNF dissolution. At the end of the dissolution process, the

[6] An accountability vessel is a tank in which the liquid contents are measured to fine tune the separation process and determine the amount of plutonium present for regulatory purposes.

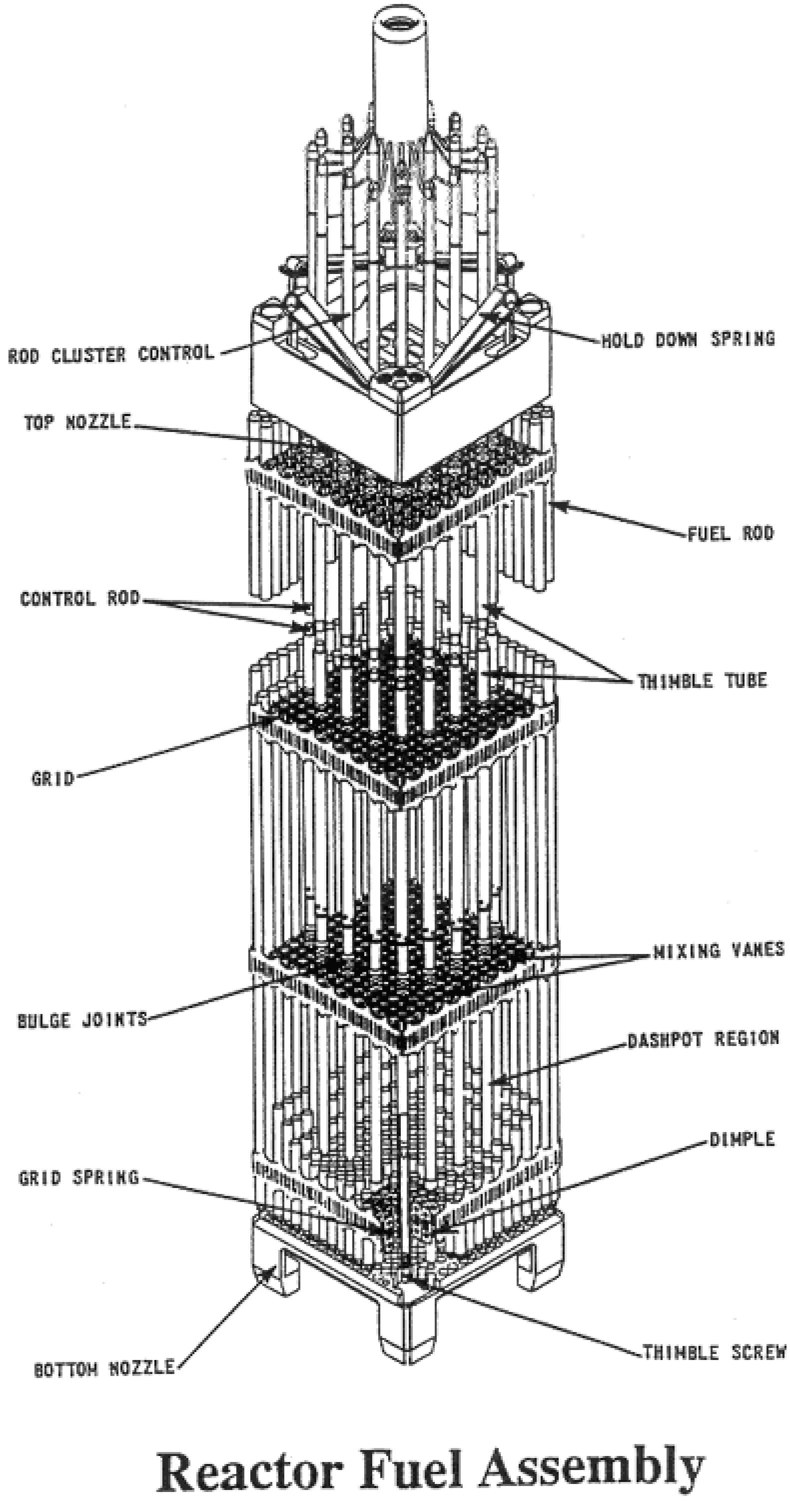

Figure 2-3 Reactor Fuel Assembly
(Source: NRC, undated)

insoluble portions of the SNF and the pieces of cladding are transferred into the waste handling system and prepared for long-term storage or disposal (see Section 2.3.2.7). From the accountability vessel, the dissolved radionuclides are transferred to the separation process.

2.3.2.3 Separation

The PUREX process involves liquid-liquid solvent extraction, in which two immiscible liquids are mixed together, followed by separation. The mixing of liquids occurs in mixer/settler contactors or pulsed columns. The mixing and separation process can be repeated to increase the degree of separation. In the PUREX process, the two immiscible liquids are: (a) the nitric acid solution (aqueous phase) containing dissolved uranium, plutonium, minor actinides, and most of the fission products, and (b) dodecane or purified kerosene containing 30 percent TBP (organic phase). Under highly acidic conditions, the dissolved uranium and plutonium are preferentially extracted into the organic phase and the minor actinides and fission products remain in the aqueous phase. The aqueous phase containing minor actinides and fission products is transferred to the waste handling system. The plutonium- and uranium-bearing organic phase is transferred to the purification circuit for further separation and concentration.

2.3.2.4 Purification

In the purification process, the organic phase containing uranium and plutonium undergoes further separation using solvent extraction. This separation is achieved by adding a chemical reducing agent, such as hydroxylamine nitrate, that alters the behavior of dissolved plutonium in the organic phase and causes it to transfer back into the aqueous phase, while the dissolved uranium remains in the organic phase. The plutonium-rich aqueous phase and uranium-rich organic phase are further purified using separate chemical processes.

The plutonium-rich aqueous phase undergoes further purification to remove any residual TBP, uranium, and fission products, and is concentrated before being transferred to the plutonium denitration and product storage systems. The uranium-rich organic phase purification process involves transferring uranium from the organic phase to the aqueous phase followed by further purification to remove any residual TBP, plutonium, and fission products and concentration before being transferred to the uranium denitration and product storage systems. Any residual minor actinides and fission products removed during plutonium and uranium purification are transferred to the waste handling system.

2.3.2.5 Denitration, Calcination, and Product Storage

The purified uranium and plutonium are dissolved in nitrate solutions. The uranium and plutonium must be converted to their oxide forms for use in fuel fabrication, through a process called denitration designed to remove the nitrate from the aqueous solutions.

The aqueous uranyl nitrate solution (uranium dissolved in nitric acid) from the uranium purification cycle is converted to UO_3 powder at high temperature (Haas, et al., 1981). The aqueous solution is evaporated to produce concentrated uranyl nitrates. The concentrate is then heated to 250 to 400°C (480 to 750°F) to thermally break down the uranyl nitrate to produce UO_3 powder, which is then stored in containers for later use in fabrication of fuel for use in nuclear power plants.

Plutonium denitration at the La Hague facility and the THORP facility at Sellafield is a two-step process. The dissolved plutonium in nitric acid solution is first precipitated as plutonium oxalate by addition of oxalic acid. The plutonium oxalate powder is then filtered and dried before conversion to plutonium oxide (PuO_2) powder in a high temperature calcination furnace[7]. The PuO_2 powder is transferred to containers and stored for later use in fabrication of nuclear power plant fuel.

The purification process at the Rokkasho facility produces purified uranium nitrate solution and a mixed uranium and plutonium nitrate solution. This solution is concentrated and then converted to a mixed UO_3 and PuO_2 powder by heating to a high temperature in a calcination furnace, followed by heating to a high temperature in a reduction furnace[8]. The resulting MOX (UO_3 + PuO_2) powder is stored in containers for later use in fabrication of nuclear power plant fuel. In contrast to the standard PUREX process described above, the process used at Rokkasho does not produce a separate plutonium stream, a potential benefit when considered in the context of proliferation concerns.

2.3.2.6 Recovery of Acids and Solvents

To reduce waste generation and therefore reduce operational and disposal costs, PUREX reprocessing facilities decontaminate and reuse acid solutions and organic solvents to the extent practicable. Both acid and solvent recovery systems involve one or more processes to remove any residual radioactive or non-radioactive contamination prior to reuse. The decontaminated acids and solvents are typically reintroduced back into the dissolution, separation, or purification processes. Radioactive and non-radioactive contamination, once separated, would be transferred to the waste handling system.

2.3.2.7 Waste Handling

PUREX reprocessing facilities generate large volumes of radioactive and non-radioactive solid, liquid and gaseous wastes that require monitoring, treatment, management, and disposal. Solid and liquid waste treatment and storage is typically handled separate from the processing circuit. The off-gas treatment systems collect air, gases, and particulates from all process areas to remove unacceptable levels of both radioactive and non-radioactive contaminants prior to discharge into the atmosphere. The general types of waste from reprocessing by the PUREX process are defined in the text box below. Specific information on the various reprocessing waste streams and associated handling procedures are described in the sections that follow.

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[7] A calcination furnace is a high temperature oven or kiln in which plutonium oxalate is converted to plutonium oxide.

[8] A reduction furnace is a high temperature oven or kiln in which oxygen is removed and replaced with a mixture of nitrogen and hydrogen.

Types of Waste from Spent Nuclear Fuel Reprocessing by the PUREX Process

High-level Waste or High-level Radioactive Waste (HLW) – The highly radioactive waste produced by the reprocessing of spent nuclear fuel (SNF). This waste includes liquid wastes that are produced directly in reprocessing; dry solid material derived from such liquid wastes; and other material designated by the U.S. Nuclear Regulatory Commission (NRC) as HLW for the purposes of protecting the public health and safety, as defined in the Nuclear Waste Policy Act of 1982, as amended (Public Law (P.L.) 97-425, 96 Stat. 2201), and as defined in Title 10 of the *Code of Federal Regulations* (10 CFR) 60.2 and 63.2.

Low-level Radioactive Waste (LLW) – As defined in the 10 CFR 20.1003 definition of "waste," radioactive waste not classified as HLW, transuranic waste, SNF, or byproduct material as defined in paragraphs (2), (3), and (4) of the definition of Byproduct material set forth in § 20.1003. Pursuant to NRC regulations at 10 CFR 61.55, LLW for near surface disposal is classified into Class A, Class B, or Class C waste, and must be disposed in facilities licensed by the NRC or an NRC Agreement State.

Greater-Than-Class C* (GTCC*) Waste – LLW that exceeds the concentration limits established for Class C LLW in 10 CFR 61.55. The Low-Level Radioactive Waste Policy Amendments Act of 1985 (P.L. 99-240) assigned the responsibility for disposal of GTCC LLW to the U.S. Department of Energy; and disposal of GTCC LLW that is designated a federal responsibility under Section 3(b)(1)(D) must be in a facility licensed by the NRC. Current LLW regulations in 10 CFR 61.55 require disposal of GTCC waste in a geologic repository as defined in 10 CFR Part 60 or 63, unless proposals for disposal of such waste in a disposal site licensed pursuant to this part are approved by the Commission.

Mixed Low-level Radioactive Waste – LLW that also contains hazardous waste regulated under the Resource Conservation and Recovery Act of 1976 (RCRA) (42 United States Code (U.S.C.) 6901 et seq.) (see below).

Hazardous Waste – A category of non-radioactive waste regulated under RCRA. To be considered hazardous, a waste must be a solid waste under RCRA and must exhibit at least one of four characteristics described in 40 CFR 261.20-24--ignitability, corrosivity, reactivity, or toxicity (40 CFR 261.20-24)--or be specifically listed by the U.S. Environmental Protection Agency in 40 CFR 261.30-33.

Non-hazardous Waste – Waste that does not meet any of the waste characteristics described above, including solid, semisolid, or contained liquid and gaseous material resulting from construction, demolition, industrial, or commercial operations.

2.3.2.7.1 Radioactive Waste

Radioactive gaseous, liquid, and solid waste products are collected throughout reprocessing. All solid and liquid wastes must be placed in containers suitable for transportation, storage, or disposal. The level of radioactive contamination determines if a waste must be conditioned, or treated, to alter its physical or chemical form prior to enclosure in a shipping container or cask.

Radioactive Solid Waste

The solid radioactive wastes produced during reprocessing consist primarily of cladding and insoluble material from the SNF, used process equipment, and material generated as part of routine operations and maintenance.

- Cladding and insoluble material--The primary source of radioactive solid waste is the dissolution process. The waste stream consists primarily of fuel assembly cladding pieces and other material that is insoluble in nitric acid. These high activity wastes typically must be stabilized prior to storage or disposal.

- Used equipment--Equipment that is no longer operational and that has been in contact with the SNF or its components typically has become radioactively contaminated with particulate matter or activation products and requires stabilization prior to storage and disposal. The level of radioactive contamination will determine if used equipment may be decontaminated for reuse in other nuclear industries, would require storage or disposal, or meet the requirements for disposal as LLW as defined in 10 CFR Part 61.

- Operations and maintenance materials--Routine operations and maintenance generate low-activity solid waste including contaminated protective clothing, paper, rags, glassware, compactable and non-compactable trash, and non-irradiated components and equipment. Low-activity solid waste typically undergoes onsite treatment before it is containerized in preparation for transportation to and disposal in a licensed LLW disposal facility.

Radioactive Liquid Waste

The liquid radioactive wastes produced during reprocessing consist primarily of highly radioactive fission products and minor actinides present in SNF and separated from the usable uranium and plutonium during reprocessing. There also are other liquid waste streams that contain low-activity radioactive contamination.

- High-level Liquid Waste--The fission products and minor actinides that dissolve in nitric acid are the major components of the high-activity radioactive liquid waste. These highly radioactive components require stabilization prior to transportation and storage or disposal. At the La Hague and Rokkasho facilities, this waste stream is first concentrated and then heated until only a dry residue remains. This dry residue is incorporated into a glassy matrix at extremely high temperature, in a process known as vitrification. The vitrified glass containing the radioactive waste is typically poured, while still molten, into a container designed for disposal. Once cooled, the containers containing vitrified radioactive waste are stored onsite until disposal. An alternative to the above approach would be to concentrate the liquid waste and then heat until only a dry residue remains. This dry residue could then be containerized and stored until it could be transported to an offsite HLW treatment, storage or disposal facility.

- Low-level Liquid Waste--Certain liquid waste streams from the purification process and recovery of acid and solvent may have a radionuclide concentration and composition to be considered LLW. This waste stream requires treatment to convert the liquid into a more stable solid form prior to transportation to and disposal in a licensed LLW disposal facility.

Radioactive (and Non-Radioactive) Gaseous Waste

Radioactive and non-radioactive gases are generated during all processes, beginning with shearing and dissolution and ending with the transfer of products into storage containers. Consequently, the air from all of the process cells and glove boxes must first go through an off-gas treatment system prior to discharge to the atmosphere. Off-gas treatment systems typically consist of a series of high-efficiency particulate air (HEPA) filters to capture particulates, and contaminant-specific filters and absorption or scrubbing columns to remove gases. Any contaminated filters and columns would be handled and treated appropriately according to the nature and level of radioactive and/or non-radioactive contamination present.

Non-Radioactive Waste

As indicated above, PUREX is a chemical separation process that involves large quantities of nitric acid, organic solvents, as well as a variety of other chemicals that are not inherently radioactive. Although some of these are recovered for reuse, as discussed in Section 2.3.2.6, some must eventually be handled as non-radioactive waste. Other sources of non-radioactive waste include non-contact water used for temperature control systems, laboratory wastes, stormwater runoff, floor drain runoff, sanitary wastes, and trash. Liquid and solid wastes (e.g., organic solvents and chemicals) that are considered to be hazardous may require treatment prior to disposal at a licensed hazardous waste disposal facility. Water-based liquid wastes (e.g., nitric acid solutions) that are considered to be hazardous may require treatment prior to discharge to the environment in accordance with an approved discharge permit. Non-hazardous solid wastes would be handled at appropriate licensed solid waste recycling, treatment, or disposal facilities.

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3 POTENTIAL ENVIRONMENTAL SETTINGS FOR U.S. SPENT NUCLEAR FUEL REPROCESSING FACILITIES

Since no specific locations for potential commercial spent nuclear fuel (SNF) reprocessing facilities in the United States have been identified, for the purposes of this Environmental Topical Report (ETR), this chapter provides preliminary, generic descriptions of, and related information regarding, characteristics of potential environmental settings, or “affected environments,” for such facilities. These environmental settings are described in the contexts of the generalized rural, industrial, and U.S. Department of Energy (DOE) site types, where applicable. This information establishes a basis, or baseline, for defining and evaluating environmental-related considerations and issues for potential reprocessing facility projects in this report.

3.1 Generalized Environmental Settings

For the purposes of this report, the affected environments are described in terms of generalized, hypothetical environmental settings that may exist around three types, or categories, of potential SNF reprocessing facility “hosting sites” that were originally proposed by DOE for the Global Nuclear Energy Partnership (GNEP) Program (DOE, 2008). These three categories are rural, industrial, and DOE sites. Characteristics of these site types are summarized in this section.

DOE prepared the “Draft Global Nuclear Energy Partnership Programmatic Environmental Impact Statement,” October 2008 (DOE, 2008) (Draft PEIS), to assess the potential environmental impacts of expanding nuclear power in the United States, including SNF reprocessing. In preparing the Draft PEIS, DOE solicited potential hosting sites for an SNF reprocessing facility location. Eleven different entities responded to DOE, proposing 11 potential locations to be considered for a reprocessing facility, along with a summary of the site characteristics at these locations. These 11 site locations, which are shown in Figure 3-1 and listed below, span the continental United States and embody a broad set of site characteristics used in the Draft PEIS to identify a range of environments for the rural, industrial, and DOE site types. The characteristics of the 11 site locations are described in Appendix J of the Draft PEIS and are not repeated in this ETR.

The Eleven “Hosting Sites” Identified in the DOE GNEP Program Draft PEIS

Rural Sites	Industrial Sites	DOE Sites
Lea County, NM	Barnwell, SC	Atomic City, ID
Paducah, KY	Morris, IL	Hanford, WA
Roswell, NM		Idaho National Laboratory, ID
		Oak Ridge Reservation, TN
		Portsmouth, OH
		Savannah River, SC

The environmental settings described in the Draft PEIS for the 11 locations are based on conditions at the sites of actual, current and former nuclear and non-nuclear facilities with physical characteristics comparable to potential SNF reprocessing facilities; and are assumed in this ETR to be possible representative conditions for reprocessing facility sites. In this ETR, the characteristics of these sites are aggregated to establish generalized, hypothetical characteristics of the three site types for use as generic baselines for discussing environmental-related considerations and issues for preconstruction, construction, operation, and decommissioning of potential SNF reprocessing facilities in Chapter 4 of this report.

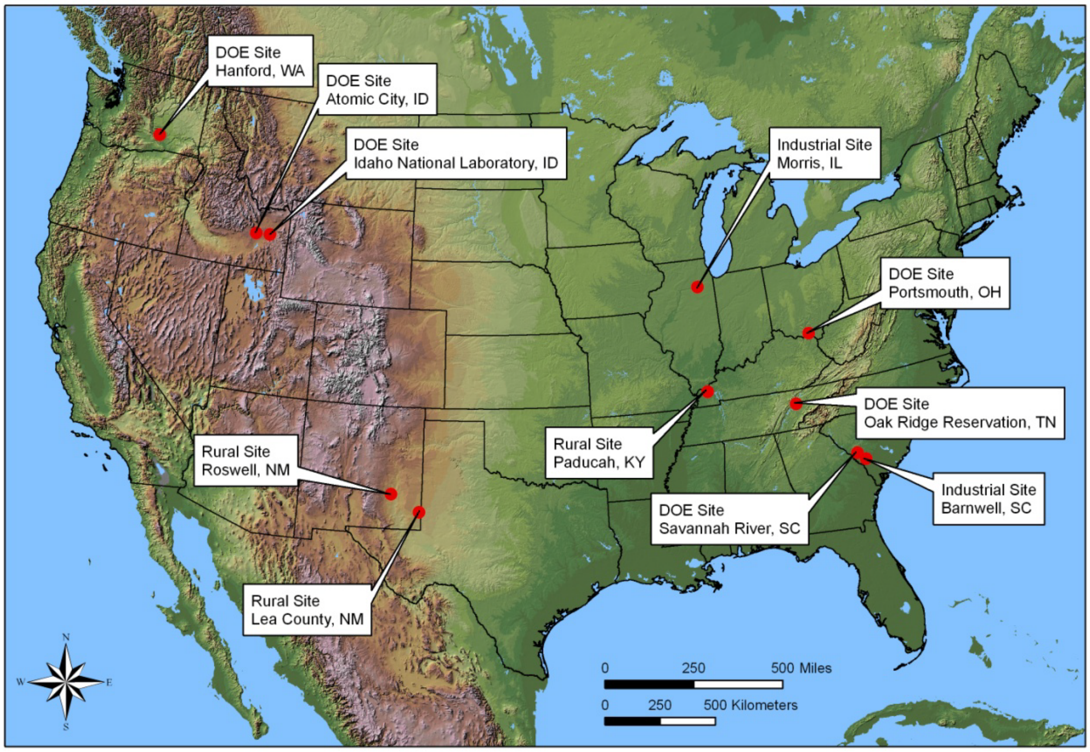

Figure 3-1 Map Showing Potential SNF Reprocessing Facility Sites Proposed for DOE GNEP Program
(Source: DOE, 2008)

Thus, based on the information on the site characteristics of the 11 sites in the DOE Draft PEIS, the general assumptions listed and described below have been developed and are used in defining generic baselines for the three affected environment categories in relation to a potential commercial SNF reprocessing facility project. The following resource areas, in which there could be potential effects on human health or the environment resulting from a reprocessing facility project, are addressed: land use and site infrastructure, transportation, geology and soils, water resources (water use and water quality), air quality, noise, ecological resources, waste management, historic and cultural resources, visual and scenic resources, public and occupational health (radiological and non-radiological), socioeconomics, and environmental justice (EJ).

Of course, there are many uncertainties involved in generically describing site characteristics in broad classifications such as rural, industrial, and DOE sites. Generalizations may not fully depict the conditions at a given location. However, for this ETR, it is reasonably assumed that companies developing reprocessing facilities would select suitable sites with environmental conditions favorable to such facilities.

3.1.1 Rural Site Type

The rural environment is generally free from prior industrial or heavy commercial activity. Consequently, it is assumed that electrical power lines, water and sewer, and roadways, railways, or barge access necessary to support industrial activity would need to be constructed. Radiological and non-radiological discharges or effluents associated with industrial or heavy commercial activity have not affected the air quality, water quality, and soil in this environment.

Following are the postulated, generalized characteristics of the rural site type for each of the resource areas considered:

- <u>Land Use and Site Infrastructure</u>--Land undisturbed or in agricultural use; no existing commercial or industrial facilities at or near proposed reprocessing facility site; limited existing infrastructure to support reprocessing facility (e.g., electric power transmission, water supply).

- <u>Transportation</u>--Limited existing transportation infrastructure to support reprocessing facility.

- <u>Geology and Soils</u>--Land undisturbed or in agricultural use at proposed reprocessing facility site.

- <u>Water Resources</u>

    - Water Use - Assumed sufficient water availability for reprocessing facility, with appropriation rights acquired if necessary.

    - Water Quality - Generally good water quality with potential minor effects from agricultural chemicals.

- <u>Air Quality</u>--Low level of existing commercial or industrial development with limited potential effects on air quality.

- <u>Noise</u>--Low level of existing commercial or industrial development with limited potential effects on noise levels.

- <u>Ecological Resources</u>--Low level of existing development with limited potential effects on biodiversity and ecosystems, except for potential effects from agricultural activity.

- Waste Management--Waste management infrastructure to support reprocessing facility does not exist for radioactive and non-radioactive hazardous solid and liquid waste management.

- Historic and Cultural Resources--Land undisturbed or in agricultural use at proposed reprocessing facility site; may contain historic and cultural resources that may be impacted by the reprocessing facility.

- Visual and Scenic Resources--Low level of existing development with potentially limited or no effects on visual and scenic resources.

- Public and Occupational Health

    - Radiological – Natural background levels of radiation present.

    - Non-Radiological – Natural background levels or potential presence of chemicals and airborne pollutants from agricultural activities.

- Socioeconomics--Agricultural community with little pre-existing public infrastructure and limited workforce and employment opportunities.

- Environmental Justice--Potential low-income, minority, or tribal communities, but low population density.

3.1.2 Industrial Site Type

The industrial environment has been previously developed for non-nuclear industrial or heavy commercial activity. Electrical power lines, water and sewer, and roadways, railways, or barge access necessary to support industrial activity already exist. Non-radiological discharges or effluents associated with industrial or heavy commercial activity may have affected air quality, water quality, and soil. There have been no radiological discharges or effluents that would have affected this environment, although there may have been releases of hazardous materials to the environment.

Following are the postulated, generalized characteristics of the industrial site type for each of the resource areas considered:

- Land Use and Site Infrastructure--Land disturbed by past or current industrial or commercial development; some elements of infrastructure in place to support reprocessing facility, with minor improvements needed.

- Transportation--Existing transportation infrastructure in place to support reprocessing facility, with minor improvements needed

- Geology and Soils--Limited geologic disturbance, if any; soils disturbed and potential soil contamination due to construction and operation of past or current industrial or commercial facilities.

- Water Resources

    - Water Use - Assumed sufficient water availability for reprocessing facility, with appropriation rights acquired if necessary.

    - Water Quality - Potential effects on water quality due to past and present industrial or commercial activities.

- Air Quality--Existing industrial or commercial activities affecting air quality.

- Noise--Existing industrial or commercial activities affecting noise levels.

- Ecological Resources—Past or current industrial or commercial development affecting biodiversity and ecosystems.

- Waste Management--Non-hazardous and hazardous solid and liquid waste management infrastructure exists due to industrial or commercial development, with minor improvements needed; low and high activity radioactive waste management infrastructure to support reprocessing facility does not exist.

- Historic and Cultural Resources--Land disturbed due to industrial or commercial development; historic and cultural sites in disturbed areas and adverse effects may have been identified and possibly mitigated.

- Visual and Scenic Resources--Past or current industrial or commercial development potentially affecting visual and scenic resources.

- Public and Occupational Health

    - Radiological – Natural background levels of radiation present.

    - Non-Radiological – Natural background levels or potential presence of chemicals and airborne pollutants from industrial or commercial activities.

- Socioeconomics--Mixed economic community with existing public infrastructure, services, and housing and potentially available workforce for a reprocessing facility.

- Environmental Justice--Potential mixed-income, minority, and tribal communities, with medium to high population density.

3.1.3 DOE Site Type

A “DOE site” is one at which past and present DOE operations have occurred, and at which a potential SNF reprocessing facility might be co-located. Such sites may also accommodate other privately owned and operated facilities co-located with DOE operations, which may exist or are planned.

The DOE site environment has been previously developed for nuclear and non-nuclear research, industrial, or testing activities. Thus, environmental conditions may be somewhat similar those at industrial sites, as described in Section 3.1.2 above, except that it is likely that radioactive materials were handled, used, and possibly disposed of at DOE nuclear sites. Electrical power lines, water and sewer, and roadways, railways, or barge access necessary to support industrial activity already exist. Radiological and non-radiological discharges or effluents associated with DOE site activities may have affected air quality, water quality, and soil in this environment. Note, however, that some DOE sites are very large and may include significantly sized undeveloped areas with environmental conditions and characteristics similar to rural site types, as described in Section 3.1.1 above.

Following are the postulated, generalized characteristics of the DOE site type for each of the resource areas considered, based on an SNF reprocessing facility located in a developed, industrialized area of a DOE site:

- Land Use and Site Infrastructure--Land disturbed by past or current research, industrial, or testing activities; some elements of infrastructure in place to support reprocessing facility, with minor improvements needed.

- Transportation--Existing transportation infrastructure in place to support reprocessing facility, with minor improvements needed.

- Geology and Soils--Limited geologic disturbance, if any; soils disturbed and potential soil contamination due to construction, operation, and decommissioning of past or current research, industrial, commercial, or testing facilities and activities.

- Water Resources

    - Water Use - Assumed sufficient water availability for reprocessing facility, with appropriation rights acquired if necessary.

    - Water Quality - Potential effects on water quality due to past and present DOE research, industrial, commercial, or testing activities.

- Air Quality--Existing research, industrial, commercial, or testing facilities and activities affecting air quality.

- Noise--Existing research, industrial, commercial, or testing facilities and activities affecting noise levels.

- Ecological Resources—Past and current research, industrial, commercial, or testing facilities and activities affecting biodiversity and ecosystems.

- Waste Management--Non-hazardous, hazardous, and low activity radioactive solid and liquid waste management infrastructure exists due to past or current research, industrial, commercial, or testing activities, with minor improvements needed; high activity radioactive waste management infrastructure maybe needed or require upgrade. (Note, however, that commercial SNF reprocessing facilities co-located with DOE facilities may or may not have access to existing DOE facilities for LLW and HLW management, and may need to access offsite waste management facilities.)

- Historic and Cultural Resources--Land disturbed due to past and current research, industrial, commercial, or testing activities; historic and cultural sites likely identified and adverse effects possibly mitigated in disturbed areas.

- Visual and Scenic Resources--Past or current DOE research, industrial, commercial, or testing activities potentially affecting visual and scenic resources.

- Public and Occupational Health

    - Radiological – Radiological sources from past and current DOE research, industrial, commercial, and testing activities, although natural background levels of radiation may be present in some areas.

    - Non-Radiological – Natural background or potential presence of chemicals and airborne pollutants from DOE research, industrial, commercial, and testing activities.

- Socioeconomics--Mixed economic community with existing public infrastructure, services, and housing and potentially available workforce for reprocessing facility.

- Environmental Justice--Potential mix-income, minority, and tribal communities, with low to high population density.

3.2 Additional Considerations Regarding Potential Affected Environments

For each resource area, this section presents preliminary, general discussions regarding additional considerations related to potential environmental settings for commercial SNF reprocessing facilities, in the contexts of the generalized rural, industrial and DOE site types where applicable. In conjunction with the generalized environmental settings described in Section 3.1 above, these discussions expand upon the basis for the identification and analysis of environmental-related considerations and issues associated with preconstruction, construction, operation, and decommissioning of reprocessing facilities in Chapter 4. Considerations regarding potential co-location of commercial SNF reprocessing facilities with other nuclear facilities, with both related and unrelated functions, are discussed in Section 4.1.1.4.

3.2.1 Land Use and Site Infrastructure

Site infrastructure, as used in this report, is defined as the basic physical systems that serve and support a community's population and would be needed for operation of an SNF reprocessing facility, and includes roads, railroads, barge transport, utilities, water services, sewage treatment, and waste management. Issues regarding roads, rail, and barge systems are discussed separately in Section 3.2.2 (Transportation). Water supply and water quality issues are discussed in Section 3.2.4 (Water Resources). Waste management considerations are discussed in Section 3.2.8.

Because of the large size of an SNF reprocessing facility complex, the need to maintain adequate buffer zones for safety and security purposes, and the need for supporting infrastructure, land use patterns may be affected by the preconstruction, construction, and operation of a reprocessing facility. Environmental effects related to land use would depend on zoning and the types of land use occurring in and around the facility site prior to development. In general, if a reprocessing facility is consistent with existing land uses in and around a potential site, effects on land use would be expected to be smaller compared to cases where the facility would be inconsistent with local land uses. The effects on land use of a given facility would also depend on factors such as local population and population density, availability of water and power, and access to major thoroughfares, railroad systems, or navigable waterways.

Development of a reprocessing facility would include construction of a number of buildings and other structures and appurtenances, which would result in the disturbance of hundreds to thousands of acres of land. Typical structures found onsite would include a main processing building, a fuel receiving and storage building, and assorted auxiliary buildings. Additionally, electric transmission lines and roadway, rail lines, or other transportation facilities may need to be constructed to supply adequate power and access to and from the facility, respectively. Given the nature of the types of large-scale chemical processes involved and the need to maintain security and safety, zoning issues make it unlikely that a facility would be located in an urban or residential setting. For reasons associated with planning, permitting, and licensing, the reprocessing facility could be sited on property that is currently owned by a Federal or state government agency and that could house past or existing nuclear facilities of other types.

Any site under consideration would need to be assessed in terms of possible conflicts between Federal, tribal, state, regional, and local land use plans, policies, and controls (NRC, 2003). Additionally, in the vicinity of the proposed reprocessing facility, it would be important to identify features including, but not necessarily limited to, the following:

- wilderness areas
- wildlife preserves
- other special land use classification areas
- rare, threatened, or endangered species critical habitats
- public recreational facilities
- historic and cultural resources
- floodplains and wetlands

- Federal lands
- locations of schools, hospitals, and other public infrastructure
- areas of prime farmland

Rural sites are likely to feature little development, and primary uses may be agricultural or agriculture-related activities, such as farming, ranching, or logging. Some sites may not have been developed for any previous purposes. Rural sites may also lack much of the infrastructure necessary to construct and operate a reprocessing facility, including roads, rail service, and connections to a dependable water source and an electrical grid.

The infrastructure in and around industrialized areas is likely to be highly developed and include roads, rail service, connections to dependable water sources, and access to the electrical grid. The region around these sites may be heavily developed and located in or near sizable population centers.

DOE sites may have many features similar to those associated with both rural and industrial sites. Some DOE sites are remote and located on Federal government land that is leased for agriculture and has no infrastructure components. Other DOE sites have been heavily developed for various DOE research, industrial, or testing activities. The existing infrastructure associated with these types of sites could be extensive.

3.2.2 Transportation

Transportation by highway, rail, or water would be important considerations for a reprocessing facility. A reprocessing facility would require ready access to interstate highway systems and rail lines to promote the shipment of materials to and from the site and transport of preconstruction, construction, and operations labor forces. Depending on facility location, access to navigable waterways may also be desirable. A reprocessing facility would need to import SNF from domestic nuclear power plants that may be located regionally or at some distance from the facility. Significant quantities of hazardous chemicals would be shipped to the site. A reprocessing facility would need to ship out reprocessed product to fuel fabrication facilities that may be located regionally or at some distance from the site. Additionally, some amounts of low-level and high-level radioactive wastes and hazardous wastes produced during reprocessing would need to be shipped to disposal or storage facilities. Access to existing transportation nodes may already be in place at or near a site or may have to be developed if transportation access points are nonexistent.

Rural and DOE sites in remote locations may have to construct roads and rail spurs necessary to access main lines of transportation. They may also have to travel greater distances to do so. Industrialized sites, in general, would have ready access to main transportation routes which are likely to be found nearby.

3.2.3 Geology and Soils

The geology and soils of any potential SNF reprocessing site would need to be evaluated on a site-specific basis and cannot be easily subdivided into the three categories of rural, industrial, and DOE sites. For the purposes of this report, the general geologic and soil characteristics of four of the 10 different geologic provinces in the U.S. shown in Figure 3-2, in which the 11 sites identified in the GNEP Draft PEIS (DOE, 2008) are located, are summarized below. With regard to soil contamination, which is not location-specific, such contamination may or may not be present at potential SNF reprocessing sites. Rural sites are likely to contain little or no contamination, with any limited contamination resulting from use of agricultural chemicals. Soil at industrial sites may be contaminated with hazardous materials and at DOE sites with radioactive and hazardous materials, both from past facility operations.

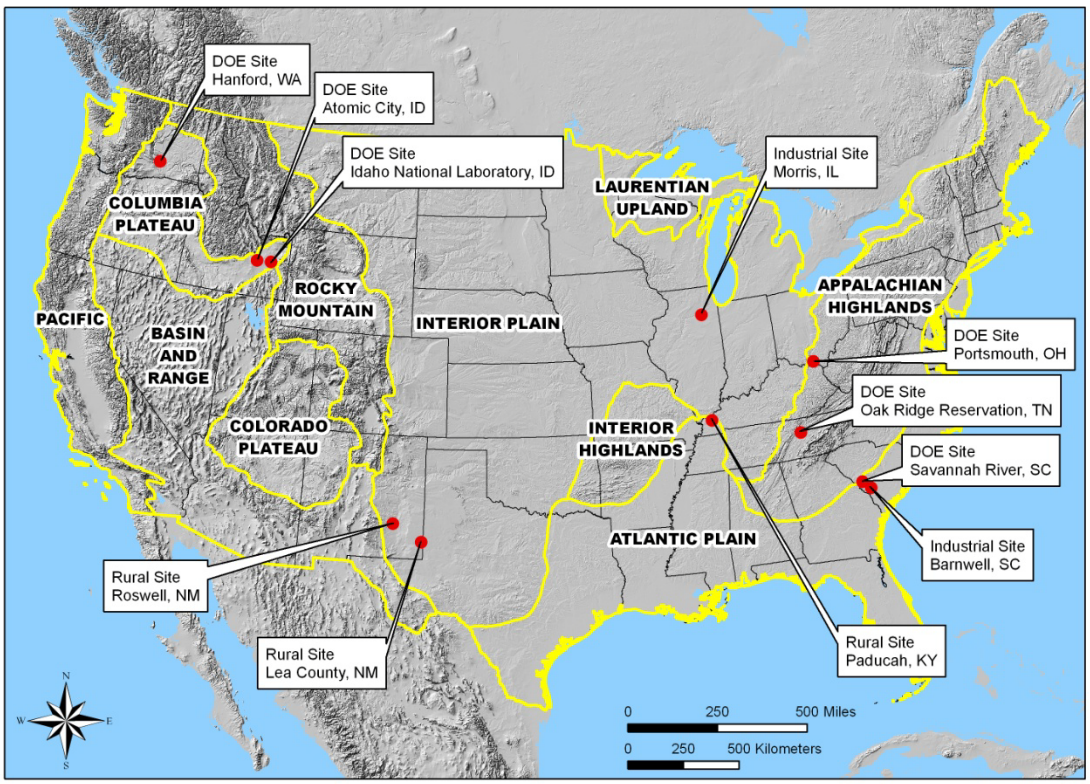

Figure 3-2 Geologic Provinces of the Continental United States with Potential SNF Reprocessing Facility Locations
(Sources: DOE, 2005a; DOE, 2008; USGS, 2004a-c)

3.2.3.1 Columbia Plateau Province

The GNEP Draft PEIS sites in the Columbia Plateau Province are the DOE sites in Hanford, WA, Atomic City, ID, and Idaho National Laboratory (INL), ID. This province is characterized by a broad plain that has been built up from the eruptions of multiple flows of basaltic lava over the past 4 million years. The upper 1.0 to 1.9 kilometer (km) (0.6 to 1.2 mile (mi)) of the crust is composed of a sequence of Quaternary age (recent to 2 million years old) basalt lava flows and poorly consolidated sedimentary interbeds collectively called the Snake River Group. The lava flows at the surface range from 2,100 to 2 million years old. The sediments are composed of fine-grained silts that were deposited by wind; silts, sands, and gravels deposited by streams, and clays, silts, and sands deposited in Idaho lakes such as Mud Lake and its much larger ice-age predecessor, Lake Terreton. The accumulation of these materials in the Eastern Snake River Plain has resulted in the observed sequence of interlayered basalt lava flows and sedimentary interbeds (DOE, 2005a).

Potential sites located near INL could be influenced by segments of both the Lost River Fault and Lemhi Fault. Both faults are considered capable or potentially active. Based on the maximum considered earthquake ground motions, sites near INL are located in a broadly defined region of low and moderate seismicity to high seismicity. Ground motions in these regions are influenced by earthquake sources that are not well defined, with estimated maximum earthquake magnitudes having relatively long return periods (i.e. reoccurrence intervals) (DOE, 2005a).

Sediments in the area vary but fall into four basic types: river-transported sediments deposited on loose, consolidated sediment plains; fine-grained sediments deposited into lake or dry lake basins; sediments originating from bordering mountains; and wind-blown sediments over lava flows. Soils in the area range from moderately deep to deep are from mixed sources and are well drained (DOE, 2005a).

3.2.3.2 Interior Plain Province

The GNEP Draft PEIS sites in the Interior Plain Province are the rural sites in Lea County, NM, and Roswell, NM, and the industrial site in Morris, IL. This area, as defined by the U.S. Geological Survey (USGS), represents a vast region and the stable nucleus of North America. Precambrian metamorphic and igneous rocks form the basement of the Interior Plains. With the exception of the Black Hills of South Dakota, the entire region has low relief. There are numerous subprovinces within the Interior Plain Providence and site characterization would require a site-specific geologic assessment (USGS, 2004a).

Due to the large size of this province, the rock, soil, and sediment characteristics represent a wide range. Terrains transition from glacial sediments in the northern regions into sandstones, siltstones, and limestones in the southern portions of the province. Within the vicinity of the three Interior Plain Province sites, there are no capable faults as defined by in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 100 (USGS, 2004a).

3.2.3.3 Appalachian Highlands Province

The GNEP Draft PEIS sites in the Appalachian Highlands Province are the DOE sites in Portsmouth, OH, and Oak Ridge, TN. This province reveals elongate belts of folded and thrust faulted marine sedimentary rocks (i.e. rock bent or curved as a result of permanent deformation), volcanic rocks and ancient ocean floor. The topography consists of steep hills and narrow valleys, except where major rivers have formed broad floodplains. Sediment and soil types and seismicity within the province are highly variable (USGS, 2004b).

3.2.3.4 Atlantic Plain Province

The GNEP Draft PEIS sites in the Atlantic Plain Province are the DOE site in Savannah River, SC, the industrial site in Barnwell, SC, and the rural site in Paducah, KY. This province stretches over 3,500 km (2,200 mi) and is the flattest of the provinces, covering an area from Cape Cod to the Mexican border and southward another 1,600 km (1,000 mi) to the Yucatan Peninsula (USGS, 2004c).

The sediments of the Atlantic Plain dip gently seaward and range from essentially 0 meters (m) (0 feet (ft)) thick to more than 1,219 m (4,000 ft) at the coast. The topmost sediment layer consists of occasional beds of clean sand, gravel, clay, or carbonate. Deposits of pebbly, clayey sand, conglomerate, and clay occur at higher elevations. Such layers are noteworthy because they contain small, discontinuous, thin calcareous sand zones (i.e., sand containing calcium carbonate) that are potentially subject to dissolution by water. These “soft-zone” areas have the potential to subside, causing settling of the ground surface (NRC, 2005). The second layer of sediments overlies bedrock and consists of about 210 m (700 ft) of quartz sand, pebbly sand, and clay. The underlying bedrock consists of sandstones and older metamorphic and igneous rocks (DOE, 2002).

The Atlantic Plain tectonic province is characterized by generally low seismic activity. For example, at the Savannah River site, there are six subsurface faults: Pen Branch, Steel Creek, Advanced Tactical Training Area, Crackerneck, Ellenton, and Upper Three Runs. The faults do not reach the surface, but stop several hundred meters below. These are referred to as blind faults, due to the lack of surface expression of this fault type. This makes them difficult to detect until they rupture (DOE, 2005b).

3.2.4 Water Resources

Water use and water quality issues associated with potential SNF reprocessing sites would need to be evaluated on a site-specific basis, and cannot be easily subdivided into the three categories of rural, industrial, and DOE facilities. Surface water or groundwater availability for plant use is generally focused on issues related to water quantity or quality. The trans-boundary nature of surface water systems may need to be evaluated as usage effects in one location may have implications in a distant location. If a facility will utilize wells as a source of water, it would be important to ensure that water is withdrawn at a rate lower than its replenishment rate and that water appropriation rights are available where necessary. For both surface water and groundwater use, water quality is a consideration as the water may require treatment prior to use, or may be unusable if sufficiently contaminated. Remediation of any shallow contaminated groundwater during preconstruction and construction may be necessary. Surface water or groundwater contamination is more likely to occur at industrial and DOE sites due to discharges of hazardous or radioactive materials, than at rural sites.

Regardless of the location, SNF reprocessing facilities must comply with state and local regulations that have been developed to regulate water use and maintain a certain level of water quality. Most states, for example, require permits for surface water usage. Groundwater usage regulations vary considerably from state to state, and permits are typically required.

3.2.5 Air Quality, Climatology, and Meteorology

Describing the interaction of an SNF reprocessing facility with the environment requires an understanding of the existing air quality for the region of influence (ROI), the emissions associated with the proposed facility, and the climatology and meteorology of the ROI.

3.2.5.1 Air Quality

The U.S. Environmental Protection Agency (EPA) has established air quality standards to protect human health and welfare and to protect against damage to the environment and property. These standards include the National Ambient Air Quality Standards (NAAQS) that regulate the six criteria air pollutants shown in Table 3-1 (40 CFR Part 50). In association with the NAAQS, EPA divided the country into Air Quality Control Regions for air quality planning and management purposes (40 CFR Part 81). The Air Quality Control Regions are based on meteorological and topographical factors of air pollution, and are composed of large areas covering many counties, sometimes from more than one state.

NAAQS compliance status, as documented in 40 CFR Part 81, is typically reported at the county level. In some cases, even smaller compliance areas are identified such as a portion of a county. As such, air quality compliance status is not directly related to the rural, industrial, and DOE site categorization. Air quality categorization and NAAQS compliance status (i.e., attainment or nonattainment) are established for large areas such as counties that may encompass various levels of development ranging from rural to urban. Rural areas may tend to have fewer NAAQS compliance issues than developed areas and are more likely to be in attainment. Many developed areas (which are areas more likely to be associated with industrial or DOE sites) are classified as nonattainment. Therefore, the description of the affected environment for air quality is site-specific and relates to the NAAQS compliance status rather than the three site categories.

Atmospheric releases from an SNF reprocessing facility may also need to comply with EPA's National Emissions Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 61) or stricter state requirements. NESHAPs defines emissions standards for hazardous air pollutants (HAPs), which include both chemical and radiological emissions. A complete listing of emissions standards for HAPs can be found in 40 CFR Part 61. The radiological requirements in NESHAPs specify that the total radiological emissions from a facility cannot cause any member to the public to receive an annual dose of radiation in excess of 0.1 millisieverts/year (mSv/year) (10 millirem/year (mrem/year)).[1]

Table 3-1 National Ambient Air Quality Standards

Pollutant		Primary/ Secondary	Averaging Time	Level[a]	Form
Carbon Monoxide		primary	8-hour	9 ppm	Not to be exceeded more than once per year
			1-hour	35 ppm	
Lead		primary and secondary	Rolling 3 month average	0.15 μg/m^3	Not to be exceeded
Nitrogen Dioxide		primary	1-hour	100 ppb	98th percentile, averaged over 3 years
		primary and secondary	Annual	53 ppb	Annual mean
Ozone		primary and secondary	8-hour	0.075 ppm	Annual fourth highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution	**$PM_{2.5}$**	primary and secondary	Annual	15 μg/m^3	Annual mean, averaged over 3 years
			24-hour	35 μg/m^3	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24-hour	150 μg/m^3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide		primary	1-hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

Source: EPA, 2012 (standards are as of October 2011).

[a] Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter of air (μg/m^3).

3.2.5.2 Climatology and Meteorology

As with air quality attainment and nonattainment, there is no correspondence between climatological or meteorological conditions and the rural, industrial, and DOE site categories. For example, a rural site could be in a New Mexico desert or a Kentucky farming area. The factors that influence climatic and meteorological metrics such as temperature, precipitation, wind, humidity, and storm events are not primarily associated with the level of anthropogenic development or activity as characterized by the three site categories. Therefore the description

[1] Radiation dose, or simply dose, is a measure of the biological damage to an individual from ionizing radiation. Millisieverts (mSv) or millirem (mrem) are the units of measure of the effect ionizing radiation has on people.

of the affected environment for climatological and meteorological characteristics is site-specific and relates to local conditions and metrics rather than the rural, industrial, and DOE site categories.

3.2.6 Noise

Noise is defined as unwanted sound and is measured in decibels (dB). Rural areas tend to be undeveloped and relatively quiet. Natural phenomena such as wind, rain, birds, and other wildlife account for most of the background sounds. Typical rural area baseline noise levels range from about 22 to 38 dB (DOE, 2007). Urban and suburban areas are more developed and, therefore, noisier. Human noise sources such as street noise, traffic, emergency vehicles, and construction equipment account for some of the background sounds. Typical urban and suburban area baseline noise levels range from about 45 to 78 dB, with lower noise levels at night (Washington State Department of Transportation, 2012).

However, the generalized rural and urban-suburban background noise background environments described above do not directly correlate with the rural, industrial and DOE site categories because baseline environmental noise levels at such sites can be highly localized. For example, DOE sites can cover large land areas and baseline noise levels in the immediate vicinity of operating facilities would be high. However, noise levels dissipate as distance from the source increases, and noise levels in an undeveloped area of the same DOE site could be low. Similarly, an isolated rural area would typically experience low baseline noise levels; however, at a rural site located next to a busy roadway, the noise levels in the immediate vicinity would be high. In general, noise levels over background associated with the location of a proposed reprocessing facility are site-specific and are related to the distance between the noise source and the receptor.

Target noise thresholds are a function of both site-specific environmental conditions and the receptor group classification. For reprocessing facility projects, there are two receptor group categories--site workers and the general public. At the Federal level, the Occupational Health and Safety Administration (OSHA) regulates noise levels for workers. The permissible noise exposure limit varies by time duration. The limit ranges from 90 dB for a duration of 8 hours per day up to 115 dB for 15 minutes or less (29 CFR 1910.95, Table G-16). Identifying target environmental noise thresholds for the general public can be a more complicated process.

Prior to 1981, EPA coordinated all Federal noise control activities. In 1981, EPA transitioned primary responsibility for regulating noise to state and local governments. However, EPA did identify noise levels requisite to protect public health and welfare against hearing loss and annoyance and activity interference. These thresholds do not constitute a standard, specification, or regulation, but are intended to provide a basis for state and local governments establishing noise standards. EPA identified thresholds for preventing activity interference and annoyance for a 24-hour period at 45 dB for indoors and 55 dB for outdoors (EPA, 1978). These levels are not single event or peak noise levels, but instead represent averages over time so occasional higher noise levels would be balanced by sufficient amounts of quiet.

In a similar manner, 23 CFR 772 identifies noise abatement criteria and procedures for highway construction and traffic noise using dB levels averaged over one hour. The indoor threshold was set at 52 dB. Outdoor thresholds varied by different land use categories. A threshold of 57 dB was established for lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purposes. A threshold of 67 dB was established for picnic areas, recreational areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals. A threshold of 72 dB was established for developed lands, properties, and activities not included in the previous two outdoor categories.

3.2.7 Ecological Resources

This section describes the principal ecological (terrestrial and aquatic) features and processes that may be associated with an SNF reprocessing facility site. Terrestrial plant and animal communities as well as aquatic biota may be subject to effects potentially associated with this type of project. A survey of ecological resources (e.g., of rare, threatened, endangered, and important species, including estimates of their abundance) would be conducted at a proposed SNF reprocessing facility site and special and critical habitat needs (e.g., cover, forage, and prey species) of species in the area would be identified. A number of ecological processes and functions are necessary in order to maintain a healthy ecosystem, such as nutrient cycling, connectivity of habitat patches, a successful natural disturbance regime, population dynamics, and genetic diversity.   Disruption or elimination of any of these ecological processes could affect ecosystem health.

The potential loss of plant and animal habitat, both terrestrial and aquatic, resulting from preconstruction, construction, operation, or decommissioning of a reprocessing facility would be the principal ecological consideration. The significance of lost habitat depends on the importance of the plant and animal community that is affected. Particularly important habitats are wetlands, riparian habitats, staging or resting areas for large numbers of waterfowl, rookeries, restricted wintering areas for wildlife, communal roost sites, strutting or breeding grounds of gallinaceous (i.e. ground-feeding) birds, and areas containing rare plant communities (NRC, 1996)

The existence and nature of such ecological features would be site-specific. Some generalizations, however, can be made regarding potential site locations. Rural sites are more likely to have relatively intact, functioning ecosystems due to the lack of development and disturbance, although this biodiversity would vary from site to site. For example, an arid desert location is likely to have less biodiversity than a temperate rainforest. Industrialized sites would be expected to offer lower biodiversity levels and decreased ecosystem services in most cases due to previous disturbance and habitat loss that are characteristic of these types of locations. It is difficult to generalize about DOE sites because they can be highly variable in terms of habitat quality. Some DOE sites or portions of DOE sites could be categorized as highly rural while others have undergone to extensive industrialization.

3.2.8 Waste Management

Commercial reprocessing facilities that use the PUREX process are generally large facilities that produce significant quantities of a variety of waste types. A general description of these waste handling systems is provided in Section 2.3.2.7. Large quantities of nitric acid solutions, organic solvents, and chemicals are required to process these large amounts of SNF. These facilities generate solid, liquid, and gaseous waste streams. Following onsite treatment to remove contamination, some liquid and gaseous waste streams may be discharged to the environment. Industrial discharges to the air, surface water, or groundwater would require permits from EPA or responsible state agencies. It is assumed for this report that wastes containing high levels of radioactivity would require onsite treatment prior to transportation and storage or disposal at a licensed facility. Wastes containing high levels of toxic chemicals would require disposal at a licensed hazardous waste disposal facility. Non-hazardous solid waste would be disposed at a licensed solid waste disposal facility. The potential environmental effects associated with waste management will depend on the availability of existing waste management facilities relative to the SNF reprocessing facility location. Baseline conditions for waste management are discussed below for the rural, industrial, and DOE site types.

In general, rural sites would have no existing onsite facilities or structures and no waste management services would be available on or near these sites. The industrial and DOE site environments would have existing facilities or structures and industrial activity would have occurred at the location at or before the time of reprocessing facility development. Facilities for the treatment and disposal of hazardous and non-hazardous waste generated by a reprocessing facility may be available on or near such sites. Low and high level radioactive wastes would require transportation to licensed storage or disposal facilities that may not exist near industrial sites where non-radiological operations occur, but may exist near DOE sites in some cases. For a commercial reprocessing facility located at any of the three site types, the license applicant would need to have the appropriate agreements in place with DOE to ensure access to the high level waste management services at a DOE facility.

3.2.9 Historic and Cultural Resources

3.2.9.1 Overview

Historic and cultural resources include prehistoric and historic era archaeological sites, historic districts, and buildings, as well as any site, structure, or object that may be considered eligible for listing on the National Register of Historic Places (NRHP). The Federal government established the NRHP and devised the way historic properties become eligible and can be nominated to be listed in the NRHP; this process is intended to help preserve significant historic properties. (See Section 3.2.9.2 for more information on the NRHP.) Archaeological resources consist of prehistoric and historic period sites that contain evidence of past human lifeways and adaptations. Historic and cultural resources may also include cultural, ethnographic, rural historic, and historic mining landscapes.

The National Historic Preservation Act of 1966, as amended (NHPA) (United States Code, Title 16, Section 470 (16 U.S.C. 470 et seq.)) is the primary Federal law that addresses historic preservation requirements for Federal "undertakings". Undertaking is defined in Section 301(7)(c) of the NHPA as any project or activity that is funded or under the direct jurisdiction of a Federal agency, or, most importantly for the SNF reprocessing facility construction and operation addressed in this ETR, any project or activity that requires a Federal permit, license, or approval.

Licensing an SNF reprocessing facility would be a Federal undertaking that would require compliance with the NHPA, including compliance with Section 106 of the NHPA, which requires Federal agencies to take into account the effects of their undertakings on historic properties and afford the Advisory Council on Historic Preservation (ACHP) a reasonable opportunity to comment on such undertakings. ACHP is an independent Federal agency that provides guidance on the application of Federal historic and cultural resource laws and serves as an arbiter when disputes arise. ACHP's regulations for protection of historic properties are in 36 CFR Part 800.

Historic and cultural resources background information and authorities regarding historic and cultural resources are provided on a state-by-state basis as the historic and cultural resource information and agencies are organized at the state level. The NHPA called for each state to establish a State Historic Preservation Office with a State Historic Preservation Officer (SHPO) that administers and is responsible for oversight and compliance with the NRHP, compliance and review for Section 106 of the NHPA, enforcement of the Native American Graves Protection and Repatriation Act (NAGPRA), and compliance with other Federal and state historic preservation laws and regulations. In areas of Native American tribal land, a Tribal Historic Preservation Officer (THPO) may exist with authority and responsibility on tribal land equivalent to that of a SHPO.

Section 106 of the NHPA identifies the process for considering historic and cultural resources during a Federal undertaking (see also 36 CFR Part 800). The process requires that Federal agencies consult with the SHPO (or THPO), and appropriate Federally-recognized Native American Tribes, when making determinations on the identification of historic properties, evaluation of potential adverse effects, and proposed mitigation measures. The regulations also require adequate public participation in the process. SHPOs are authorized only to comment on an undertaking. Identification of historic properties in the area of potential effect (APE) and consultation with appropriate authorities would be initiated as part of the Section 106 process. The lead Federal agency must determine if historic and cultural resources eligible for listing on the NRHP are present. A determination is generally accomplished through a combination of a literature search, review of SHPO or THPO files for the area of interest, and field investigations conducted by individuals who meet the Secretary of the Interior's Guidelines for Historic Preservation (cultural resource professionals) and information provided by other parties and the public.

Only cultural resource professionals can determine whether significant resources are present. If resources are present, their significance is determined through application of the NRHP evaluation criteria in 36 CFR Part 60. Effects resulting from an undertaking to properties eligible for the NRHP can be mitigated. Mitigation is commonly achieved through protection or documentation of the resource prior to disturbance.

Information on where historic and cultural resources are located is considered proprietary; i.e., the NHPA requires that information on the locations of historic and cultural resources be withheld from the public to protect the resources (36 CFR 800.11(c)(1)). This designation is intended to protect historic and cultural resources (primarily archaeological resources) from illegal collecting.

3.2.9.2 Historic Properties

The listing of historic properties in the NRHP helps preserve such properties under provisions of the NHPA. In addition, properties deemed potentially eligible for inclusion in the NRHP are given this same protection. The term "historic properties" can include properties of religious and cultural significance to Native American Tribes, such as Traditional Cultural Properties (TCPs), so long as those properties meet the eligibility criteria in 36 CFR Part 60 for listing on the NRHP.

In the context of a Federal undertaking, the significance of a cultural resource is judged according to NRHP eligibility criteria. These criteria are defined in 36 CFR 60.4, which states that

> "The quality of significance in American history, architecture, archeology, engineering, and culture is present in districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling, and association, and;
>
> "(a) that are associated with events that have made a significant contribution to the broad patterns of our history; or
>
> "(b) that are associated with the lives of persons significant in our past; or
>
> "(c) that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
>
> "(d) that have yielded, or may be likely to yield, information important in pre-history or history."

3.2.9.3 Considerations for Potential SNF Reprocessing Facility Sites

3.2.9.3.1 General Considerations

There is no specific correlation between the rural, industrial, or DOE site types and the presence of historic and cultural resources that may require protection or other special treatment as a result of the development of SNF reprocessing facilities. Rural sites tend to be undisturbed or less disturbed and, therefore, historic or cultural resources may not have been previously identified. Industrial and DOE sites may contain areas disturbed by industrial or commercial development, and historic and cultural sites in such areas may have been identified and possibly mitigated. Considerations associated with the potential for the presence of historic and cultural resources at potential SNF reprocessing facility sites are further discussed below.

3.2.9.3.2 Resources from the Prehistoric and Historic Eras

In the United States, the prehistoric era is the time period prior to the arrival of Europeans. Some of the most heavily used areas on the landscape for prehistoric era people were along rivers, lakes, and the seashore. These locations provided freshwater and the most abundant food sources, as well as the most efficient ways to travel. Waterways formed the primary transportation routes in North America for thousands of years. As a result, prehistoric era archaeological sites tend to be found along these waterways. The types of prehistoric archaeological resources found include small temporary camps, larger seasonal camps that were returned to year after year, large village sites that were occupied continuously over several years or potentially centuries, and specialized-use areas associated with fishing or hunting or with tool or pottery manufacture.

Historic era resources are those associated with Europeans or their descendants. Like sites used by prehistoric peoples, historic era sites tend to cluster near waterways because water was the most efficient form of transportation. Historic era resources include farmsteads, mills, forts, residences, industrial sites (such as mines or canals), and shipwrecks.

The fact that past human activities were focused along waterways is important to note since many nuclear-related facilities that could serve as potential host sites (including some of the DOE GNEP Program sites and many others) for an SNF reprocessing facility are located along major rivers, lakes, or the ocean for the use of cooling water. Some sites associated with water may have low archaeological potential due to a moderate to steep terrain, and drainages with low banks and wide floodplains that likely washed away evidence of historic findings. Nevertheless, the potential for the presence of historic and cultural resources near a potential SNF reprocessing facility near a waterway is high.

3.2.9.3.3 Special Consideration for DOE Sites

Many energy-related facilities in the United States have been operated for 50 years or more by DOE and its predecessor agencies, for the purposes of supporting the national nuclear weapons program and conducting government-sponsored research into nuclear energy technology. Although the NHPA was passed in 1966, the process for complying with the law was developing during the 1970s and early 1980s. Over the last 30 years, the process for complying with the NHPA has been modified. Some of the changes involve the role of the SHPO in the Section 106 consultation process, the role of Native American Tribes, and the methods used for field investigations.

Due to less emphasis on historic preservation in past ground disturbing activities that have taken place at some commercial and DOE nuclear-related facilities (both during construction and operations), it is unlikely that there would remain any historic and cultural resources in heavily disturbed areas. However, developed and less-developed portions of a large DOE complex, including areas that were previously examined, could still contain undiscovered historic and cultural resources. In any event, both areas should be examined.

Further, some national defense sites and spent fuel storage sites, which could potentially be considered to host an SNF reprocessing facility, are located inland, including locations in mountainous and arid desert environments. Evidence of historic inland lifeways would include ceremonial stone arrangements, cemeteries, homesteads and campgrounds, hearths, middens, quarries, wells, irrigation ditches, agricultural fields, stone artifacts, and scatters. Historical period sites, such as the Oregon Trail that crosses many western states and the Old Spanish Trail that served as a major passage into California, are designated as National Historic Trails. Desert trails are likely to include historic sites along the trail, and remnants of Native Americans and later settlers who lived and worked in the area. Prehistoric sites would likely be present atop buttes, and within craters and caves.

3.2.10 Visual and Scenic Resources

Visual and scenic resources generally describe landscape characteristics, manmade features, and viewsheds. Assigning values to visual and scenic resources is subjective, but basic design elements such as form, line, color, and texture can be used to describe and evaluate landscapes. Federal land management agencies have established guidelines to inventory and manage visual resources, such as the Bureau of Land Management (BLM) with its Visual Resource Inventory and Evaluation System (BLM, 1984; BLM, 1986a; BLM, 1986b; BLM, 2012) and the U.S. Forest Service (USFS, 1995).

Because there are a variety of visual values, different levels of management are necessary. These activities are typically part of a visual resource management (VRM) system. A VRM system identifies and inventories existing scenic values and establishes management objectives for those values (BLM, 1984; BLM, 1986a; BLM, 1986b). These area-specific objectives provide the standards for planning, designing, and evaluating the potential effects on visual and scenic resources resulting from future management projects. A VRM system also provides for mitigation measures that can reduce potentially adverse visual effects. The final VRM class determinations by BLM are typically established in the resource management plans developed by BLM field offices.

BLM's VRM system includes objectives for four visual resource classifications, as follows (BLM, 1984; BLM, 1986a):

- Class I: To preserve the existing character of the landscape. This class provides for natural ecological changes; however, it does not preclude very limited management activity. The level of change to the characteristic landscape should be very low and must not attract attention.

- Class II: To retain the existing character of the landscape. The level of change to the characteristic landscape should be low. Management activities may be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture found in the predominant natural features of the characteristic landscape.

- Class III: To partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. Management activities may attract attention but should not dominate the view of the casual observer. Changes should repeat the basic elements found in the predominant natural features of the characteristic landscape.

- Class IV: To provide for management activities that require major modifications of the existing character of the landscape. The level of change to the characteristic landscape can be high. These management activities may dominate the view and be the major focus of viewer attention. However, every attempt should be made to minimize the impact of these activities through careful location, minimal disturbance, and repeating the basic elements.

The USFS system for VRM is slightly different from that used by the BLM, with five classifications based on visual quality and scenic integrity objectives.

The following characteristics are examples of the site-specific conditions that would be considered during the visual inventory process for a proposed commercial SNF reprocessing facility (NRC, 2003):

- Boundaries of the viewshed or viewscape of the facility;

- Identification of local residents and/or regular visitors to the area who might be affected by aesthetic impacts;

- Information related to the landscape characteristics including open spaces, mountain ranges, ecological environment (e.g., flora, fauna, and ecosystems), bodies of water (e.g., waterfalls, waterways, and oceans), color of soils, recreational areas (e.g., parks wilderness areas), architectural features, aesthetic (e.g., historical, archaeological, cultural, and natural) features that would attract tourists, and uncultivated land;

- Location of constructed features including radar towers, transmission towers, and overhead power distribution line and production activities;

- Visibility from access roads (i.e., existing natural or constructed barriers, screens or buffers);

- Regionally or locally important or high quality views that might be affected;

- Photos and information related to the view of the facility from different directions including views from roads, highways, homes, and recreational areas (e.g., forest and wilderness area and campgrounds);

- Regulatory information related to land-use zoning requirements of the local community or urban areas, sign ordinances or regulations of the local community or urban area, design guides of the local community or urban area, and buffer-zone (or greenbelt-zone) requirements of the local community or urban area; and

- Summary of any coordination with appropriate local area community planners and/or urban planners.

Landscape inventories are determined by taking scenic quality, visual sensitivity, and distance from existing travel routes and dividing these factors into as many as four classes. Planning areas fall into physiographic provinces and are subdivided into scenic quality rating units for rating purposes (BLM, 1986a). Although BLM does not manage all public lands, the BLM resource management plans prepared by a regional field office establish VRM classifications for that particular region, including private land or land managed by other agencies. A facility such as a commercial SNF reprocessing facility would be assigned a VRM Inventory Class I, II, III, or IV as explained below.

VRM Inventory Class I areas are where only natural ecological changes and very limited management activities occur. Class I is assigned to all special areas where the current management situations require maintaining a natural environment essentially unaltered by man. Any contrast created within the characteristic landscape must not attract attention. This classification is applied to wilderness areas, visual areas of critical environmental concern, key natural areas bordering scenic travel routes, and other similar situations. (BLM, 1986a)

Classes II, III, and IV are assigned based on combinations of scenic quality, sensitivity levels, and distance zones as shown in Table 3-2, Visual Resource Management Classification Matrix (BLM, 1986a). VRM Inventory Class II areas are where changes in any of the basic elements (form, line, color, texture) caused by a surface disturbing activity should not be evident in the characteristic landscape. Contrasts must not attract attention. VRM Inventory Class III areas are where contrasts to the basic elements caused by a management activity may be evident, but should remain subordinated to the natural landscape. VRM Inventory Class IV areas are where contrasts may attract attention and be a dominant feature of the landscape in terms of scale, but should repeat the form, line, color and texture of the characteristic landscape (BLM, 1986a).

Because of the diversity of landscapes potentially affected by an SNF reprocessing facility, a site-specific study area for the visual resources analysis using the VRM system would be determined for a facility.

Table 3-2 Visual Resource Management Classification Matrix

Visual Sensitivity Levels		High			Medium			Low
Special Areas		I	I	I	I	I	I	I
Scenic Quality	A	II	II	II	II	II	II	II
	B	II	III	III[a] IV[a]	III	IV	IV	IV
	C	III	IV	IV	IV	IV	IV	IV
Distance Zones[b]		f/m	s/s	b	f/m	b	s/s	s/s

Source: BLM, 1986a.

[a] If adjacent area is Class III or lower assign Class III, if higher assign Class IV.

[b] f/m – foreground/middleground zone; s/s – seldom seen zone; background zone.

3.2.11 Public and Occupational Health

This section summarizes the natural background radiation levels and existing sources of both radiological and non-radiological exposures to the public and workers in and around potential project areas. Descriptions of these levels are known as preoperational or baseline conditions, and they are used for evaluating potential effects associated with proposed nuclear project operations, such as those of a commercial SNF reprocessing facility. This section also describes applicable radiation dose limits and safety criteria that have been established for public protection and occupational health and safety. Because no specific site has been proposed or selected, these dose limits and safety criteria are discussed in general terms. The following sections describe the radiological and non-radiological exposure conditions, respectively, applicable to the potential project areas.

3.2.11.1 Radiological

Radiation dose is a measure of the amount of ionizing energy that is deposited in the body. Ionizing radiation is a natural component of the environment, and members of the public are exposed to natural radiation continuously. Radiation doses to the general public occur from radioactive materials found in the earth soils, rocks, and minerals. Radon-222 is a radioactive gas that escapes into ambient air from the decay of uranium (and its progeny, radium-226) found in most soils and rocks. Naturally-occurring low levels of uranium and radium are also found in drinking water and foods. Cosmic radiation from outer space is another natural source of radiation. In addition to natural sources of radiation, there are also artificial or manmade sources that contribute to the dose received by the general public. Medical diagnostic procedures using radioisotopes and x-rays are a primary manmade radiation source. The National Council for Radiation Protection (NCRP) estimates the annual average dose to the public from all natural background radiation sources (terrestrial and cosmic) is 3.1 mSv (310 mrem) and the annual average dose to the public from all sources (natural and manmade) is 6.2 mSv (620 mrem) (NCRP, 2009).

The NRC has the statutory responsibility, under the Atomic Energy Act of 1954, as amended (AEA), to protect the public health and safety and the environment. NRC regulations in 10 CFR Part 20 specify that a licensee must conduct operations so that the annual dose to a member of the public does not exceed 1 mSv (100 mrem) total effective dose equivalent and 0.02 mSv per hour (2 mrem per hour). This public dose limit for NRC licensed operations is set at a fraction of the background radiation dose.

The NRC also regulates occupational health and safety risks to workers from exposure to radiation, mainly through its Radiation Protection Standards contained in 10 CFR Part 20. In addition to annual radiation dose limits, these regulations incorporate the principal of maintaining doses "as low as reasonably achievable" (ALARA), taking into consideration the purpose of the licensed activity and its benefits, technology for reducing doses, and the associated health and safety benefits. To comply with these standards, radiation safety measures are implemented for protecting workers at NRC licensed facilities, ensuring radiation exposures and resulting doses are less than the occupational limits as well as ALARA.

Measured occupational exposures to radiation vary depending on the types of operational activities conducted, but are regulated to ensure doses do not exceed occupational exposure limits. Both DOE and NRC enforce standards that include a 5-mSv (5-rem) annual worker dose limit and apply the concept of ALARA. Both DOE and NRC annually document measured occupational doses at facilities they regulate (DOE, 2008; NRC, 2012).

3.2.11.2 Non-radiological

Public and occupational non-radiological hazards can result from sources such as industrial processes, use of chemicals, and generation of airborne pollutants. Such sources would likely be present at or in the vicinities of industrial and DOE sites considered for locations of SNF reprocessing facilities, but are less likely in rural site areas. Industrial safety associated with the use of hazardous chemicals at a proposed reprocessing facility would be regulated by OSHA. Existing hazardous material contamination at potential industrial and DOE sites may require cleanup in accordance with Resource Conservation and Recovery Act (RCRA) or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements enforced by EPA or responsible state agencies.

3.2.12 Socioeconomics

Socioeconomic conditions relevant to development and operation of a potential commercial SNF reprocessing facility would include demographics, economics (employment and income), housing, and public health and community services. The potentially affected environment around such a facility could be identified at the local level, in the county in which a facility is proposed, at the regional level, in the counties in which the majority of the facility employees would reside, and at the State level.

3.2.12.1 Demographics

This section describes potentially affected populations, using census data, in rural and metropolitan areas and at government and commercial facilities with a nuclear presence. Such data would establish demographics for potential commercial SNF reprocessing facility locations.

The most densely populated areas in the United States in 2010, as shown in Figure 3-3, are the in states east of the Mississippi River and states along the west coast, with pockets in the western states near metropolitan areas. From 2000 to 2010, regional growth was over three and a half times more for areas in the south and west (14.3 and 13.8 percent, respectively) than for the Midwest (3.9 percent) and northeast (3.2 percent) (Mackun and Wilson, 2011). Figure 3-4 shows the population growth by state by decade for the last 30 years based on census data. Most counties along the coasts and the southern U.S. border gained in total population (Mackun and Wilson, 2011). Although most nuclear facilities are situated in smaller, rural communities (NRC, 1996), the population density may increase radically and relatively quickly into micro and metropolitan areas. Table 3-3 shows the most populous and fastest growing metropolitan areas. Growth is important because it is one of the main drivers of socioeconomic effects (NRC, 1996).

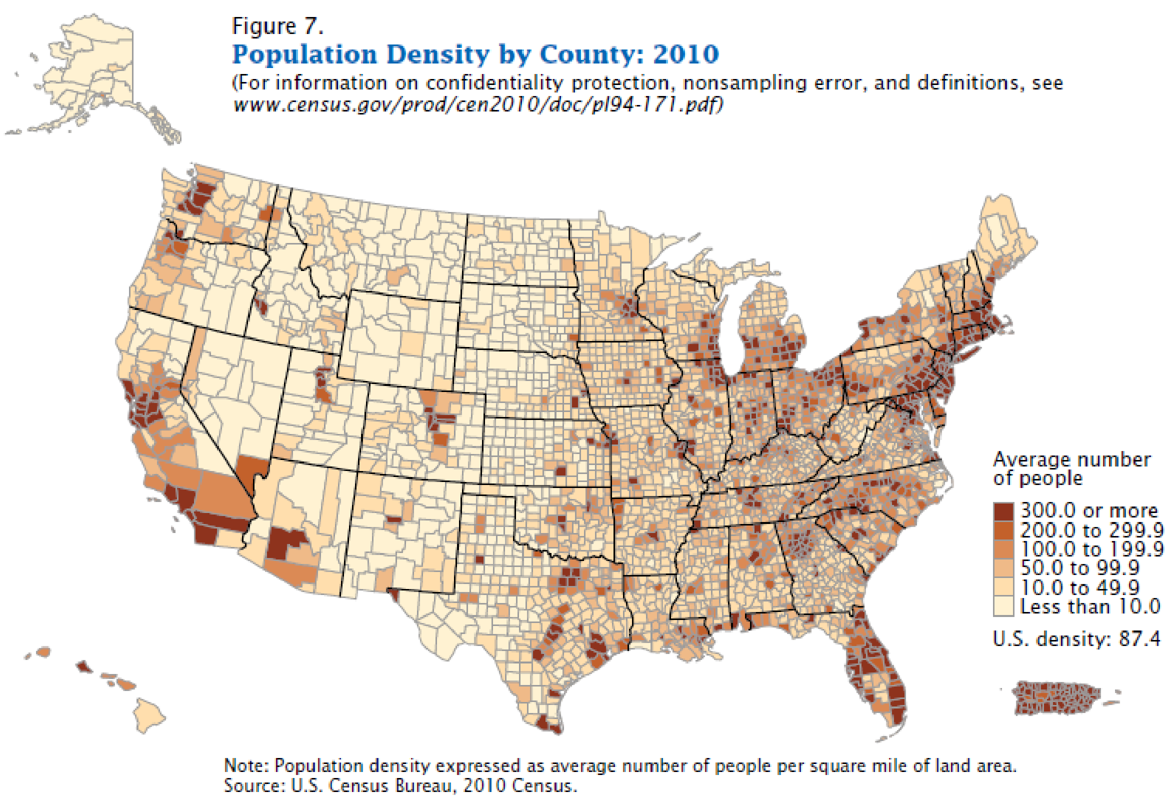

Figure 3-3 2010 U.S. Population Density by County
(Source: USCB, 2010)

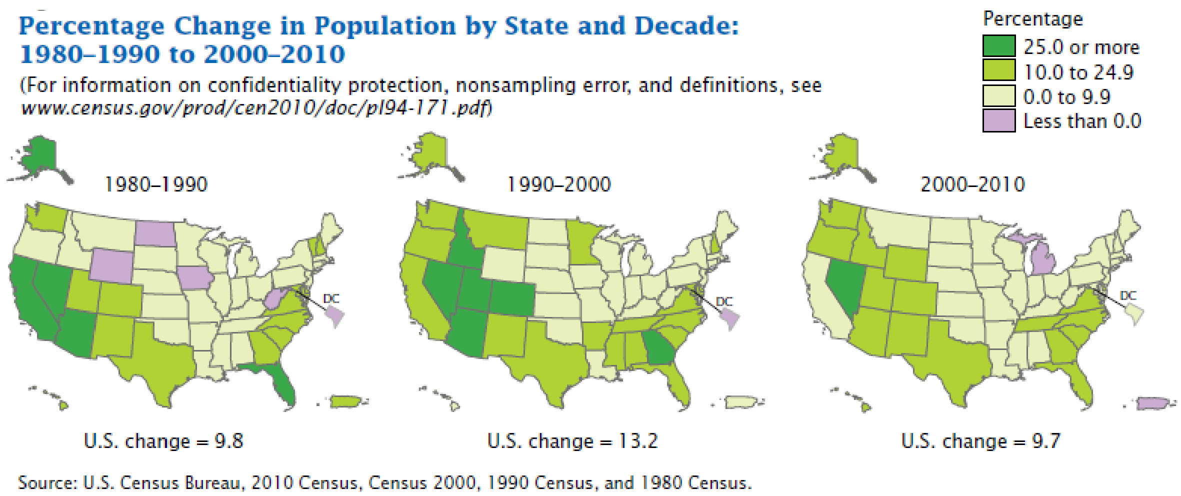

Figure 3-4 Change in Population by Decade from 1980 to 2010
(Source: Mackun and Wilson, 2011)

Table 3-3 Ten Fastest Growing Metropolitan Areas from 2000 to 2010

Metropolitan Area	2000 Population	2010 Population	Percent Change
Palm Coast, FL	49,832	95,656	92.0
St. George, UT	90,354	138,115	52.9
Las Vegas-Paradise, NV	1,375,765	1,951,269	41.8
Raleigh-Cary, NC	797,071	1,130,490	41.8
Cape Coral-Fort Myers, FL	440,888	618,754	40.3
Provo-Orem, UT	376,774	526,810	39.8
Greeley, CO	180,926	252,825	39.7
Austin-Round Rock-San Marcos, TX	1,249,763	1,716,289	37.3
Myrtle Beach-North Myrtle Beach-Conway, SC	196,629	269,291	37.0
Bend, OR	115,367	157,733	36.7

Source: Mackun and Wilson, 2011.

Some communities are expected to have more transient populations than others. These are often associated with regional tourist and recreational activities, sporting events, weekend and summer homes, or populations of students who attend regional colleges and other educational institutions. Coastal regions especially may have summer, weekend, and retirement populations and a range of recreational and environmental amenities that attract visitors from nearby metropolitan population centers. Other areas with mountain ranges offer specific outdoor recreational activities, such as skiing, that attract visitors. In addition to transient populations, communities in rural areas may also have varying numbers of migrant workers employed on a seasonal basis on farms and in factories that process farm produce. Transients and migrant workers are not fully characterized by census data, which generally captures only resident populations.

3.2.12.2 Economics

The study of economic structure examines employment and income because of their interrelationship and primary role in determining the economic well-being of an area. Information on median income by county is shown in Figure 3-5. The size and availability of the potential workforce could vary considerably depending on the type and capacity of a potential SNF reprocessing facility and its location. In rural or low population communities, permanent jobs associated with a commercial SNF reprocessing facility would provide employment for a substantial portion of the local work force, although the availability of such a workforce in such areas would be limited. Larger, appropriately skilled workforces may be available at DOE site locations and to a lesser extent in industrial site areas.

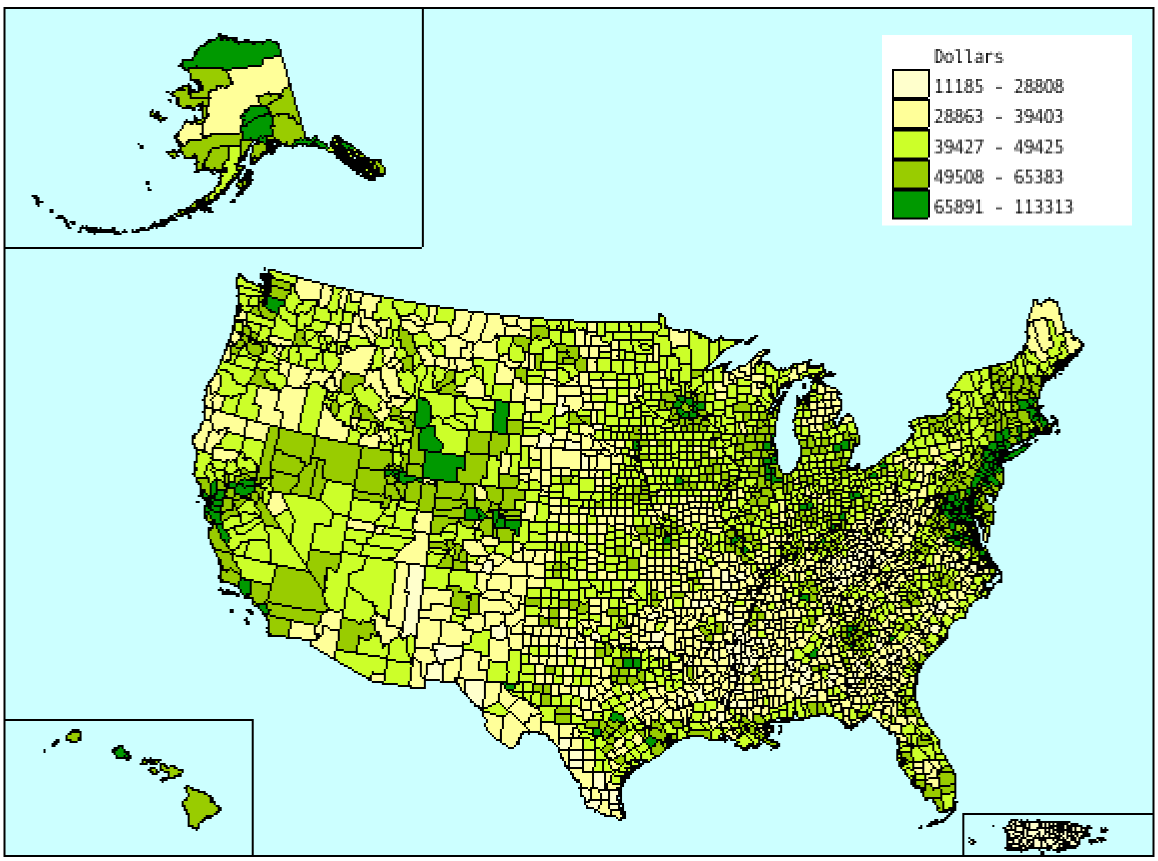

Figure 3-5 Median Household Income by County (in 2009 Inflation-Adjusted Dollars)
(Source: USCB, 2009a)

In addition to a permanent work force, many nonpermanent personnel would be required for various tasks that occur during preconstruction, construction, or major refurbishments. These temporary personnel would be in the local community only a short time, but during these periods of extensive activity, the additional personnel could have a substantial effect on the local economics. DOE facilities and installations that may serve as locations for a commercial SNF reprocessing facility are generally large and complex facilities, with a potential direct workforce (both skilled and unskilled labor) in the thousands. As a result, these kinds of potential host facilities are typically among the largest employers in any given area, and the surrounding communities may be home to a potentially substantial indirect workforce of subcontractors and consulting organizations that support activities at the facility. Although the land is developed (and therefore disturbed), commercial industrial sites tend to be smaller, perhaps 1,300 hectares (ha) (3,200 acres (ac)) or less, compared to DOE facilities and installations (DOE, 2008). As a result, the infrastructure tends to be less developed with respect to nuclear activities, and the labor force would be likely to be smaller and not contain as many workers with nuclear training.

The capital cost of constructing an SNF reprocessing facility would be high. Many of the industries that provide equipment and services important to heavy construction operations are largely absent in rural areas, which have smaller, less diversified labor markets, with often lower skilled, lower paying occupations. In addition to agriculture and related activities, in some rural locations there may also be a range of other activities, including resource extraction, manufacturing, and transportation industries that provide employment and income. In semi-urban areas, where economic structures are more complex than in rural areas, there is a wider range of industries and larger and more diverse labor markets. Semi-urban areas may also serve specialized economic functions, including maritime shipping, fishing, boatbuilding, recreation, and tourism and numerous locations featuring residential areas hosting second homes and retirement communities.

The employment structure in the nuclear industry could be affected on a national level. Licensing an SNF reprocessing facility would require a number of staff knowledgeable about the technical and regulatory aspects of spent fuel reprocessing facility design and operation. The design and operation of a reprocessing facility would be particularly challenging because staff members trained as nuclear chemical operators and engineers are required. With the virtual disappearance of work in the civilian nuclear fuel cycle in the 1976-1985 timeframe and the cessation of defense reprocessing activities in the following decade, workers moved into other areas and most have now retired with their expertise not having been replaced because there has been little demand. While the Nuclear Navy continues to offer a good supply of reactor operators, there is no parallel source for nuclear chemical operators (such as those needed for an SNF reprocessing facility), who usually have an associate degree and are then trained on the job. Nuclear chemical engineers historically have had an undergraduate degree in chemical engineering and obtained graduate degrees in nuclear engineering and then practical experience on the job. Unfortunately, nuclear chemical engineering programs have been drastically reduced or eliminated, and many of the faculty that taught this subject have retired. Organizations performing spent fuel reprocessing research and development, designing and operating an SNF reprocessing facility, and regulating the facility will be seeking this same expertise, especially that of nuclear chemical engineers, thus exacerbating the supply-demand imbalance for this very limited expertise.

3.2.12.3 Housing

Housing markets in the vicinities of a potential SNF reprocessing facility sites also may vary considerably, with ranges in the number of housing units and the type and quality of housing. Much of the variation is related to the nature of the economy in which the facility would be located, particularly regional population and income levels; proximity to metropolitan areas; and the importance of recreation, tourism, second homes, and retirement communities. Although housing demand in a local community is related to the number of permanently employed workers, there may be significant variation in housing demand when temporary workers occupy vacant rental accommodations, thus affecting local and regional vacancy rates for this type of housing. Where suitable housing is not available, some workers may occupy motels and other temporary accommodations, including housing provided onsite at some government or commercial facilities.

A commercial SNF reprocessing facility potentially located in a rural community, where traditional employment is in agriculture, may experience relatively small housing markets (i.e., low housing availability), stable prices for most types of housing, lower median house values, and moderate and stable vacancy rates. If there is a large differential between facility employee earnings and average regional earnings, nuclear industry workers may occupy housing with a higher price than the regional median price. Limits to housing growth are less likely in rural communities. In semi-urban regions, housing markets are likely to change more rapidly with suburban and exurban population growth near metropolitan areas, including influxes of temporary populations to support recreational and tourist activities and the development of retirement communities. Development of a commercial SNF reprocessing facility in a semi-urban area could potentially produce more housing turnover, higher prices for most types of housing, and lower vacancy rates. Given a scenario of a smaller differential between reprocessing employee earnings and average earnings in a semi-urban area, SNF reprocessing-related workers may occupy housing with prices close to the regional median price. Controls on housing development are more likely in semi-urban communities, particularly where there is a transient seasonal population.

3.2.12.4 Public Services

If an SNF reprocessing facility was constructed on property not already generating property taxes, local and State government entities would benefit from property taxes generated from the facility. Local and State government entities would also collect income taxes from workers at a SNF reprocessing facility. Tax types and rates would be dependent on local and State taxation laws, and revenues would vary depending on the number of employees required by the reprocessing plant. Tax revenues may be used by local, regional, and State governmental entities to fund education, public safety, local government services, and transportation. In smaller rural communities, tax revenues can affect the level and quality of public services available to local residents.

3.2.13 Environmental Justice

3.2.13.1 Overview

Environmental justice refers to a Federal policy that ensures that minority, low-income, and tribal communities that have historically been excluded from environmental decision-making are given equal opportunities to participate in decision-making processes. Executive Order 12898, § 1-101, February 11, 1994, directs Federal executive agencies to make achieving EJ part of their missions by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations (59 FR 7629). Although it is not subject to the executive order, the NRC has committed to conduct EJ reviews for certain actions (69 FR 52040). In the licensing process for an SNF reprocessing facility, the NRC would include an analysis of effects on low-income and minority populations to analyze whether disproportionately high and adverse effects of an action could have EJ implications. EJ impacts may include effects on health, ecological resources, water quality, water availability, or social, cultural, economic, or aesthetic resources.

The Council of Environmental Quality (CEQ) provides the following approach to consider EJ within compliance process for the National Environmental Policy Act of 1969, as amended (NEPA), in "Environmental Justice: Guidance Under the National Environmental Policy Act" (CEQ, 1997):

- Disproportionately High and Adverse Human Health Effects-- Adverse health effects are measured in risks and rates that could result in latent cancer fatalities, as well as other fatal or nonfatal adverse impacts on human health. Adverse health effects may include bodily impairment, infirmity, illness, or death. Disproportionately high and adverse human health effects occur when the risk or rate of exposure to an environmental hazard for a minority or low-income population is significant (as defined by CEQ) and appreciably exceeds the risk or exposure rate for the general population or for another appropriate comparison group.

- Disproportionately High and Adverse Environmental Effects-- A disproportionately high environmental impact that is significant (as defined by CEQ) refers to an impact or risk of an impact on the natural or physical environment in a low-income or minority community that appreciably exceeds the environmental impact on the larger community. Such effects may include ecological, cultural, human health, economic, or social impacts. An adverse environmental impact is an impact that is determined to be both harmful and significant (as defined by CEQ). In assessing cultural and aesthetic environmental impacts, impacts that uniquely affect geographically dislocated or dispersed minority or low-income populations or American Indian tribes are considered.

According to CEQ, a minority population is identified as consisting of individuals who are American Indian or Alaskan Native, Asian or Pacific Islander, Black (not of Hispanic origin), or Hispanic; and a low-income population is identified in comparison to statistical poverty thresholds identified in U.S. Census Bureau (USCB) information. To identify minority or low-income populations, NRC guidance (NRC, 2003) recommends (1) gathering demographic and socioeconomic data for the immediate site and surrounding communities to identify minority or low-income populations, and (2) comparing the census block group percentage of minority populations and economically stressed households in the area for assessment to the state and county percentages. Affected populations are considered those who reside within an 80-km (50-mi) radius of an action (i.e., the ROI). This analysis ensures consideration of an adequate sample of the surrounding population, because the goal of EJ analysis is to evaluate the communities, neighborhoods, or areas that may be disproportionately affected. Once that is complete, it is possible to determine whether the effects disproportionately impact the minority or low-income populations.

Facilities could potentially be surrounded by a range of low to high density census block groups with low to high numbers of minority or low-income residents. Minority residents are of special concern because their behaviors may cause higher exposures to environmental contaminants; they may do more subsistence fishing, for example, and thus be more affected by water pollution. Residents of a region who are both a minority and have incomes below the poverty line are of particular concern from an EJ perspective.

Employing a geographic information system and census data to identify minority and low-income populations, demographic and geographic characteristics of potential hosting sites provide general descriptions of potentially affected environments related to EJ. The presence of minority and low-income individuals located within 80 km (50 mi) of a potential hosting site could vary considerably depending on the proximity to larger communities, the location of Native American tribal lands, historical population trends in the region, and the nature of regional economic activity. Typically, rural areas in the southern and southwestern United States are more likely to have larger minority populations (NRC, 2009). Figure 3-6 depicts the highest percentage of minority populations (expressed by lighter colors) in the U.S. along the California coast line, most of the southwest states (Arizona, New Mexico, and Texas), the gulf coast states, and the mid-Atlantic states. Figure 3-7 follows a similar pattern of populations living below the poverty level (expressed by darker colors). Sites closer to metropolitan areas may have both larger minority populations and larger low-income populations (NRC, 2009). From 2000 to 2010, more than half of the growth in total population of the United States, approximately 15.2 million persons, was from the Hispanic population, while the White non-Hispanic population declined by 5 percent of the total population (Humes, et al., 2011).

Based on broad regional observations, potential sensitive minority and low-income populations from which potential EJ effects could be identified could be broadly grouped into four regions; the northwest, southwest, Midwest, and southeast. Based on the national distribution of minority and low-income populations, the potential that an SNF reprocessing facility would be located near potential sensitive minority and low-income populations is more likely to occur in the southwest and southeast. However, site-specific information is needed to accurately identify potential sensitive minority and low-income populations.

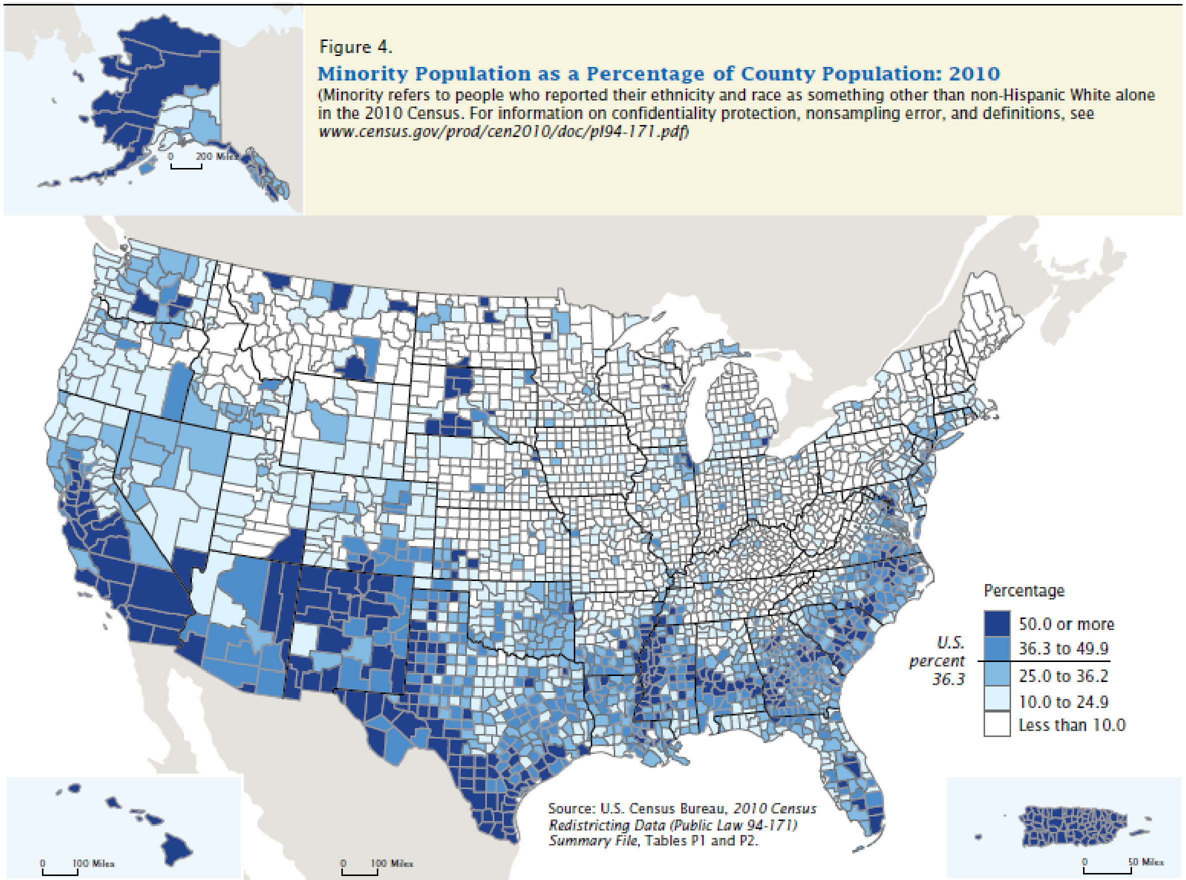

Figure 3-6 2010 Minority Population as a Percentage of County Population
(Source: Humes, et al., 2011)

3.2.13.2 Subsistence Consumption of Fish and Wildlife

Section 4-4 of Executive Order 12898 directs Federal agencies, whenever practical and appropriate, to collect and analyze information on the consumption patterns of populations who rely principally on fish or wildlife for subsistence and to communicate the risks of these consumption patterns to the public. Consideration is given to whether there are any ways in which minority or low-income populations could be disproportionately affected by examining effects on American Indian, Hispanic, and other traditional-lifestyle, special-pathway receptors. Special pathways take into account the levels of contamination in native vegetation, crops, soils and sediments, surface water, fish, and game animals on or near power plant sites in order to assess the risk of radiological exposure through subsistence consumption of fish, native vegetation, surface water, sediment, and local produce; the absorption of contaminants in sediments through the skin; and the inhalation of airborne particulate matter.

The identification of special-pathway receptors can be important in an EJ analysis because consumption patterns may reflect the traditional or cultural practices of minority and low-income populations in the area. Aquatic pathways generally include fish, surface water, and sediment,

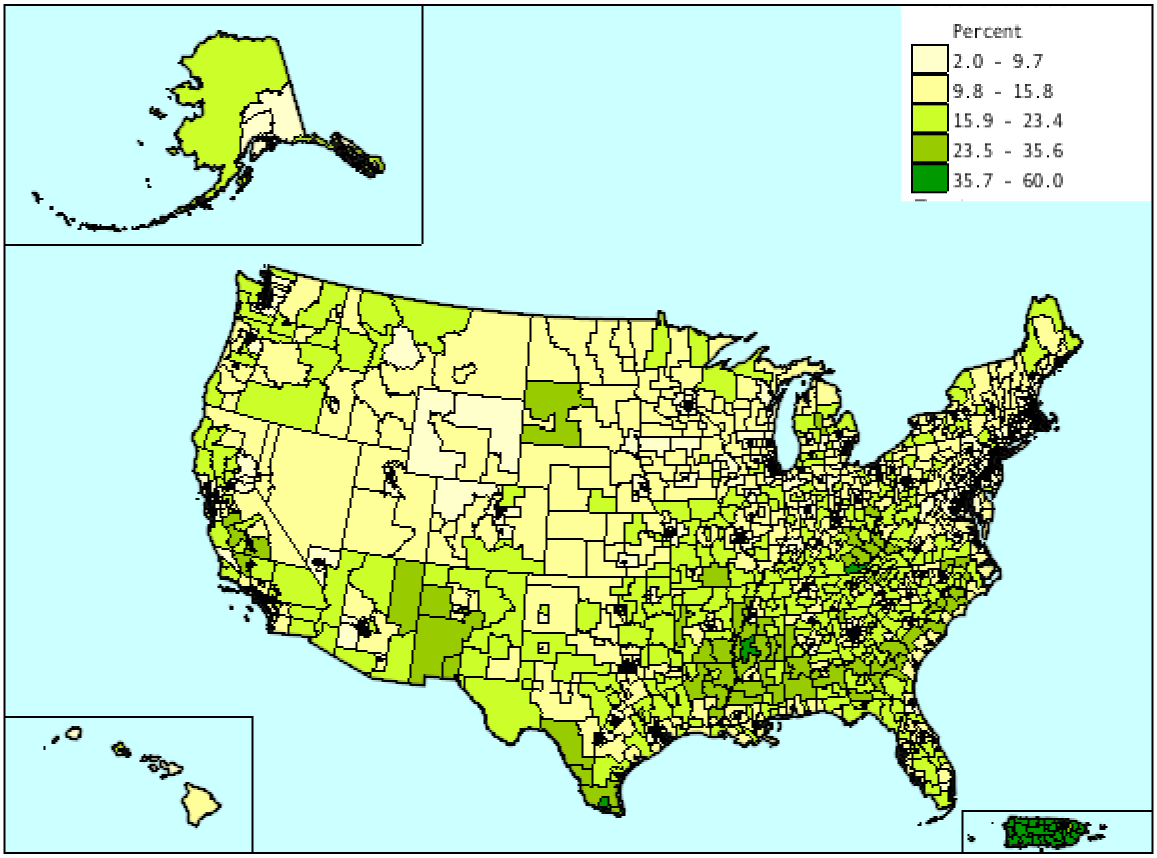

Figure 3-7 Percent of People Below Poverty Level in the Past 12 Months (2009 Estimate)
(Source: USCB, 2009b)

while terrestrial pathways include airborne particulates, radioiodine, milk, food products, crops, and direct radiation. Terrestrial pathways generally include native vegetation, crops, soils, sediment, and game animals. (NRC, 2009)

Nuclear facilities and installations that could serve as potential host sites for a reprocessing facility have comprehensive radiological environmental monitoring programs in place to assess the effect of site operations on the environment. Samples are collected from the aquatic and terrestrial pathways applicable to the site.

3.2.13.3 Health Preconditions and Special Circumstances of Minority and Low-income Populations

During the scoping process for an SNF reprocessing facility, the NRC staff may identify special socioeconomic and health circumstances and potential pathways for disproportionate health and environmental effects. Data may be gathered on mortality statistics of minority populations in the ROI. When examining the data, the staff may find that there is evidence that certain populations in the ROI are less healthy than other comparable populations or if a population is more vulnerable to diseases. However, site-specific information is needed to determine the potentially affected environment regarding health preconditions and special circumstances (NRC, 2009).

3.2.13.4 Migrant Populations

Migrant workers can be members of low-income or minority populations. Because they travel and can spend a significant amount of time in an area without being actual residents, migrant workers may be unavailable for counting by census takers. The USCB defines a migrant worker as an individual employed in the agricultural industry in a seasonal or temporary nature and who is required to be absent overnight from his or her permanent place of residence. From an EJ perspective, there is a potential for such groups in some circumstances to be disproportionately affected by emissions in the environment (NRC, 2009).

During the scoping process for an SNF fuel reprocessing facility, the NRC staff may identify significant concentrations of migrant workers within the ROI. Agricultural activities in the southeast and mid-Atlantic have traditionally been concentrated on tobacco, corn, soy beans, and cotton. Typically, none of these products require the intensive applications of migrant labor. However, citrus fruit trees harvested in the southeast (Florida) traditionally do require migrant labor. Regardless of the region, site-specific information is needed to determine the potentially affected environment regarding migrant workers.

3.3 References

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4 POTENTIAL ENVIRONMENTAL-RELATED CONSIDERATIONS FOR U.S. COMMERCIAL SPENT NUCLEAR FUEL REPROCESSING FACILITY PROJECTS

4.1 Introduction

Potential environmental-related considerations associated with preconstruction, construction, operation, and decommissioning of potential commercial spent nuclear fuel (SNF) reprocessing facilities are discussed in this chapter. These potential environmental-related considerations include environmental factors and information that the U.S. Nuclear Regulatory Commission (NRC) staff could take into account in preparing an environmental assessment (EA), or environmental impact statement (EIS) if necessary, for the future rulemaking for licensing and regulating commercial SNF reprocessing facilities.

4.1.1 Scope of the Analysis

This section discusses the factors that define the scope of the discussions and analysis in this chapter. These include the general considerations for the scope and approach, the resource areas evaluated, the key characteristics of the three site types that form the generalized baseline environmental settings for the analysis, consideration of potential co-location of reprocessing facilities with other nuclear facilities, and the treatment of potential environmental-related considerations from preconstruction and construction.

4.1.1.1 General Considerations and Approach

As discussed in Section 1.2 of this report, because this Environmental Topical Report (ETR) is for potential U.S. commercial SNF reprocessing facilities, no commercial reprocessing facilities are currently operating in the United States, and only limited information on commercial reprocessing facilities in other countries is in the public record, no detailed plant- and site-specific information is available upon which to base the discussions and analyses in this chapter. Furthermore, the exact nature and scope of the proposed rulemaking has not yet been finalized and, therefore, specific design and siting requirements for any future reprocessing facilities in the U.S. have not been established. Thus, the potential reprocessing-related environmental considerations and issues presented in this chapter are neither project- nor location-specific; and instead, this chapter identifies and describes potential environmental-related considerations roughly based on the Plutonium-Uranium Extraction (PUREX) reprocessing technology (described in Section 2.3 of this report), at potential generic PUREX reprocessing facilities that could be located at each of the three generalized types, or categories, of sites--rural site, industrial site, and U.S. Department of Energy (DOE) site. These three site types represent a range of potential environments for commercial reprocessing facilities.

Additionally, consistent with generic, non-location-specific PUREX process-based reprocessing facilities (as described in Section 4.1.1) upon which this ETR is based, the discussions and analyses presented in this chapter are preliminary, high level, generic, and largely qualitative; and this chapter cannot provide exhaustive information or be all inclusive. To the extent possible, this chapter concentrates on a broad range of potentially important, anticipated environmental-related considerations and issues, within the contexts of generalized, potential environmental settings, on which a future EA or EIS for the proposed reprocessing rulemaking might be focused, but does not speculate on their significance or provide any conclusions or recommendations.

Furthermore, it is reasonably assumed for purposes of this report that new commercial SNF reprocessing facilities would consist entirely of newly constructed buildings and other structures and appurtenances, and that no existing buildings or facilities would be used. This assumption results in precluding potential impacts, for example, from reuse of buildings at DOE or industrial sites that may be contaminated with radioactive or hazardous materials causing worker exposures and requiring cleanup prior to use of such facilities for SNF reprocessing.

Finally, for the most part, management or mitigation of potential adverse environmental effects is not considered in the generic discussions in this chapter as such measures would be highly site-, project-, and design-specific. However, for future reference, examples of such measures are identified and described in general terms in Chapter 5.

4.1.1.2 Resource Areas Evaluated

Potential environmental-related considerations and issues for potential U.S. commercial SNF reprocessing facilities are identified and discussed for the following resource areas:

- Land Use and Site Infrastructure
- Transportation
- Geology and Soils
- Water Resources (Water Use and Water Quality)
- Air Quality
- Noise
- Ecological Resources
- Waste Management
- Historic and Cultural Resources
- Visual and Scenic Resources
- Public and Occupational Health (Radiological and Non-radiological)
- Socioeconomics
- Environmental Justice

In addition, greenhouse gas (GHG) emissions potentially associated with a commercial SNF reprocessing facility are addressed. Environmental-related considerations for postulated accidents potentially associated with reprocessing are described in Chapter 6.

Note that the analysis to identify potential environmental-related considerations for certain resource areas—e.g., geology and soils, water resources, air quality--does not readily conform to the rural, industrial, and DOE site categories. As indicated in Chapter 3, the affected environments associated with these resource areas are highly variable for these site types across the different regions of the country and are highly site-specific. For example, the geologic environments for rural sites across the U.S. are highly dependent upon specific site location (i.e., different sites would be located in difference geologic provinces). Consequently, the discussions for these resource areas are based on general process- and site-related considerations rather than on general environmental conditions within the three site types.

4.1.1.3 Generalized Environmental Settings (Site Types)

The key characteristics of the three site types that form the generalized baseline environmental settings (affected environments) in this ETR are summarized below. These site types and environmental issues associated with them are further described in Chapter 3.

4.1.1.3.1 Rural Site

The rural environment is generally free from prior industrial or heavy commercial activity. Consequently, it is assumed that electrical power lines, water and sewer, and roadways, railways, or barge access necessary to support industrial activity would need to be constructed. Radiological and non-radiological discharges or effluents associated with industrial or heavy commercial activity have not affected the air quality, water quality, and soil in this environment.

4.1.1.3.2 Industrial Site

The industrial environment has been previously developed for non-nuclear industrial or heavy commercial activity. Electrical power lines, water and sewer, and roadways, railways, or barge access necessary to support industrial activity already exist. Non-radiological discharges or effluents associated with industrial or heavy commercial activity may have affected air quality, water quality, and soil. There have been no radiological discharges or effluents that would have affected this environment, although there may have been releases of hazardous materials to the environment.

4.1.1.3.3 DOE Site

A “DOE site” is one at which past and present DOE operations have occurred, and at which a potential SNF reprocessing facility might be co-located. Such sites may also accommodate other privately owned and operated facilities co-located with DOE operations, which may be existing or planned.

The DOE site environment has been previously developed for nuclear and non-nuclear research, industrial, or testing activities. Thus, environmental conditions may be somewhat similar those at industrial sites, as described above, except that it is likely that radioactive materials were handled, used, and possibly disposed of at DOE nuclear sites. Electrical power lines, water and sewer, and roadways, railways, or barge access necessary to support industrial activity already exist. Radiological and non-radiological discharges or effluents associated with DOE site activities may have affected air quality, water quality, and soil in this environment. Note, however, that some DOE sites are very large and may include significantly sized undeveloped areas with environmental conditions and characteristics similar to rural site types, as described above.

4.1.1.4 Consideration of Potential Co-location with Other Nuclear Facilities

The NRC staff recognizes that for reasons such as efficiency and to minimize costs and risks associated with the transport of high activity nuclear materials, SNF reprocessing facilities could be co-located with other nuclear facilities with purposes or operations directly related to SNF reprocessing. Such related nuclear facilities may include:

- Commercial nuclear power plants
- Independent spent fuel storage installations (ISFSIs) or monitored retrievable storage (MRS) installations for storage of SNF or HLW
- Reprocessed uranium enrichment facilities
- Enriched uranium or mixed oxide (MOX) nuclear fuel fabrication facilities.

Such co-located facilities may already exist at potential reprocessing facility sites or may be constructed concurrent with or following reprocessing facility construction. If regulated by the NRC, these facilities may be licensed by the NRC under a single license, or each of these facilities may be licensed separately and at different times. As discussed in Section 4.1.1.3.3, such co-location could occur at DOE sites with both existing and future nuclear facilities (with both related and unrelated functions), although it could also occur at rural and non-DOE industrial sites (although more likely with related nuclear facilities at such locations).

At this time, it would be difficult to predict in what forms and at what locations, if any, the co-location of SNF reprocessing facilities with other types of nuclear facilities, both related and unrelated, may occur. Many facility combinations and potential locations are possible, resulting in a multitude of factors that would need to be considered. Further, as discussed below, the timing and interrelationships of potential co-located facilities would be a significant factor relating to how the potential environmental effects of such projects would be addressed in an environmental effects document.

For example, NRC-regulated, concurrently licensed, co-located nuclear facilities may be considered a single action or connected actions depending on whether they are licensed together as a single entity or separately but within approximately the same timeframe, respectively. For such single or connected actions, the potential direct and indirect environmental effects of the SNF reprocessing facility and any co-located nuclear facility or facilities may be considered together in an environmental evaluation. However, in the case of co-located facilities that are licensed and constructed at different times, assuming that the SNF reprocessing facility is licensed first, the facility co-located with the SNF reprocessing facility may be considered as a separate, but reasonably foreseeable future action; and the evaluation of potential environmental effects of the reprocessing facility project may be addressed within the context of cumulative effects, in that the evaluation would consider the potential effects of the co-located projects separately but would take into account the incremental effects of the reprocessing project when added to the effects of the co-located project(s) and any other past, present, and reasonably foreseeable future actions, if any. Considerations regarding potential cumulative environmental effects are further discussed in Section 4.4.

Consequently, in consideration of the above issues and complications, potential environmental-related considerations associated with the possible co-location of SNF reprocessing facilities with other nuclear facilities is not addressed in any detail within the limited scope of this high-level, generic, qualitative report.

4.1.1.5 Treatment of Potential Environmental-related Considerations from Preconstruction and Construction

Before moving on to the discussions of potential environmental-related considerations in this chapter, it is important to understand the distinction that the NRC makes between "preconstruction" and "construction" of commercial nuclear facilities, with regard to how the NRC defines these activities.

4.1.1.5.1 Definition of Construction and Preconstruction

Construction

In 10 CFR 51.4, the NRC provides the following definition of "construction":

> ***Construction* means:**
>
> (1) For production[1] and utilization facilities, the activities in paragraph (1)(i) of this definition, and does not mean the activities in paragraph (1)(ii) of this definition.
>
> > (i) Activities constituting construction are the driving of piles, subsurface preparation, placement of backfill, concrete, or permanent retaining walls within an excavation, installation of foundations, or in-place assembly, erection, fabrication, or testing, which are for:
> >
> > > (A) Safety-related structures, systems, or components (SSCs) of a facility, as defined in 10 CFR 50.2;
> > >
> > > (B) SSCs relied upon to mitigate accidents or transients or used in plant emergency operating procedures;

[1] As discussed in Section 1.1 of this report, based on language in the Atomic Energy Act of 1954, as amended, spent nuclear fuel (SNF) reprocessing facilities are considered production facilities, as they are designed and used for the separation of the isotopes of plutonium and for the processing of irradiated materials containing special nuclear material.

(C) SSCs whose failure could prevent safety-related SSCs from fulfilling their safety-related function;

(D) SSCs whose failure could cause a reactor scram or actuation of a safety-related system;

(E) SSCs necessary to comply with 10 CFR Part 73;

(F) SSCs necessary to comply with 10 CFR 50.48 and criterion 3 of 10 CFR Part 50, Appendix A; and

(G) Onsite emergency facilities (*i.e.*, technical support and operations support centers), necessary to comply with 10 CFR 50.47 and 10 CFR Part 50, Appendix E.

(ii) **Construction does not include:**

(A) Changes for temporary use of the land for public recreational purposes;

(B) Site exploration, including necessary borings to determine foundation conditions or other preconstruction monitoring to establish background information related to the suitability of the site, the environmental impacts of construction or operation, or the protection of environmental values;

(C) Preparation of a site for construction of a facility, including clearing of the site, grading, installation of drainage, erosion and other environmental mitigation measures, and construction of temporary roads and borrow areas;

(D) Erection of fences and other access control measures that are not safety or security related, and do not pertain to radiological controls;

(E) Excavation;

(F) Erection of support buildings (*e.g.*, construction equipment storage sheds, warehouse and shop facilities, utilities, concrete mixing plants, docking and unloading facilities, and office buildings) for use in connection with the construction of the facility;

(G) Building of service facilities (*e.g.*, paved roads, parking lots, railroad spurs, exterior utility and lighting systems, potable water systems, sanitary sewerage treatment facilities, and transmission lines);

(H) Procurement or fabrication of components or portions of the proposed facility occurring at other than the final, in-place location at the facility;

(I) Manufacture of a nuclear power reactor under a manufacturing license under subpart F of part 52 of this chapter to be installed at the proposed site and to be part of the proposed facility; or

(J) With respect to production or utilization facilities, other than testing facilities and nuclear power plants, required to be licensed under Section 104.a or Section 104.c of the Act, the erection of buildings which will be used for activities other than operation of a facility and which may also be used to house a facility (e.g., the construction of a college laboratory building with space for installation of a training reactor).

[*Construction* also means:]

(2) For materials licenses[2], taking any site-preparation activity at the site of a facility subject to the regulations in 10 CFR Parts 30, 36, 40, and 70 that has a reasonable nexus to radiological health and safety or the common defense and security; provided, however, that construction does not mean:

(i) Those actions or activities listed in paragraphs (1)(ii)(A)–(H) of this definition; or

(ii) Taking any other action that has no reasonable nexus to radiological health and safety or the common defense and security.

(Emphasis in boldface type added above.)

Note that not all of the elements that are included in the above definition of what *"construction means"* may apply to construction of potential commercial SNF reprocessing facilities. However, they do all have "a nexus to radiological health and safety or the common defense and security," which is consistent with the NRC's mission: *"To license and regulate the nation's civilian use of byproduct, source, and special nuclear materials in order to ensure the adequate protection of public health and safety, promote the common defense and security, and to protect the environment."* Thus, part of the NRC's mission is to license and regulate construction (as defined above) of commercial nuclear facilities (including SNF reprocessing facilities, among others) that are within its jurisdictional authority.

[2] If as discussed in Section 1.1 of Chapter 1, if commercial SNF reprocessing facilities are licensed and regulated under a new 10 CFR Part 7X, then the licenses for these facilities would be materials licenses.

Preconstruction

"Preconstruction" includes certain construction-related activities (such as certain site preparation activities) that are not included in the NRC's definition of what *"construction means"* in 10 CFR 51.4(1)(i) and 10 CFR 51.4(2) shown above. Preconstruction includes those activities identified in the definition of *"construction does not mean"* in 10 CFR 51.4(1)(ii) shown above, although the term "preconstruction" is not specifically used in this regard in 10 CFR 51.4. Thus, preconstruction comprises activities that do not have "a nexus to radiological health and safety or the common defense and security" and, therefore, are not licensed or regulated by the NRC because they are not within the NRC's jurisdictional authority.

4.1.1.5.2 Treatment of Preconstruction and Construction in this ETR

For the purposes of this ETR, potential environmental-related considerations and issues for preconstruction and construction of potential commercial SNF reprocessing facilities are discussed together since they would likely be closely related, and are not distinguished from each other in Section 4.2 for each of the resource areas considered.

4.1.2 Chapter Organization

Discussions in this chapter of potential environmental-related considerations for potential U.S. commercial SNF reprocessing facilities are organized as follows. Section 4.2 discusses potential environmental-related considerations for preconstruction, construction and operation of potential reprocessing facilities. Section 4.3 discusses potential environmental-related considerations for facility decontamination and decommissioning. Section 4.4 addresses preliminary considerations for potential cumulative environmental effects. Finally, Section 4.5 addresses preliminary considerations regarding GHG emissions associated with SNF reprocessing facilities.

4.2 Potential Environmental-Related Considerations for Preconstruction, Construction, and Facility Operation

This section describes potential environmental-related considerations for preconstruction, construction, and operation of potential commercial SNF reprocessing facilities for each of the resource areas.

4.2.1 Land Use and Site Infrastructure

4.2.1.1 Preconstruction and Construction

4.2.1.1.1 Land Use

Preconstruction and construction of an SNF reprocessing facility may affect land use patterns due to the large spatial size of the facility and necessary buffer areas for safety and security that would likely be required for that type of plant. Specific effects would depend on the types of land use occurring in and around the facility site prior to site development. Regardless of location, development of such a facility must be consistent with local zoning requirements.

Preconstruction could involve considerable site preparation (e.g., land clearing, grading, blasting, road construction), and construction would include erection of a number of buildings. All of these activities would contribute to land disturbance. Structures that would be constructed may include a fuel receiving and storage building, the main processing building, and assorted auxiliary buildings and appurtenances. Additionally, an applicant for a license for such a facility may restrict existing land uses prior to commencement of preconstruction and construction activities, over all or parts of the affected property.

Preconstruction and construction of an SNF reprocessing facility would result in permanent surface disturbance of an area equal to the size of the footprint of the facility for the duration of the licensing and facility decommissioning period (assuming that the plant site would be restored to its original condition at the end of this period). For example, the Sellafield and La Hague reprocessing facilities cover areas of 285 hectares (ha) (700 acres (ac)) and 300 ha (750 ac), respectively (Sellafield Ltd, 2012; Hylko, 2008). Additional land area could be temporarily disturbed if it were to be utilized as a staging area for preconstruction- and construction-related equipment, materials, and activities.

In rural areas, it may be necessary to build access roads, railroad lines, or barge access facilities to allow transportation to and from the facility (during preconstruction and construction or facility operation), and electric transmission lines to bring power to the facility. This could alter land use patterns onsite as well as over an area much larger than that of the facility itself (see further discussion below under Site Infrastructure). Any agricultural and grazing lands that may exist in rural settings would be subject to changes in land use patterns because the property would be fenced and not available for previous uses. However, in rural areas where significant agricultural and grazing activities may be occurring over large land areas outside the SNF reprocessing facility property, the impact to these land uses would likely be limited.

Industrial sites and developed areas of certain DOE sites, by their very nature, may have already been subject to varying degrees of land disturbance and land repurposing. Land use patterns in and around such sites would generally be consistent with and support preconstruction and construction of an SNF reprocessing facility.

Some of the larger DOE sites that could accommodate a reprocessing facility contain large areas of undeveloped, rural-type lands in which a reprocessing facility might be constructed. Such areas may comprise agricultural, ranching, and forested and other natural environments, and potential environmental effects may be similar to those described above for non-DOE rural sites.

4.2.1.1.2 Site Infrastructure

Site infrastructure includes roads, railroads, barge transport, utilities, water services, sewage treatment, and waste management necessary for the operation of an SNF reprocessing facility.

Potential environmental related considerations related to roads, rail, and barge systems are discussed separately in Section 4.2.2 (Transportation). Water supply and water quality considerations and issues are discussed in Section 4.2.4 (Water Resources). Waste management considerations are discussed in Section 4.2.8.

Rural sites, as well as large rural site areas at some of the major DOE facilities, generally lack the infrastructure that would be necessary for operation of an SNF reprocessing facility and, therefore, would need to be installed during the preconstruction and construction phase of the project. Proposed reprocessing sites must be connected to electrical grids as well as to some type of surface water or groundwater sources. Access to wastewater treatment and waste management facilities would also be required. These connections would be in use throughout facility operation and decommissioning. All of these infrastructure extensions would have to meet zoning requirements, as applicable.

Industrial sites and the industrialized portions of certain DOE sites would likely be located in proximity to necessary infrastructure portals, and access for a reprocessing facility to local infrastructure portals would be relatively straightforward in such areas.

Regardless of whether a site is categorized as rural or industrial, connecting to infrastructure portals during the preconstruction and construction phase is anticipated to occur with little or no disruption to the local infrastructure network or services. While there may be temporary interruptions to services while connections are being established, these would be localized and short-term. Also, additional land areas needed for such infrastructure, such as for electrical transmission lines and waste and wastewater pipeline corridors, could be relatively small, especially in industrialized areas. Electrical transmission lines could be constructed in existing transmission line corridors or existing lines could be upgraded. Pipelines would be underground so land disturbances and disruptions associated with their construction would be temporary and short-term. There may be instances where new extended transmission line corridors may be needed or where they may cross significant resources such as parks and recreational areas, historic roads and trails, or other historic and cultural resources.

4.2.1.2 Facility Operation

Ongoing operations at a commercial SNF reprocessing facility would continue to affect land use patterns and infrastructure in the same manner as when altered during preconstruction and construction. The effects to both land use and infrastructure would last for the duration of the preconstruction, construction, and operation periods and facility decommissioning, and perhaps longer if the facility property is not restored to original condition and use.

Facility operation would restrict land use to SNF reprocessing, including facilities operating at rural, industrial, and DOE sites. Once connections to the local infrastructure have been established, it is anticipated that operations would occur with no noticeable disruptions to basic infrastructure services. Regardless of location at a rural, industrial, or DOE site, any additional stresses to local infrastructure services could likely be absorbed and managed, and facility operations would likely have a limited effect on the local infrastructure’s network or services.

4.2.2 Transportation

This section outlines environmental-related considerations for transportation associated with an SNF reprocessing facility project. There would be potential environmental effects associated with development of a transportation network, as well as with routine transportation[3] of preconstruction, construction, and operational workforces, SNF, construction materials and supplies, process chemicals, and process wastes to and from the facility. Routine transportation could also affect air quality, noise, and road surface wear. In addition, transporting radioactive and hazardous materials under any conditions could pose inherent risks to members of the public due to possible radiation or toxic chemical exposure during routine transportation or as a result of transportation accidents. Facilities and transporters that handle radioactive materials must comply with regulatory requirements and have standard operating procedures (SOPs) in place to minimize these risks and protect worker and public health and safety. Note that "radiation workers" involving in transportation (e.g., truck crews, package handlers, inspectors) are specially trained in, and knowledgeable of, necessary radiation safety requirements and procedures, and are monitored and have radiation exposure limits stipulated by NRC regulation in 10 CFR 20.1201.

The discussion in this section focuses on the following key transportation-related environmental issues:

- Transportation network development;
- Traffic volumes and levels of service (e.g., traffic congestion);
- Radiological effects on members of the public from routine, incident-free transport of radioactive materials; and
- Non-radiological and radiological effects on members of the public from transportation accidents.

4.2.2.1 Preconstruction and Construction

4.2.2.1.1 Transportation Network Development

A transportation network would be required during the preconstruction and construction period to bring construction workers, equipment, materials, and supplies to the site of a proposed SNF reprocessing facility and for the transportation of wastes from preconstruction and construction to offsite facilities. Access to a transportation network would also be required to receive shipments and forward finished product and wastes once the proposed facility becomes

[3] As used in this Environmental Topical Report, "routine transportation" takes place without incident. A transportation incident is any event that interferes with transportation between origin and destination. A transportation accident is an event that results in death, injury, or enough damage to an involved vehicle that the vehicle cannot move under its own power. All accidents are incidents.

operational and for facility workers to travel to and from the site, and this network would need to be developed, if not already in existence, during preconstruction and construction. Depending on facility location, the required transportation network may consist of roads, rail, and possibly barge transport at locations near navigable, commercial waterways.

In undeveloped, rural settings, connections or improvements may need to be made to existing transportation portals such as interstate highways, state roads and county roads, and main rail lines and spurs. For remote locations, this may require building lengthy road and railroad spur extensions that would span several miles. At industrial sites, it is likely that access to major roads, rail lines, and other transportation infrastructure already exists in relatively close proximity to the proposed reprocessing facility site. Proposed DOE sites may or may not have ready access to transportation networks depending on whether the reprocessing facility is to be located in a rural or industrialized zone of the DOE site, and depending on the general locations of the DOE sites relative to transportation networks supporting them.

4.2.2.1.2 Traffic Volumes and Levels of Service

Preconstruction and construction traffic-related environmental effects would last as long as the preconstruction and construction phase, which would over extend several years. At rural sites, preconstruction and construction is likely to result in a marked increase in truck traffic as well as traffic associated with commuting construction workers. Traffic volume increases of similar magnitude would occur at industrial sites and at DOE sites (both in industrial- and rural-type settings), although the percentage relative increase in traffic volume would be expected to be much smaller in industrialized areas (for both private industry and at DOE sites) due to the larger expected existing population densities and associated traffic volumes in industrial areas. Increased traffic volumes correlate directly with increased numbers of traffic accidents. Additionally, delivery of construction equipment and materials via local roads and increased commuter traffic would cause extra wear on roadways and increased road degradation along routes that are most heavily traveled. Incremental effects on interstate highways and other major roadways that already carry significant traffic volumes would likely be much less pronounced. These effects would occur over a period of several years, perhaps on the order of five to eight years, more or less, depending on factors such as facility size, construction scheduling, and phasing in of operations).

The magnitude of traffic impacts on roads in the vicinities of rural, industrial, and DOE sites during preconstruction and construction, as well as during facility operation, is dependent upon both the existing average daily traffic (ADT) and current level of service (LOS), and the increases in ADT and effects on LOS due to increased traffic from the reprocessing facility project. ADT refers to the average number of vehicles two-way passing a specific point in a 24-hour period. LOS is a system used to categorize traffic flow with corresponding safe driving conditions. LOS standards use the letters A through F, with A being the best and F being the worst. Category A describes free-flowing traffic while category F indicates a breakdown in vehicular flow or constant traffic jam. Assessment of effects on ADT and LOS requires quantitative analysis, which is not within the scope of the preliminary, qualitative analysis in the ETR.

Effects resulting from construction or improvements to rail or barge access, as well as use of these transportation modes during preconstruction and construction as well as facility operations, may also occur. These effects would be highly site specific and difficult to predict on a generic, non-location-specific basis as in this ETR.

4.2.2.1.3 Radiological Effects from Routine Transportation of Radioactive Materials

No radiological effects from routine transportation would be expected during preconstruction and construction since no radiological materials would be used in those activities. Radiological materials would not be brought onsite until the NRC authorized/licensed facility operations would be allowed to commence.

An exception would be if radiological materials from site remediation (e.g., contaminated soils) at radiologically-contaminated DOE sites were transported offsite for disposal. Radiological effects of routine transportation of such materials would be assed as discussed in Section 4.2.2.2.3.

4.2.2.1.4 Non-radiological and Radiological Effects from Transportation Accidents

Trucks carrying hazardous or radioactive materials or unloaded trucks are as likely to be involved in traffic accidents as any other similar heavy trucks. Potential non-radiological and radiological impacts of transportation accidents as a result of traffic collisions during the preconstruction and construction phase would be evaluated.

Non-radiological effects of transportation accidents may be measured in terms of the number of traffic accidents and the number of traffic accident fatalities involving both loaded and unloaded trucks. These potential effects may be estimated using tractor-trailer truck traffic accident and accident fatality rate information from U.S. Department of Transportation (USDOT) transportation statistics and the total distances driven with loaded and unloaded trucks. To put these estimated potential non-radiological impacts in perspective, the annual numbers of potential truck accidents and associated traffic accident fatalities may be compared with annual total numbers of tractor-trailer truck accidents and accident fatalities in the U.S., respectively, as reported by USDOT.

Non-radiological effects of transportation accidents may also be evaluated in terms of the exposure effects from releases of non-radiological hazardous materials to the environment as a result of accidents (e.g., from inhalation of gaseous releases). Environmental transport modeling (e.g., air dispersion modeling) may be employed in such analyses. Note, however, that only limited quantities of hazardous materials, e.g., fuels, lubricants, paints, would be expected to be transported during preconstruction and construction, thus limiting the anticipated extent of non-radiological effects from releases of these materials in accidents occurring during this phase of the project.

Again, no radiological effects from routine transportation would be expected during preconstruction and construction since no radiological materials would be used in those activities.

4.2.2.2 Facility Operation

4.2.2.2.1 Transportation Network Development

As discussed above, ready access to a comprehensive transportation network would be required for an SNF reprocessing facility, and this network as needed for facility operation would have been established during the preconstruction and construction phase. The facility must be able to receive various shipments of spent fuel, process chemicals, and other materials, and forward finished product as part of the overall operating process. Depending on location, such shipments could be made by road, rail, or barge. Additionally, workers must utilize local transportation routes, primarily roads in most cases, to access their place of employment.

4.2.2.2.2 Traffic Volumes and Levels of Service

During facility operations, transportation routes would experience increases in vehicle traffic over levels existing prior to facility development. For roadways, facility operations would result in an increase in ADT near the facility. For sites located in rural settings, the increase in ADT could be substantial. In industrial areas, major roads and rail lines likely already exist in relatively close proximity to the site; and industrial sites are also more likely to be located in areas of higher population density. Therefore, these sites may already experience elevated ADT, and any additional traffic associated with a reprocessing facility may be nominal. DOE site locations may have low or high ADT depending on whether they have existing access to transportation networks and whether the DOE site is located in a rural or developed industrialized area.

Operation of SNF reprocessing facilities at rural sites would likely result in marked increases in truck traffic as well as traffic associated with commuting workers. However, rural areas may exhibit better traffic flow and as such, may be better able to absorb additional truck traffic load. Increased truck and commuter traffic would also occur at industrial sites, and adverse impacts would likely be of greater magnitude than at rural sites since developed areas are often already characterized by impaired traffic flow. Therefore, increased traffic inputs in industrial areas would further degrade traffic flow. Additionally, increased truck traffic and employee commuting would cause extra wear and accelerated road degradation along routes that are most heavily traveled. Operation-related impacts would last as long as the operations period.

4.2.2.2.3 Radiological Effects from Routine Transportation of Radioactive Materials

During facility operations, there could be potential radiological impacts from routine, incident-free transportation of radioactive materials—including SNF and radioactive process wastes with varying activity levels ranging from low to high--on individual receptors and populations, from both moving and stationary vehicles (e.g., trucks, rail cars). For the purposes of this discussion, it is assumed that the bulk of this transport would be by truck. SNF, Class B and C LLW, and higher activity wastes would be transported in Type B certified transportation casks, which are specially designed, extremely robust shipping containers. Lower activity wastes, e.g., Class A LLW, would be transported in Type A shipping casks.

Individual receptors are persons at various locations along transportation routes. Populations are groups of residents along the transportation routes. During routine transportation, external radiation from the shipping casks used to transport radioactive materials would be the source of the radiation dose to the various potential receptors. Potential radiological effects due to possible exposures of various individual human receptors to this external radiation, in terms of doses of radiation in millisieverts (mSv) (or millirem (mrem)), are typically estimated using the RADTRAN model, the most recent version being RADTRAN 6 (Weiner et al., 2009). For a radiation dose to a population, RADTRAN calculates the "collective dose" (expressed in units of person-mSv[4]), by integrating the average radiation dose over the area occupied by the population. RADTRAN is the nationally accepted, standard computer program for calculating the risks of transporting radioactive materials.

In modeling radiological impacts from routine transportation, RADTRAN models the external radiation dose rate[5] from the shipping cask as if the radiation were emitted from a point source located where the center of the cask would be (Weiner et al., 2009). When the actual external radiation dose rate from the shipping cask is not specifically known, as may the case for shipments or radiological materials to and from a reprocessing facility, the maximum external dose rate for a shipping cask allowed by NRC regulation is used in RADTRAN to assess radiation doses to individuals and populations. NRC regulations allow shipping containers, or casks, that hold radioactive materials to emit minor amounts of ionizing radiation from the external cask surfaces. The Type A and Type B casks used to transport radioactive materials, as all containers certified for use to transport radioactive materials, must meet the NRC standard for external radiation during normal transport. In the case of flat-bed style trucks such as those used to transport casks of radioactive materials, by NRC regulation in 10 CFR 71.47(b)(3), the dose rate from this external radiation must not exceed 0.1 mSv per hour (10 mrem per hour) at a distance of 2 meters (m) (6.6 feet (ft)) from the vertical planes projected by the outer edges of the trailer carrying the cask. Basing the RADTRAN modeling on this maximum, legally allowable dose rate would be conservative because actual dose rates from shipping casks would generally be lower than the allowable limit.

To put the annual doses to individuals in perspective, they are often compared with the average annual U.S. background dose of 3.6 mSv/year (360 mrem/year) (Shleien et al., 1998) (or similar values reported by others, e.g., see Section 3.2.11.1), as a percentage of this background dose. Actual data on background radiation level may be available for specific site locations. For populations, the annual collective dose is compared to the background level multiplied by the affected population, since each member of the population sustains this annual average background dose. The use of the annual U.S. background radiation level allows for the assumption that the background level would be the same for all receptors. Also, from the

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[4] Person-mSv is a unit of dose that represents an individual dose integrated over an area that is occupied by a population. It can be thought of as an average individual dose multiplied by the number of people over which it is averaged.

[5] Radiation dose rate, or dose rate, is the radiation dose per unit time, expressed as millisieverts (mSv) per hour (or millirem (mrem) per hour).

estimated radiation doses, the corresponding probabilities of fatal cancers resulting from exposure to these radiation doses, or latent cancer fatalities (LCFs), are derived. Specifically, LCFs are the expected number of additional cancer fatalities that may occur during the lifetime of individuals, because of (or latent to) an exposure to ionizing radiation. LCF values may be derived by multiplying the dose by a conversion factor, 6×10^{-5} LCF per mSv (ISCORS, 2002). To put the calculated LCFs in perspective, they are often expressed as a fraction (percentage) of estimated total U.S. cancer fatalities, as reported by the American Cancer Society (2010).

Effects on Individual Receptors

Potential radiological impacts can be calculated using RADTRAN for the following types of individual receptors:

- Individual maximally exposed to a moving truck (maximally exposed individual, or MEI)
- Average person along the transportation route: rural–suburban
- Average person along the transportation route: urban
- Average resident near a truck stop: rural–suburban[6]

The MEI is the individual receiving the maximum exposure to a moving truck carrying a radioactive cargo.

Effects on Populations

The RADTRAN calculation of collective (population) dose requires identification of specific transportation origins and destinations, and data on the route miles and populations and population densities for the transportation routes between these origins and destinations. TRAGIS (TRAnsportation Geographic Information System), the routing code maintained by Oak Ridge National Laboratory (Johnson and Michelhaugh, 2003), is typically used to provide transportation route parameters for use in RADTRAN. Potential radiological effects on populations from routine transportation may be estimated separately for moving trucks and for trucks at rest and refueling stops.

4.2.2.2.4 Non-radiological and Radiological Effects from Transportation Accidents

Non-radiological effects of transportation accidents during facility operations, in terms of the numbers of traffic accidents and traffic accident fatalities and the exposure effects from releases of non-radiological hazardous materials to the environment as a result of transportation accidents, could be evaluated as for the preconstruction and construction phase. Note that during operations, larger quantities of hazardous raw materials and wastes posing greater hazard risks (e.g., acids and toxic chemicals) would be expected to be transported.

[6] Truck stops would be for rest and refueling. Truck stops are typically not modeled in urban areas because stops used by trucks carrying radioactive materials would generally be away from heavily populated areas.

Radiological effects could be assessed from traffic accidents involving trucks carrying radioactive materials, under radiological exposure scenarios in which radioactive materials are and are not released from the shipping casks. In the former case, trucks involved in accidents would be stopped and radiological effects on individuals and populations could result from radiation exposures as during routine transportation (see above), except that in the accident scenarios, trucks could be stationary for several hours resulting in longer potential exposure times. In the latter cases, trucks would also be stopped and individuals and populations could be exposed to radiation through such mechanisms as direct contact with or inhalation of released radioactive materials. In either case, effects on human health could be assessed using RADTRAN or other methodologies, tailored to the specific exposure scenarios to be evaluated.

4.2.2.3 Recent Spent Fuel Transportation Risk Assessment

In May 2012, the NRC staff issued a Draft EIS titled, "Spent Fuel Transportation Risk Assessment" (NUREG-2125) (NRC, 2012a). In this study, the risk associated with the transportation of SNF was estimated by examining the behavior of three NRC-certified cask designs during routine transportation and in transportation accidents. Two of the cask designs were for transport by railroad: (1) a cask with steel gamma shielding and an inner welded canister for the spent fuel, and (2) a cask with lead gamma shielding that can transport SNF within an inner welded canister (referred to in the Draft EIS as "canistered fuel") or without an inner canister (referred to as "directly loaded fuel"). A third cask design with depleted uranium (DU) gamma shielding was for transport of directly loaded spent fuel by highway. Information from this study may be useful in preparing the EA or EIS for the future rulemaking for licensing and regulating SNF reprocessing facilities.

4.2.3 Geology and Soils

Preconstruction, construction, and operation of a commercial SNF reprocessing facility could have potential effects on geology and soils. Because no specific reprocessing facility site has been proposed or selected, potential project areas considered in this report are the locations previously described in Section 3.2.3, which could encompass sites throughout the continental United States. That is, for the purpose of describing affected environments, the geology of the locations was grouped as the: Columbia Plateau Province, Interior Plain Province, Appalachian Province, and Atlantic Plain Province. Potential effects on geology and soil would vary by these geologic province locations, but would still be highly variable and site specific and, in general, would not correlate with the generalized rural, industrial, or DOE site types. Therefore, the discussions in the sections that follow are very general in nature.

4.2.3.1 Preconstruction and Construction

In general, geologic resources at specific locations may include groups of mineral ores, fossil fuels, and aggregate (sand and gravel) materials that can have economic value. Access to or quantities of these resources could be affected by site development. A site's geology and soil conditions are useful indicators in evaluating effluent transport through the subsurface as well as the impact of surficial processes (i.e., relating to, or occurring on or near, the surface of the earth) such as surface runoff, erosion, slope stability, and flood control. Preconstruction and construction activities would be required to comply with National Pollutant Discharge Elimination System (NPDES) requirements permit requirements for stormwater management. Soil surveys would be performed prior to preconstruction and construction to determine soil type and characterization, and also provide a baseline of constituents (both radiological and non-radiological). A seismic assessment would determine if there are any capable faults in the project area. A seismic assessment would also provide information about the occurrence of earthquakes in the region and their magnitudes, and the associated peak ground acceleration and annual probability of exceedance.

There is the potential for soils to be covered by buildings and paved surfaces or removed altogether as part of preconstruction (site preparation) and construction. The final design of the facility would require earth moving activities. Also, truck and construction equipment movements may compact soils in localized areas. There is also a potential for spills of oils, lubricants, and other materials from construction equipment that could contaminate soils. At industrial and DOE sites, soil contamination may already be present.

4.2.3.2 Facility Operation

Most effects on geology and soils would have occurred during preconstruction and construction. Following construction, surface runoff would be increased as a result of the larger amount of impenetrable/impermeable surfaces onsite (i.e., paved areas, roofs of buildings). The facility would be required to comply with NPDES permit requirements for stormwater management, Also, the potential exists that accidental releases (i.e., spills) or deposition from airborne releases of contaminated material during normal operations might affect soils. At industrial and DOE sites, soil contamination may already be present, although that would likely have been cleaned up or otherwise remediated during preconstruction and construction

4.2.4 Water Resources

This section addresses potential effects on surface water and groundwater resources, in terms of potential effects on water use and water quality that may occur during preconstruction, construction, and operation of an SNF reprocessing facility. At rural sites (or rural DOE sites) where little or no previous development has occurred, water quality may not have been impaired by previous activities. In industrialized areas, (including those at certain DOE sites), water quality impacts may have already occurred prior to SNF reprocessing facility development. Laws and regulations are in place to protect both surface water and groundwater quality during preconstruction, construction and operation (e.g., Clean Water Act (CWA), Federal Water Pollution Control Act (FWPCA), NPDES requirements). Additionally, the facility would be required to secure appropriate permits that would require the adoption and implementation of specific best management practices (BMPs) regarding protection of water quality.

4.2.4.1 Preconstruction and Construction

4.2.4.1.1 Water Use

Substantial volumes of water would be required during preconstruction and construction of an SNF reprocessing facility. For example, water would be used to clean trucks and equipment, control dust emissions (i.e., fugitive dust) along roadways and in areas of soil disturbance, and for drinking and sanitation purposes, and is a critical component in the creation of concrete mix. Surface water may be drawn from nearby rivers, lakes, and reservoirs, where they exist. For sites with no perennial surface water sources present on or near the site, groundwater may be withdrawn from aquifers via onsite or nearby wells. Appropriate local water rights and water withdrawal permits may need to be secured to access both surface water and groundwater sources during preconstruction and construction. Where insufficient water sources exist, water may need to be brought onsite.

Rural sites may or may not have access to surface water depending on location and distance from perennial sources. If no surface water is available, groundwater resources may be used if available. Some rural and rural DOE sites in arid environments may have no surface water options and could be subject to restricted or inadequate groundwater supply. Such sites may need to truck in water during the preconstruction and construction phase until permanent access to a permanent water supply can be established. Industrialized areas (including those at certain DOE sites) generally utilize sizable quantities of water, and an SNF reprocessing facility under construction at such industrial sites may be able to obtain ready access to these locally available water supplies.

Water usage during preconstruction and construction would last only as long as this phase of the project and, therefore, would be of relatively limited duration. Additionally, the acquisition of proper water permits, where required, would ensure that local water supplies are not overexploited.

4.2.4.1.2 Water Quality

<u>Surface Water</u>

At rural, industrial and DOE sites proximate to surface water bodies (e.g., lakes, rivers, streams), surface water quality degradation associated with preconstruction and construction of an SNF reprocessing facility could occur from temporary increases in suspended solids concentrations above background levels from runoff stemming from land disturbance. Increased sedimentation could occur in certain water bodies. Reduced flows in water bodies could occur where fills have occurred. Surface water quality could also be impaired due to spills or leaks of fuel, lubricants, or other hazardous materials. Stormwater runoff is another potential pollution source that could result in reductions in water quality; however, facilities would be required to acquire an NPDES permit for construction.

Rural, industrial, and DOE sites in arid environments may not contain or be near any natural perennial surface water features and, correspondingly, there would be no impacts to surface water quality from preconstruction- and construction-related activities in such areas.

Groundwater

Impacts to groundwater quality at rural, industrial, and DOE sites associated with SNF reprocessing facility preconstruction and construction may occur, and the risk of groundwater contamination would be dependent on such factors as local topography, hydrogeology, soil composition, depth to groundwater, and sources of groundwater recharge. For example, facilities built on permeable limestone, fractured bedrock, or sandy soil, may be especially susceptible to groundwater contamination from surface sources. At locations where the depth to groundwater is substantial, or where impermeable barriers to contaminant infiltration (e.g., clay) may exist, the probability of contaminants reaching aquifers would be expected to be small. Spills or leaks of hazardous materials during preconstruction and construction would pose the greatest risk.

4.2.4.2 Facility Operation

4.2.4.2.1 Water Use

Water would be used for many purposes during operation of an SNF reprocessing facility, and large volumes of water may be required which would vary depending on facility design. For example, water may be used to cool SNF as it cycles through fuel storage pools and during several other stages of reprocessing. Issues regarding surface water and groundwater availability and rights to use during facility operation would be the same as during the preconstruction and contraction phase, except that larger quantities of water may be required for operations; and in any event, a permanent water supply would be essential to maintaining operations. Access to this water supply would be developed during the preconstruction and construction phase.

Water usage during operations would be essentially continuous and last as long as the allotted operations period. Water use may decrease briefly during plant shutdowns as part of upgrades, repairs, reconstruction, or other plant maintenance activities. Proper siting of facilities in areas where adequate water supplies are available and acquisition of appropriate water rights and permits would ensure that local water supplies are not overexploited.

4.2.4.2.2 Water Quality

Surface Water

Depending on facility location, liquid effluent from an SNF reprocessing facility could be released into local surface water bodies. However, the effluent would have to meet standards outlined in the facility's NPDES discharge permit. Potential surface water quality degradation associated with operation of an SNF reprocessing facility could also occur from temporary increases in suspended solids concentrations above background levels due to stormwater runoff from impervious surfaces at the facility, but would also be controlled through NPDES permitting. Surface water quality could also potentially be impaired due to hazardous materials spills.

Groundwater

As during preconstruction and construction, effects on groundwater quality associated with operation of an SNF reprocessing facility would be dependent on such factors as local topography, hydrogeology, depth to groundwater, and sources of groundwater recharge (see that discussion for additional information). Spills or leaks of radioactive or hazardous materials may pose the greatest risk, and large quantities of these materials would be onsite during the operations phase.

4.2.5 Air Quality

4.2.5.1 Preconstruction and Construction

Preconstruction and construction of a major industrial project like an SNF reprocessing facility would have the potential to affect air quality. The vehicles and diesel equipment (e.g., diesel generators) used during land-disturbing activities generate combustion and cause fugitive dust emissions. Air quality impacts can be evaluated by comparing the relevant regulatory requirements (discussed in Section 3.2.5) and baseline conditions to estimated level of preconstruction and construction air emissions.

The Air Quality Control Region in which the reprocessing facility is located would typically be used as a basis for the air quality region of influence (ROI). A smaller area within the Air Quality Control Region may actually serve as the ROI for a specific facility. This corresponds to how National Ambient Air Quality Standards (NAAQS) compliance is reported in 40 CFR Part 81, which specifies the attainment status for smaller geographic areas within the Air Quality Control Regions (e.g., an individual county). A site-specific environmental review would identify the ROI and provide any necessary explanation for the selection rationale.

The U.S. Environmental Protection Agency's (EPA's) New Source Review (NSR) program is the part of the air permitting process that applies to the construction of new stationary sources of air emissions, such as an SNF reprocessing facility. Although the permits apply to facility operation, the permitting process must be completed and appropriate permits must be obtained before preconstruction and construction can commence. These are often referred to as construction permits.

Three types of NSR permits exist: (1) Prevention of Significant Deterioration (PSD), (2) nonattainment NSR, and (3) minor NSR. In attainment areas (i.e., those areas where air quality meets the NAAQS), PSD permits are required for major stationary pollutant sources that are new or making major modifications. Under 40 CFR Part 70, the annual threshold for classification as a major source in an attainment area is either 90.7 or 227 metric tons (100 or 250 tons) of a regulated criteria pollutant, depending on the source. In nonattainment areas, nonattainment NSR permits are required for major stationary pollutant sources that are new or making major modifications. The annual threshold for classification as a major source in a nonattainment area is generally 90.7 metric tons (100 tons) of a regulated criteria pollutant. This threshold can be lower for areas with more serious nonattainment problems. The minor NSR permits are for sources that do not require PSD or nonattainment NSR permits. A minor NSR permit is intended to support the PSD and nonattainment NSR programs by implementing permit conditions as needed that limit emissions from sources not covered by those two programs.

The factors that determine which permit applies to a particular proposed SNF reprocessing facility are the NAAQS compliance status and whether the facility was classified as a major or minor source (which would be highly dependent on facility design). Specific requirements would be determined by the appropriate regulatory authority on a site-specific basis. Based on the emission levels of existing reprocessing facilities in other countries, SNF reprocessing facilities could emit or have the potential to emit pollutants at a level that would classify these facilities as major air emission sources (see Section 4.2.5.2 for more information).

Air quality impacts could vary depending upon several key considerations including the magnitude of the emissions generated by a facility and the local air quality as expressed in the NAAQS compliance status. Actions where the ROI includes NAAQS nonattainment or maintenance areas typically would generate more scrutiny in the permitting process. Because of the existing air quality condition in these areas, any activity generating air emissions could potentially create impacts of concern to air quality. Classification as a major source under the permit program indicates facility emission levels that would require analyses (e.g., air quality modeling) to determine the magnitude of potential impacts. However, the magnitude of the emissions generated by a facility is not just characterized by the categorization as a major or minor source (i.e., the annual mass emitted). Another consideration is how these mass emissions translate in ambient air concentrations and compare to relevant requirements such as NAAQS or PSD thresholds. Site-specific environmental reviews would be conducted that account for the local affected environment and the specific action proposed.

4.2.5.2 Facility Operation

During operations, an SNF reprocessing facility includes both stationary and mobile sources that produce air emissions. Stationary sources including generators, scrubbers, boilers, and other equipment produce combustion emissions. Mobile sources from onsite and offsite transportation generate combustion emissions and possibly fugitive dust. As discussed above, air quality impacts can be evaluated by comparing the relevant regulatory requirements and baseline conditions to the estimated level of operation emissions. As discussed in Section 3.2.5, compliance with both the NAAQS and National Emission Standards for Hazardous Air Pollutants (NESHAPs) may be required.

To the extent that a reprocessing facility would meet the general requirements for operating permits identified in EPA regulations, an applicant would need to obtain the necessary Title V operating permit before beginning operations.[7] As discussed earlier, whether the EPA classifies a source as major depends on the type and amount of air pollutants emitted.

As mentioned above, based on the emission levels of existing reprocessing facilities in other countries, SNF reprocessing facilities could emit or have the potential to emit pollutants at a level that would classify these facilities as major air emission sources, thus requiring Title V operating permits. For example, Table 4-1 provides data on stationary source gas emissions from La Hague's central production plant. The La Hague annual report (AREVA, 2009) provides data from several years and provided some rationale for variations in the annual releases. For example, the transition to electric boilers resulted in a decrease in air emissions in 2009 compared to 2007 levels.

Table 4-1 Gaseous Discharge from La Hague's Central Production Plant

Constituent	Annual Release, metric tons (tons)		
	2007	**2008**	**2009**
Sulfur Dioxide (SO_2)	257 (283)	163 (180)	105 (116)
Nitrogen Oxides (NO_x)	118 (130)	89 (98)	47 (52)
Dust	4.6 (5.1)	3.63 (4.00)	2.87 (3.16)
Carbon Monoxide (CO)	--[a]	3 (3.3)	1.6 (1.8)

Source: AREVA, 2009.
[a] Not available.

However, this is not to say that all reprocessing facilities would be classified as major sources. A potential applicant could propose a facility that, based on equipment design, could potentially emit pollutants at levels below the major source category. Specific determinations concerning the classification of a facility and the necessity for an operating permit would be made by the appropriate regulatory authority on a site-specific basis.

Effects on air quality impacts from facility operations vary depending upon several key considerations, including the magnitude of the emissions generated by a facility and the local air quality as expressed in the NAAQS compliance status. Facilities where the ROI includes NAAQS nonattainment or maintenance areas typically would generate more scrutiny in the permitting process. Classification as a major source under the permit program indicates facility emission levels that would require analyses to determine the magnitude of potential impacts. However, the magnitude of the emissions generated by a facility is not just characterized by the categorization as a major or minor source (i.e. the annual mass emitted). Another consideration is how these mass emissions translate to ambient air concentrations and compare to relevant requirements such as NAAQS or PSD thresholds. Site-specific environmental reviews would need to be conducted that account for the local affected environment and the specific facility proposed.

[7] A Title V operating permit is an air permit that most large sources and some smaller sources of air pollution are required to obtain. This requirement comes from Title V of the Clean Air Act, as amended in 1990.

4.2.6 Noise

Preconstruction, construction, and operation of an SNF reprocessing facility project would generate noise from a number of sources. For evaluating potential environmental effects, noise levels can be compared to the low and high level environmental condition thresholds of 57 decibels (dB) and 72 dB, respectively (see Section 3.2.6).

Noise levels would likely be highest during the day when preconstruction, construction, and operations activities would be more likely to occur (unless these activities were also conducted during night shifts). Potential noise effects would be greatest for areas with low noise-level environmental conditions, although the presence of potential receptors would also be a key factor in evaluating effects.

Noise could affect both humans and wildlife. Wildlife would be anticipated to avoid areas where noise-generating activities are ongoing. Human noise receptor groups can be classified into two categories: workers and the general public. The Occupational Safety and Health Administration (OSHA) sets permissible exposure limits for workplace noise levels. When workplace noise levels exceed 85 dB as an 8-hour time-weighted average, OSHA requires the employer to have a hearing conservation program and ensure that employees wear personal hearing protection (29 CFR 1910.95). The magnitude of noise experienced by members of the general public would be based primarily on the source's noise level and the receptor's distance from the source.

At rural sites and rural areas at DOE sites, although SNF reprocessing facility preconstruction, construction, and operations noise levels would be expected to considerably exceed ambient noise levels, the lower population densities in such areas would mean that fewer members of the public would be affected. On the other hand, at industrial sites and at the industrialized areas of some DOE sites, ambient noise levels would be expected to be higher due to the many possible noise producing activities in such areas and more members of the general public would be affected due to the higher population densities in those areas; however, the incremental increase in noise levels due to SNF reprocessing facility preconstruction, construction, and operation would likely be less than in rural areas.

4.2.6.1 Preconstruction and Construction

During preconstruction and construction of an SNF reprocessing facility, the two main noise sources would be construction equipment and vehicle traffic.

4.2.6.1.1 Construction Equipment Noise

Construction equipment use would generate noise that would be audible above ambient levels. Standard construction techniques using heavy equipment (e.g., backhoes, graders, cranes) would likely be used to build a reprocessing plant and ancillary facilities. This equipment generates noise. Table 4-2 shows typical noise levels at a distance of 15 m (50 ft) from representative heavy construction equipment.

Table 4-2 Typical Noise Levels at 15 meters (50 feet) from Representative Construction Heavy Equipment

Equipment	Noise Level (dB)
Front Loaders	72-83
Backhoes	72-92
Tractors	76-95
Scrapers, Graders	79-92
Trucks	82-93
Concrete Mixers	74-87
Cranes	75-86
Pumps	68-71
Generators	71-82
Compressors	74-86
Jack Hammers, Rock Drills	80-97

Source: Adapted from EPA, 1971.

A key consideration when characterizing noise levels and effects on the general public is the distance from the receptor. Noise levels decrease as the distance from the source increases. For a point source such as a stationary piece of equipment, noise is reduced by about 6 dB per doubling of distance from the source. For a line source such as a road, noise is reduced by 3 dB per doubling of distance (Washington State Department of Transportation, 2012). These values are for conditions where the noise travels over flat, hard surfaces such as water, concrete, or hard-packed soil. The presence of vegetation and topography between the noise-generating activity and the receptor reduces noise levels by an additional 1.5 dB per doubling of distance (Washington State Department of Transportation, 2012). Buildings can also serve as noise barriers. The level of noise reduction depends on the building material and type and whether the windows are open, and noise levels can be reduced between 10 to 35 dB (Federal Highway Administration, 1995). Table 4-3 shows construction equipment noise levels as a function of distance from the source.

4.2.6.1.2 Traffic Noise

Preconstruction and construction phase vehicle traffic would include commuter vehicles, trucks, and construction equipment. This traffic noise would be localized and limited to roads that access the site and are within the site. Road noise levels are influenced by traffic volume and speed. Potential noise effects from vehicle traffic would be greatest for lightly travelled roads because of lower baseline noise levels and conversely, least for heavily travelled roads. Table 4-4 shows typical noise levels for traffic that accounts for both vehicle speed and volume. Typical road noise levels range between 57 and 83 dB (Washington State Department of Transportation, 2012). Table 4-5 provides an illustrative example of vehicle traffic noise levels as a function of distance from a road.

Table 4-3 Construction Equipment Noise Levels as a Function of Distance from the Source

Distance from Source		Noise Level (dB)[a]	
Meters	Feet	At 6 dB Reduction per Distance Doubling	At 7.5 dB Reduction per Distance Doubling
15	50	95	95
30	100	89	88
60	200	83	80
120	400	77	73
240	800	71	65
490	1,600	65	58
980	3,200	59	50
1,950	6,400	53	43

[a] Calculated using 95 dB at 15 meters (50 feet) as a starting point, which is near the high end of noise levels for typical construction equipment (see Table 4-2).

Table 4-4 Typical Traffic Noise Levels (Average for One Hour at 15 m (50 ft)) Accounting for Both Traffic Volume and Speed

Traffic Volume (vehicles per hour)	Noise Levels (dB)								
	56.3 kph[a] (35 mph)	64.4 kph (40 mph)	72.4 kph (45 mph)	80.5 kph (50 mph)	88.5 kph (55 mph)	97.6 kph (60 kph)	104.6 kph (65 mph)	112.6 kph (70 mph)	120.7 kph (75 mph)
125	57.3	58.5	59.7	60.9	62.0	63.1	64.1	65.1	66.1
250	60.2	61.4	62.6	63.8	64.9	66.0	67.0	68.0	69.0
500	63.2	64.4	65.6	66.8	67.9	69.0	70.0	71.0	72.0
1,000	66.2	67.4	68.6	69.8	70.9	72.0	73.0	74.0	75.0
2,000	69.2	70.4	71.6	72.8	73.9	75.0	76.1	77.0	78.0
3,000	71.0	72.2	73.4	74.6	75.7	76.8	77.8	78.8	79.8
4,000	72.2	73.4	74.6	75.8	76.9	78.0	79.1	80.1	81.0
5,000	73.2	74.4	75.6	76.8	77.9	79.0	80.0	81.0	82.0
6,000	74.0	75.2	76.4	77.6	78.7	79.8	80.8	81.8	82.8

Source: Washington State Department of Transportation, 2012.

[a] kph = kilometers per hour; mph = miles per hour.

Table 4-5 Traffic Noise Levels from Vehicles Traveling at 120.7 kph (75 mph) as a Function of Distance from a Road

Distance from Road		Low Volume Traffic Noise Level (dB) at 3 dB Reduction per Distance Doubling[a]	High Volume Traffic Noise Level (dB) at 3 dB Reduction per Distance Doubling[b]
Meters	Feet		
15	50	66	81
30	100	63	78
60	200	60	75
120	400	57	72

[a] Low volume is defined as 125 vehicles per hour.
[b] High volume is defined as 4,000 vehicles per hour.

4.2.6.2 Facility Operation

During operation of an SNF reprocessing facility, the two main noise sources are facility equipment (e.g., compressors, generators, scrubbers) and vehicle traffic. According to an occupational noise exposure study of two nuclear facilities in England, levels ranged from 60 to 97 dB, with a median of 86 dB (Burgess, et al., 2004). The study utilized historical noise exposure data collected since 1965 derived from more than 6,850 workplace sound pressure measurements from 393 different buildings at the two separate nuclear sites. Activities at the two unspecified sites included reprocessing SNF and nuclear power production, the manufacture of fuel rods, and nuclear fuel enrichment.

4.2.6.2.1 Facility Equipment Noise

Equipment use at an SNF reprocessing facility would generate noise that would be audible above ambient levels. Noise-generating equipment associated with a reprocessing facility includes compressors, generators, scrubbers, ventilations systems, and boilers. Some of this equipment would operate inside buildings that would function as noise barriers and reduce noise levels away from the sources. The highest noise levels for operation phase equipment would be about 97 dB (Burgess, et al., 2004). Noise levels would lessen as distance from the source increases in the same manner as for preconstruction and construction equipment, as discussed above and illustrated in Table 4-3.

4.2.6.2.1 Traffic Noise

During operations, traffic noise would be generated by commuting workers and shipments to and from the facility by truck or possible freight train. This traffic noise would be localized and limited to roads that access the site and are within the site. As discussed above for preconstruction and construction traffic and illustrated in Tables 4-4 and 4-5, road noise levels are influenced by traffic volume, speed, and distance to potential receptors.

4.2.7 Ecological Resources

This section discusses potential environmental effects on ecological resources (aquatic and terrestrial) that may be associated with preconstruction, construction, and operation of an SNF reprocessing facility. Potential effects on threatened and endangered (T&E) species protected under the Endangered Species Act (ESA) (16 U.S.C. §1531) are also discussed.

4.2.7.1 Preconstruction and Construction

4.2.7.1.1 Aquatic Resources

Wetland, riverbank, and other aquatic ecosystems provide habitat for many species of plants, fish, and wildlife. Jurisdictional wetlands[8] are protected under Section 404 of the CWA, which gives the U.S. Army Corps of Engineers (USACE) permitting authority for discharges of dredged or fill materials into waters of the United States. These systems could be present at potential SNF reprocessing facility sites in rural and industrial areas and at DOE sites.

Aquatic resources could be affected by SNF reprocessing facility preconstruction- and construction-related activities in several ways. Temporary increases in suspended solids concentrations from disturbed lands may adversely affect aquatic organisms. Construction could alter local hydrology, which could have negative consequences for aquatic organisms. For example, existing water runoff patterns could be impacted by preconstruction or construction, resulting in increased sediment load to nearby wetlands and waterways. In addition, leakage of preconstruction- or construction-related chemicals and fuels could introduce toxic elements and impair aquatic systems. Introduction of invasive species is another possible consequence of preconstruction and construction activities. Additionally, the increase of impervious surface area associated with the facility's construction could increase water and pollutant runoff into wetlands and waterways. The destruction or degradation of riparian, wetland, and aquatic systems could negatively impact plant and animal species that are dependent on these habitat types for all or part of their lifecycles. Candidate sites for an SNF reprocessing facility should be delineated to evaluate the existence of any wetlands under USACE jurisdiction.

An SNF reprocessing facility may be located in semi-arid environments that do not support riparian systems, wetlands, or perennial streams.[9] Several DOE sites feature these characteristics, which could also be present in certain rural and industrial areas. At such sites lacking aquatic habitats, no preconstruction- and construction-related adverse effects on aquatic resources would be anticipated.

[8] Jurisdictional wetlands are regulated by the U.S. Army Corps of Engineers (USACE) under Section 404 of the Clean Water Act and must exhibit all three of the following characteristics: hydrology, hydrophytes, and hydric soils (USACE, 1987). Some areas may function as wetlands ecologically, but exhibit only one or two of the three characteristics. Therefore, they do not currently qualify as jurisdictional wetlands and activities in these wetlands are not regulated under the Section 404 program.

[9] Perennial streams are streams or river channels that have continuous flow in parts of the stream beds all year round during years of normal rainfall.

Industrial sites and some DOE sites are likely to have seen some level of development, so any direct destruction to wetlands may have already occurred as part of that development. Such may not be the case in rural areas at which little or no development has occurred. However, in any case, there is still the potential that remaining wetlands or other nearby aquatic resources could be impacted by sedimentation from runoff and from leakage of hazardous materials associated with reprocessing facility preconstruction and construction. For example, even small alterations to uplands[10] surrounding wetlands could make habitat inhospitable for amphibians and reptiles.

Laws and regulations are in place to protect wetlands and other aquatic resources during the preconstruction and construction phase, and are applicable at rural, industrial, and DOE sites. Applicants would be required to secure appropriate permits that would require the adoption and implementation of specific BMPs at and around the construction site.

4.2.7.1.2 Terrestrial Resources

Preconstruction and construction activities could also affect terrestrial resources, including vegetation and wildlife. Vegetation could be affected by the direct removal of trees, plants, shrubs and grasses from the construction site. This could result in an associated reduction in wildlife habitat and forage productivity; modification of existing vegetative communities; and potential spread of invasive species. Primary preconstruction and construction effects on terrestrial wildlife may include habitat loss or alteration and incremental habitat fragmentation; displacement of wildlife; and direct and indirect mortalities. However, in general, most wildlife would disperse from the project area as construction activities approach and may re-colonize in adjacent, undisturbed areas. In addition, as discussed earlier, wildlife could be disturbed by noise from construction equipment and vehicle traffic. Collisions with vehicles could be responsible for direct mortality of both large and small animals.

Sites in semi-arid locations, including some rural and DOE sites, may offer limited biodiversity due to the relatively harsh nature of these environments. These sites may also feature habitat types that are common and widespread. Preconstruction- and construction-related effects at these types of sites would be expected to be limited. Potential rural sites and certain DOE sites may be located in regions that are undeveloped and characterized by locally or regionally high levels of biodiversity. Effects on terrestrial biota at these sites could possibly be more substantial. Industrial sites (including certain DOE sites) in a range of environmental settings that have already experienced some level of development may contain populations of common plant and animal species, but would not be expected to host complex ecological communities or significant levels of biodiversity. Effects on terrestrial biota at these industrialized sites would be expected to be limited due to previous disturbances that may have already impacted terrestrial resources.

Comprehensive species surveys should be conducted at proposed reprocessing facility sites. Depending on the local climate conditions and wildlife communities, it may be valuable to

[10] Upland is ground at a generally higher elevation than land along lower elevation rivers and stream valleys.

conduct the surveys during different seasons to account for migratory species that may utilize the habitat. Additionally, consultations with State game, fish, and wildlife agencies should take place to identify sensitive habitats and wildlife. Individual states may have compiled lists of “species of concern”. This is an informal term that refers to species that are declining or appear to be in need of targeted conservation action. Such identified species may not have the benefit of legal protection as is provided under the ESA. Policies and procedures have been put in place by Federal and state resource agencies to identify and minimize negative impacts to sensitive vegetative and wildlife communities.

4.2.7.1.3 Threatened and Endangered Species

The ESA provides a program for the conservation of T&E plants and animals and the habitats in which they are found. The ESA was intended to prevent the further decline of T&E species and to restore these species and their habitats. Section 7 of the Act requires consultation with the U.S. Fish and Wildlife Service (USFWS) and/or National Marine Fisheries Service (NMFS) to determine whether T&E species or their critical habitats are known to be in the vicinity of a proposed project. The law requires Federal agencies, in consultation with the USFWS and/or NMFS, to ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of designated critical habitat of such species. The law also prohibits any action that causes a "taking" of any listed species of endangered fish or wildlife.

The ESA protects only plants and animals that have been officially listed as "threatened or endangered." A "threatened" species is one that is "likely to become endangered" within the foreseeable future. An "endangered" species is one that is "in danger of extinction" throughout all or a significant portion of its range. When a species is designated as threatened or endangered, the species' "critical habitat" is also designated. Critical habitat includes the areas within the geographic area occupied by the species on which are found physical or biological features "essential to the conservation of the species" and which may require special management considerations or protection. It also includes other specific areas, not presently occupied by the species, which are essential for its conservation.

A series of procedures should be followed to determine if preconstruction or construction activities are likely to affect listed T&E species or their critical habitats and to determine if measures can be implemented to avoid, minimize, or mitigate adverse effects. Potential adverse preconstruction- and construction-related adverse effects on T&E species may include direct killing or “taking” of listed species, destruction of critical habitat, and degradation of critical habitat. Rural sites and large DOE sites with rural areas are more likely to feature T&E species than industrial sites because habitat at these types of locations tends to be largely unbroken and, in some cases, offer high biodiversity values. There may also be less chance of human disturbance at these locations. Industrial sites (including certain DOE sites) have experienced varying degrees of disturbance which has likely reduced or completely eliminated habitat favorable to T&E species. Some form of intermittent or continuous human disturbance is usually present at industrial sites. There may be rare and unique situations, however, where a disturbed or industrialized site offers highly specific habitat features that attract and support T&E species.

A number of policies and procedures are in place to identify, assess and protect federally-listed T&E species under the ESA. If T&E species are found on private lands, the landowner is required to develop a Habitat Conservation Plan (HCP) approved by the USFWS or NMFS, which must specify impacts to species that will occur and delineate steps to minimize and mitigate impacts. As described above, Federal agencies must also consult with the USFWS and/or NMFS to identify T&E species and critical habitats. Appropriate actions must be taken to ensure that T&E species and critical habitats are not jeopardized.

4.2.7.2 Facility Operation

Additional effects on aquatic and terrestrial resources could occur as a result of operations-related activities. As discussed above under preconstruction and construction, the level of biodiversity that could be affected would be related to the type of environment in which a potential reprocessing facility site is located and the extent of previous development. Laws and regulations must be followed in order to protect wetlands and other aquatic resources during the operations phase and would be applicable at rural, industrial and DOE sites. Permits must be secured that would likely require the implementation of specific BMPs at a given facility.

4.2.7.2.1 Aquatic Resources

Liquid effluent discharges from the plant and leakage of chemicals or fuels employed as part of plant operations could introduce radioactive or toxic elements and impair aquatic systems. Bioaccumulation of radionuclides in aquatic species and the sensitivities of some species to such bioaccumulation would be a concern. Additionally, the increase of impervious surface area associated with the facility's design, such as parking lots, roads, and rooftops, could increase water and pollutant runoff into wetlands and water bodies. Withdrawal of water from surface water bodies could also affect aquatic biota (e.g., fish) as a result of possible impingement or entrainment in water intake structures. The destruction or degradation of riparian, wetland, and aquatic systems would negatively impact species that are dependent on these habitat types for all or part of their lifecycles.

4.2.7.2.2 Terrestrial Resources

Most effects on terrestrial vegetation and wildlife would have already occurred during the preconstruction and construction phase as described above. During operations, wildlife could be disturbed by various plant activities and noise. Collisions with vehicles could be responsible for direct mortality of both large and small animals. Traffic could also promote the spread of invasive species as undesirable species may be carried on vehicles into or out of a facility. Wildlife would likely stay away from areas of increased noise levels. However, certain species that were driven away for various reasons during preconstruction and construction, could return as habitats are reestablished in restored (e.g., to revegetated) areas of the site.

4.2.7.2.3 Threatened and Endangered Species

Issues associated with the ESA and T&E species and their critical habitats would be the same as those discussed above under preconstruction and construction.

4.2.8 Waste Management

4.2.8.1 Preconstruction and Construction

Preconstruction and construction of an SNF reprocessing facility would be similar to that for many other types of industrial facilities and, for the most part, would generate similar solid and liquid non-hazardous and hazardous wastes. All wastes would be managed consistent with applicable local, state, and Federal requirements for the various waste types. No radioactive waste or radiologically contaminated soil would be expected to be generated during construction at rural sites and typical industrial sites. Radioactive waste or radiologically contaminated soil or groundwater may be generated during preconstruction and construction at a potential DOE site if the reprocessing facility is constructed in a location where radioactive contamination exists due to prior activities; and such materials would be treated and disposed appropriately. Construction at DOE sites, as well as at industrial sites, may also generate non-radioactive contaminated soil or groundwater, depending on prior site-specific activities, that would need to be treated and disposed of as hazardous or nonhazardous waste as appropriate.

The primary nonhazardous solid wastes that would be generated during reprocessing facility preconstruction and construction would be building materials and piping. Liquid sanitary waste water would also be generated. In addition to potentially contaminated soils, hazardous wastes would be generated, examples of which include liquids (such as motor oil, fuels, and paints), batteries and other machinery-related products, cleaning products, and other chemicals (such as pesticides and herbicides).

For the purposes of this analysis, it is assumed that the waste types and their estimated volumes generated during preconstruction and construction of a moderately sized reprocessing facility would be similar to those projected for the construction of other fuel cycle facilities that were recently licensed by the NRC, as presented in Table 4-6. These facilities include a MOX fuel fabrication facility and three uranium enrichment facilities (National Enrichment Facility (NEF), American Centrifuge Plant (ACP), and Eagle Rock Enrichment Facility (EREF)). The preconstruction and construction periods for these fuel cycle facilities range from five to eight years. Note that a large capacity reprocessing facility such as the 1,500-metric tons of heavy metal (MTHM) (1,750-tons of heavy metal (tHM)) AREVA La Hague plant may generate significantly larger volumes of preconstruction and construction wastes relative to the fuel cycle facilities presented here.

As illustrated in Table 4-6, preconstruction and construction of fuel cycle facilities generates relatively small volumes of hazardous and nonhazardous solid wastes over the limited time period of the 5- to 8-year preconstruction and construction phase. In the source documents identified in Table 4-6, the NRC staff determined that these waste volumes would potentially have small impacts on waste management resources (i.e., waste treatment and disposal facilities); therefore, similar impacts might be expected for preconstruction and construction of a moderately sized SNF reprocessing facility for the rural, industrial, or DOE site environments, where adequate disposal capacity is available.

Table 4-6 Estimated Construction Waste Volumes for Various Fuel Cycle Facilities in the United States

Waste Type[a]	Estimated Waste Volumes by Fuel Cycle Facility			
	MOX Fuel Fabrication Facility[b]	National Enrichment Facility[c]	American Centrifuge Plant[d]	Eagle Rock Enrichment Facility[e]
Hazardous, m^3/year (yd^3/year)	162 (212)	23 (30)	147-201 (192-263)	23 (30)
Non-hazardous Liquid, L/year (gal/year)	62,000,000 (16,000,000)	--[f]	--	--
Nonhazardous Solid, m^3/year (yd^3/year)	8,750 (11,400)	3,060 (3,890)	9,770 (12,800)	6,200 (8,100)
Low-level Radioactive, m^3 (yd^3)	0	0	7,800-8,510[g] (10,000-11,100)	0

[a] m^3 = cubic meters; yd^3 = cubic yard; L = liter; gal = gallon.

[b] Source: NRC, 2005a.

[c] Source: NRC, 2005b.

[d] Source: NRC, 2006a.

[e] Source: NRC, 2011.

[f] Estimate not available.

[g] Primarily waste water.

As stated previously, the generation of radioactive waste or radioactively contaminated soil would generally be limited to DOE site types. The American Centrifuge Plant shown in Table 4-6 is located at the DOE reservation in Piketon, Ohio. Construction of this fuel cycle facility involved refurbishing of existing buildings and dismantling of a former gas centrifuge enrichment plant (NRC, 2006a). These activities were estimated to generate 7,800 to 8,510 cubic meters (m^3) (10,160 to 11,090 cubic yards ($yd^{3)}$) of low-level radioactive waste (LLW) requiring disposal in a licensed LLW disposal facility.

4.2.8.2 Facility Operation

This section discusses the potential waste management considerations associated with the operation of a PUREX reprocessing facility, including issues related to the types and quantities of radioactive, hazardous, and non-hazardous wastes expected to be generated and how these wastes would be handled. A description of the PUREX process wastes is provided in Section 2.3.2.7.

4.2.8.2.1 Radioactive Waste

As discussed in Section 2.3.2.7, PUREX reprocessing generates liquid and solid high-level radioactive waste (HLW) and LLW. Liquid HLW streams would be treated to remove as much liquid as practicable and the solid residue would typically be incorporated into a glass matrix at high temperatures in a process known as vitrification. Consequently, no liquid HLW is generated that requires disposal. Transuranic (TRU), or alpha, waste and greater-than-Class C (GTCC) LLW generated in the PUREX process are included in the discussion of HLW.

Both solid and liquid LLW are generated during PUREX reprocessing of SNF. Types of LLW generated are process control equipment, wipes, protective clothing, solidified inorganic solutions, and tritium. Liquid LLW solutions would be treated and solidified in a manner similar to liquid HLW prior to disposal. Any water-based waste streams containing radioactive contamination would be treated to remove radioactivity to an acceptable level for discharge into the environment or disposal as non-radioactive waste (see Section 2.3.2.7).

High-level Waste

Estimates of the volumes of HLW generated by reprocessing at the PUREX facilities in La Hague, France, and THORP Sellafield, England, are presented in Table 4-7. Estimates of technological waste or alpha waste were not available in the open literature for the THORP facility. The large difference in the estimated volume for hulls and end pieces is attributed to compaction prior to encapsulation at the La Hague facility. The HLW volumes presented in Table 4-7 include high-activity waste and intermediate-activity waste volumes. In the U.S., a portion of these HLW volumes may be classified as GTCC LLW. Depending on the specific characteristics, alpha waste may be characterized as TRU waste in the U.S.

Table 4-7 Estimated Volumes of HLW from Reprocessing at the La Hague and THORP Sellafield Facilities

Waste Description	Waste Volumes	
	La Hague, m^3/MTHM[a] (yd^3/tHM)	**THORP Sellafield, m^3/metric ton U processed[b] (yd^3/ton U processed)**
Vitrified Fission Products and Minor Actinides	0.1 (0.12)	0.05-0.09 (0.06-0.1)
Encapsulated Hulls and End Pieces	0.1 (0.12)	0.49-0.55 (0.58-0.65)
Technological Waste[c]	0.01 (0.012)	--[d]
Alpha Waste[e]	0.06 (0.07)	--

[a] Davidson, 2009.

[b] Phillips, 1999; Phillips and Milliken, 2000.

[c] Waste generated during recycling: tools, piping, etc.

[d] Not available.

[e] Waste containing alpha emitters.

The potential effects associated with storage of HLW would vary as a function of the volume of waste and duration of storage.

Low-level Waste

Following is LLW generation information for the La Hague and THORP facilities:

- Solid LLW--Reprocessing at the La Hague facility generates an estimated 1.4 m^3/MTHM (50 ft^3/MTHM) of solid LLW (Davidson, 2009). The THORP facility reports only 0.01 to 0.06 m^3/metric ton of uranium processed as "cement encapsulated floc from treating low active salt-containing wastes" (Phillips, 1999; Phillips and Milliken, 2000). The total volume of LLW produced from reprocessing from the THORP facility is not publically available. In the U.S., all solid LLW would be containerized, and transported to a facility licensed for the disposal of LLW.

- Liquid LLW--The La Hague and THORP facilities generate liquid LLW streams that are treated to remove radioactivity to a level that they can be discharged to the sea. Based on their composition, these waste streams might be classified as LLW by the NRC. Table 4-8 provides information on the liquid LLW discharges and discharge limits for liquid effluents from the La Hague facility.

Table 4-8 Low-level Liquid Radioactive Liquid Effluent Release Limits and Annual Releases from the La Hague Facility

Radionuclides	Release Limits, TBq/year[a,b] (Ci/year)	Annual Releases, TBq/year[c] (Ci/year[d])		
		2007	2008	2009
Tritium	18,500 (50,000)	12,000 (32.000)	8,200 (22,000)	9,130 (24,700)
Radioactive Iodine	2.6 (70)	1.4 (38)	1.17 (31.6)	1.08 (29.2)
Carbon-14	42.0 (1,130)	7.08 (192)	6.24 (168)	6.12 (165)
Alpha Emitters	0.07 (2)	0.021 (0.57)	0.02 (0.5)	0.016 (0.43)
Ruthenium-106	15.0 (405)	2.23 (60.2)	3.37 (91.0)	1.58 (42.7)
Cesium-137	2.0 (54)	1 (27)	1 (27)	1 (27)
Cesium-134	0.5 (14)	0.068 (2.2)	0.075 (2.0)	0.069 (1.9)
Strontium-90	1.2 (32)	0.12 (3.2)	0.17 (4.6)	0.12 (3.2)
Cobalt-60	0.9 (24)	0.47 (13)	0.12 (3.2)	0.09 (2)
Other Beta and Gamma Emitters	30.0 (810)	2.7 (73)	4.18 (113)	2.04 (55.1)

[a] Philippe, 2010.

[b] TBq = terabecquerel, 10^{12} becquerels (Bq).

[c] AREVA, 2009.

[d] Ci = curie.

Liquid wastes containing certain levels of radioactivity may be considered LLW in the U.S. Such liquid wastes would not typically be eligible for discharge to the environment, although they could be treated to reduce the concentration of radioactive contamination to levels acceptable for discharge. The levels of contamination would be specified in a discharge permit issued by EPA or a state regulatory authority. Any residues from the treatment process would likely be considered LLW and would need to be disposed of appropriately.

4.2.8.2.2 Non-radiological Hazardous Waste

PUREX reprocessing uses large volumes of nitric acid, organic solvents, and a variety of other chemicals to facilitate the separation and purification of uranium and plutonium from SNF. Some of these chemicals, in particular acids and organic solvents, would be recycled and reused (see Section 2.3.2.6). Any liquid or solid hazardous wastes would be transported to a licensed treatment or disposal facility. The volume of hazardous waste generated by the La Hague and THORP facilities is not publically available. Estimates of hazardous waste volume for other types of fuel cycle facilities are presented in Table 4-9. The types of hazardous waste generated during the operation of various fuel cycle facilities include solvents and chemicals, spent cleaning solutions, vacuum pump oils, film processing fluids, hydraulic fluids, antifreeze solutions, paints, lead packaging, and contaminated rags or wipes, hydrocarbon sludge, and empty hazardous material containers. Note that while there are some similarities between the operations at other fuel cycle facilities and a reprocessing facility, there are also significant differences. For example, PUREX reprocessing would generate liquid organic waste solvents that are not part of uranium enrichment processes. Therefore the hazardous waste volume estimates presented in Table 4-9 may not reflect the actual volumes generated by a commercial SNF reprocessing facility.

4.2.8.2.3 Non-hazardous Waste

PUREX reprocessing facilities also generate various non-hazardous solid and liquid wastes. The liquid wastes would be treated onsite or offsite and the solid wastes would be transported and disposed of in a licensed solid waste landfill.

The volumes of liquid and solid non-hazardous waste generated for the La Hague or THORP facilities are not publically available. Publicly available estimates of nonhazardous waste volumes for other types of fuel cycle facilities are presented in Table 4-9. The types of nonhazardous solid waste generated during the operation of various fuel cycle facilities include office garbage, machine shop waste, and other industrial wastes from utility and maintenance operations. The types of non-hazardous liquid waste generated during the operation of various fuel cycle facilities include sanitary waste from sinks, showers, and toilets and process wastewater from lab sinks and drains, mop water, and cooling tower blow down.

Table 4-9 Estimated Operations Hazardous and Nonhazardous (Non-radiological) Waste Volumes for Various Fuel Cycle Facilities in the United States

Waste Type	Fuel Cycle Facility			
	MOX Fuel Fabrication Facility[a]	National Enrichment Facility[b]	American Centrifuge Plant[c]	Eagle Rock Enrichment Facility[d]
Hazardous Solid, m^3/year (yd^3/year)	12 (16)	1,184[e] (1,229)	3 (3.1)	11 (11.4)
Hazardous Liquid, L/year (gal/year)	--	1,900 (500)	--[f]	--
Nonhazardous Solid, m^3/year (yd^3/year)	4,140 (4,300)	--	558-647 (579-672)	148 (154)
Nonhazardous Liquid, L/year (gal/year)	60,200,000 (1,590,000)	--	--	--

[a] Source: NRC, 2005a.
[b] Source: NRC, 2005b.
[c] Source: NRC, 2006a.
[d] Source: NRC, 2011.
[e] Reported as non-radioactive solid waste in NRC, 2005b. Volume may also include nonhazardous solid waste.
[f] "--"estimate not provided.

4.2.9 Historic and Cultural Resources

4.2.9.1 Preconstruction and Construction

Construction of an SNF reprocessing facility could result in potential direct and indirect effects on historic and cultural resources, depending on the specific location of the facility and characteristics of the site and surrounding environment. As discussed in Section 3.2.9.2, identification of historic, cultural, and archaeological sites, and evaluations to determine listing or eligibility for listing of these sites in the National Register of Historic Places (NRHP), are necessary to designate historic properties and subsequently evaluate potential adverse effects to these properties. Adverse effects during reprocessing facility preconstruction and construction could occur because this is the phase during which most of the land surface disturbance would occur and the facility structures are erected.

Potential direct adverse effects on historic properties could include alteration or destruction of, restriction of access to, or inaccessibility of these sites due to preconstruction or construction activities. Literature and records searches would help identify known or potential historic and cultural resources and Native American sites and features. A cultural resources inventory would identify the previously documented sites and any newly identified sites. The eligibility evaluation of cultural resources for listing in the NRHP under criteria in 36 CFR 60.4(a)–(d) or as Native American Traditional Cultural Properties (TCPs) would be conducted as part of the site-specific review. Potential indirect adverse effects may occur either offsite or in combination with onsite components. Indirect effects may include visual intrusions; increased access to formerly remote or inaccessible resources; and impacts to culturally or ethnographically significant landscapes. Significant cultural landscapes should be identified during literature and records searches and may require additional archival, ethnographic, or ethnohistorical research that encompasses areas well outside the area of direct impacts. Indirect effects on cultural resources may be unavoidable.

The most significant effects, if any, to identified historic properties that may be present on or near a proposed SNF reprocessing facility project would be expected to occur during initial preconstruction and construction activities (e.g., site clearing and grading, building foundation excavations) within the project boundary. Subsequent changes in the footprint of the project (i.e., expansion outside of the original area of potential effect) may also result in effects on historic properties that may be present. There would be no impacts to historic and cultural resources if none are present. Adverse effects would be expected to be mitigated through consultations with appropriate Federal, tribal, or state agencies as described in Section 3.2.9.1. Such planning could help to avoid or mitigate the degree and intensity of effects from preconstruction and construction activities. However, surveying and due diligence activities might not be sufficient to identify all historic and cultural resources, and an unanticipated discoveries plan would need to be developed and implemented to ensure that any additional cultural resources that may be found during preconstruction or construction are properly identified and treated.

Depending on the location, historic and cultural resources at a large complex such as a DOE facility may be managed under the terms of an existing Memorandum of Agreement (MOA) or Programmatic Agreement (PA) executed between DOE and the State Historic Preservation Officer and/or one or more Native American tribes. The Advisory Council on Historic Preservation may also be a party to such agreements. In this situation, previously identified historic and cultural sites are documented and the MOA or PA records the terms and conditions agreed upon between the consulting parties to resolve adverse effects to historic properties that are known to exist or that may be identified at some future time. MOAs or PAs could also be developed for non-DOE rural and industrial sites.

If the location of the historic and cultural sites on and around a DOE property are well documented as a result of previous surveys and are appropriately managed, potential impacts to these resources from preconstruction and construction would be minimized. Construction of an SNF reprocessing facility in an industrial setting, although possibly constructed on previously developed or otherwise disturbed land, could still potentially have adverse effects on historic and cultural resources. This is because an industrial or urban setting could have historically significant properties or features in close proximity to the site. Historic and cultural resources may be found at undeveloped or minimally developed lands at rural sites. The potential effects on historic and cultural resources would not be established until site-specific conditions are assessed.

4.2.9.2 Facility Operation

Most impacts to historic and cultural resources would occur during the preconstruction and construction phase when the bulk of ground disturbing activities occur and facility structures are erected. However, continued operations, repairs, and potential reconstruction activities at a commercial SNF reprocessing facility could affect historic and cultural resources through ground disturbing activities associated with plant operations, supporting activities (e.g., new parking lots, access roads, or buildings), transmission line maintenance (e.g., maintenance of access roads or removal of vegetation), major renovation or reconstruction actions, landscaping, or recreational use of facility property. These activities could include grading an area for use, excavating soil to be used in landscaping or filling, driving large vehicles over undisturbed areas, or making new agricultural use of previously undisturbed portions of the site. All of these activities could result in direct effects such as damage or movement of artifacts, and some could result in indirect effects such as described earlier. Activities such as mowing or spreading herbicides would not be expected to affect most historic and cultural resources. Activities that could result in ground disturbance or erosion would be of greatest concern.

Even a small amount of ground clearing could critically alter a small, but significant historic and cultural resource. Development and implementation of unanticipated discoveries plans or of MOAs or PAs, as described earlier, would serve as controls to ensure proper treatment and handling of discoveries of any additional historic and cultural resources during facility operations. Issues discussed earlier with regard to finding historic and cultural resources at rural, industrial and DOE sites would also apply during SNF reprocessing facility operations.

4.2.10 Visual and Scenic Resources

4.2.10.1 Preconstruction and Construction

Potential impacts on visual and scenic resources would be evaluated based on likely features that may result from the preconstruction and construction of an SNF reprocessing facility, from the perspectives of both facility design and time of construction. Visibility of the facility from surrounding points of observation (i.e., publicly accessible locations) would be dependent upon the physical characteristics of the site and the surrounding area, such as topography and distance of the facility to site boundaries. Considering that SNF reprocessing plants are large industrial facilities and would require significant preconstruction and construction activities, important visual considerations from preconstruction and construction may include (NRC, 2003):

- Equipment and structures that are out of character with overall existing architectural features
- Equipment and structures that may partially or completely destroy existing landscape or obstruct views of existing landscape in surrounding areas
- Structures that create visual intrusions in the existing landscape character (e.g., large buildings, tall stacks, power poles and lines

- Structures that may require the removal of natural or built barriers, screens or buffers, thus enabling lower quality viewscapes to be seen

- Alteration of historic or cultural resources or the character of the settings of such resources when that character contributes to the resources' significance

- Structures that create visual audible or atmospheric elements that are out of character with the site area or alter its setting.

There are several site features that could result in varying effects on visual and scenic resources during preconstruction and construction of an SNF reprocessing facility. Construction and material emplacement activities would involve the use of heavy equipment and trucks to transport construction materials, conduct earthmoving activities, etc., although impacts from these operations would be temporary in nature. Also, the site would be cleared and grubbed in preparation for construction and the site topography would be altered through site grading. As construction proceeds, the facility buildings and associated structures would become visible as they are erected. Stacks for air emissions are expected to be the tallest structures associated with a reprocessing facility that could cause visual intrusion (DOE, 2008). Lighting for construction areas and newly constructed operations areas at the facility may be visible from public access points.

Industrial facilities generally have a low scenic-quality rating using the Bureau of Land Management (BLM) Visual Resource Inventory and Evaluation System (BLM, 1984; BLM, 1986a; BLM, 1986b; BLM, 2012) (see Section 3.2.10). An SNF reprocessing facility constructed in an area with moderate to low scenic value, where dominant viewsheds may consist of buildings, highways, storage yards, transmission lines, and undeveloped buffer areas (such as industrial sites and industrialized areas of certain DOE sites), would have less visual impacts than if the facility were constructed in an undeveloped area with a high scenic quality (such as in rural areas).

Potential visual and scenic impacts would be expected to be greatest for an SNF reprocessing facility constructed in a rural, previously undeveloped area. This is because the baseline visual landscape would likely be less disturbed for these areas than for more developed settings that may have existing industrial or DOE facilities; and facility preconstruction and construction in a previously undeveloped area would be expected to present more contrast with the existing landscape.

Visual and scenic resources relating to the quality of recreational experiences on public lands and the protection of landscapes along sensitive resources such as National Historic Trails and national and state parks could be potentially affected by development and transportation associated with an SNF reprocessing facility. Areas in flat, open desert with low vegetation and little development would have extensive viewsheds given the relative openness of much of the landscape, the height of the structures, and the potential availability of viewing opportunities from travel routes, recreational use areas, and nearby residential and commercial areas. Lacking foreground screening features or background blending opportunities, a facility would be highly visible in the foreground of views. Although some travelers may anticipate the occasional presence of industrial type infrastructure, adding a facility like an SNF reprocessing plant in a predominantly natural setting may drastically change the character of the surrounding landscape and block desired views and features (i.e., open sky or distant mountains). Also, an SNF reprocessing facility would require security lights that would likely be brightly lit at night and highly visible from many areas.

Terrain with gently rolling or sloping hills surrounded by pasture and farmland may obscure views of the facility. The presence of forests would further limit views of a reprocessing facility. Views from a river also tend to be somewhat limiting to foreground landscapes due to bordering vegetation and levees. A facility in these settings would experience varying degrees of viewer exposure and viewer concern depending on surrounding landscape features (river or recreation areas); however, bright lights at night would continue to be a viewer concern and highly visible regardless of the location.

Potential affected viewsheds at a large DOE complex or industrial area would primarily encompass structures and public access roadways. The limited public areas that have views of some structures may be one or more miles away from viewable structures. At DOE sites, structures may be scattered across the complex resulting in low viewer sensitivity because of the visual degradation from the widely spaced industrial development. DOE and industrial facilities tend to have bright security lights and the addition of an SNF reprocessing facility may not cause a noticeable difference to viewers. Thus, buildings and structures associated with an SNF reprocessing facility would not substantially change the existing setting of an industrialized area and would generally not be visible from outside the boundary of a DOE facility site. However, some DOE facilities have large undeveloped areas where sensitive viewsheds could be present and viewer sensitivity could be higher.

To evaluate effects on visual and scenic resources, the views from particular viewpoints around an SNF reprocessing facility's construction site would be selected to represent the visual changes or contrasts that could result from preconstruction and construction activities that would affect visual quality, viewer concern, viewer exposure, and overall sensitivity. Depending on the facility's location relative to various types of viewpoints, facility preconstruction and construction may or may not equally affect the visual quality, viewer concern, viewer exposure, and overall sensitivity. For example, preconstruction or construction activities located in an area surrounded by a wilderness study area may have low viewer exposure due to its remote location, but may have a high viewer concern because of the natural sensitivity of the area. Low visual quality combined with high viewer concern and viewer exposure may lead to heightened overall visual sensitivity of the visual setting and viewing characteristics.

4.2.10.2 Facility Operation

At rural, Industrial, and DOE sites, potential visual and scenic impacts at a commercial SNF reprocessing facility resulting from erection of facility structures would remain relatively unchanged during the operational phase unless additional facilities or supporting activities are implemented (e.g., additional lighting, parking lots, access roads, buildings). However, such facility modifications are not expected to create significant new visual impacts or different looking activity beyond those created during construction; i.e., they would not substantially alter the present look and feel of the area or of the facility as a whole. However, the impacts would persist throughout the operations phase and would not change until site characteristic are altered (e.g., if buildings are removed during decommissioning).

If there is an increase in vehicle traffic around a reprocessing facility during operations, it would occur along existing roads and should not substantially change the present look and feel of the area beyond those visual changes experienced during the preconstruction and construction phase. Operational activities would involve the use of heavy equipment and trucks to transport the SNF packages. Lighting for operation areas at a facility may be visible from public access points. While any emissions from the stacks, as well as other evidence of operations at each facility (such as area lighting), might be visible from certain viewing point, visibility of a commercial SNF reprocessing facility would be highly dependent on the site and the surrounding area's physical characteristics, including topography and distance of the facility to a site boundary.

4.2.11 Public and Occupational Health

This section summarizes considerations regarding potential effects on public and occupational health from preconstruction, construction, and normal operations of a commercial SNF reprocessing facility. Both radiological and non-radiological exposure conditions and effects are discussed. Potential public and occupational health effects due to transportation activities are addressed under Transportation in Section 4.2.2. Environmental-related considerations for postulated accidents at SNF reprocessing facilities are discussed in Chapter 6.

4.2.11.1 Preconstruction and Construction

4.2.11.1.1 Radiological

At rural and industrial sites, there would be no radiological impacts on worker and public health during preconstruction and construction because radiological materials would not be present onsite. Note that no SNF or other radiological materials could be brought onsite until the NRC would determine that construction has been completed in accordance with applicable safety requirements, at which point facility operation could commence.

Radiological impacts to construction workers could occur at some DOE sites where preconstruction and construction may take place in areas of radioactive soil contamination from previous operations. However, it is likely that an exploration and sampling program across the project site would be conducted prior to beginning preconstruction and construction, in which soil and groundwater would be sampled and analyzed for radioactive contamination. If contamination is found, potential exposures and health impacts to construction workers would be assessed and site remediation would be conducted to remove the contamination to safe levels or alternate construction locations might be selected if necessary.

No radiological impacts to members of the public offsite would be expected because preconstruction and construction would occur well within DOE facility boundaries. An exception would be if members of the public are exposed to radioactive contaminated materials from any necessary site remediation being transported offsite for treatment and disposal, and could be assessed as described in Section 4.2.2.2.

4.2.11.1.2 Non-radiological

Potential non-radiological public and occupational hazards during preconstruction and construction may result from the use and accidental release (i.e., spills, leaks) of toxic chemicals and generation of airborne pollutants, particularly fugitive dust. Hazardous chemical spills and leaks would generally be cleaned up quickly to avoid offsite migration. Another potential public and occupational health concern is that existing hazardous material contamination at potential industrial and DOE sites may require cleanup in accordance with Resource Conservation and Recovery Act (RCRA) or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements prior to commencement of preconstruction and construction.

DOE sites with a long history of operations, including Idaho National Laboratory (INL), Hanford, Oak Ridge, Paducah, Portsmouth, and the Savannah River Site (SRS) have a variety of existing hazardous material site contamination conditions involving organic solvents, heavy metals, and chlorinated compounds that would require additional worker and public health and safety considerations for cleanup and safety if new construction projects were to be executed. INL, Paducah, and SRS are on EPA's national priorities list for remediation of hazardous materials.

Worker safety associated with accidents and the use of hazardous chemicals at a proposed reprocessing facility construction site would be regulated by OSHA. One measure of non-radiological occupational health is the OSHA incident rate. OSHA requires employers to compile information on workplace total recordable incident rates and lost-time incident rates.[11] The U.S. Department of Labor, Bureau of Labor Statistics (BLS) reports annual incident rates for the nonresidential construction industry (North American Industry Classification System Number 2362). The incident rate is the total number of reportable accidents that occur per 200,000 hours worked and includes lost-time incidents. Lost-time incidents are accidents that result in a worker missing one or more days because of the accident. Thus, the lost-time incident rate provides a measure of the severity of the incident. Incident rates for the past five years are provided in Table 4-10.

[11] Total recordable incidents are work-related deaths, illnesses, or injuries resulting in loss of consciousness, restriction of work or motion, transfer to another job, or required medical treatment beyond first aid. A lost-time incident is a recordable incident that results in one or more days away from work, days of restricted work activity, or both, for affected employees. Fatalities are the number of occupationally related deaths. The incident rate includes both the number of Occupational Safety and Health Administration-recordable injuries and illnesses and the total number of man-hours worked. The incident rate is used for measuring and comparing work injuries, illnesses, and accidents within and between industries.

Table 4-10 Incident Rates (Incidents per 200,000 Worker Hours) for 2005–2009

Year	Average Recordable Incident Rate	Average Lost Time Incident Rate	Number of Fatalities
2009	3.6	0.9	60
2008	4.4	1.4	99
2007	4.5	1.2	103
2006	5.4	1.7	69
2005	5.4	1.7	71

Source: BLS, 2011.

The incident rate and number of fatalities in the nonresidential construction industry are high compared to other industries. Most of the fatalities are from falls, but contact with equipment, transportation accidents, and exposure to hazardous materials also contribute significantly.

4.2.11.2 Facility Operation

Public and occupational health and safety risks related to SNF reprocessing facility operations would include public and worker exposure to radioactive and hazardous materials and worker accidents. Exposure to radiation would be the primary concern with the presence of high activity SNF and process waste products.

NRC regulations in 10 CFR Part 20 address the radiological health and safety of workers and the public in the event of exposure to radiation from all phases of a nuclear facility's lifecycle, and would apply to a commercial SNF reprocessing facility. These regulations require reprocessing facility operators to develop and implement an NRC-approved radiation protection program. During NRC inspections and other oversight activities, including reviews of monitoring and incident reports, NRC inspectors check compliance with this program.

Reprocessing facilities are also subject to the EPA's environmental standards for the uranium fuel cycle in 40 CFR Part 190, Subpart B, which provide an annual dose limit of 0.25 mSv (25 mrem) whole body (plus limits for organ doses) from fuel cycle operations, but not including dose due to radon and its progeny.

The NRC has the statutory responsibility under the Atomic Energy Act of 1954, as amended (AEA), to protect the public health and safety and the environment. NRC's regulations in 10 CFR Part 20 specify annual dose limits to members of the public of 1 mSv (100 mrem) total effective dose equivalent and 0.02 mSv/hour (2 mrem/hour) from any external sources. In addition, NRC has the responsibility for ensuring that licensees meet the air and liquid effluent limits established in 10 CFR Part 20, Appendix B.

Worker safety during operations at an SNF reprocessing facility construction site would be regulated by OSHA. In addition, radiation safety practices for workers at reprocessing facilities should be such that the dose to the workers is kept as low as is reasonably achievable (ALARA). Radiation exposure limits are specified by the NRC in 10 CFR Part 20. Occupational dose is determined by the more limiting of (1) 0.05 sieverts (Sv) (5 rem) total effective dose equivalent, or (2) sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye being equal to 0.5 Sv (50 rem). The lens of the eye is limited to a dose equivalent of 0.15 Sv (15 rem) and the skin (of the whole body or any extremity) is limited to a shallow dose equivalent of 0.5 Sv (50 rem).

4.2.11.2.1 Radiological Effects from Normal Operations

Public Health and Safety

Potential public exposures to radiation from normal SNF reprocessing operations could occur from normal radioactive releases from the facility (e.g., airborne and liquid effluent discharges). However, these releases must be below the regulatory limits in 10 CFR Part 20, Appendix B. These limits are considered protective of public health and will not result in a dose to a member of the public above the regulatory limit of 1 mSv (100 mrem]). Actual doses to the public are expected to be only a fraction of these regulated limits.

Historical calculated public dose data for reprocessing operations at the La Hague facility is provided in Table 4-11. The total effective dose equivalent to potential offsite human receptor locations is expected to be on the order of 0.02 mSv (2 mrem) per year depending on the site selection. This is well below the 10 CFR Part 20 annual radiation dose limit in 10 CFR 20.1301 of 1 mSv/year (100 mrem/year) and the 40 CFR 190.10a annual radiation dose limit of 0.75 mSv (75 mrem) to the thyroid and 0.25 mSv (25 mrem) for the whole body and any other individual organ.

Table 4-11 EPA and NRC Regulatory Limits and Calculated Doses to Members of the Public from Reprocessing Operations at the La Hague Facility

Organ	Regulatory Limits, mSv/year (mrem/year)		Calculated Doses, mSv/year (mrem/year)		
	EPA 40 CFR 190.10(a)	NRC 10 CFR 20.1301	Dose from Airborne Effluents	Dose from Liquid Effluents	Total Dose
Whole Body	0.25 (25)	1 (100)	0.005 (0.5)	0.0141 (1.41)	0.0191 (1.91)
Thyroid	0.75 (75)	NA[a]	0.0022 (0.22)	0.0239 (2.39)	0.0261 (2.61)
Other Organs	0.25 (25)	NA	0.0046 (0.46)	0.0140 (1.4)	0.0186 (1.86)

Source: Davidson, 2009.

[a] None available.

However, several radionuclides have the potential to be emitted from a reprocessing facility in quantities in excess of the 40 CFR 190.10(b) limits for a uranium fuel cycle facility established by EPA. These limits are shown in Table 4-12, which also shows the quantity of radioactivity released by the La Hague facility from 2007 through 2010 by radionuclide, and the doses to the public associated with these releases. The data in Table 4-12 illustrate that emissions from the La Hague reprocessing facility would exceed emission limits in 40 CFR 190.10(b). However, as demonstrated in the last row of Table 4-12, the total dose associated with these emissions at the La Hague facility is less than 10 percent of the 40 CFR 190.10(a) whole body dose limit of 25 mrem.

Table 4-12 Selected Radioactive Emissions and Resulting Dose to Members of the Public from the La Hague Facility

Radionuclide	EPA 40 CFR 190.10(b) Limit	Emissions, TBq (Ci)			
		2007[a]	2008[a]	2009[b]	2010[b]
Krypton-85	1.85×10^{3} (50,000 Ci)	2.37×10^{5} (6.41×10^{6})	1.55×10^{5} (4.19×10^{6})	1.96×10^{5} (5.30×10^{6})	2.26×10^{5} (6.11×10^{6})
Iodine-129	1.85×10^{-4} (0.005)	1.4 (37.8)	1.17 (31.6)	1.08 (29.2)	1.38 (37.3)
Plutonium-239 and Other Alpha Emitters	1.85×10^{-5} (0.0005)	0.021 (0.57)	0.02 (0.54)	0.016 (0.43)	0.0257 (0.69)
Maximum Dose to Offsite Member of the Public, mSv (mrem)	**0.25 (25)**	**0.014 (1.4)**	**0. 010 (1.0)**	**0. 011 (1.1)**	**NA[c]**

[a] AREVA, 2009.

[b] AREVA, 2012a.

[c] Not available.

Note, however, that the La Hague facility discharges liquid effluents into the sea, which is not a source of drinking water or irrigation water and which provides a very large dilution factor. The hosting sites identified by the DOE GNEP program (DOE, 2008) as possible locations for a reprocessing facility in the United States (see Section 3.1) are not located on or near seashores, and liquid effluents from a commercial reprocessing facility in the U.S. would be required to discharge within all applicable regulatory discharge limits into water bodies used for drinking, irrigation, and/or recreational use. Also, liquid effluents are dependent upon facility design and the location of the outfall(s) in relation to the nearest downstream use of the water body and the use of the water body receiving the effluent. For airborne effluents, environmental effects would be site dependent and would also depend on the location of the facility relative to the location of the nearest receptor.

Worker Health and Safety

Potential radiological impacts to workers from normal reprocessing operations could result from: (1) exposure to direct radiation, (2) exposure to surface contamination, and (3) exposure to airborne contamination. Radiation doses to occupationally exposed workers at reprocessing facilities would be similar regardless of the facility's location, and have historically been well below the 10 CFR Part 20 annual occupational dose limit of 50 mSv (5 rem). For example, in 2008, doses from all sources received by workers at the La Hague reprocessing facility ranged from 0.038 mSv/yr (3.8 mrem/yr) to 0.246 mSv/yr (24.6 mrem/yr) (AREVA, 2009). These doses to La Hague workers are also less than the public dose limit of 1 mSv/yr (100 mrem/yr).

Radiation Protection

A 10 CFR Part 20 radiological protection program, which the NRC would require to be implemented at an SNF reprocessing facility, includes plans and procedures addressing the following topics for the protection of worker and public health and safety:

- Effluent Control--Effluents to air and surface water (e.g., permitted wastewater discharges) must meet NRC limits established in 10 CFR Part 20, Appendix B for radioactive effluents in air and liquids. To ensure proper performance to specifications, plans and procedures include minimum performance specifications for control technologies (e.g., emission controls) and frequencies of tests and inspections.

- External Radiation Exposure Monitoring Program--This program specifies survey methods (including monitoring locations), instrumentation, and equipment for measuring worker exposures to external radiation during routine and non-routine operations, maintenance, and cleanup activities. The program is designed to ensure worker dose levels are as low as reasonably achievable and comply with 10 CFR Part 20 requirements.

- Airborne Radiation Monitoring Program--This program determines concentrations of airborne radioactive materials in the workplace during routine and non-routine operations, maintenance, and cleanup. This program is designed to ensure airborne radiation releases and worker exposures are as low as reasonably achievable and meet requirements specified in 10 CFR Part 20.

- Exposure Calculations--Procedures document the methodologies used to calculate intake of airborne radioactive materials in the workplace during routine and non-routine operations, maintenance, and cleanup activities.

- Bioassay Program--A bioassay program assesses biological intake of radionuclides by workers routinely involved in operations where radioactive material can be inhaled (e.g., in areas with removable contamination). These programs include collection and analysis of urine samples that are assessed for the presence of radionuclides. Action levels are set to maintain exposures as low as reasonably achievable and within worker requirements in 10 CFR Part 20.

- Contamination Control Program--A contamination control program includes standard operating procedures to prevent employees from entering clean areas or leaving the site while contaminated with radioactive materials. These programs involve radiation surveys of personnel and surfaces, housekeeping requirements, specifications to control contamination in contamination areas, and controls for the release of contaminated equipment.

- Environmental Monitoring Program--This program measures concentrations and quantities of radioactive and nonradioactive materials released to uncontrolled areas in the environment surrounding the facility. These programs measure concentrations of constituents in the environment near and beyond the site boundary emphasizing surface water, groundwater, vegetation, food and fish, and soil and sediment. Direct radiation and radon are also measured.

Radiological Monitoring

NRC regulations at 10 CFR Part 20 address radiological effluents and exposures to the public. The NRC requires that licensees have a radiological effluent and environmental monitoring program that complies with these rules. An effluent and environmental monitoring program includes a number of monitoring sites where direct radiation measurements are made and surface waters, groundwater, sediments, soils, and the air are sampled for radionuclides. Licensees must document the sampling and monitoring results and maintain records for a specified period of time.

Specific NRC monitoring guidance for commercial SNF reprocessing facilities has not been established, although other NRC guidance on radiological monitoring practice for fuel cycle facilities and other nuclear facilities is in place, including:

- NUREG-1520 - Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility (NRC, 2010a) (Provides radiological monitoring program acceptance criteria for NRC staff's safety review: 14 criteria for effluent monitoring and 9 criteria for environmental monitoring.)

- Regulatory Guide (RG) 4.15 - Quality Assurance for Radiological Monitoring Programs (Inception Through Normal Operations to License Termination) — Effluent Streams and the Environment (NRC, 2007)

- RG 4.16 - Monitoring and Reporting Radioactivity in Releases of Radioactive Materials in Liquid and Gaseous Effluent from Nuclear Fuel Processing and Fabrication Plants and Uranium Hexafluoride Production Plants (NRC, 2010b)

- NUREG-1302 - Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for BWRs (NRC, 1991)

Licensees of reprocessing facilities would be required to establish monitoring stations and environmental sampling areas. Sampling locations would likely be selected based on the proposed facility, nearest residences, and population centers. Existing NRC guidance recommends sampling locations be the same as those used to establish pre-operational baseline conditions, and that filters are changed at least weekly depending on dust conditions.

4.2.11.2.2 Non-radiological Effects from Normal Operations

Non-radiological Exposures

Reprocessing facilities use hazardous chemicals to separate uranium, plutonium, and fission products. The following hazardous chemicals are typically used at reprocessing facilities in large quantities (see Section 2.3.2):

- Nitric acid
- Tri-n-butyl phosphate (solvent)
- Kerosene or dodecane
- Hydrazine nitrate
- Hydroxylamine nitrate
- Oxalic acid
- Sodium hydroxide

If released within the plant or to the surrounding environment, these chemicals could pose significant hazards to public and occupational health and safety. As with other industrial operations, releases of hazardous chemicals of sufficient magnitude to adversely affect public and occupational health and safety are possible, but are generally considered unlikely with the proper controls in place at a facility.

In general, the handling and storage of chemicals at a reprocessing facility would follow standard industrial safety standards and practices. Industrial safety aspects associated with the use of hazardous chemicals at a reprocessing facility would be regulated by OSHA. Chemical storage facilities would include hazardous and nonhazardous material storage areas. Bulk hazardous materials would be stored outside and segregated from areas where licensed materials are processed and stored to minimize potential impact on radiation safety. Bulk storage of hazardous chemicals would be separated to avoid mixing of incompatible materials; and storage areas would be located at a sufficient distance from site boundaries to minimize hazards to people during an accidental release.

Operations at a reprocessing facility could potentially result in the release of non-radiological contaminants into the air or aquatic environments. These chemicals include copper, chromium, lead, volatile organic compounds, SO_x, NO_x, ammonia, and chlorofluorocarbons. The quantity of the contaminants would be controlled by permits issued by EPA or by the state in which the reprocessing facility is located.

Occupational Injury and Illness

Workplace safety regulations are administered by OSHA. Occupational hazards would be minimized when workers adhere to safety standards and use appropriate protective equipment; however, injuries and fatalities from worker accidents during normal operations could still occur.

Occupational hazards to be expected at a reprocessing facility can be evaluated using an incident rate. BLS reports annual incident rates for chemical facilities (North American Industry Classification System Number 3251) (BLS, 2011). Based on these data, the occupational injury and illness rates estimated for operations at a proposed reprocessing facility could potentially result in 1.9 nonfatal occupational injuries and illnesses per 200,000 hours of labor (BLS, 2011).

4.2.12 Socioeconomics

4.2.12.1 Preconstruction and Construction

Preconstruction and construction of major industrial projects like SNF reprocessing facilities have the potential to affect the socioeconomic dynamics of the communities in the vicinities of such facilities. Capital expenditures and the migration of workers and their families into a community may influence factors such as regional income; employment levels; local tax revenue; housing availability; area community services such as healthcare, schools, and law enforcement; and the availability and cost of public utilities such as electricity, water, sanitary services, and roads.

An ROI around an SNF reprocessing facility (to be determined on a project-specific basis, but typically an 80-kilometer (km) (50-mile (mi)) diameter area) would likely be used as the basis for the socioeconomic impact analysis for preconstruction and construction. The relevant ROI would be limited to areas necessary to include social and economic baseline data for (a) the county in which the proposed facility would be located, and (b) those specific portions of surrounding counties and urbanized areas (generally up to 80 km (50 mi) from the site boundary) from which the preconstruction and construction workforce would be principally drawn, or the stress on community services from in-migrating construction workers. The objective of a socioeconomic impact analysis is to assess the likely beneficial and adverse effects on these and other factors important to the social and economic well-being of local communities, and to suggest measures to mitigate potentially adverse impacts if necessary. Methodologies for impact assessment may include both quantitative and qualitative approaches.

Socioeconomic impact information in EIS's for other fuel cycle facilities was considered in the development of this section, including those for the ACP in Piketon, Ohio (NRC, 2006a), NEF in Lea County, New Mexico (NRC, 2005b), and a MOX fuel fabrication facility at the SRS in Aiken, South Carolina (NRC, 2005a).

4.2.12.1.1 Demographics

The effects of preconstruction and construction of a nuclear fuel cycle facility (such as an SNF reprocessing facility) on population characteristics are generally evaluated by estimating the fraction of direct and indirect jobs that would be filled by migration of workers from outside the ROI. The average family size and age profiles of migrating families are estimated using appropriate demographic assumptions based on U.S. Census Bureau (USCB) statistics. These estimates of potential migration are compared to existing regional population levels to assess the relative magnitude of impacts to population characteristics.

As described in Section 3.2.12.1, important population factors such as density, growth, and transient populations strongly depend on site-specific circumstances, but some regional trends can be observed. Depending on its size and makeup, a nuclear fuel facility's construction could produce peak employment of 800 to over 1,000 direct jobs and 582 to over 1,000 indirect jobs (NRC, 2005a). Construction in a large industrial area or at a DOE complex would likely draw some workers from the existing workforce. DOE facilities could employ 8,000 to 15,000 workers (see Section 3.2.12.2). However, structural, mechanical, and electrical trades would be in higher demand during preconstruction and construction activities rather than the engineering and regulatory positions filled at operating industrial or DOE facilities.

Assuming a peak preconstruction and construction workforce near a thousand, in-migration of construction workers, although temporary, would likely have a limited effect on the local demographics at an industrial or DOE site if most of the construction workers needed already reside in the ROI. In rural areas, the demographics may be more significantly influenced by the influx of a thousand construction workers because of a relatively smaller local population and because there would be fewer construction-related skilled workers to draw from in the surrounding region.

4.2.12.1.2 Economics

Economic effects due to an SNF reprocessing facility's preconstruction and construction would be highly localized and dependent on site-specific economic circumstances and trends. Direct and indirect employment dynamics could strongly influence the economic structure of a community. Changes in employment are evaluated by estimating the level of direct and indirect employment that would be created by construction. Direct employment refers to jobs created by construction activities and facility operations. Indirect employment refers to jobs created in the ROI to support the needs of the workers directly employed at the facility and jobs created to support site purchase and non-payroll expenditures. The number of direct jobs created in each stage is estimated based on anticipated labor inputs for various engineering and construction activities. Indirect employment is estimated using an economic model known as an input-output model.

For previously proposed nuclear fuel cycle facilities, NRC has used the Regional Input-Output Modeling System-II (RIMS-II), an input-output model developed by the Bureau for Economic Analysis, to estimate the indirect employment that may benefit from construction activities (BEA, 1997). Input-output models such as RIMS-II rely on regional input-output multipliers to account for inter-industry relationships within regions. Inputs into the model include information on the initial changes in output, earnings, or employment that are associated with the project. The relative magnitude of the influence on regional employment can be assessed by comparing total project-generated employment to current regional employment levels.

Potential effects from preconstruction and construction activities on economics would be highly localized and dependent on site-specific economic circumstances and trends. Estimates from a proposed gas centrifuge plant for uranium enrichment at a DOE facility indicate that the employment expected to be generated by construction activities represented 3.5 percent of the total employment in the ROI in 2000 (NRC, 2006a). The peak employment estimate for the MOX facility at the SRS, in Aiken, SC (NRC, 2006a) was approximately 8 percent of the total regional construction workforce in 1997. In areas with relatively dense populations, this demand for preconstruction and construction workers could adversely affect other construction activities in the region as a result of direct competition for labor. It is not unreasonable to expect that the employment of construction workers needed for construction of an SNF reprocessing facility at an industrial or DOE site would be between 3 and 10 percent of the total employment in the ROI. This estimate could be significantly higher in rural economies or where regional construction activities have been slowed by other economic factors causing construction workers to leave to find work elsewhere resulting in fewer available regional workers. For example, for a proposed uranium enrichment facility at a commercial site in rural New Mexico, the NRC estimated that the construction labor force would represent about 19 percent of the construction labor force of the two counties where the proposed site was to be located and 4.4 percent of the construction labor force of the eight counties in the ROI (NRC, 2005b).

Using 2004 estimates, construction of a uranium enrichment facility was proposed to take approximately 8 years to complete and cost $1.24 billion (NRC, 2005b), excluding escalation, contingencies, and interest. The applicant estimated that it would spend about $411 million locally on construction expenditures over an 8-year period, about one-third on wages and benefits and two-thirds on goods and services. The applicant estimated employment during the 8-year construction period would average 397 jobs per year with employment peaking at 800 jobs in the fourth year. Most of the construction jobs (about 75 percent) would be expected to pay between $34,000 and $49,000 annually (inflated to 2011 $40,000 to $56,000 (U.S. Inflation Calculator: http://www.usinflationcalculator.com/), and average slightly more than $39,000 (inflated to 2011 $46,000). The pay for these jobs would be slightly under the national median household income of $52,000 (inflated to 2011). Initial employment would consist predominately of structural trades with the majority of these workers coming from the local area.

As preconstruction and construction progresses, there would be a gradual shift from structural trades to mechanical and electrical trades. The majority of these higher paying skilled jobs would be expected to be filled by workers from farther outside the surrounding area. The direct spending or local purchases made would generate indirect impacts in other local industries—additional output, earnings, and new jobs. In addition, spending on goods, services, and wages would create indirect jobs. It is not unreasonable to expect an 8-year construction period and that construction salaries for an SNF reprocessing facility would fall in the range of salaries expected for a uranium enrichment facility, considering inflation. If the majority of construction activities rely on the use of a local workforce, and the local area median household income is between the expected average pay for construction workers at the time, small positive effects would be anticipated depending upon the size of the local workforce.

According to a RIMS-II analysis conducted in 2004 for the proposed uranium enrichment facility in a rural area of New Mexico (NRC, 2005b), approximately $50.3 million ($59.5 million in 2011) in average annual construction spending would generate additional annual output of $67.9 million ($80.3 million in 2011) and earnings of $18.7 million ($22.1 million in 2011) for each year the facility is under construction. Spending on goods, services, and wages would create additional indirect jobs. This estimate would not be expected to be significantly different if the enrichment facility was located at an industrial or DOE facility. It is anticipated that SNF reprocessing facility development could have a significant impact on local finances within the ROI depending on the local economy. Because of the expected spike of direct and indirect jobs and then a decline as facility construction nears completion, the economic impacts of preconstruction and construction to the ROI would be greater than during operations; however, the intensity of potential economic changes to the community from construction spending could vary depending on several factors, especially the cost of materials and transportation.

State income tax revenues are estimated by assuming appropriate remuneration rates for project-related jobs and applying state income tax rates. Sales tax revenues are estimated by applying appropriate assumptions to the fraction of after-tax income generated by construction jobs that will be spent within the ROI and applying state sales tax rates. Changes to local tax revenues are estimated by applying appropriate assumptions to the fraction of after-tax income generated by project-related jobs that will be spent within each county and applying county-specific sales tax rates. The relative tax revenues dynamics in the ROI is assessed by comparing total project-generated tax revenues to current regional tax revenues (NRC, 2006a).

4.2.12.1.3 Housing

Housing resources are estimated by a quantitative comparison of current housing vacancy statistics for rental and owner-occupied houses to the estimated population influx into the ROI. The maximum population increase would be expected in the ROI during peak construction. In later stages of construction, the increase in the local population would be less. A relatively small number of people would be expected to move into the local area permanently due to preconstruction and construction. Impacts to housing from preconstruction and construction activities would be expected to be short term even if the workforce is primarily filled from outside the ROI.

Preconstruction and construction could last up to eight years, and each phase would require workers with different skill sets, making it unlikely that a large portion of the construction workforce from outside the ROI would remain in the ROI for the entire preconstruction and construction period. It is likely that the majority of construction workers would use temporary housing such as apartments, hotels, or trailer parks. Many construction workers use personal trailers for housing on short-term projects. The magnitude of these housing demands would be influenced by site-specific conditions including the proximity of local residential housing. However, the demand upon specific markets (apartment complexes, hotels, or campgrounds) could potentially be significant if construction workers concentrated in one general area. This concentration of workers would be more likely to affect rural areas with low rental housing vacancy.

Although an SNF reprocessing facility's preconstruction and construction phase may result in migration of people into the region, it is expected that the average rental vacancy rate in each region would be at least 6 percent, as discussed in Section 3.2.12.3. If the expected in-migration is greater than the available rental vacancy rate, the population influx due to construction phase jobs would have a significant influence on the housing market. However, the housing market is not expected to affect either the pricing or availability of public utilities within an ROI.

Effects on housing from facility preconstruction and construction are dependent on the proximity of local residential housing, worker concentration, and available rental vacancy rate, which are site-specific. However, impacts to housing from construction activities would be expected to be short term.

4.2.12.1.4 Public Services

Changes to community and social services from a large project are estimated using a level-of-service assessment approach. Level-of-service indicators typically measure the ratio of service providers to the recipient population for a particular service; for example, the student-to-teacher ratio for educational services and the number of physicians per 1,000 people for healthcare services. The most recent data on existing levels-of-service for education, healthcare, law enforcement, and fire services in an ROI, if available, are combined with estimates of population influx and standard demographic assumptions to derive expected new levels-of-service. These are compared to state average levels-of-service for each community service to identify potential effects of the change.

Changes to public utilities (such as water, sanitary wastewater, solid waste, and transportation and road services) are estimated by identifying any stages of a project that would procure utilities from offsite vendors that service communities in the ROI. Where applicable, the levels of potential procurement are compared to the existing capacities of the utilities and existing demand levels to assess whether the procurements are likely to affect the availability and pricing of services to local communities.

For public services, considerations described for transportation (Section 4.2.2), water use (Section 4.2.4), and waste management (Section 4.2.8) due to preconstruction and construction would collectively influence the public services in the ROI.

4.2.12.2 Facility Operation

Section 4.2.12.1 describes the objectives and methods of socioeconomic analyses and uses information from previous NRC EIS's for other fuel cycle facilities to demonstrate the range of potential impacts from preconstruction and construction of a potential commercial SNF reprocessing facility. Operations may employ fewer workers than peak construction; however, operations of a commercial SNF reprocessing facility include the potential impacts on individual communities, the surrounding region, and minority and low-income populations. Employment, population, economic measures, housing, and public services could all be affected by operations.

4.2.12.2.1 Demographics

Employment during operations would be highly dependent on the capacity of an SNF reprocessing facility and the availability of SNF for reprocessing. Direct full-time employment at an SNF reprocessing facility could create more than 500 jobs and potentially up to 1,000 jobs or much more. Indirect employment in the region could create 900 jobs (NRC, 2006a). For example, approximately 1,200 people are employed at the Westinghouse fuel fabrication facility in Columbia, SC (Westinghouse, 2008). Employment at a nuclear fuel cycle facility could have an impact on surrounding demographics depending on the employment growth rate and the number of operation-related workers required to move into the ROI.

For operations of the ACP in Piketon, OH, the NRC staff estimated that the project would create 600 full-time jobs and 900 indirect jobs in the ROI for that project (NRC, 2006a). This represents 1.6 percent of the total employment in the region and 10 percent of the employment of Pike County, the plant's location. However, no substantial population influx was expected during the operations phase of the plant because most of the direct and indirect jobs resulting from operations were expected to be filled from within the ROI. The NRC staff considered that potential impacts to regional population characteristics of the ACP operations phase would be small. NRC staff also concluded the potential socioeconomic impacts from constructing and operating a MOX fuel fabrication facility at the SRS in South Carolina would be insignificant because the increase in the annual average employment growth rate would be less than 0.1 of a percentage point during the operation phase (NRC, 2005a). Similar to the ACP site, the majority of the expected jobs created at the SRS were projected to be from the ROI, thus insignificant socioeconomic impacts would be expected. Thus, the population increase during the operations phase of an SNF reprocessing facility would be expected to be limited if the proposed facility is located in an ROI where most operations workers already reside. Potential effects on demographics for rural sites would likely be somewhat larger due to the smaller populations in such areas.

4.2.12.2.2 Economics

Local economies have the potential to be directly or indirectly affected by facility operations. The primary economic impacts from employing at least 500 new workers, and potentially more than 1,000 new workers, to operate an SNF reprocessing facility would be related to taxes, housing, and increased demand for goods and services, including potential effects associated with facility property tax revenues paid to local governments and public school systems. Other effects of operations would be the continuation or change in the amount of taxes paid by the facility to support a range of community services, including public water, safety, fire protection, health, and judicial, social, and educational services. In smaller communities, tax revenues from major industrial facilities can have a sizeable impact on the quality of services available to local residents although many of the community services paid for by tax revenues from such facilities would be used by plant workers and their families. In larger communities where the availability and quality of community services and education would not change due to operations, the impact on community services and education would be expected to be small. Because of the relatively short duration of additions or reconstruction-related activities (modifications, upgrades, maintenance, or other renovations) that may be required during operations, additional construction-related workers would not be expected to bring families and school-age children with them; therefore, impacts from potential reconstruction activities on educational services would not be anticipated.

The labor force in Lea, Andrews, and Gaines Counties, the ROI for the NEF in Lea County, NM, totals over 33,000, and is a relatively rural setting (NRC, 2005b). The expected labor force for operations at this facility was about 381 jobs, 210 direct and 173 indirect (approximately 1 percent of the jobs in Lea, Andrews, and Gaines Counties). The NRC staff expected that there would be moderate impacts on local employment during operations because the number of skilled positions that would be filled by workers moving into the area from outside the ROI was undetermined (NRC, 2005b). One reason for the uncertain estimates regarding the economic impact from the number of skilled positions that would be filled by workers moving into the area from outside the ROI is that once appropriate training is provided, many operations positions could eventually be filled by workers that reside within the ROI (NRC, 2005b), thus stabilizing the influx of workers into the ROI. For the ACP operations in Piketon, OH, which is on a DOE reservation in a rural area, the employment expected to be generated during operations represented 1.6 percent of the total employment in the region and 10 percent of Pike County employment where the proposed site is located (NRC, 2006a). The NRC staff also considered that there would be moderate economic impacts from regional employment during facility operation.

The applicant for the ACP located in the northeast U.S., with projected 900 direct and 600 indirect jobs, estimated that the average income in 2013 dollars would be $36,226 per year during the operations phase and would generate $54.3 million in income (NRC, 2006a). The applicant for the NEF located in the southwest U.S., with projected 210 direct and 173 indirect jobs, anticipated the operating work force in 2004 would earn an average salary of approximately $50,100 (inflated to 2011 $59,650) (NRC, 2005b) and generate a total of more than $10.9 million (inflated to 2011 $13 million) in salaries and wages. These two fuel cycle facilities represent a large range of possible incomes and tax revenues that could also represent similar income ranges for a SNF reprocessing facilities as explained in Section 4.2.12.2. If the majority of operations-related jobs at an SNF reprocessing facility rely on the use of a local workforce, and the local area median household income is between the expected average pay for operations workers described for ACP and NEF at the time operations begin at an SNF reprocessing facility, positive effects would be anticipated. However, the potential economic impacts from operations spending and wages could still vary depending on several factors and regardless of the site type or location, but are expected to make less of an overall economic impact than those impacts experienced during preconstruction and construction.

4.2.12.2.3 Housing

The population increase during the operations phase of an SNF reprocessing facility may be less than that experienced during the preconstruction and construction phase because fewer workers may be needed for facility operation than for preconstruction and construction. Therefore, the potential impact to population and housing also would be expected to be less than that experienced during preconstruction and construction. As previously discussed, operations employment could be expected to generate an increase of 1 to 2 percent of the total employment in the region requiring a 1 to 2 percent vacancy rate. None of the regional U.S. vacancy rates for the fourth quarters of 2009 and 2010 presented in Section 3.2.12.3 show less than a 7 percent vacancy rate. In-migration of the expected operations workers would not be expected to exceed the available vacant owner occupied housing units required for facility operations. Property values for nearby private residences could be affected. Property value impacts may be greater on communities in rural areas. Housing demand is not expected to affect either the pricing or availability of public utilities within the ROI of DOE or industrial sites.

4.2.12.2.4 Public Services

An SNF reprocessing facility would have an ongoing effect on the local demand for social services. Social issues differ from site to site and normally cannot be resolved generically. An SNF reprocessing facility would create the demand and pay for goods and services. The creation of permanent jobs in a region would lead to some additional demands for public services.

If most of the direct and indirect jobs resulting from proposed operations are expected to be filled from within the ROI, no substantial population influx is expected during the operations phase. Therefore, the population influx on account of operations would not be expected to affect either the pricing or availability of public utilities in the region.

Facility operations are not likely to affect local transportation conditions in the vicinity of the facility beyond what was experienced during the preconstruction and construction phase. Transportation impacts are ongoing and would have become well established and mitigated during the operations phase.

There may be less of an impact on public finances or the need for additional local public service employees during normal operation than during preconstruction construction. Minor impacts would occur to agriculture and commercial fishing as demand for their products increase during normal operations. No significant impacts on agriculture and downstream fisheries are expected from facility operations that use BMPs and mitigation measures.

For public services, the assessment of potential impacts due to operations is collectively based on the impact assessments previously made for transportation (Section 4.2.2), water use (Section 4.2.4), and waste management (Section 4.2.8).

4.2.13 Environmental Justice

An SNF reprocessing facility would affect resources and surrounding populations. In particular, minority or low-income populations could be subject to disproportionately high adverse effects from the facility's preconstruction and construction or operation. Guidelines for performing environmental justice (EJ) analyses are described in NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs" (NRC, 2003). The analysis method is multi-step and is conducted for an ROI with a radius of 80 km (50 mi) from the site.

Census block groups of minority and low-income populations having more than 20 percentage points above the state or county value are designated as EJ populations. Any block group where minority and low-income populations exceed 50 percent of the block group population is also considered in the analysis. Since data for each population group and identification of special-pathway receptors are necessary to adequately assess potential EJ effects from a project, potential EJ impacts could vary widely between site locations associated with rural or industrial areas or DOE facilities.

Minority and low-income populations are subsets of the general public residing around the site and all populations are exposed to the same potential risks and hazards. Generally, potential risks are larger the closer a person is to the source of the impact. Therefore, low-income and minority populations could be disproportionately affected if they are located closer to the source of the impact than other members of the general population. The location and magnitude of environmental effects may affect population groups that are particularly sensitive because of their resource dependencies or practices (e.g., subsistence agriculture, hunting, fishing) that reflect the traditional or cultural practices of minority and low-income populations. Others in the affected group may not understand the potential impacts and may have varying perceptions of how the SNF reprocessing facility project affects them.

4.2.13.1 Preconstruction and Construction

Land disturbances and changes to land forms, including scenic landscapes, historic and cultural sites, water sources, and subsistence living, could result from preconstruction and construction of an SNF reprocessing facility and its associated infrastructure. Fugitive dust and noise emissions from such activities, if not properly controlled, might affect the nearest homes, which could have minority or low-income residents. These impacts would be most likely to occur during preconstruction and construction in an area which is either vacant (such as in rural areas) or low-density industrial land. Noise, dust, and other emissions associated with preconstruction and construction would not be expected to affect the nearest residents surrounding a DOE installation because of the expected large distance to the nearest residents, and would only slightly and temporarily affect wildlife that have become habituated to human presence. DOE facilities are considered controlled areas with limited access; therefore, the effects on vegetation and wildlife present on DOE-owned lands for public use would be limited. Impacts to vegetation and terrestrial wildlife for subsistence would be expected only in areas that are available to the public and that have not experienced previous development, which would most often occur in rural settings.

As described in Section 3.2.13, potential subsistence impacts require identification of special pathways that account for the levels of contamination through exposure, consumption, and inhalation. No radiological risks and low non-radiological, chemical exposure risks would be expected during preconstruction and construction. Preconstruction and construction activities are projected to cause a temporary increase in air pollutants, sedimentation discharges to waterways, chemical spills, stormwater runoff, and wastewater discharges. While surface releases that might enter local streams or interfere with subsistence activities by low-income or minority populations are expected to occur, these potential impacts could be minimized by implementing mitigation measures.

Incremental EJ impacts with regard to scenic qualities and historic and cultural sites would be unlikely in areas already devoted to industrial purposes with low scenic value and previously disturbed land. For DOE facilities that are closed to the public, these facilities provide very little other productive economic, cultural, or recreational use. Native American tribes or other groups could have some historical and ethnic ties to an undeveloped or rural area that may have not been identified as having any cultural resource or service. These resources could be altered, destroyed, restricted, or made inaccessible in areas where groups associate importance to certain land form characteristics. Thus, impacts to scenic and historic and cultural resources could be disproportionate to minority or low-income residents, depending on local conditions.

A significant increase in transportation requirements during the preconstruction and construction phase could result in impacts during the period in which most of the activity is projected to occur. These impacts would likely increase traffic congestion for everyone including those workers traveling to the site, but may not disproportionately affect minority or low-income populations.

Data can be collected to identify any exceptional health problems among low-income and minority residents within an 80-km (50-mi) radius of an SNF reprocessing facility. These problems could include pre-existing conditions, unusual incidences of birth defects, chronic diseases, or cancer clusters; however, a county is generally the smallest area for which published health information is available and could extend beyond the 80-km (50-mi) radius of a site for EJ impacts. No disproportionate health effects on minority or low-income residents would be expected during preconstruction and construction.

The population in the ROI would be expected to grow slightly due to preconstruction and construction, which could affect the local housing market and rental vacancy rates. As described in Section 3.2.13, a dynamic range of populations, income levels, housing values, and vacancy rates could influence the minority or low-income residents in the area around an SNF reprocessing facility site. These factors change over time and are highly dependent on local conditions; therefore, disproportionate impacts on minority or low-income residents from housing market variations could vary widely.

For rural areas that are available to the public and have not experienced previous development, changes to the surrounding minority or low-income communities may be large compared to DOE facility areas that are likely closed to the public and provide very little other productive economic, cultural, or recreational use. Minority or low-income communities around sites that are already devoted to industrial purposes may also experience some effects from development of a large nuclear fuel cycle facility.

4.2.13.2 Facility Operation

Disproportionate impacts on minority and low-income populations from facility operations, repairs, or reconstruction facility would be possible. In addition to impact considerations on land disturbances, noise, dust, emissions, transportation, visual and scenic qualities, and historic and cultural sites described as having an influence on EJ, pathways associated with continued operations and other potential activities associated with a commercial SNF reprocessing facility and how they might affect human populations would also be considered in particular with operations. Important elements of the EJ analysis would address the disposal process and locations of disposal sites for used structural materials remaining from construction activities or materials that would be generated or replaced for maintenance would need to be considered. Wastes produced by facility operations would be managed in accordance with appropriate laws, guidelines, and procedures. EJ impacts surrounding transportation routes would be uncertain until a site-specific study is conducted because of the unknown routes that would be used, and the timing, contents, and quantity of shipments to and from the reprocessing facility. Other considerations would be the extent to which minority and low-income populations in the area around a reprocessing facility could be disproportionately affected through resource dependencies and practices (e.g., subsistence, agriculture, hunting, fishing). Data can be collected to identify any exceptional health problems such as unusual incidences of birth defects, chronic diseases, or cancer clusters among low-income and minority residents within an 80-km (50-mi) radius of a proposed SNF reprocessing facility.

NRC EIS's for other proposed fuel cycle facilities include the most recent EJ analyses conducted with similar potential environmental effects expected for a commercial SNF reprocessing facility. The NRC staff concluded in the environmental analysis conducted for the operations of a proposed MOX fuel fabrication facility at SRS that radiological impacts to the general public during routine operation of the proposed facilities would be small and would not cause any adverse health impacts (NRC, 2005a). The staff further concluded that there would be no disproportionately high adverse impact on low-income or minority population groups within the 80-km (50-mi) assessment area. No surface releases were expected that might enter local streams or interfere with subsistence activities by low-income or minority populations, and there would be no releases that would affect any water or food used for subsistence. For the NEF in Lea County, NM, the staff also found no activities, resource dependencies, pre-existing health conditions, or health service availability issues resulting from normal operations at this enrichment facility that would cause a health impact for the members of minority or low-income communities, either as an individual facility or combined with the effects of other nearby facilities (NRC, 2005b). The impacts expected for the ACP in Piketon, OH also did not appear to be disproportionately high and adverse for minority or low-income populations (NRC, 2006a). Based on these previous considerations, it is unlikely that minority or low-income populations would be disproportionately and adversely affected by normal operations of an SNF reprocessing facility, assuming that the SNF reprocessing facilities would be sited with the appropriate considerations.

4.3 Potential Environmental-Related Considerations for Decommissioning

Decommissioning a fuel cycle facility such as an SNF reprocessing plant involves removing that facility or site safely from service and reducing residual radioactivity to a level that permits (1) release of the property for unrestricted use and termination of the license, or (2) release of the property under restricted conditions and termination of the license (10 CFR 20, Subpart E; NRC, 2006b)

The decommissioning process for NRC regulated facilities is initiated by any one or a combination of the following conditions:

- The license expires;
- The licensee has decided to permanently cease principal activities at the entire site or in any separate building or outdoor area;
- No principal activities have been conducted for 24 months; or
- No principal activities have been conducted for 24 months in any separate building or outdoor area.

The NRC's decommissioning process for an SNF reprocessing facility would likely include steps similar to those for other NRC regulated fuel cycle facilities. These steps are (NRC, 2012b):

- Notification;
- Submittal and review of a decommissioning plan (DP);
- Implementation of the DP; and
- Completion of decommissioning.

The DP would include locations of contamination, plans for collecting and disposing of radioactive, hazardous, and nonhazardous wastes, cost estimates for decommissioning the facility, and a plan for demonstrating that the site can be released for either uncontrolled or controlled use once decommissioning is completed. The DP would be subject to environmental review to identify potential impacts of decommissioning on human health and the environment.

4.3.1 Decommissioning Methods

There are three primary methods for decommissioning a fuel cycle facility:

- Immediate decontamination and dismantlement, known as DECON.
- Deferred decommissioning, which allows for a period of safe shutdown of a facility prior to DECON. The option is referred to as SAFSTOR.

- In place entombment of the facility’s radioactive components, known as ENTOMB.

Facilities may elect to combine two or more of these options as part of a DP.

As part of the final stage of decommissioning, the licensee is required to do the following:

- Ensure the end state of the site meets the commitments identified in the approved DP;
- Certify the disposition of all licensed nuclear material; and
- Perform a radiation survey or demonstrate that the premises are suitable for release in accordance with the requirements of license termination.

The exact methods to be used for decontamination and decommissioning of a commercial SNF reprocessing facility would be dependent upon several factors, such as facility design, site location, extent of any environmental contamination that may be present, and plans for future land use. All equipment, structures, and ancillary facilities would be decontaminated as necessary and removed from the site, and the land returned to existing conditions prior to facility preconstruction, construction, and operation. Alternatively, only the facility equipment would be removed from the site while some or all of the building and ancillary facilities could be left in place for possible future industrial or commercial use. There is no obvious correlation between the decommissioning approach chosen and a facility’s location at a rural, industrial, or DOE site, although it may be more likely that buildings and ancillary facilities would be left in place for future industrial or commercial uses at industrial and DOE sites than at rural sites.

Brief descriptions of the DECON, SAFSTOR, and ENTOMB decommissioning methods are presented below.

4.3.1.1 Immediate Decommissioning (DECON)

Under DECON, soon after the facility closes, surveys would be conducted to identify potential areas of contamination. Equipment, structures, and portions of the facility containing radioactive contaminants would then then removed or decontaminated to a level that permits release of the property and termination of the NRC license (NRC, 2012c). Because DECON operations are expected to be completed within 24 months following closure of a facility, radiation exposures to workers generally are higher than for decommissioning methods that allow for radioactive decay by delaying or extending the work over a longer period. DECON usually requires larger commitments of money and commercial waste disposal site space compared to the two other decommissioning methods. The principal advantage of DECON is that the site is available for unrestricted use after a relatively short time (NRC, 1996).

4.3.1.2 Deferred Decommissioning (SAFSTOR)

Under SAFSTOR, which can be characterized as “delayed DECON,” the facility is maintained and monitored in a safe shutdown condition that allows the residual radioactivity to decay. Later, the facility is dismantled and the property decontaminated (NRC, 2012c). SAFSTOR may be used as a means of satisfying requirements for protection of the public while minimizing radiation exposure, and managing availability of waste disposal capacity. SAFSTOR may also have some advantage when there are other operational nuclear facilities at the same site and may be a more cost effective approach. A disadvantage of SAFSTOR is that the site is unavailable for other uses for some period of time. During this time, maintenance, security, and surveillance are required until the final decontamination is complete. As the SAFSTOR process may take many years, even decades, few personnel familiar with the facility may be available at the time of decontamination (NRC, 1996).

4.3.1.3 Entombment (ENTOMB)

ENTOMB involves removing all fuel and radioactive fluids and wastes and possibly removing selected nuclear components. The remaining radioactive components are sealed into the containment structure. ENTOMB allows the licensee to possess, but not operate, the facility. It is worth noting that no NRC licensed facility has been decommissioned in this manner. Those facilities (mainly reactors) that have been entombed were owned either by DOE or other Federal agencies (NRC, 2012c).

4.3.2 Facility Decommissioning Experience

The NRC is currently involved in the decommissioning of two former fuel cycle facilities, although decommissioning has not been completed at either.

The West Valley SNF reprocessing site is located in West Valley, NY, at the Western New York Nuclear Service Center (Center). The Center is 1,300 ha (3,300 ac) in size. West Valley operated from 1966 to 1972, and produced approximately 600,000 gallons of liquid HLW. The site contains contaminated structures, radioactive waste disposal areas, and additional areas featuring contaminated soil and groundwater. DOE has been decommissioning the Center since the passage of the West Valley Demonstration Project Act in 1980. The NRC is acting in an advisory capacity to DOE. In December 2008, DOE submitted a DP for NRC review and comment. In February 2010, NRC issued a Technical Evaluation Report documenting its review of the Phase 1 DP. The West Valley DP includes plans to release a large portion of the site for unrestricted use, while the remainder of the site may have a perpetual license or be released with restrictions (NRC, 2012d).

The Westinghouse Electric Company is in the process of decommissioning a former fuel cycle facility, known as the Hematite Facility, located in Festus Township, Jefferson County, MO. The facility sits on 92 ha (228 acres) and consists of two main plant buildings, an administration building, several support buildings, and a parking area. Previous plant operations included low-enriched uranium fuel fabrication and processing and treating uranium compounds (including all forms of uranium from depleted to enriched uranium) and thorium fuel. Contamination at the site consists of uranium and thorium in soil and groundwater. The licensee submitted a DP to the NRC in April 2004 and subsequent revisions (NRC, 2012e).

4.3.3 Potential Environmental Considerations

Because the primary purpose of facility decommissioning is to remove radioactive materials to move the site towards a less contaminated end state for license termination, decommissioning would, in general, tend to reduce the environmental effects and risks associated with operation of a commercial SNF reprocessing facility. Potential environmental effects of decommissioning would be temporary, lasting only as long as the decommissioning time period. For each resource area, this section describes the potential environmental considerations for decommissioning potential commercial SNF reprocessing facilities. It is anticipated that the type of site at which the reprocessing facility was constructed (i.e., rural, industrial, or DOE site) would matter little or not at all in terms of what the specific environmental effects of decommissioning the facility might have (with the possible exception that there could be residual soil or water contamination from other facilities or operations at DOE and industrial sites that may need to be dealt with during SNF reprocessing facility decommissioning).

For purposes of this report, it is presumed that the DECON approach would be employed for decommissioning the facility, in consideration of clean operation in compliance with all applicable Federal and state regulations throughout the operations phase. It is further assumed that the reprocessing facility would be decommissioned independently from any other nuclear facilities with which it may be co-located. Assuming that the facility is decommissioned all at once rather than in stages and that no significant remediation of soil, groundwater, or surface water contamination would be required, the staff estimates that the decontamination and decommissioning phase could take about 5 years, or somewhat longer.

4.3.3.1 Land Use and Site Infrastructure

4.3.3.1.1 Land Use

Temporary changes in land use could occur at an SNF reprocessing facility during decommissioning. These changes could include the addition of staging areas or construction of temporary buildings and parking areas. The need for additional land during the decommissioning process is dependent on the layout of a given site. It is anticipated that most sites would have enough space within the previously disturbed area to carry out all decommissioning activities. The influx of temporary workers required for decommissioning may require temporary installation of facilities for onsite parking, training, and office space. However, many of the site workers employed during facility operation may be involved in the decommissioning phase, make this unnecessary. The site could be restored to its existing condition prior to facility preconstruction, construction, and operation. However, decontaminated buildings and structures may be left in place for other industrial or commercial uses. Also, depending on the extent of decontamination, the site may be available for unrestricted or restricted uses.

4.3.3.1.2 Site Infrastructure

As part of decommissioning, the facility may disconnect from local infrastructure (e.g. electrical grid, groundwater or surface water, wastewater treatment facilities). It is anticipated that disconnection from the local infrastructure would occur with no local disruption to these services. Additionally, decommissioning would not be expected to put undue stress on any infrastructure components or services. While not anticipated, it is possible that there may be some temporary interruptions to services, but these would be localized and short-term.

4.3.3.2 Transportation

Decommissioning would require transport of decontamination and demolition equipment and supplies to the facility, transport of waste materials away from the site, and transport of site workers to and from the facility. This would result in increased traffic and wear on roadways, railroads, and perhaps barge traffic. Increased traffic may be more noticeable in rural settings compared to industrial or DOE sites. However, the existing transportation infrastructure could be used for these purposes. There could also be associated radiological exposures to member of the general public due to routine transportation of radioactive materials and non-radiological and radiological effects resulting from transportation accidents, as discussed in Section 4.2.2.

However, all of the above effects would likely be similar, or less than, to those during the preconstruction, construction and operations phases. Also, decommissioning-related environmental effects would be temporary and of relatively short duration, lasting only as long the decommissioning phase.

4.3.3.3 Geology and Soils

The effects on geology and soils due to decontamination and decommissioning are not expected to exceed those impacts associated with preconstruction and construction. The approved DP would require identification of potentially contaminated soils that would require offsite disposal. Consequently, during the decommissioning phase, there is a potential for additional removal of contaminated surface soils from DOE or industrial site locations; however, any such removal is anticipated to be limited as a result of following the operational radiation protection program. Post-closure surveys would ensure all soil areas are properly remediated.

4.3.3.4 Water Resources

4.3.3.4.1 Water Use

Water use during decommissioning is likely to be similar to or less than during preconstruction, construction, or operation. Water may be needed for equipment decontamination, for cleaning trucks and demolition equipment, and to control dust along roadways and other areas. Potable water must also be made available for workers. Water usage during decommissioning would last only as long as the phase itself and would therefore be limited in duration. Additionally, existing water permits and appropriations could be used and would ensure that local water supplies are not overexploited.

4.3.3.4.2 Water Quality

The potential for surface water and groundwater quality degradation associated with decommissioning would be similar to that during preconstruction and construction, assuming that all liquid and solid wastes from building and equipment decontamination are properly contained and any spills or leaks are prevented or immediately cleaned up. Impacts to groundwater quality associated with decommissioning are possible and would be dependent on local topography, hydrogeology, and sources of groundwater recharge. Temporary increases in suspended solids concentrations, above background levels, from runoff stemming from land disturbance could occur. Increased sedimentation could occur in certain nearby water bodies. Water quality could be impaired due to spills or leaks of incidental materials, such as fuel, lubricants, or other hazardous materials, although such spills or leaks would be expeditiously cleaned up. Stormwater runoff could result in reduced water quality. A stormwater management plan would be implemented to control runoff. Solid and liquid wastes from decontamination processes would be collected, properly treated, and disposed offsite.

The approved DP would require identification of potentially contaminated surface water and groundwater that would require remediation. Consequently, during the decommissioning phase, there is a potential for additional removal of contaminated water from DOE or industrial site locations; however, any such removal is anticipated to be limited as a result of following the operational radiation protection program. Post-closure surveys would ensure that water quality is properly remediated.

4.3.3.5 Air Quality

Decontamination and decommissioning activities would result in air quality impacts similar to those resulting from preconstruction and construction, although to a lesser magnitude and for a potentially shorter duration. Primary sources of air impacts during decontamination and decommissioning would include the operation of various construction equipment, onsite fueling and maintenance of construction equipment, the use of explosives to remove foundations if necessary, material handling and stockpiling, commuting to the proposed site (by a workforce that is expected to be somewhat smaller than the initial construction workforce), and offsite transfer of recyclable materials and equipment and wastes destined for offsite treatment and disposal facilities. The most significant sources of fugitive dust expected in preconstruction and construction, cut-and-fill operations and travel on unpaved onsite roads would either not be operative during decontamination and decommissioning or would be undertaken at reduced levels. Unique aspects of the DP, such as whether buried utilities and improvements are removed or abandoned in place, can be expected to have incremental impacts on associated air quality impacts. Air quality impacts would vary depending upon several key considerations, including the magnitude of the emissions generated by the decontamination and decommissioning processes and the local air quality as expressed in the NAAQS compliance status.

4.3.3.6 Noise

Noise sources and levels would be similar to noise during preconstruction and construction, and peaking noise levels would be expected to occur for short durations. Major noise sources would be expected to include: operation of heavy construction equipment; traffic noise resulting from the commuting decontamination and decommissioning workforce and delivery vehicles used to transport disassembled components and waste materials to offsite facilities for redeployment, recycling, or disposal; the potential use of explosives or impact hammers to break up some structures if necessary, such as foundations, roads, and pavements; excavations of buried utilities and components; and cut-and-fill operations designed to return the proposed site to its original grades and contours in some areas.

Offsite noise impacts would be expected to be similar to those for preconstruction and construction. Noise associated with excavation and removal of buried utilities would not occur for those belowground components that are abandoned in place.

4.3.3.7 Ecological Resources

Federal and state laws, regulations, and permitting requirements are in place to protect sensitive aquatic and terrestrial species and habitats, and would apply to an SNF reprocessing facility undergoing decommissioning. Aquatic and terrestrial resources at the facility, including any T&E species, would have already been affected by development and disturbance during preconstruction, construction, and operation. As such, associated habitats would be of diminished quality. Depending on the DP implemented, site restoration could result in some degree of return of any species and habitats that may have been depleted during the preconstruction, construction, and operations phases. Additional potential effects on aquatic and terrestrial resources resulting from decontamination and decommissioning are described below. These effects would be temporary, lasting only as long as the decommissioning phase.

4.3.3.7.1 Aquatic Resources

Effects on aquatic resources during decommissioning would be similar to, but probably less than, those during preconstruction and construction. This is mainly due to the fact that the footprint of activity associated with decommissioning may be less than that that required during preconstruction and construction. Temporary increases in suspended solids concentrations associated with dismantling and decontamination may affect aquatic organisms. Leakage of hazardous chemicals and fuels could introduce toxic elements and impair aquatic systems. In most cases, disturbance of lands beyond the operational areas of the facility is not anticipated, reducing effects aquatic ecology.

4.3.3.7.2 Terrestrial Resources

Decommissioning-related effects on terrestrial resources would also likely be similar to, but probably less than, those during preconstruction and construction. The amount of land required to support the decommissioning process would, in most cases, likely be located within the operational footprint of the site. Any terrestrial habitats disturbed during preconstruction and construction would remain habitats of low quality during plant operations and decommissioning. Vegetation could be impacted by the direct removal of trees, plants, shrubs, and grasses from the operating site and any associated staging and laydown areas. This would result in potential reduction in wildlife habitat and spread of invasive species and noxious weed populations. Effects on terrestrial resources could also result from dust generation due to traffic and construction-type activities, noise from dismantlement of facilities and heavy equipment traffic, and surface erosion and runoff. In general, most wildlife would disperse from the project area as decommissioning activities get underway and may re-colonize in adjacent, undisturbed areas.

4.3.3.8 Waste Management

4.3.3.8.1 General Considerations

This section presents the waste management impacts associated with the decommissioning of PUREX reprocessing facilities with features such as those described in Section 2.3. Decommissioning of a reprocessing facility, like other fuel cycle facilities, would generate radioactive, hazardous, and nonhazardous solid and liquid wastes. All wastes would be managed consistent with local, state, and Federal requirements for the various waste types. It can be reasonably assumed that there would be no SNF or reprocessed product remaining onsite when facility operations cease.

PUREX reprocessing is a complex chemical separation process that requires several buildings and structures to house and support the necessary vessels, tanks, columns, and piping. Over the course of operations, many of these components are in direct contact with radioactive and hazardous materials and would become contaminated. In some cases, these components can be decontaminated to remove the radioactivity or hazardous contamination and disposed of in the same manner as uncontaminated construction debris. In other cases, the radioactive or hazardous contamination may not be totally removed and the components would require disposal in a licensed radioactive or hazardous waste disposal facility appropriate for the level of contamination. Decontamination of a PUREX reprocessing facility has the potential to generate large volumes of radioactive and hazardous wastes. Demolition of decontaminated buildings and structures would generate large volumes of nonhazardous construction debris. The volumes and types of waste would vary as a function of facility size, design, and operating history.

The types and quantities of wastes generated during decommissioning would depend on the DP for final disposition of the facility. For example, if the intent of facility decommissioning is release for unrestricted use, then more waste would typically be generated as compared to a facility that is decommissioned for release for restricted use. In the former case, decommissioning would remove contamination to a greater extent than the latter.

4.3.3.8.2 Illustrative Examples

The two PUREX reprocessing facilities listed below (with their operational reprocessing capacities shown in parentheses) have undergone decommissioning to varying degrees (DOE, 2010; AREVA, 2012b). Information on estimated or actual decommissioning waste types and volumes from these facilities is presented as illustrative examples of what wastes might be expected to be generated from decontamination and decommissioning of a potential commercial SNF reprocessing facility in the U.S.:

- Nuclear Fuel Services West Valley Plant, West Valley, NY (300 MTHM/year (330 tHM/year))

- Marcoule UP1 Reprocessing Plant, Marcoule, France (600 MTHM/year (660 tHM/year))

Note that at these two facilities, historical (or legacy) waste from reprocessing operations remained onsite at the time of facility closure and decommissioning. These historical waste volumes contributed to the decommissioning waste volume estimates for each facility. New commercial SNF reprocessing operations in the U.S. are expected to treat and dispose of waste on an ongoing basis. Therefore, the waste management effects for a proposed commercial reprocessing facility would not include impacts from historical waste. Consequently, the historical waste volumes are not included in the discussions below.

Nuclear Fuel Services West Valley Plant

The goal of decommissioning the Nuclear Fuel Services West Valley Plant is to decontaminate the site to the extent that it may be used in the future with specific restrictions or without restrictions. Any portions of the site where sufficient decontamination cannot be achieved would remain under long term management or stewardship of DOE. Details of the decommissioning EIS and record of decision can be found at the West Valley Demonstration Project EIS website (http://www.westvalleyeis.com/). A range of alternatives were considered to meet the decommissioning goals. Table 4-13 shows the waste types and estimated ranges of waste volumes for the alternatives considered.

Marcoule UP1 Reprocessing Plant

The goal of decommissioning the Marcoule UP1 Reprocessing Plant is to reduce residual radioactivity to a level that would eliminate radiologically restricted access zones (Nuclear 3engineering International, 2004). The facility is located within the Marcoule nuclear site, which is restricted from access by the general public. Decommissioning consisted of the following three activities: (1) advanced rinsing and removal of nuclear material; (2) retrieval and conditioning of historical (operational) waste on site; and (3) decommissioning and demolition of facilities (Masson et al., 2000). The first two activities are currently underway. As of mid 2003, the following types and amounts of waste have been generated (Cranes, 2004):

- Plutonium - 20 kilograms (kg) (44 pounds (lb))
- Equipment - 1,800 metric tons (2000 tons)
- Effluents from rinsing and removal operations - 11,000 m^3 (14,000 yd^3)
- Radioactive waste – 5,400 m^3 (7,100 yd^3) (95 percent LLW and 5 percent HLW)

Figure 4-13 Nuclear Fuel Services West Valley Plant Estimated Solid Waste Volume Estimates for Decommissioning Alternatives Considered

Waste Type	Waste Volume, m^3 (yd^3)
Non-hazardous	140,000-15,000 (145,000-15,600)
Hazardous	15-3 (15.6-3.1)
Low-level Radioactive	1,500,000-9,900 (1,560,000-10,300)
Greater-Than-Class C	4,200-0 (4,400-0)
Transuranic	1,000-35 (1,040-36)
Mixed Waste	570-410 (590-430)
Total	1,600,000-26,000 (1,660,000-27,000)

Source: DOE, 2010.

4.3.3.8.3 Special Considerations

The staff recognizes that there could be certain site-specific, long-term waste management-related issues associated with facility decommissioning. These are listed below for future consideration, but are not discussed in detail.

- Site remediation and monitoring—If there has been nay significant soil, groundwater, or surface water contamination resulting from practices during facility operation or decommissioning, then it could be necessary to remediate the contaminated media (e.g., by soil removal, groundwater pump and treat). In the case of contaminated groundwater or surface water, periodic monitoring (i.e., sample collection and analysis) may be necessary to check on the progress of ongoing remediation. Note, however, that it is anticipated that the reprocessing facility would be run as a clean operation and there would be no residual contamination in soil or water following decontamination and decommissioning.

- Radioactive waste storage—in the event that offsite management options for HLW or LLW (e.g., disposal, storage) are not available for decommissioning wastes, these wastes may need to be stored onsite for some period of time until offsite facilities for their management become available. Such wastes would be stored in properly designed containers and storage facilities and would be appropriately monitored and maintained throughout the storage period, thus minimizing the potential for any adverse environmental effects (e.g., from leaks, spills, air emissions, worker or public radiation exposure).

- Onsite disposal of LLW—it is possible that LWW generated during decommissioning, or perhaps throughout the facility operation, would be disposed onsite in an LLW disposal facility. Such a facility would be properly designed, licensed by the NRC or an Agreement State, and monitored and maintained in accordance with license conditions and applicable Federal and state regulations.

4.3.3.9 Historic and Cultural Resources

Most, if not all, historic and cultural resources should have already been identified and appropriately managed during preconstruction, construction, and operation. However, decommissioning of an SNF reprocessing facility could potentially affect known or undiscovered resources if any previously undisturbed areas are affected. Note also that because the potential length of life of an SNF reprocessing facility could be 50 years or more, the facility itself could potentially be considered historic at the time of decommissioning, and would need to be treated accordingly. Procedures for identifying historic properties, consulting with appropriate authorities, and mitigating adverse effects would be as described earlier in this report.

4.3.3.10 Visual and Scenic Resources

Effects on visual and scenic resources from decommissioning an SNF reprocessing facility would be similar to those during preconstruction and construction. Visual and scenic quality may be improved in rural areas if buildings and other structures are removed and any cleared areas are revegetated with native species; however, such changes would not be as pronounced in industrialized areas both outside and within DOE sites. If facility buildings and other structures are reused for other industrial or commercial operations, effects on visual or scenic resources from construction and operation would be unchanged.

4.3.3.11 Public and Occupational Health

The following sections describe the radiological and non-radiological exposure conditions applicable to decontamination and decommissioning of SNF reprocessing facilities. The nuclear industry has significant experience in decontaminating and decommissioning fuel cycle facilities and other nuclear operations in manners protective of public and worker health and safety.

4.3.3.11.1 Radiological

<u>Worker Health and Safety</u>

It is expected that the bulk of radioactive material in the process line would be removed prior to termination of operations and commencement of decontamination and decommissioning. If operations were performed in accordance with an operational radiation protection program, it is unlikely that any soil, surface water, or groundwater surrounding the facility would be contaminated by radioactive materials. Consequently, the radioactivity present in the facility at the start of the decontamination and decommissioning phase would be limited to surface contamination within the shielded cells, on and in piping, and on surfaces that routinely came in contact with radioactive material. The levels of surface contamination could be high. However, the amount of radioactive material, and therefore the radiological hazard, would be greatly reduced compared to the amount of radioactive material in the process line during operations.

Decontamination activities would include removing as much of the radioactive material in the process lines and in the shielded hot cells as possible using remotely-operated technology (i.e., manipulators in shielded cells). This material would be packaged and disposed of as radioactive waste. Once the bulk of the surface contamination is removed, contaminated equipment in the process line would be size-reduced using cutting tools operated with manipulators in the shielded cells. This material would be disposed as radioactive waste. Finally, the shielded cells would either be dismantled or, if it is possible to adequately decontaminate them, they could be used for a new mission. Dismantling of the shielded cells would be performed in a filtered containment or enclosure environment to prevent the clean portions of the facility from becoming contaminated. These procedures would also serve to protect worker health and safety. Final disposition of the facility would depend on the intended future use of the facility.

Further, decommissioning would be conducted under an operational radiation protection program in accordance with 10 CFR Part 20. One of the major goals of this program would be to keep worker exposures to radiation and radioactive material as low as reasonably achievable (ALARA); i.e., worker doses during decontamination activities would be within the dose limits in 10 CFR Part 20 and subject to ALARA. The radiation protection program must evaluate both external and internal exposures, with the goal being to minimize the total effective dose equivalent. An effective ALARA program must also take into account minimizing individual worker doses with minimizing the collective dose to workers in a group. For example, using many workers to perform small portions of a task would reduce the individual worker dose to low levels. However, frequent worker changes would make the work inefficient, resulting in a significantly higher collective dose to all the workers than if fewer had received slightly higher individual doses.

Public Health and Safety

As discussed above, the quantity of radioactive material in a reprocessing during decommissioning activities is expected to be greatly reduced as compared to the amount of material in the facility during operations. In addition, operations involving shearing spent fuel rods and dissolving spent nuclear fuel would not be conducted during decommissioning activities. As a result of the radiation protection program implemented during normal operations, it is not likely that soil, surface water, and groundwater outside of the facility would become contaminated and thus require removal. Therefore, the likelihood of release of radioactive material and subsequent exposure of the public would be very low during decommissioning activities. Provided that all radioactive contamination is confined to the operational facilities and conducted within filtered containment as described above, the likelihood of generating airborne radioactive contamination would also be very low.

4.3.3.11.2 Non-radiological

Worker Health and Safety

As discussed above for radioactive material, it is expected that nearly all hazardous materials in the process line would also be removed prior to termination of operations. Thus, the likelihood of worker exposure to hazardous materials associated with decommissioning activities would be greatly reduced as compared to the likelihood of exposure during operations. Radiological decontamination activities would avoid the use of hazardous materials because radiologically contaminated hazardous materials are considered mixed waste when they are disposed. The generation of mixed waste is avoided, perhaps by license condition, unless absolutely necessary because there is no disposal pathway for mixed waste. Appropriate safety precaution, in accordance with OSHA requirements, would be employed in the handling of hazardous materials.

Although work activities during decontamination and decommissioning differ from those during operation, the occupational hazards are expected to be similar. Consequently, injury rates during decontamination and decommissioning activities are expected to be similar to injury and illness rates during operations.

Public Health and Safety

As discussed above, it is expected that nearly all hazardous materials in the process lines would be removed as part of operations and prior to commencement of decontamination and decommissioning activities. Thus, the likelihood of the release of hazardous materials associated with decommissioning would be greatly reduced compared to the likelihood of release during operations. As also described earlier, radiological decontamination activities would avoid the use of hazardous materials.

4.3.3.12 Socioeconomics

Decontamination and decommissioning would provide continuing employment opportunities for some of the existing operations workforce and for other residents of the ROI. However, additional specialized decommissioning workers would be required from outside the ROI. Although at a lower level than during operations, expenditures on salaries and materials would be expected to contribute to the area economy, and state and local governments would continue to collect tax revenues. As decommissioning nears completion and fewer site workers are needed, the housing market would be affected as more housing would become available, and there would be a decreased need for public services.

4.3.3.13 Environmental Justice

During decommissioning of an SNF reprocessing facility, potential effects may occur on soils through mobilization of contaminants by water or wind and affect surrounding communities. Decommissioning could also affect water around the site through surface runoff and affect the quality of subsistence resources such as crops and fish. However, because decommissioning could take place well in the future, the exact nature and scope of these impacts are uncertain because only present-day technologies are available. Advanced technologies or regulations improving the current decontamination and decommissioning process could be available when decommissioning is planned. Additionally, the nature of the community surrounding the site and presence of minority and low-income populations could have changed over the decades since preconstruction, construction, and commencement of operations. A review of the locations, practices, and health conditions of any minority and low-income populations within the ROI at the time of decommissioning would provide information whether environmental effects would fall disproportionately on these EJ populations.

4.4 Preliminary Considerations for Potential Cumulative Environmental Effects

4.4.1 Evaluation of Cumulative Environmental Effects

The Council on Environmental Quality (CEQ) regulations implementing NEPA define cumulative impacts as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions” (40 CFR 1508.7). For an SNF reprocessing project, cumulative effects would be assessed from the anticipated impacts of the SNF reprocessing project when added to other identified projects, facilities, or activities in the region that have impacts that affect the same resources or human populations. Effects from the various sources may be direct or indirect and they may be additive or interactive. Such effects are assessed that, when on their own, may be minor, but in combination with other effects may produce a cumulative effect that is of greater concern.

Examples of cumulative impacts that may be considered include (NRC, 2003):

- Pollutant discharges into surface water;
- Deterioration of recreational uses from loading water bodies with discharges of sediment, nutrients, or thermal effluents;
- Reduction or contamination of ground water supplies; and
- Physically segmenting a community through incremental development.

To determine cumulative impacts, the NRC staff typically follows CEQ guidelines as outlined in "Considering Cumulative Effects Under the National Environmental Policy Act" (CEQ, 1997) and NUREG-1748 (NRC, 2003).

4.4.2 Actions that May Contribute to Cumulative Effects

4.4.2.1 General Considerations

This section provides a brief general discussion of the types of past, present, and reasonably foreseeable future actions that could be taken into account in considering potential cumulative effects associated with preconstruction, construction, operation, and decommissioning of a commercial SNF reprocessing facility. As described previously, at present there is no defined location for such a facility. Due to the complex and site-specific nature of a cumulative impact assessment, this section is intended to provide general information for understanding the potential for cumulative impacts based on the three general site types—i.e., rural sites, industrial sites, and DOE sites--that might be considered for future commercial SNF reprocessing facilities. Based on these broad categories, it is possible to provide a general discussion of the types of activities that may be anticipated to occur in each type of location.

The timeframe for a cumulative impact assessment associated with an SNF reprocessing facility project could generally extend through approximately 50 years. This time period is based on the projected lifecycle of a commercial SNF reprocessing facility, assuming a 5-year construction period, 40-year operating license, and 5 years for decontamination and decommissioning at the end of the facility lifecycle. However, cumulative effects on some resource areas may continue beyond 50 years. For example, some additional monitoring requirements beyond 50 years may be established as part of the license termination for the facility.

To identify the past, present, and reasonably foreseeable future actions in a region that could contribute to cumulative effects, an ROI would be defined for each resource that is expected to be impacted by the proposed project. An ROI for a particular resource is the size of the surrounding area within which environmental effects from multiple sources may be additive or interactive. The sizes of the ROIs may be different for various resources, and some resources may be remote from the proposed site, such as a waste disposal facility or a receiving water body downstream of the proposed project. Still others might cover large areas, such as a watershed or airshed. Impacts on the full extent of the resources affected, such as an ecoregion, should be analyzed, even if the resource extends beyond the identified ROIs. Table 4-14 presents examples geographic ROIs that might be used in site-specific cumulative impact analyses once specific SNF reprocessing facility locations are identified.

Another key consideration in the assessment of cumulative effects is that, for reasons such as efficiency and to minimize costs and risks associated with the transport of high activity nuclear materials, an SNF reprocessing facility could be co-located with other nuclear facilities with purposes or operations directly related to SNF reprocessing. Such related nuclear facilities may include:

- Commercial nuclear power plants
- ISFSIs or MRS installations for storage of SNF or HLW
- Reprocessed uranium enrichment facilities
- Enriched uranium or MOX Fuel fabrication facilities.

These co-located facilities may be licensed by the NRC under a single license, or each of these facilities may be licensed separately and at different times. The evaluation of potential cumulative effects would need to take into account the incremental effects of the SNF reprocessing project when added to the environmental effects from these associated facilities.

Table 4-14 Examples of Possible Regions of Influence for Resource Types

Resource Type	Possible Regions of Influence
Air Quality	Airshed
Water Quality	Watershed, River Basin, Estuary, and Aquifer
Vegetative Resources	Forest, Range, or Vegetation Ecosystem
Resident Wildlife	Species Habitat or Ecosystem
Migratory Wildlife	Breeding Grounds, Migration Route, and Wintering Areas
Fishery Resources	Stream, River Basin, Estuary, and Spawning Area
Historic Resources	Historic District and Tribal Territory
Land Use	Community, Metropolitan Area, County, State, or Region
Coastal Zone	Coastal Region
Recreation	River, Lake, and Land Management Unit
Socioeconomics	Community, Metropolitan Area, and Census Boundary

Source: CEQ, 1997.

Note that for actions to be considered reasonably foreseeable future actions (RFFAs) in a cumulative effects assessment, there generally should exist some documentation of plans for such projects (e.g., in local government planning documents). Courts have held that "[a]n impact is 'reasonably foreseeable' if it is 'sufficiently likely to occur that a person of ordinary prudence would take it into account in reaching a decision'" (*City of Shoreacres v. Waterworth,* 420 F.3d 440, 453 (5th Cir.2005) (citing *Sierra Club v. Marsh,* 976 F.2d 763, 767 (1st Cir.1992). Courts have also recognized that "An environmental impact is considered 'too speculative' for inclusion in an EIS if it cannot be described at the time the EIS is drafted with sufficient specificity to make its consideration useful to a reasonable decision-maker" (*Dubois v. U.S. Dept. of Agriculture*, 102 F.3d 1273, 1286 (1st Cir. 1996). RFFAs should also be probable, i.e., those effects that are "possible" but not "probable" should be excluded. Some indications that a future action is "reasonably foreseeable" may include:

- It has been Federally-approved;
- There is funding pending before any agency for the project; and
- There is evidence of active preparation to make a decision on alternatives to the project (*Clairton Sportsmen's Club v. Pennsylvania Turnpike Commission*, 882 F. Supp 455 (W.D. Pa 1995).

Note also that if, as discussed in Section 4.1.1.5.2, the NRC staff determines that preconstruction of an SNF reprocessing facility is not part of the proposed action, then preconstruction may be treated as a past or present actions in NEPA documents, the environmental effects of which would be analyzed under the cumulative effects of construction, operation, and decommissioning of the reprocessing facility.

4.4.2.2 Considerations for the Three Generalized Site Types

4.4.2.2.1 Rural Sites

Regions in which rural sites for an SNF reprocessing facility may be located can cover large areas that are mostly undeveloped. Thus, there may be few past actions to be considered in a cumulative effects assessment. Past actions in such areas may include agricultural activities and limited commercial development. As discussed previously, it would be necessary to construct infrastructure, such as electrical transmission lines and roads, necessary to support the reprocessing project; and such projects may be considered past or present actions if deemed preconstruction activities that are not part of the proposed action. RFFAs could include construction of additional socioeconomic infrastructure (e.g., housing, public and emergency services facilities) needed as a result of in-migration of workers for the reprocessing project, or other nuclear facilities that might be constructed in association, or be co-located, with a reprocessing facility.

4.4.2.2.2 Industrial Sites

In commercial industrial areas, the land typically has been disturbed and developed, and past actions would likely include various industrial and commercial facilities and related activities in the area, existing residential development associated with higher population densities in such areas, and associated electric power, transportation, and socioeconomic infrastructure. Additionally, there could be existing soil, groundwater, or surface water contamination in such areas contributing potential impacts to the environment. However, such areas would tend to be less developed with respect to nuclear activities, and additional socioeconomic infrastructure may be needed to support the influx of workers with nuclear skills. As at rural sites, RFFAs could also include installation of other nuclear facilities that might be constructed in association, or be co-located, with a reprocessing facility.

4.4.2.2.3 DOE Sites

DOE facilities and installations that may serve as locations for a commercial SNF reprocessing facility are mostly large (potentially 100,000 ha (247,000 ac) or more) and complex facilities, with a direct work force (both skilled and unskilled labor) that numbers in the thousands, and annual budgets of $U.S. billions (DOE, 2007). Such facilities may already have much of the infrastructure such as transportation (e.g., rail links, road, intermodal transport), emergency response, security, waste management, and a local pool of labor with nuclear facility experience that would be needed for a SNF reprocessing facility. As at rural sites, RFFAs could also include installation of other nuclear facilities that might be constructed in association, or be co-located, with a reprocessing facility.

However, the sheer size and complexity of these facilities makes it difficult to make generalizations about site-specific past, present, and RFFAs. Historically, these facilities have been operated for 50 years or more by DOE and its predecessor agencies for the purposes of supporting the national nuclear weapons program, and conducting government-sponsored research into nuclear energy technology. At present, although still engaged in nuclear technology research, the mission of these facilities has shifted to focus in large part on:

- Cleaning up Cold War legacy sites
- Mothballing/closing, decontaminating, and decommissioning facilities that have reached the end of their lifecycle
- Managing and radioactive wastes that are stored onsite
- Cleaning up previous contamination of soils and groundwater

In their environmental management programs, these facilities deal with many different types of both radioactive and nonradioactive wastes, including LLW, liquid and solid HLW, SNF, GTCC waste, TRU defense wastes, and non-radioactive hazardous wastes. Some of these waste streams are legacy materials from historic Cold War activities, while others are generated by ongoing operations. In most cases, these environmental management activities are governed by agreements between DOE and different stakeholders, and are projected to last for decades (DOE, 2007).

In addition, these types of government facilities may have other missions that are not related to nuclear technology. Consistent with one of the core missions of DOE to address the nation's energy challenges (DOE, 2012), most of these activities are related to energy technology, including:

- Basic research and development
- High performance computing
- Alternative energy
- Energy efficiency
- Nanotechnology
- Environmental remediation technologies
- Homeland security
- Materials science
- Geoscience
- Biology, Microbiology, and Biotechnology
- Atmospheric technologies
- Biotechnology

Finally, different DOE facilities may have programs or projects that are under the control of Federal agencies other than DOE, such as the Departments of Defense and Homeland Security.

4.5 Preliminary Considerations Regarding Greenhouse Gas Emissions

This section presents a discussion of considerations associated with the effects an SNF reprocessing facility project may be expected to have on carbon dioxide (CO_2) and other GHGs.

4.5.1 Greenhouse Gases

GHGs include those gases that are transparent to solar (short-wave) radiation but opaque to long wave (infrared) radiation from the earth's surface. GHGs include such as CO_2, water vapor, nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The net effect from GHGs in the atmosphere over time is a trapping of absorbed radiation and a tendency to warm the planet's surface and the boundary layer of the earth's atmosphere, which constitute the "greenhouse effect" (IPCC, 2007). Some direct GHGs (gases that can directly affect global warming once they are released into the atmosphere, such as CO_2, CH_4, and N_2O) are both naturally occurring and the product of industrial activities, while others such as the HFCs are man-made and present in the atmosphere exclusively due to human activities. Each GHG has a different radiative forcing potential (the ability to affect a change in climatic conditions in the troposphere, expressed as the amount of thermal energy (in watts) trapped by the gas per square meter of the earth's surface) (IPCC, 2007). The radiative efficiency of a GHG is directly related to its concentration in the atmosphere.

As a way to compare the radiative forcing potentials of various GHGs without directly calculating changes in their atmospheric concentrations, an index known as the Global Warming Potential (GWP) (IPCC, 2007) has been established with CO_2, the most abundant of GHGs released to the atmosphere (after water vapor[12]), established as the reference point. GWPs are calculated as the ratio of the radiative forcing that would result from the emission of 1 kg (2.2 lbs) of a GHG to that which would result from the emission of 1 kg (2.2 lbs) of CO_2 over a fixed period of time. GWPs represent the combined effect of the amount of time each GHG remains in the atmosphere and its ability to absorb outgoing thermal infrared radiation. As the reference point in this index, CO_2 has a GWP of 1. On the basis of a 100-year time horizon, GWPs for other key GHGs are as follows: 21 for CH_4, 310 for N_2O, 11,700 for HFC-23, and 23,900 for SF_6 (IPCC, 2007).

Indirect GHGs, carbon monoxide (CO), nitrogen oxides (NO_x)[13], nonmethane volatile organic compounds (NMVOCs), and sulfur dioxide (SO_2), indirectly affect terrestrial solar radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone or, in the case of SO_2, by affecting the absorptive characteristics of the atmosphere.

4.5.2 Greenhouse Gas Emissions in the United States

EPA is responsible for preparation and maintenance of the official U.S. Inventory of Greenhouse Gas Emissions and Sinks[14] to comply with existing commitments under the United Nations Framework Convention on Climate Change (UNFCCC). The most recent version of this

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[12] Water vapor is the most abundant and most dominant greenhouse gas (GHG) in the atmosphere. However, it is neither long-lived nor well mixed in the atmosphere, varying spatially from 0 to 2 percent.

[13] NOx represents all thermodynamically stable oxides of nitrogen, excluding nitrous oxide (N_2O).

[14] GHG sinks are those activities or processes that can remove GHGs from the atmosphere.

inventory was published by EPA in April 2012 (EPA, 2012). GHG emissions[15] are reported in sectors, using the GWPs established in the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).[16] Preconstruction, construction, operation,

and decommissioning of a PUREX process-based SNF reprocessing facility would result in the release of GHGs as a result of human activities that are identified by EPA as the sources of GHGs in the U.S. Inventory including combustion of fossil fuel primarily related to electricity generation, transportation (e.g., for privately-owned vehicles, diesel trucks), use of other mobile sources (e.g., certain construction equipment), industrial applications, heating, and commercial applications.

4.5.3 Greenhouse Gases from Preconstruction, Construction, Operation, and Decommissioning

Preconstruction, construction, operation, and decommissioning of an SNF reprocessing facility can be expected to directly result in emissions of CO_2 and other GHGs through various mechanisms, primarily from combustion of fossil fuels in both mobile and stationary sources. Possible major sources for each project phase are identified in the sections that follow. Note that during all phases of the SNF reprocessing project, there would also be indirect emissions of GHGs from electric generating facilities supplying power to the facility, although the quantities of these indirect GHGs produced would depend on the types of electric generating facilities supplying the power (e.g., coal-fired power plants would produce significantly more GHG emission than hydroelectric power plants).

4.5.3.1 Preconstruction and Construction

During preconstruction and construction, fossil fuels would be consumed onsite to support construction vehicles and equipment, as a result of commuting to and from the proposed site by the construction workforce, and by delivery vehicles bringing materials and equipment to the proposed site and removing construction-related wastes from the proposed site to area landfills and waste treatment and disposal facilities.

4.5.3.2 Facility Operation

During operations, GHG emissions would be likely to result primarily from activities including commuting of the operational workforce, deliveries of SNF and process chemicals to the facility,

[15] In keeping with the Global Warming Potential (GWP) convention that names CO_2 as the reference gas, assigning it a GWP of 1, GWPs of other direct GHGs are expressed as equivalents (Eq.) of CO_2, expressed in teragrams (Tg) of CO_2 equivalent (Tg CO2 Eq.). One Tg is equal to 1 million metric tons (1.12 million tons).

[16] Intergovernmental Panel on Climate Change (IPCC) assessment reports are a compilation of separate reports of the various working groups that are established by the Panel. IPCC periodically updates assessment reports to incorporate newly established data, including revisions to GWPs and radiative forcing potentials of GHGs. The latest is the Fourth Assessment Report, published in 2007. Revised GWPs are contained in the report of Working Group I (IPCC, 2007). However, to provide for the analysis of trends of GHG emissions and sinks over time, nations responsible for GHG inventories continue to use the GHG GWPs established in the Second Assessment Report published in 1996.

deliveries of product to fuel fabrication facilities, fossil fuel combustion in process equipment (e.g., generators and boilers), return of empty transport containers to their points of origin, and delivery of operational wastes to designated offsite treatment and disposal facilities. An incidental amount of GHG emissions would also result from the onsite storage and dispensing of fossil fuels to support operations.

Table 4-15 shows CO_2 emissions for La Hague's central production plant.

Table 4-15 Annual Carbon Dioxide Discharge from La Hague Central Production Plant

Year	2007	2008	2009
Annual Release, metric tons (tons)	80,551 (88,791)	53,611 (59,095)	40,117 (44,221)

Source: AREVA, 2009.

Note that there would be indirect positive effects from facility operations. Nuclear power generated with fuel fabricated from reprocessed SNF would indirectly displace GHG emissions that would otherwise be released from fossil-fueled power plants. Accordingly, SNF reprocessing can be thought of as indirectly helping to avoid GHG emissions.

4.5.3.3 Decommissioning

GHG emissions associated with decommissioning would likely result primarily from three activities: (1) onsite consumption of fossil fuels in vehicles and equipment used to dismantle and demolish existing structures and excavate buried utilities and components; (2) transportation of waste and salvage materials from the site to appropriate offsite treatment, disposal, or recycling facilities; and (3) commuting to the site of the decommissioning workforce.

4.5.4 Greenhouse Gas Regulations

In June 2010, EPA released a final rule implementing a phased approach to monitoring and reporting of GHGs by stationary sources (75 FR 31514). The first phase began on January 2, 2011, and applies to facilities already subject to PSD (construction) or Title V (operation) permitting due to their non-GHG pollutants. EPA set the threshold for requiring GHG monitoring and reporting at 75,000 metric ton (82,672 tons) per year CO_2e[17] for these facilities. The second phase began on July 1, 2011, and PSD and Title V permitting requirements can apply to facilities based only on GHG emissions (i.e., permitting requirements apply even if the facility does not exceed the thresholds for any non-GHG). EPA set the threshold for requiring GHG monitoring and reporting at 100,000 metric tons (110,230 tons) per year CO_2e for these facilities.

[17] CO_2e, "equivalent carbon dioxide," is the concentration of CO_2 that would cause the same level of radiative forcing as a given type and concentration of greenhouse gas. It is the internationally recognized measure of GHG emissions.

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5 EXAMPLES OF MANAGEMENT AND MITIGATION MEASURES FOR POTENTIAL ADVERSE ENVIRONMENTAL EFFECTS

5.1 Overview

This chapter provides examples of possible measures to manage or mitigate potential adverse environmental effects from preconstruction, construction, and operation of potential commercial spent nuclear fuel (SNF) reprocessing facilities, such as those that may be associated with environmental-related considerations discussed in Section 4.2 of this Environmental Topical Report (ETR). Measures are identified for each resource area, where applicable. Management and mitigation measures for potential environmental effects from decommissioning are not discussed in this report as they would be similar to many of those employed during facility preconstruction, construction, or operation, and would be tailored to the specific procedures in use at the time of decommissioning well in the future when new technologies may be available.

Note also that the list of management and mitigation measures presented in this chapter is not meant to be all inclusive, but is meant only as examples for future consideration by the NRC staff that prepare an environmental assessment (EA), or environmental impact statement (EIS) if necessary, for the future rulemaking or licensing and regulating SNF reprocessing facilities; and many other possible measures could be applicable on project-, design-, and site-specific bases. Inclusion of management and mitigation measures in the ETR does not imply that they are, or will be, applicable or complete when applied to a potential license application for an SNF reprocessing facility.

Management actions are active measures a licensee or facility operator would implement to reduce potential adverse impacts to a specific resource area. These site-specific actions are sometimes related to environmental (or adaptive) management systems (CEQ, 2007). With regard to mitigation measures, under the Council on Environmental Quality (CEQ) regulation in Title 40 of the *Code of Federal Regulations* (40 CFR) 1500.2(f), Federal agencies shall, to the fullest extent possible, “use all practicable means consistent with the requirements of the National Environmental Policy Act and other essential considerations of national policy to restore and enhance the quality of the human environment and avoid or minimize any possible adverse effects of their actions on the quality of the human environment.” The CEQ regulations define mitigation to include activities that (1) avoid the impact altogether by not taking a certain action or parts of an action; (2) minimize impacts by limiting the degree or magnitude of the action and its implementation; (3) repair, rehabilitate, or restore the affected environment; (4) reduce or eliminate impacts over time by preservation or maintenance operations during the life of the action; or (5) compensate for the impact by replacing or substituting resources or environments (40 CFR 1508.20).

The above definitions have been used in identifying potential environmental management and mitigation measures in this ETR as actions or processes (e.g., process controls and management plans) that would be implemented to control and minimize potential adverse environmental effects associated with SNF reprocessing facility projects. In addition, an applicant for a license to construct and operate a commercial SNF reprocessing facility must comply with applicable laws and regulations, including obtaining and adhering to the requirements of all appropriate construction and operating permits.

The management and mitigation measures identified in this chapter do not include environmental monitoring activities. Facility- and site-specific environmental monitoring programs would be developed in accordance with specific NRC licensing requirements.

5.2 Possible Management and Mitigation Measures by Resource Area

For each resource area, the sections that follow provide lists of possible management and mitigation measures that may be applicable to addressing potential adverse environmental effects of (1) preconstruction and construction, and (2) operation of commercial SNF reprocessing facilities. The measures are not listed in any particular order.

5.2.1 Land Use and Site Infrastructure

5.2.1.1 Preconstruction and Construction

- Implementation of best management practices (BMPs) to minimize impacts to surrounding areas, e.g., use of sedimentation detention basins, protection of undisturbed areas with silt fencing and straw bales, use of site stabilization practices such as placing crushed stone on disturbed soil in areas of concentrated runoff, and watering onsite construction roads at least twice daily, when needed, to control fugitive dust emissions.

- Limitation of land disturbance to only the areas that are necessary for preconstruction and construction activities (i.e., minimize the construction footprint to the extent practicable).

- Restoration and reclamation of land disturbed during preconstruction and construction but not required for facility operations, including stabilization of the site with natural low-water consumption, low-maintenance landscaping, and pavement, to the extent practicable.

5.2.1.2 Facility Operation

- Limitation of land disturbance to only the areas necessary for operational activities.

- Implementation of plant- and site-specific practices that minimize effects on surrounding land uses.

5.2.2 Transportation

5.2 2.1 Preconstruction and Construction

- Consultation with State departments of transportation or Federal Highway Administration (roads), Surface Transportation Board (rail), or U.S. Coast Guard (barge), as required depending on mode(s) of transportation under consideration.

- Use of accepted industry codes and standards for handling and transporting hazardous materials during transport.

- Implementation of emergency response plans for spillage of hazardous materials during transport.

- Safe driving and emergency response training for truck crews.

- Employee car pooling and staggering shifts to reduce facility-associated traffic on local roads during shift changes.

- Maintaining low speed limits onsite to reduce noise, avoid accidents, and minimize impacts to wildlife.

- Prompt removal of earthen materials on paved roads carried onto the roadways by wind, trucks, or earthmoving equipment.

- Prompt stabilization or covering of bare earthen areas once roadway and highway entrance earthmoving activities are completed.

- Tire washing, as needed, on a stabilized stone (gravel) area or concrete pad that drains to a sediment trap.

- Prior to entering public roadways, inspection of vehicles for cleanliness from dirt and other matter that could be released onto highways.

- Covering open-bodied trucks (e.g., install tarps over open beds) to prevent debris from falling off or blowing out of vehicles onto public roadways.

5.2.2.2 Facility Operation

- Use of accepted industry codes and standards for handling and transporting radioactive and hazardous materials.

- Implementation of emergency response plans for spillage of hazardous materials.

- Safe driving and emergency response training for truck crews.

- Employee car pooling and staggering shifts to reduce facility-associated traffic on local roads during shift changes.

- Maintenance of low speed limits onsite to reduce noise, avoid accidents, and minimize impacts to wildlife.

- For reprocessing facilities located at DOE sites, working with the DOE facility to facilitate carpooling or operation of a joint bus system, and establish shift changes outside of DOE facility peak commuting periods.

5.2.3 Geology and Soils

5.2.3.1 Preconstruction and Construction

- Minimizing the construction footprint to the extent possible.

- Covering stockpiles to reduce exposure to wind and rain.

- Limiting routine vehicle traffic to paved or gravel roads.

- Training of employees in the handling, storage, distribution, and use of hazardous materials.

- Conduct of fueling operations and hazardous materials storage in bermed areas.

- Implementation of a sampling and analysis program to identify and manage contaminated soils in accordance with NRC and other Federal and state requirements.

- Implementation of Spill Prevention, Control and Countermeasures (SPCC) plans and BMPs consistent with state and Federal standards for construction activities, to reduce potential impacts from chemical spills or releases around vehicle maintenance and fueling locations, storage tanks, and painting operations, and ensure prompt and appropriate cleanup (with verification of complete cleanup through soil sampling and analysis).

- Use of BMPs to reduce soil erosion (e.g., earth berms, dikes, and sediment fences).

- Prompt revegetation or cover of bare areas with natural materials.

- Placement of soil stockpiles in a manner to reduce erosion.

- Reuse of onsite excavated materials whenever possible.

- Use of a stormwater detention basin.

- Implementation of BMPs and good construction practices to minimize the extent of excavation, e.g., use of standard drilling and blasting techniques to minimize impact to bedrock, reducing the potential for over-excavation and thereby minimizing damage to the surrounding rock and protecting adjacent surfaces that are intended to remain intact.

- Installation and use of physical barriers and wetting devices to minimize soil erosion and fugitive dust emissions.

- Following appropriate waste management procedures to minimize impacts on soils from solid waste and hazardous materials, and implementation of a recycling program for materials suitable for recycling where practical.

5.2.3.2 Facility Operation

- Training employees in the handling, storage, distribution, and use of hazardous and radioactive materials.

- Conduct of fueling operations and hazardous and radioactive materials storage in properly designed facilities.

- Implementation of SPCC plans consistent with state and Federal standards for industrial activities.

- Implementation of BMPs to minimize chemical and radiological impacts to soils.

- Implementation of a sampling and analysis program to identify and manage contaminated soils in accordance with NRC and other Federal and state requirements.

5.2.4 Water Resources

5.2 4.1 Preconstruction and Construction

5.2.4.1.1 Water Use

- Use of low-water-consumption landscaping rather than conventional landscaping to reduce water usage.

- Implementation of conservation practices when spraying water for dust control, equipment cleaning, etc.

5.2.4.1.2 Water Quality

- Use of BMPs to control the use of hazardous materials and fuels.

- Maintenance of construction equipment in good repair without visible leaks of oil, greases, or hydraulic fluids.

- Implementation of SPPC plan and BMPs to minimize chemical impacts due to spills or leaks.

- Training employees in the handling, storage, distribution, and use of hazardous materials.

- Conduct of fueling operations and hazardous materials storage in bermed areas with proper set back distances from water bodies.

- Implementation of Stormwater Pollution Prevention Plans (SPPPs), Stormwater Management Plans (SWMPs), and SPCC plans consistent with state and Federal standards for construction activities.

- Ensuring discharges to surface impoundments meet the standards for stormwater and treated domestic sanitary wastewater.

- Use of BMPs to control stormwater runoff to prevent releases to nearby areas.

- Use of BMPs for dust control associated with excavation and fill operations and other land disturbing activities.

- Minimizing disturbance of surface areas and vegetation to reduce changes in surface water flow and soil porosity that could change infiltration and runoff rates.

- Use of sediment-trapping devices such as hay or straw bales, fabric fences, and sediment detention basins to control water flow and discharge and trap sediments moved by runoff.

- Implementation of grading and landscaping plans to maintain natural contours and stabilize slopes to minimize erosion.

- Prohibiting unnecessary off-road vehicle travel to minimize erosion.

- Reducing the size of impervious surfaces (parking lots, roads, and roofs) to the extent possible.

- Implementation of a “fix-it-first” infrastructure policy to set spending priorities on the repair of existing infrastructure over the installation of new infrastructure.

- Employing low-impact development strategies and practices.

- Use of only water (no detergents) for external vehicle washing.

- Placement of stone construction pads at entrance/exits where an unpaved construction access adjoins a public road.

- Arrangement of all temporary construction basins and permanent basins to provide for prompt, systematic sampling of runoff in the event of any special needs.
- Berming or self-containment of all aboveground gasoline and diesel storage tanks.
- Construction of curbing, pits, or other barriers around storage tanks and components containing hazardous materials and wastes.
- Handling hazardous materials by approved methods and shipment offsite to approved disposal sites.
- Handling sanitary wastes by portable systems until an onsite of offsite domestic sanitary sewage treatment facility is available for facility use (and providing an adequate number of these portable systems.)
- Control of water quality impacts by compliance with National Pollution Discharge Elimination System (NPDES) Construction General Permit requirements.

5.2.4.2 Facility Operation

5.2.4.2.1 Water Use

- Use of low-water-consumption landscaping rather than conventional landscaping to reduce water usage.
- Installation of low-flow toilets, sinks, and showers to reduce water usage.
- Implementation of localized floor washing using mops and self-contained cleaning machines rather than conventional washing with hoses to reduce water usage.
- Incorporation of closed-loop cooling systems instead of cooling towers, where possible, thereby eliminating evaporative losses and cooling tower blowdown and resulting in reduced water usage.

5.2.4.2.2 Water Quality

- Reducing the size of impervious surfaces (parking lots, roads, and roofs) to the extent possible.
- Implementation of a “fix-it-first” infrastructure policy to set spending priorities on the repair of existing infrastructure over the installation of new infrastructure.
- Employing low-impact development strategies and practices during operations.
- Implementation of BMPs to minimize chemical and radiological impacts due to spills or leaks.

- Following appropriate waste management procedures to minimize the impacts on soils and water quality from liquid and solid non-hazardous, hazardous and radioactive wastes.

- Appropriate management of all liquid and solid non-hazardous, hazardous and radioactive wastes, including onsite handling storage, and treatment, and offsite transport, storage, treatment and disposal, as applicable.

- Where practicable, implementation of a recycling program for materials suitable for recycling.

- Training employees in the handling, storage, distribution, and use of hazardous and radioactive materials.

- Ensuring that discharges to surface impoundments meet the standards for plant liquid effluents, stormwater, and treated domestic sanitary wastewater, as applicable.

- Use of BMPs to control stormwater runoff to prevent releases to nearby areas.

- Use of only water (no detergents) for external vehicle and equipment washing.

- Arrangement of all catchment basins to provide for the prompt, systematic sampling of runoff in the event of any special needs.

- Berming or self-containment of all aboveground gasoline and diesel storage tanks.

- Construction of curbing, pits, or other barriers around storage tanks and components containing radioactive materials wastes.

- Conduct of fueling operations and hazardous and radioactive materials storage in properly designed facilities with proper set back distances from water bodies.

- Regular leak detection monitoring and maintenance of storage tanks, casks, ponds/impoundments, etc.

- Implementation of BMPs including SPPPs, SWMPs, and SPCC plans consistent with state and Federal standards for industrial activities.

- Control of water quality impacts by compliance with NPDES discharge permit requirements, as applicable.

5.2.5 Air Quality

5.2.5.1 Preconstruction and Construction

5.2.5.1.1 Vehicle, Equipment, and Fuel Dispensing Emissions

- Limiting the number of hours per day that the air emissions generating preconstruction and construction activities can be conducted.
- Utilization of newer vehicles and equipment with better emission controls.
- Ensuring that construction equipment and vehicles are properly tuned and pollution control devices are functioning properly.
- Identifying and selecting construction-related products and chemicals that are free of volatile solvents.
- Implementation of carpooling for site workers.
- Equipping storage tanks with appropriate volatile organic compound (VOC) controls, liquid level gauges, and overfill protection.
- Providing training to fuel delivery drivers.
- Posting appropriate warning signs and spill response directives at the fuel dispensing facility.
- Paving fuel unloading and dispensing areas and equipping them with curbs to control spills.
- Ensuring that delivery contractors carry spill kits and are required to address minor spills during fuel deliveries.
- Installation of hard-surface pavements, curbs, scupper drains, and drainage ways at fuel dispensing island that will channel spilled fuels to fire-safe containment sumps.
- Requiring delivery drivers to remain in attendance throughout all fuel deliveries.
- Placing spill containment and response equipment at fuel dispensing stations.
- Providing first responder training to selected workers.
- Ensuring that storage tanks are equipped with fully functional overflow and vapor control features.
- Installing emergency shut-offs for fuel dispensing pumps.

- Providing spill cleanup materials at the fuel dispensing islands for cleanup of small spills, and adopting a policy that requires prompt cleanup of all spilled materials.

- Ensuring that fuel dispensing islands have adequate lighting.

5.2.5.1.2 Fugitive Dust

- Implementation of standard dust control practices including watering roads and exposed areas.

- Use of alternative dust palliatives (inorganic salts, asphaltic products, synthetic organics) where possible.

- Application of gravel to unpaved surfaces of onsite haul roads as an interim measure before permanent pavements are installed.

- Application of erosion mitigation methods in areas of disturbed soils.

- Use of water sprays at material drop and conveyor transfer points.

- Limiting the height and disturbance of material stockpiles.

- Application of water to the surfaces of stockpiles.

- Covering open-bodied trucks that transport materials that could be sources of airborne dust.

- Prompt removal of earthen materials deposited on paved roadways by wind, trucks, or earthmoving equipment.

- Prompt stabilization or covering of bare areas resulting from roadway construction.

- Establishing and enforcing speed limits for unpaved roads or areas onsite.

- Timely restoration and reclamation of disturbed land areas.

- Suspension of dust-producing activities during windy conditions.

- Paving or putting gravel on dirt roads.

- Sequencing dust-generating activities to minimize overall dust levels (e.g., identify activities that can occur simultaneously or in succession).

5.2.5.2 Facility Operation

5.2.5.2.1 Criteria and Hazardous Air Pollutant and Radioactive Emissions

- Equipping storage tanks with appropriate VOC controls, liquid level gauges, and overfill protection.
- Providing training to fuel delivery drivers.
- Posting appropriate warning signs at the fuel dispensing facility.
- Paving fuel unloading and dispensing areas and equipping them with curbs to control spills.
- Ensuring that delivery contractors carry spill kits and are required to address minor spills during fuel deliveries.
- Utilization of appropriate pollution abatement systems and detection instrumentation for industrial equipment.
- Utilization of newer vehicles and equipment with better emission controls.
- Ensuring equipment and vehicles are properly tuned and pollution control devices are functioning properly.
- Limiting the number of hours per day that air emissions generating activities can be conducted.
- Implementation of car pooling for plant workers.

5.2.5.2.2 Fugitive Dust

- Application of gravel to any unpaved road surfaces.
- Establishing and enforcing speed limits for any unpaved roads or areas onsite.
- Road maintenance (e.g. prompt removal of earthen material on paved roads).
- Paving or putting gravel on any dirt roads.

5.2.6 Noise

5.2.6.1 Preconstruction and Construction

- Implementation of noise abatement, including use of equipment and vehicle mufflers, acoustic baffles, shrouding, barriers, and noise blankets.

- Sequencing preconstruction and construction activities to minimize overall noise and vibration impact (e.g., establish the activities that can occur simultaneously or in succession).

- Use of blast mats, if necessary.

- Suspending the use of explosives during periods when meteorological conditions can be expected to reduce sound attenuation (e.g., low cloud cover).

- Posting appropriate State highway signs warning of blasting.

- Limiting the number of hours per day that noise generating preconstruction and construction activities can be conducted.

- Limiting the times when certain noise generating activities can be conducted (i.e., to nights or weekends).

- Establishing and enforcing site speed limits on site roads.

- Creation of buffer zones between the noise sources and receptors (e.g., siting facilities away from property boundaries).

- Compliance with Occupational Safety and Health Administration (OSHA) noise regulations for workers (i.e., administrative controls, engineering controls, personal protective equipment).

- Compliance with State local noise regulations or ordinances, where applicable.

- Utilization and maintenance of noise suppression equipment and systems on construction equipment and vehicles.

- Use of noise barriers where necessary (e.g., vegetation, walls).

- Development and implementation of procedures for notifying government agencies, residents, and businesses of construction activities that may produce high noise levels.

- Publicizing notification of atypically loud or unexpected construction activities.

- Development and implementation of a procedure to accept and respond to noise complaints.

5.2.6.2 Facility Operation

- Compliance with OSHA regulations for workers (i.e. administrative controls, engineering controls, personal protective equipment).

- Compliance with State local noise regulations or ordinances, where applicable.
- Utilization and maintenance of noise suppression systems on equipment.
- Use of noise barriers (e.g., vegetation, walls).
- Mitigation of operational noise sources by plant design, whereby cooling systems, valves, transformers, pumps, generators, and other facility equipment are located mostly within plant structures, and the buildings absorb the majority of the noise located within.
- Installation of noise insulation in buildings where necessary.
- Establishing preventative maintenance programs that ensure all equipment is working at peak performance.
- Establishment and enforcement of speed limits on site roads.
- Limiting the number of hours per day that noise generating operational activities can be conducted.
- Limiting the times when certain noise generating activities can be conducted (i.e., night or weekends).
- Sequencing of noise generating operational activities to minimize overall noise levels (e.g., establish activities that can occur simultaneously or in succession).
- Development and implementation of procedures to accept and respond to noise complaints.

5.2.7 Ecological Resources

5.2.7.1 Preconstruction and Construction

- Control of soil erosion, surface water pollution, and dust and particulate emissions that may affect aquatic and terrestrial resources (see Sections 5.2.3.1, 5.2.4.1.2, and 5.2.5.1 above).
- Consultation and coordination with U.S. Fish and Wildlife Service, National Marine Fisheries Service, and state fish and game agencies; and consideration of all resource agency concerns and recommendations.
- Conducting ecological surveys, prior to commencement of preconstruction and construction, to identify, characterize, and evaluate important ecological resources and habitats.

- Avoidance or relocation of sensitive species that would be affected during preconstruction or construction.
- Avoidance of groundbreaking, land-clearing, and other types of disturbance during the critical nesting period for migratory birds.
- Restoration of disturbed areas to minimize impacts to sensitive habitats.
- Implementation of weed control practices and revegetation of disturbed areas with native species to revegetate disturbed areas, enhance wildlife habitat, and minimize establishment of invasive species.
- Management of unused open areas (i.e., leave undisturbed), including areas of native grasses and shrubs, for the benefit of wildlife.
- Reducing onsite vehicle speeds onsite.
- Implementation of noise mitigation measures (see Section 5.2.6.1).
- Where applicable, performing clearing or removal of habitat outside of the migratory bird breeding and nesting season; surveying additional areas to be cleared for active nests during migratory bird breeding and nesting season; and avoiding activities in areas containing active nests of migratory birds.
- Avoiding use of herbicides during preconstruction and construction.
- Focusing all lights downward.
- Development and implementation of a noxious weed control program to prevent the establishment and spread of invasive plant species:
    - Hosing down tires and undercarriages of off-road vehicles prior to site access to dislodge seeds or other propagules of noxious weeds.
    - Monitoring for noxious weeds throughout the preconstruction and construction phase and immediately eradicating new infestations.
    - Minimizing indirect impacts of weed control activities, such as herbicide effects on nontarget species, and soil disturbance and fire hazards from vehicle operation in undisturbed areas during weed control activities.

5.2.7.2 Facility Operation

- Reduce vehicle speeds onsite.
- Focusing all lights downward.

- Using herbicides in limited amounts during operations along access roads, industrial area, and security fence surrounding the facility.

- Using herbicides according to government regulations and manufacturer's instructions to control noxious weeds.

- Revegetating any bare areas with native species.

- Conducting periodic species surveys to identify and evaluate important ecological resources and habitats.

- Limiting disturbances during critical nesting periods for migratory birds.

- Implementation of weed control practices to minimize the establishment of invasive species.

- Where possible, development of areas that will retain water of suitable quality for wildlife and provide wildlife access to such areas with suitable water quality.

- For basins with water quality unsuitable for wildlife, use of animal friendly fencing and netting or other suitable material over basins to prevent use by migratory birds or other animals.

- Considering all recommendations of appropriate State and Federal resource agencies.

5.2.8 Waste Management

5.2.8.1 Preconstruction and Construction

- Development and implementation of a waste minimization plan.

- Recycling of nonhazardous construction debris, including wood, metals, and plastics.

- Recycling of hazardous materials, such as lead acid batteries, solvents, and paints.

- Onsite treatment of wastewater prior to discharge to local waste water treatment facilities, surface waters, or groundwater.

5.2.8.2 Facility Operation

- Design of system features to minimize the generation of solid waste, liquid waste, and gaseous effluents.

- Storing all waste in designated, appropriately designed areas until administrative limits are reached, then shipment offsite to appropriately licensed treatment, storage, or disposal facilities for radioactive, hazardous, mixed, and nonhazardous wastes.

- No disposal of waste onsite.

- Development and maintenance of a management program to monitor conditions at SNF, radioactive waste, and hazardous waste storage facilities, to monitor storage container integrity and leaks by conducting routine inspections for breaches and performing maintenance and repairs as needed.

- Segregation of storage pad areas from the rest of the facility by barriers, such as vehicle guard rails.

- Allowing only designated vehicles, operated by trained and qualified personnel, at radioactive and hazardous waste storage areas.

- Recycling of nonhazardous materials, such as paper and packaging materials.

- Recycling of hazardous materials, such as lead acid batteries, solvents, and paints.

- Onsite treatment of radiological and hazardous solid waste to reduce volume prior to disposal (e.g., by compaction).

- Onsite treatment of radiological liquid waste to reduce volume prior to discharge or disposal (e.g., by evaporation).

- Onsite treatment of wastewater prior to discharge to local wastewater treatment facilities, surface waters, or groundwater.

- Control of process effluents by means of the following liquid and solid waste handling systems and techniques:

    - Following careful application of basic principles for waste handling in all of the systems and processes.

    - Collecting different waste types in separate containers to avoid contamination of one waste type with another;

    - Carefully packaging materials that can cause airborne contamination.

    - Providing ventilation and filtration of the air in operations areas as necessary.

    - Confining liquid wastes to piping, tanks, and other containers.

    - Use of curbing, pits, and sumps to collect and contain leaks and spills.

    - Storing hazardous and radioactive wastes in designated areas in carefully labeled containers; and containing and storing mixed wastes separately.

- Neutralizing waste strong acids and caustics before they enter an effluent stream.
- Decontaminating or reusing radioactively contaminated wastes to reduce waste volumes to the extent possible.
- Reducing the volume of collected waste such as trash, compressible dry waste, scrap metals, and other candidate wastes at a centralized waste processing facility.
- Implementing administrative procedures and practices in waste management systems that provide for the collection, temporary storage, processing, and disposal of categorized solid waste in accordance with regulatory requirements.
- Designing handling and treatment processes to limit wastes and effluent.
- Performing sampling and monitoring to assure that plant administrative and regulatory limits are not exceeded.
- Monitoring gaseous effluents and hazardous and radioactive contamination as required before release.
- Sampling or monitoring liquid wastes in liquid waste treatment and containment systems.
- Sampling or monitoring solid wastes prior to offsite treatment and disposal.
- Returning process system samples to their sources, where feasible, to minimize input to waste streams.

- Implementation of a spill control program for accidental oil spills, including preparation of an SPCC plan prior to the start of operations, which should contain the following information:
    - Identification of potential significant sources of spills and prediction of the direction and quantity of flow that would likely result from a spill from each source.
    - Identification of the use of containment or diversionary structures, such as dikes, berms, culverts, booms, sumps, and diversion ponds, to control discharged oil and fuel.
    - Procedures for inspection of potential sources of spills and spill containment and diversion structures.
    - Assigned responsibilities for implementing the plan, inspections, and reporting.

    - Other measures including control of drainage of rain water from diked areas, containment of oil and fuel in bulk storage tanks, aboveground tank integrity testing, and oil and fuel transfer operational safeguards.

5.2.9 Historic and Cultural Resources

5.2.9.1 Preconstruction and Construction

- Following the guidelines of 36 CFR 800.11 (historic properties).

- Following the guidelines of 43 CFR 10.4 (Native American human remains, funerary objects, objects of cultural patrimony, and objects that are sacred).

- Implementation of the management or mitigation requirements of a Memorandum of Agreement (MOA) or Programmatic Agreement (PA), where applicable.

- Development and implementation of an unanticipated discoveries plan; i.e., cease activities in areas around any discovery of human remains or item of archaeological significance and notify the State Historic Preservation Officer or Tribal Historic Preservation Officer to make the determination of appropriate measures to identify, evaluate, and treat the discoveries.

- Use of onsite cultural resource monitors during preconstruction and construction activities.

- Conduct of awareness training for workers on cultural resources regulations and requirements.

- Implementation of restrictions on where heavy machinery is allowed, where possible.

5.2.9.2 Facility Operation

- Continued implementation of the requirements of an MOA or PA, where applicable.

- Continued implementation of an unanticipated discoveries plan.

- Following the guidelines of 36 CFR 800.11 (historic properties).

- Following the guidelines of 43 CFR 10.4 (Native American human remains, funerary objects, objects of cultural patrimony, and objects that are sacred).

- Conduct of awareness training for workers on cultural resources regulations and requirements.

- Implementation of restrictions on where heavy machinery is allowed, where possible.

5.2.10 Visual and Scenic Resources

5.2.10.1 Preconstruction and Construction

- Performing viewscape studies for new structures onsite.
- Utilization of the presence of trees and rolling terrain, or planting additional trees and other vegetation, to effectively screen the facility from view.
- Providing sufficient distance from the facility to the nearest publicly accessible viewpoints.
- Selection of landscaping and building colors consistent with the environment.
- Reduced use of lighting at night and appropriate use of shielding.
- Use of landscaping techniques and prompt covering of bare areas to blend into the surrounding ground cover to help keep the visual characteristics of the site consistent with the surrounding terrain.
- Use of accepted natural, low-water-consumption landscaping techniques to limit any potential visual impacts, such as techniques that would incorporate the use of native landscape plantings and crushed stone pavements on difficult-to-reclaim areas.
- Prompt revegetation or covering of bare areas with natural materials.
- Painting the facility in colors that would blend with the surrounding vegetation to reduce the contrast between the plant and the surrounding landscape.
- Creation of earthen berms or other types of visual screens made of other natural material to help reduce the visibility of the facility.
- Focusing all perimeter lights to be downfacing to minimize light pollution.

5.2.10.2 Facility Operation

- Performing viewscape studies for new structures onsite.
- Utilization of the presence of trees and rolling terrain, or planting additional trees and vegetation, to effectively screen the facility from view.
- Providing sufficient distance from any new structures at the facility to the nearest publicly accessible viewpoints.
- Maintenance of landscaping and building colors consistent with the environment, and use of neutral colors for structures.

- Use of landscaping techniques and prompt covering of bare areas to blend into the surrounding ground cover to help keep the visual characteristics of the site consistent with the surrounding terrain.

- Use of aesthetically pleasing screening measures such as berms and earthen barriers, natural stone, and other physical means to soften the impact of the buildings.

- Limiting lighting to that necessary to meet security requirements.

- Focusing lighting downward and use of appropriate shielding to reduce night lighting in surrounding areas.

5.2.11 Public and Occupational Health

5.2.11.1 Preconstruction and Construction

- Use of proper personal protective equipment by site workers handling hazardous materials.

- Training site workers on safe handling procedures by site of hazardous materials.

- Implementation of other applicable OSHA requirements.

5.2.11.2 Facility Operation

5.2.11.2.1 Non-radiological

- Use of administrative controls, practices, and procedures to assure compliance with the facility's Health, Safety, and Environmental Program. Design the program to ensure safe storage, use, and handling of hazardous and toxic chemicals and waste to minimize the potential for worker exposure, releases to the environment, and effects on the general public.

- Use of proper personal protective equipment by site workers handling hazardous materials.

- Training site workers on safe handling of hazardous materials and waste.

- Implementation of other applicable OSHA requirements.

- Implementation of procedures described in previous sections to control spills and leaks of hazardous materials and for prompt cleanup, to avoid offsite migration.

5.2.11.2.2 Radiological

- Implementation of radiological practices and procedures to ensure compliance with the facility's Radiation Protection Program. Design the program to achieve and maintain radiological exposure to levels that are as low as reasonably achievable (ALARA).
- Conducting routine facility radiation and radiological surveys to characterize and minimize potential radiological dose/exposure.
- Monitoring of all radiation workers by use of dosimeters and area air sampling to ensure that radiological doses remain within regulatory limits and are ALARA.
- Providing radiation monitors in gaseous effluent discharge locations to detect, alarm, and effect automatic safe shutdown of process equipment in the event contaminants are detected in the system exhaust above regulatory limits. Design systems to automatically shut down, switch trains, or rely on operator actions to mitigate potential releases.
- Designing the facility to delay and reduce radiological releases inside the buildings in a potential fire or explosion incident from reaching the outside environment, such as automatic shutoff of room heating, ventilation, and air conditioning (HVAC) systems.
- Use of liquid and solid waste handling systems and techniques to control wastes and effluent concentrations.
- Passing gaseous effluents through pre-filters, high-efficiency particulate air (HEPA) filters, and activated carbon filters to reduce radioactivity in the final discharged effluent to very low concentrations.
- Routing process liquid waste to collection tanks and treatment to remove most of the radioactive material.
- Monitoring all process systems by instrumentation that will activate alarms and will either automatically shut down the proposed facility to a safe condition or alert operators to take the appropriate action to prevent releases in the event of operational problems.
- Use of proper personal protective equipment by site workers handling or exposed to hazardous and radioactive materials.
- Training on and implementation of safe handling procedures by plant workers for hazardous and radioactive materials.
- Using current technology, in addition to HEPA filters, to reduce Iodine-129 emissions to below regulatory limits.
- Using current technology to capture and control Krypton-85 to below regulatory limits.

- Adhering to the requirements of the radiation protection program.
- Following the guidelines of 40 CFR Part 68, Chemical Accident Prevention Provisions.
- Following the guidelines of 29 CFR 1910.119, OSHA Standards (including Process Safety Management).
- Following the guidelines of 40 CFR Part 355, Emergency Planning and Notification.
- Following the guidelines of 40 CFR 302.4, Designation, Reportable Quantities, and Notification–Designation of Hazardous Substances.
- Implementation of other applicable NRC and OSHA requirements to protect public and worker health and safety.

5.2.12 Socioeconomics and Environmental Justice

Management or mitigation measures for socioeconomics or environmental justice are generally not anticipated to be necessary because the socioeconomic effects of an SNF reprocessing facility project are expected to be mostly positive and a proposed project should be sited such that it would not result in disproportionately high impacts on low-income and minority populations.

5.3 References

(CEQ, 2007) Council on Environmental Quality. “Aligning National Environmental Policy Act Processes With Environmental Management Systems. A Guide for NEPA and EMS Practitioners.” Washington, DC. April. (http://ceq.hss.doe.gov/nepa/NEPA_EMS_Guide_final_Apr2007.pdf) Accessed August 15, 2012.

6 ENVIRONMENTAL-RELATED CONSIDERATIONS FOR POSTULATED ACCIDENTS

6.1 Introduction

This section discusses environmental-related considerations that could be associated with hypothetical accidents that could occur at potential spent nuclear fuel (SNF) reprocessing facilities that would use the PUREX process. For the purposes of this discussion, the term "accident" refers to any unintentional event outside the range of normal facility operating conditions that result in a release or the potential for release of radioactive materials or hazardous chemicals into the environment.

The PUREX process is a complex chemical separation and purification process. The inventory of radionuclides varies throughout the process. In addition, organic solvents, acid solutions, and a large variety of chemicals are used to reprocess the SNF. Accidents have the potential to cause environmental effects from radiological and chemical releases. The nature and extent of releases and associated impacts would vary as a function of the specific design of the facility, including safety and mitigation measures and procedures that are in place.

No comprehensive risk analysis of a commercial PUREX reprocessing facility is currently available in the public domain. Consequently, to provide some insights on environmental effects of potential accidents, this Environmental Topical Report (ETR) presents:

- Information on reported incidents and accidents at existing and historical reprocessing facilities
- Safety information from modern U.S. Department of Energy (DOE) analogs for reprocessing facilities and from the Barnwell Nuclear Fuels Plant (BNFP)
- Preliminary analyses based on generalized PUREX reprocessing

Partial risk analyses and historical reports of accidents provide insights into the general types of accidents at existing commercial and historical reprocessing facilities. Reported accidents include different types of criticality events[1], fires and explosions, and “red oil” excursions[2] and explosions. Other incidents of concern have included shield door misalignments (a potential risk for lethal worker doses), flammable gas accumulations, and large leaks and spills. Red oil excursions have accounted for large explosions at government reprocessing facilities in the U.S. and Russia (DNFSB, 2003).

DOE analogs include the Defense Waste Processing Facility (DWPF) at Savannah River, Waste Treatment Plant (WTP) at Hanford, and Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF) at Savannah River. The DWPF is a large processing and vitrification facility for high-

[1] A criticality event is an accidental increase of nuclear chain reactions in a fissile material, such as enriched uranium or plutonium, which releases neutron radiation.

[2] A “red oil” excursion is an explosive, runaway reaction that occurs when tri-butyl phosphate reacts with nitric acid at temperatures above 130°C (266°F).

level radioactive waste (HLW), and is currently operating. The WTP is a larger facility for HLW processing and vitrification, and is under construction. Both the DWPF and WTP handle highly radioactive materials and have extensive shielding and remote operations. Some aspects of their design and safety analyses have been previously reviewed by the U.S. Nuclear Regulatory Commission (NRC, 2001), and additional information on these two facilities is publicly available.

The MFFF is a smaller facility under construction. Although different in some process steps, the NRC has evaluated potential accidents associated with this facility which provide insights for such considerations (NRC, 2005a). The MFFF includes an “aqueous polishing” process that purifies incoming plutonium using a single cycle PUREX-like process. Therefore potential accidents associated with the MFFF aqueous polishing process may provide insights into potential accidents at a PUREX SNF reprocessing facilities. Note, however, that the incoming plutonium for the MFFF does not contain uranium or many of the fission products or minor actinides present in commercial SNF. Consequently, the accident analyses for the MFFF aqueous polishing process do not consider the risks associated with uranium purification or treatment and disposal of fission products and minor actinides that would be present in commercial PUREX facilities.

The BNFP was licensed by the NRC in the 1970s and constructed as a nominal 1,500 metric tons of heavy metal/year (MTHM/year) (1,700 tons of heavy metal (tHM) reprocessing facility. Uranium testing was conducted at the facility, but it never reprocessed any commercial SNF. Nevertheless, potentially useful documentation exists for this facility.

6.2 Accident Risk and Impact Assessment Approaches: Base and Recommended Cases

The “base case” for the NRC’s licensing and regulation of commercial SNF reprocessing facilities considers that Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50 would be used for those purposes. In 10 CFR Part 50, the NRC categorizes accidents as "design basis" or "severe", for which facilities are analyzed to determine their response. The design basis accident (DBA) category considers that the facility is designed specifically to accommodate this category of accidents. Severe accidents are those accidents involving multiple failures of equipment or function and, therefore, the likelihood of which is generally lower than DBAs but where consequences may be higher. Typically, only a few major, or severe, accident scenarios would be analyzed (perhaps two to five), in a manner analogous to nuclear reactors.

In safety analyses under 10 CFR Part 50, equipment and safety-related structures, systems, or components (SSCs) of a facility would be identified until the potential accident consequences or probability of the event is reduced to acceptable levels, while including adequate defense in depth, redundancy, and diversity. The approach assumes that by designing for this small number of specific major accidents, the balance of the facility would also be sufficiently conservatively designed and robust to adequately address safety for all potential events. Probabilistic Risk Assessment (PRA) may be used for further insights on these design basis events. The base case also involves the application of General Design Criteria (GDC) as minimum requirements, technical specifications for SSCs, and operator training requirements. Design basis analyses have been used for the BNFP, DWPF, and WTP.

The “recommended case” considers that regulations under a new 10 CFR Part 7X, which combines attributes of 10 CFR Part 50, 10 CFR Part 70, and other NRC regulations, would be used by the NRC to license and regulate commercial reprocessing facilities. As outlined in the NRC staff’s “Draft Regulatory Basis for Licensing and Regulating Reprocessing Facilities” (Draft RB) (NRC, 2011a), the accident analyses under a new 10 CFR Part 7X may use a hybrid Integrated Safety Analysis-Probabilistic Risk Assessment (ISA-PRA) approach that explicitly incorporates risk insights. This hybrid process includes the following steps, in approximate order:

- Quantify all analyses to the extent practical and as supported by the state of the art.

- Use, in a manner analogous to 10 CFR 70.61, a quantified ISA to identify all credible accident sequences that, when uncontrolled, could exceed the consequence thresholds (in Table 2-2 of the Draft RB). Such accidents would fall into one of the “Not Acceptable” bins of Table 2-3 of the Draft RB. The quantified ISA may use some conservative values as part of the binning process.

- Identify a subset of high consequence events (HCEs) based upon attributes that significantly increase consequences above the high-consequence thresholds in 10 CFR 70.61 and designate this subset as very high consequence events (VHCEs). At a minimum, these attributes would include a potential for offsite acute radiation or chemical effects, or significant contamination resulting in the loss of the use of large areas of the environment for an extended period of time. Other attributes could include the presence of reactor-grade plutonium, other transuranic (TRU) isotopes, or fission products, or other characteristics (e.g., multiple receptors, significant contamination, loss of property or use, or environmental degradation) that potentially significantly increase the consequences above 10 CFR 70.61 thresholds. Many accident sequences that have low consequences with low enriched uranium (LEU) materials would likely be categorized as VHCEs when handling many of the radioactive materials occurring at a reprocessing facility simply because of the orders of magnitude increases in dose conversion factors. Potential examples of VHCEs include large fires, red oil explosions, and SNF pool fires.

- Apply safety controls (e.g., Items Relied On For Safety, or IROFS) to render the likelihood of intermediate events, HCEs, and VHCEs acceptable, including a lower likelihood value for VHCEs as compared to HCEs because of the greater consequence of VHCEs (i.e., a lower frequency limit is required for the same level of risk).

- Conduct probabilistic (i.e., quantitative) risk analyses on HCEs and VHCEs to the extent practical and consistent with the state-of-the-art, based upon more realistic consequence and frequency information.

- Use the PRA results to aggregate risk from a subset of accident sequences (e.g., the VHCEs and HCEs) for potential receptors (as a minimum, for a member of the public).

- Adjust (reduce) risk as needed to meet the appropriate NRC risk limits and criteria (these risk limits and criteria would need to be developed and they would be informed by the generic quantitative health guidelines (QHGs) in the NRC staff document, "Risk-Informed Decision-Making for Nuclear Material and Waste Applications" (RIDM) Revision 1 (NRC, 2008). This would be accomplished by applying additional controls (e.g., IROFS) or by modifying the facility's design, and then analyzing their effect on PRA results. The PRA may be used to rank and prioritize IROFS as a function of their contribution to reducing the risk, as recommended by the Advisory Committee on Reactor Safeguards (ACRS) (NRC, 2011b).

- Further, minimize the total risk to receptors beyond the minimum requirements consistent with NRC guidance, based on a value-impact (consequence-benefit) analysis.

- Identify GDCs) (see Section 2.4 of Draft RB) or other controls (e.g., defense-in-depth measures) that reduce the risk beyond the minimum requirements as Items Supporting Safety (ISS) for accident situations.

- Require routine updates to the safety analyses and establish a facility-specific program to generate and collect data to refine and support risk quantification.

- Identify processes for ranking the various IROFS and events according to risk.

- Identify processes for risk-informed safety review and inspection programs.

The NRC staff also anticipates recommending thresholds for environmental releases; environmental contamination; economic, schedule, and availability impacts; and loss of property or land use, for HCEs and VHCEs (e.g., analogous to the requirements in 10 CFR 70.23(a)(3) and (a)(4)). Guidance will also be needed to support the application of quantitative risk analysis approaches to reprocessing facilities. The staff also anticipates criticality safety will follow an approach similar to that in 10 CFR Part 70 (e.g., double contingency).

The recommended case also involves the application of GDC as minimum requirements, technical specifications for SSCs, and operator training requirements.

In the recommended case, the applicant for an NRC license for a commercial SNF reprocessing facility would first identify the plausible accident scenarios associated with a specific separation process or technology. Then, the applicant would evaluate the potential impacts from the various accident scenarios. Finally, the applicant would develop safety controls (IROFS and ISS) that would ensure adequate protection of human health, safety, and the environment. The NRC staff, as part of its review, would look at these activities to determine if the applicant's approach meets the regulatory criteria, i.e., normally summarized as adequate to protect health and minimize danger to life and property. The staff would likely conduct multiple reviews of significant, important, high consequence events, or very high consequence events that essentially replicate the licensee analyses to verify adequacy.

The SNF reprocessing facility design, including the types and number of safety systems, would take into consideration the specific locations of radioactive materials within the plant; their amounts; their ability to be dispersed; their nuclear, physical, and chemical properties; and their potential for transport into the environment and for creating health hazards. The design would also take into consideration the specific locations of chemicals and their movement through the facility.

In addition to facility design characteristics, assessments of environmental and health impacts from accidents take into account the following factors:

- Characteristics of radioactive materials
- Characteristics of chemicals
- Meteorological considerations
- Exposure pathways
- Radiotoxicity and chemical toxicity

Each of these factors is discussed briefly in the following sections.

6.2.1 Characteristics of Radioactive Materials

SNF cladding and packaging function as containment for the radioactive constituents. By its very nature, reprocessing removes radionuclides from this containment at several steps in the reprocessing process. First, fuel rods are chopped into small segments, releasing any radioactive gases that had been contained in the fuel rod. Current NRC regulations require filtering and capturing of certain gases, including iodine-129 (I-129) and krypton-85 (Kr-85). Filter and capture efficiency requirements vary with the SNF burnup and the cooling time after reactor discharge and, thus, a small, regulated amount would be released to the environment. Next, the remaining solids from the SNF are dissolved in a nitric acid solution. As this solution progresses through the separation process, the dissolved uranium, plutonium, fission products, and minor actinides are split into increasingly pure product streams or consolidated into waste streams. As summarized in Table 6-1, these have different radiation doses that affect their hazards.

The potential for the various components to become dispersed into the environment depends not only on mechanical forces that physically transport them, but also on their location in the separation process and their inherent properties, particularly their volatility and solubility; these affect both doses (inhalation classes) as well as release fractions. In general, industry experience indicates the number, quantities, and radiotoxicity characteristics of radioactive materials in a reprocessing facility have sufficient magnitudes to require many safety controls.

6.2.2 Characteristics of Chemicals

PUREX reprocessing uses many chemicals. Several of these chemicals will likely have combinations of hazards, quantities, and physical characteristics that will potentially produce

Table 6-1 Comparison of Unit Mass Dose Conversion Factors[a,b]

Isotope/Mixture	Specific Inhalation Dose, rem/gram	Relative Inhalation Dose: Ratio to "Ideal Low-Enriched Uranium (LEU)"
Uranium-234 (U-234)	8.21×10^{5}	1.64×10^{4}
Uranium-235 (U-235)	258	5.16
Uranium-238 (U-238)	39.1	0.781
Depleted Uranium (DU): U-235 - 0.25%, U-234 - 0.00194%, balance U-238	55.5	1.11
Natural Uranium: U-235 - 0.71%, U-234 - 0.0055%, balance U-238	85.8	1.72
Low-Enriched Uranium (LEU): U-235 - 5%, U-238 - 95%	50.0	1 (reference)
LEU: U-235 - 5%, U-234 - 0.0055%, balance U-238 (similar to laser enrichment product)	97.2	1.9
LEU: U-235 - 5%, U-234 - 0.03873%, balance U-238 (similar to gas centrifuge and gaseous diffusion plant enrichment products)	368	7.36
Highly Enriched Uranium (HEU): U-235 - 80%, U-234 - 0.88%, balance U-238	7,440	149
Mixed Oxide (MOX): Pu-239 - 5%, U-238 - 95%	9.55×10^{5}	1.91×10^{4}
MOX: weapons Pu, 5% Puf[c], balance DU	1.27×10^{6}	2.54×10^{4}
MOX: reactor Pu, 5% Puf, balance DU	1.00×10^{7}	2.01×10^{5}
MOX: reactor Pu, 5% Puf, 0.25% Americium-241, balance DU	1.40×10^{7}	2.81×10^{5}
Spent Nuclear Fuel (SNF): 60,000 MWD/MTIHM[d] (only fission products considered are Cesium-135 (Cs-135), Cesium-137 (Cs-137), and Strontium-90 (Sr-90) isotopes)	1.11×10^{7}	2.2×10^{5}
Cs-135, Cs-137, and Sr-90 isotopes from 60,000 MWD/MTIHM SNF	2.05×10^{6}	4.1×10^{4}

[a] Inhalation doses are based upon 50-year committed effective dose equivalent; see (NRC, 2010), slide 5.

[b] Specific data for isotopes are from EPA-520/1-88-020 (EPA, 1988).

[c] Puf – pure fissile plutonium.

[d] MWD/MTIHM = megawatt days/metric tons of initial heavy metal.

accident scenarios with sufficient consequences requiring specific safety controls (e.g., IROFS and ISS) to protect the workers and members of the public. In addition, reprocessing facility design can exacerbate these consequences; for example, the design usually operates under negative pressures which can suck in toxic vapors from external releases, chemicals can induce lacrimation or otherwise reduce visibility thus impeding egress, shielded cells impede direct observations and warnings, and the labyrinthine design reduces response times or increases exposure times, and security and safeguards requirements can also impede egress.

Chemical quantities onsite at a reprocessing facility may be equivalent to those at some chemical plants, and may exceed reportable quantities for Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) (29 CFR Part 1900 et seq) and the U.S. Environmental Protection Agency (EPA) Risk Management Program (RMP) (40 CFR Part 68 et seq). Consequently, this introduces the potential for multiple agency interactions.

The NRC has established a Memorandum of Understanding (MOU) with OSHA covering the following four areas of chemical safety at its licensees (NRC, 1995):

- Hazardous chemical effects from licensed radioactive materials; an example would be the chemical effects of reprocessing nitrate solutions. This is codified in 10 CFR 70.61, 70.62, and 70.64. This is strictly a chemical exposure effect (e.g., measured in parts per million (ppm) or milligrams/cubic meter (mg/m^3) for a certain exposure period).

- Hazardous chemicals and their effects, produced from licensed radioactive materials; an example would be nitrogen oxides (NO_x) released from nitric acid reacting with uranium dioxide ($UO_{2)}$ or uranium metal. This is codified in 10 CFR 70.61, 70.62, and 70.64. Again, this is strictly a chemical exposure effect (e.g., measured in ppm or mg/m^3 for a certain exposure period).

- Hazardous chemicals and their effects that affect the safe handling of licensed radioactive materials; examples might include nitric acid fumes corroding or adversely impacting the operation of safety equipment (or electronics), inerting gases depressing operator reaction times (or even operator asphyxiation), or hazardous gases incapacitating or hindering operator egress from radiological areas. In general, there is some increase in radiation risk or dose (e.g., millirem (mrem)) although the principal hazard is chemical in origin (i.e., a chemical exposure effect, measured in ppm or mg/m3 for a certain exposure period). This is codified in 10 CFR 70.62 and 70.64.

- Hazardous chemicals and their effects which do not affect the safe handling of licensed radioactive materials; an example might be a chemical release from bulk storage tanks. Note, however, if the bulk storage tanks are sufficiently close to the areas handling licensed radioactive materials they may affect the safe handling or safeguards of these materials, and, thus, be regulated by the NRC.

The NRC regulates the first three areas of chemical safety, while OSHA regulates the fourth area. In addition, the NRC and OSHA agree to inform each other if their respective inspections identify potential findings in the other Agency’s jurisdiction and if imminent safety concerns are found.

For PUREX reprocessing facilities, chemicals of most concern would likely include the following:

- Nitric acid--This may be present as the concentrated form (azeotrope – ~63%), in multiple thousand- or even ten thousand-gallon quantities, and similar quantities of lower concentrations (~25%) throughout the plant. Nitric acid is used as the dissolving agent for SNF constituents, and forms the principal constituent in aqueous streams at the facility. It is sometimes recovered by distillation. Its potential environmental effects depend on temperature; sufficient quantities of hot nitric acid solutions can produce consequences of concern at up to 1.6 kilometer (km) (1 mile (mi)) from the facility.

- Nitrogen tetroxide (nitrogen tetraoxide or nitrogen oxides)--These will likely be present in multiple cylinders; each cylinder holds (0.9 metric ton (1 ton). Nitrogen oxides are used for plutonium oxidation (valence) adjustments and for destroying organic materials. They vaporize around room temperature, and can produce consequences of concern for several miles from the facility.

- Hydrazine--This is used as a covering reducing agent for nitric acid solutions containing plutonium, and can reduce plutonium from the +6 to the +4 valence state. Depending on the concentration and temperature, it can be toxic, typically for up to several hundred meters. It can also form explosive azides.

- Hydroxylamine nitrate (HAN)--This is a direct reducing agent for producing non-solvent extractible plutonium (III) from plutonium in higher oxidation states (which can be extractable). It can undergo reactive explosions.

- Hydrogen (H_2)--This is a reducing agent in the sintering furnace areas for producing ceramic dioxide fuel. It may also be used in calcining uranium oxides ($UO_{x)}$ to UO_2 powder. As such, it can be present onsite in significant quantities, as the liquid or derived from anhydrous ammonia (a potentially toxic source). Chemical and radiolytic reactions can produce H_2 rapidly. H_2 is a concern for fires and explosions that can breach confinement and containment barriers.

- Solvents--Typical PUREX-style solvents are organic alkanes, like dodecane and hydrogenated tetrapropene (TPH) (i.e., branched dodecane), likely present in quantities of several thousand gallons. These are combustible liquids with potential fire hazards due to flash points in the 55 to 65^{o}C (131 to 149^{o}F) range, depending on the composition.

- Tributyl phosphate (TBP)--This is a combustible material usually diluted in a solvent. While the combustion point of TBP is higher than that of the solvent, a TBP-solvent mixture closely follows the combustible behavior of the solvent. TBP also undergoes degradation phenomena in nitric acid and radioactive solutions than can produce very flammable and nitrated organic materials. These routinely initiate red oil reactions that, if not controlled, can propagate into explosions that release radioactive materials.

Other chemicals that could be present in sufficient quantities and with sufficient hazards include chlorine (for water treatment) and ammonia (as a source of H_2).

6.2.3 Meteorological Considerations

Accident analyses ultimately require an assessment of consequences from potential releases. Most accident scenarios affect potential receptors via atmospheric pathways that are affected by meteorological conditions (e.g., wind speed and direction).

In the base case under 10 CFR Part 50, two separate analyses of accident sequences would be performed during the licensing process for an SNF reprocessing facility. The first analysis is the determination of the consequences for DBAs. This analysis would be performed to ensure that the doses to any individual at the exclusion area boundary (EAB) over a period of two hours, or at the outer boundary of the low population zone (LPZ) during the entire period of plume passage, will not exceed the siting dose guidelines of 0.25 sievert (Sv) (25 rem) to the whole body or 3 Sv (300 rem) to the thyroid, pursuant to 10 CFR Part 20. This analysis is used to examine site suitability (10 CFR Part 100) and the mitigative capability of certain plant safety features (10 CFR Part 50). The atmospheric dispersion model for this evaluation, as described in NRC Regulatory Guide 1.145 (NRC, 1983), uses onsite meteorological data (typically a multi-year record) considered representative of the site and vicinity to calculate relative dilutions that will be exceeded no more than 0.5 percent of the time in any one sector (22.5°) and no more than 5 percent of the time for all sectors (360°) at the EAB and LPZ. These dilution factors, because they provide little plume spread, ensure site-specific calculated doses that could be exceeded only 5 percent of the time.

The second analysis of accident consequences under 10 CFR Part 50 considers a spectrum of releases, including those for severe accidents. Actual meteorological conditions from a representative one-year period of record of onsite data are used in this analysis.

The recommended case in a new 10 CFR Part 7X would be likely to use a hybrid ISA-PRA approach to identify accident sequences and analyze their consequences. Consequence calculations would consider a range of meteorological conditions appropriate for the specific facility and site. Additional analyses for HCEs and VHCEs would introduce PRA methodologies, perhaps with some assumptions to simplify the analyses. Total risk from these events would be calculated and analyzed for additional controls, as necessary.

It is important to realize the inherent uncertainties in dispersion codes and meteorology. Accepted dispersion codes can produce results differing by factors of two to three or more (NRC, 1998). Use of different meteorology can cause orders of magnitude differences in estimated consequences. It is important that the computational approaches, accepted codes, and meteorological assumptions are well delineated in guidance and that adequate safety margins are used. The NRC has typically found that Class D meteorology with a wind speed of about 3 to 5 meters/second (m/sec) (10 to 16 feet/second (ft/sec)) represents about a 50-percent condition at many of its licensee sites (i.e., conditions producing higher consequences are not exceeded about 50 percent of the time), while a Class F stability condition with a wind speed of about 1.5 to 2.5 m/sec (4.9 to 8.2 ft/sec) represents about a 90- to 95-percent condition at many sites (i.e., conditions producing higher consequences are not exceeded 90 to 95 percent of the time).

6.2.4 Exposure Pathways

In general, the radiation exposure (hazard) to individuals is determined by three factors: the individual's proximity to the radioactive materials; the duration, intensity, and type (external versus internal) of exposure; and factors that act to shield the individual from the radiation. Most of the pathways for radiation and the transport of radioactive materials that lead to radiation exposure hazards to humans are the same for accidental releases as for releases below regulatory limits. These pathways include ingestion of contaminated water, ingestion of food that was either directly contaminated or contaminated through irrigation with contaminated water, inhalation of contaminated air, and direct (external) exposure to contaminated soil or water. Food includes crops, animals, and animal products. One additional possible pathway is the fallout of radioactivity onto open water or onto land with runoff into open water bodies.

During the transport of radioactive material by wind or water, the material tends to spread and disperse, becoming less concentrated in larger volumes of air or water. The result of these natural processes is to lessen the intensity of exposure to individuals downwind or downstream of the point of release, although the number of individuals who may be exposed potentially increases. For a release into the atmosphere, the degree to which dispersion reduces the concentration in the plume at any downwind point depends largely on the local weather conditions existing at the time of the accident and distance. Thus, the location of the facility is a significant factor in accident analysis. Most accident analyses consider the weather conditions that result in the least amount of dispersion prior to exposure to individuals.

6.2.5 Radiotoxicity and Chemical Toxicity

A reprocessing facility presents both radiological and hazardous chemical effects from potential accidents. The NRC uses a linear, no-threshold theory (LNT) as the regulatory approach for assessing radiological hazards. The LNT approach assumes all radiation exposures present some risk (i.e., there is no threshold for “no risk”) and that this risk is linear with the exposure rate.

In addition, radioactive materials interact with human physiology in different ways, and can produce internal and external exposures. External exposures are due to radioactive materials external to the receptor’s body that emit penetrating radiation, such as gamma rays, x-rays, and high energy particles; an example is the fission product cesium-137 (Cs-137). Internal exposures accrue from radioactive materials ingested or inhaled into the body; an example is the fuel material plutonium-239 (Pu-239), which emits high energy alpha particles. The NRC uses a Committed Effective Dose Equivalent (CEDE) approach that considers the internal radioactive material to be present for 50 years, assesses the dose based upon biologically determined factors, and then assigns that 50-year committed dose to the year of intake. The

NRC then regulates to a Total Effective Dose Equivalent (TEDE) that sums the internal (CEDE) and external doses.

Using the LNT for converting a dose to a risk value, and using the International Commission on Radiological Protection's (ICRP's) recommendation that 400 latent cancer fatalities (LCFs) could result from a collective dose of 10,000 person-sieverts (Sv) 1,000,000 person-rem (i.e., for individual acute doses (TEDE) less than 0.1 Sv (10 rem)), a 0.05-Sv (5-rem) TEDE would correspond to an LCF risk to a worker of 2 x 10^{-3} per year. Cancers would start occurring after a period of several years (usually a minimum of 5 to 10 years after exposure). Average doses for radiation workers incurring a measurable dose at NRC licensed facilities are approximately 2 millisieverts (mSv) (200 millirem (mrem)) per year (NUREG-0713; see at http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0713/), representing an individual risk of about 8 x 10^{-5} per year. Note that 2 mSv (200 mrem) is approximately the increase in natural background radiation from moving from Washington, DC to live in Denver, CO for one year. As a practical health matter, no statistical correlation has been found between cancer incidence and such low radiation doses.

10 CFR 20.1301(a)(1) establishes an annual dose limit to the public of 1 mSv (100 mrem) (i.e., 0.1 rem), subject to as low as reasonably achievable (ALARA). Using the ICRP recommendations, this dose of 1 mSv/year (100 mrem/year) would correspond to an LCF risk of about 4 x 10^{-5} per year. Public doses from NRC regulated activities (e.g., from direct operations and routine releases to the environment) are usually under 0.01 mSv (1 mrem/year) (a risk below 4 x 10^{-7} per year).

These exposures contribute to an increased risk of developing fatal cancers. However, cancer occurs naturally whether or not an individual is exposed to radiation from a reprocessing facility and, thus, the radiation exposure results in a stochastic risk (i.e., the cancer cannot be differentiated due to its cause, from radiation from the facility or from natural occurrence). For example, using the collective dose of 10,000 person-Sv (1,000,000 person-rem) to a population of 1,000,000 people, the stochastic risk from applying the LNT would imply 400 LCFs over a time period of 10 or more years, whereas the natural cancer fatality rate in that same population would be approximately 2,000 per year, about an order of magnitude higher than the radiation induced cancer rate. In addition, the occurrence of cancer itself does not necessarily lead to a fatality because the ratio of mortality to incidence of cancer depends upon the cancer type and medical treatment.

Higher radiation doses equate to higher risks. Above an acute exposure of 0.1 Sv (10 rem) (TEDE), the ICRP recommends a higher linear risk rate of 1,000 LCFs for a collective dose of 10,000 person-Sv (1,000,000 million person-rem). Physiological effects to an individual from a whole-body radiation dose greater than about 0.25 Sv (25 rem) over a short period of time (hours) can be clinically detected shortly after the exposure. Acute radiation syndrome starts occurring with short-term exposures above around 1 Sv (100 rem), with a low percentage of short-term (within the year) fatality in the exposed individual. An acute dose of 4.5 Sv (450 rem) approximates the lethal dose (LD) 50/60, which is lethal dose at which approximately 50 percent of the exposed individuals would die within about 60 days. Acute individual doses are lethal above about 10 Sv (1,000 rem).

Unlike radiation risks, the risk from chemical exposures can be very non-linear; small changes in dose or exposure (e.g., a concentration over a time period) can produce large changes in consequences. In addition, the consequences depend greatly upon the characteristics of the exposed population; the general population usually experiences higher consequences than a work force for the same chemical and exposure (duration and concentration). This is because the workforce at a reprocessing facility would likely consist of healthy individuals, primarily a young male population, and with a health monitoring program; the workforce has been trained in the hazards of the chemicals involved, and responses to emergencies and accidents; and the workforce has immediate access to emergency equipment, including medical equipment and personnel protective equipment (e.g., protective suits and breathing equipment). Facility design can also influence chemical effects. Reprocessing facilities are heavily shielded with labyrinthine passages and a negative pressure differential; these attributes would be expected to adversely impact the ability of the workforce to respond to chemical effects and, thus, exacerbate the potential effects from chemical accidents.

10 CFR Part 50 does not explicitly list requirements for chemical effects beyond habitable. Guidance identifies recommendations for habitability based upon an Immediately Dangerous to Life and Health (IDLH) values for chemicals of concern. In short, the IDLH value and timeframe (30 minutes) are used to trigger safety actions, which might include operators donning protective clothing and equipment or activation of air isolation and bottled air supplies. In contrast, 10 CFR Part 70 codifies the requirement to address these chemical risks for fuel cycle facilities, and it is anticipated the proposed 10 CFR Part 7X will include analogous requirements for reprocessing facilities as performance requirements.

Performance requirements include chemical consequences. No explicit chemical consequence levels are listed in the 10 CFR Part 70 regulations, and 10 CFR 70.65(b)(7) states that applications must contain a description of the proposed quantitative standards used to assess chemical consequences from acute chemical exposures to licensed materials or chemicals produced from licensed materials. Note that the regulation does not mention chemical consequence levels for the third chemical safety area regulated by the NRC, i.e., chemical and facility conditions affecting the safety of licensed radioactive materials. In actual licensing practice, the same chemical consequence levels are usually applied to this area.

The regulation requires the identification of four chemical consequence levels; two each for the worker and public, with one level usually overlapping. NRC Standard Review Plans suggest the use of either Acute Exposure Guideline Levels (AEGLs) or Emergency Response Planning Guidelines (ERPGs) as acceptable chemical quantitative standards to meet the performance requirements of 10 CFR 70.61.

The definitions of AEGL Levels are as follows:

AEGL-1 The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation or certain asymptomatic, non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2 The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects, or an impaired ability to escape.

AEGL-3 The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

AEGLs are developed for 30-minute and 1-, 2-, 4-, and 8-hour acute chemical exposures. Specific chemical AEGLs are lower for longer exposure times.

Note that the "Standing Operating Procedures for Developing Acute Exposure Guideline Levels for Hazardous Chemicals" (National Research Council, 2001) defines the primary purpose of the AEGL Program and the National Advisory Committee for the Development of Acute Exposure Guideline Levels for Hazardous Substances as the development of levels for once-in-a-lifetime, short-term exposures to airborne concentrations of acutely toxic, high-priority chemicals.

The definitions of ERPG Levels are as follows:

ERPG-1 The maximum airborne concentration of a substance below which it is believed nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

ERPG-2 The maximum airborne concentration of a substance below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective actions.

ERPG-3 The maximum airborne concentration of a substance below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

ERPGs are normalized to a 1-hour nominal acute exposure to the chemicals.

Temporary Emergency Exposure Limits (TEELs) are temporary limits for chemicals until AEGLs or ERPGs are developed. Together, AEGLs, ERPGs, and TEELs are referred to as chemical Protective Action Criteria (PACs).

Only limited data exist for human exposure to chemicals. Usually, human test subjects are healthy young males and only low exposures occur in testing. Chemical exposures during incidents and accidents are not usually measured, or, if they are, the measurements are likely to be inaccurate. Most AEGL and ERPG methods modify animal data obtained over the full range of chemical exposures with this healthy young male human test data obtained over low exposure ranges. The safety reviewer must keep in mind that this may skew the exposure level values and may be non-conservative.

Note that the AEGL and ERPG definitions have similarities to the intermediate and high consequence event discussions in the regulation. However, in use, the reviewer should evaluate the chemical levels proposed by the applicant taking into account the chemicals involved, their chemical effects and mechanisms (e.g., the steepness of the dose/response curves), the derivation and data used to support the standard, the chemical effects upon the general population as compared to subgroups, and their exclusion of certain population subgroups. In actual practice, worker population subgroups usually include men and (some) women in the 18- to 65-year-old range, with some managed health conditions (e.g., asthma). The general population includes the broader spectrum of ages and health conditions; for example, on average, at least 10 percent of the general population is aged 65 or older. In addition, the safety reviewer has to be aware that site-specific conditions (e.g., nearby schools, hospitals, or nursing homes) may also influence the selection of chemical consequence levels. Thus, for some chemicals, a different level, such as Level 2, may better represent a fatality threshold than a Level 3.

Some typical acute exposure values for chemicals of concern at reprocessing facilities are shown in Table 6-2. Note that the values can differ by several factors between the different chemical standards for the “same” consequence level.

6.3 Accident Experience and Observed Effects

Reprocessing facilities have been in operation for more than 60 years worldwide. Commercial reprocessing of SNF has been underway for more than 40 years. During this time, a variety of accidents have occurred at reprocessing facilities in Canada, France, Great Britain, Japan, Russia, and the United States. The number and severity of accidents that involve injuries or fatalities to onsite workers or releases of radioactivity has decreased through time, although so has the amount of reprocessing taking place. The three major categories of accidents that have occurred at reprocessing facilities are criticality events, releases of radionuclides, and fire or explosion due to red oil excursion.

Throughout the history of reprocessing, 26 criticality accidents were identified (Martinez-Guridi, et al., 2011). Of these, 23 involved reprocessing activities at government facilities intended for weapons development, and only three involved activities related to commercial reprocessing.

Table 6-2 Some Typical Acute Exposure Values for Potential Chemicals of Concern at Reprocessing Facilities

Chemical	Acute Exposure Values		
	"Level 1"	"Level 2"	"Level 3"
Hydrazine, ppm[a]	0.1 (AEGL[b])	13 (AEGL)	35 (AEGL)
Hydrogen, ppm	65,000 (TEEL[c])	230,000 (TEEL)	400,000 (TEEL)
Hydroxylamine Nitrate, mg/m^3[d]	15 (TEEL)	40 (TEEL)	150 (TEEL)
Nitric Acid, ppm	0.53 (AEGL)	24 (AEGL)	92 (AEGL)
Nitrogen Dioxide, ppm	0.5 (AEGL)	12 (AEGL)	20 (AEGL)
Nitrogen Tetroxide, mg/m^3	0.94 (AEGL)	23 (AEGL)	38 (AEGL)
Tributyl Phosphate (TBP), ppm	0.6 (TEEL)	3.5 (TEEL)	125 (TEEL)

Source: DOE, 2012.

[a] ppm = parts per million.

[b] AEGL - Acute Exposure Guideline Level (60 minute values).

[c] TEEL – Temporary Emergency Exposure Limit (60 minute values).

[d] mg/m^3 = milligrams per cubic meter.

Sixteen fire or explosion accidents were identified, with 11 occurring at government facilities and five occurring at facilities related to commercial reprocessing. A total of 16 abnormal release accidents were identified, with four of these occurring at government facilities and 12 occurring at commercial facilities.

Possibly of more relevance for this report are accidents that have occurred in the last 30 years. A total of 14 accidents have been identified since 1980, 12 of which involved commercial reprocessing plants. Of these 12 accidents, 10 involved the abnormal release of radioactivity and two involved fire and explosion. There have been no criticality accidents involving reprocessing activities since 1978, and the majority of criticality accidents occurred between 1950 and 1965. No significant injury due to accidents has occurred since 1968, and there has never been a significant injury at a commercial reprocessing facility due to accidents involving radioactivity.

6.4 Potential Accidents and Associated Environmental-Related Considerations

This section discusses key environmental-related considerations from postulated accidents that may occur at potential SNF reprocessing facilities. The information is this section comes from previous accident analyses conducted by the NRC for spent fuel reprocessing facilities and other fuel cycle and related facilities using methods that would be applicable under the base and recommended cases described earlier.

6.4.1 Potential Accidents and Analyses under the Base Case

This section provides an overview of previous accident analyses reported in various NRC documents for fuel cycle facilities, for which the NRC staff identified potential hazards and their consequences that may also be applicable to PUREX reprocessing facilities. As discussed earlier, the base case regulation uses a DBA.

Note that quantities reported in the sections that follow may not be shown in two unit forms (e.g., metric and English) as in the previous sections of this ETR, as these quantities are reported below as given in the respective reports.

6.4.1.1 NUREG-1320 - Nuclear Fuel Cycle Facility Accident Analysis Handbook

NUREG-1320 (NRC, 1988), the predecessor to the NRC current accident analysis handbook, NUREG/CR-6410[3] (SAIC, 1998), was issued in 1988 and prepared by Pacific Northwest National Laboratory, Los Alamos National Laboratory, and the NRC. The purpose of this document was to provide the staff and license applicants with a basis upon which to realistically evaluate the consequences of major accidents in fuel cycle facilities, including spent fuel reprocessing plants and waste storage and solidification facilities. With regard to determining accidents at these facilities, it was assumed that the PUREX process would be used for separations, and that the liquid HLW would be stored for two years prior to solidification by vitrification. It was also assumed that the resulting solid waste would be stored under water in a pool and that noble gases (if recovered) would be stored in a vault.

It was recognized that in a reprocessing plant, the location of combustible, flammable, and potentially explosive materials identifies the potentially hazardous areas, not unlike fuel manufacturing facilities. These include ion exchange resins (which could potentially cause explosions by nitration of resin under certain conditions), solvents, hydrogen fluoride (HF), nitric acid, and hydrazine. H_2 gas of significant volume leaking into a process cell could also be an explosion hazard (if undetected). Hazardous reactions in normal process operation that could potentially lead to explosions were identified as:

- H_2 as a result of hydrolysis in feed solution
- Solvent in feed and loss of temperature control producing an uncontrolled reaction in evaporator
- Hydrazoic acid produced by uncontrolled reaction
- Red oil--nitrated TBP from solvent degradation

The handbook lists the major potential accidents and conditions needed for an accident to occur and the possible consequences. In a spent fuel reprocessing plant, the accidents identified can, for the most part, be grouped into three general categories: fires, explosions, and criticalities.

[3] NUREG/CR-6410 does not address potential accidents at spent nuclear fuel reprocessing facilities.

The factors in the plant process that were considered in developing major potential accidents for waste storage and vitrification facilities were the location of flammable, combustible, or explosive materials; large amounts of dispersible materials; elevated temperature operations; and attenuation in pathways from the accident site. The postulated accidents were:

- fire in cell
- H_2 or organic vapor explosion in feed tank and rupture
- canister and liner rupture at molten glass temperature with release of molten glass to cell floor
- off-gas explosion
- H_2 explosion in mixed-oxide calciner
- calciner pressurized and ruptured
- steam explosion in canister containing molten glass
- break in calciner feed line or significant leak of high-pressure spraying type
- canister distorted or breached by drop

The document also highlights an important distinction between a fuel manufacturing plant and a fuel reprocessing facility--the presence of fission products that can affect the consequences of an accident, e.g., radionuclide volatility. In fuel manufacturing, uranium and plutonium are non-volatile and do not become airborne by heating in a fire accident scenario. Mechanical force would be required to make them airborne. In a fuel reprocessing plant, volatiles (e.g., iodine) and semi-volatiles (e.g., ruthenium (Ru), cesium (Cs), and cerium (Ce)) may be involved in the fire scenario.

6.4.1.2 NUREG-0002 - Final Generic Environmental Statement on the Use of Recycled Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors (GESMO Study)

Chapter IV, Section E, of the GESMO study (NRC, 1976) looked at the potential effects of accidents at fuel reprocessing plants (and plutonium conversion facilities, which were also studied) would have on the environment. It was recognized that equipment failures or accidents could disperse significant amounts of radioactive contaminants within process cells or buildings. However, it was deemed that because structures in these facilities are designed to keep adequate confinement capability (even in the event of an accident or natural phenomena), assure adequate margins of safety to prevent accidents, cope with potential accidents, and mitigate consequences of accidents if they occur as a result of multiple failures of systems or procedures, that such occurrences would not result in the release of significant amounts of radioactivity to contaminate the offsite environment. Radioactive contamination would be confined within the process cell or within the process building and little, if any, could escape to contaminate the vicinity beyond the plant’s exclusion area. A DBA approach was used. Examples of postulated accidents which are not expected to result in discernible offsite contamination and exposure to the public were given, as shown in Table 6-3.

Table 6-3 Examples of Postulated Accidents and Potential Consequences for Reprocessing Facilities

Abnormal Events Separations	Potential Consequences
Fuel cask drop into cask unloading pool	Possible rupture of fuel pins and release of fission gas to atmosphere; contamination of storage pool water
Fuel element hung up in air during transfer to shear	Possible overheating and rupture of fuel pins and release of fission gases to atmosphere
Ignition of zirconium fines	Small fire of short duration--little, if any, damage
Rapid chemical reaction in dissolver	Vessel pressurized, seals blown, fission gases released to atmosphere; cell contaminated
Leak in recovered acid line	Contamination of cell or pipe trench in area of leak
Leak of any vessel or line confining radioactive material	Contamination of cell or pipe trench; transfer material to spare tank space, decontaminate cell and equipment, repair failure or replace equipment
Excessive entrainment of radioactivity in evaporator overheads	Contamination of recovered acid or condensate which must be recycled
Failure of an iodine scrubber	Reduced iodine removal efficiency of system; shut down plant until adequate efficiency restored
Filter failure	Detectable increase of radioactivity in stack effluent; shut down plant and replace filter
Loss of ventilation zone differential-pressure control	Possible migration or radioactivity from controlled area to limited access area; correct deficiency and decontaminate building area
Solvent fire	May plug filter, contaminate cell and ventilation on exhaust ducts; could require extensive cleanup of cell and ducts, and replacement of filter, while plant shut down for repairs

Source: NRC, 1976.

The report did identify the “upper level accidents” that could occur, resulting in release to the surrounding environment. These were:

- criticality
- high level radioactive waste concentrator or calciner explosion
- plutonium product concentrator explosions

Even though a criticality accident was deemed unlikely in a separations facility, a criticality accident of 10^{19} fissions was assumed. This was an order of magnitude greater than the yield that had been experienced for plutonium systems in past accidents at the time. It was also assumed that all noble gases and 50 percent of the halogens (or halides) would be discharged from the plant stack. The dose commitments would essentially be the same for UO_2 fuel or MOX fuel. The dose commitment to the thyroid was the dominant dose, and was given as 56 mrem to an individual and 629 mrem to the population.

In the case of a waste concentrator explosion accident, it was assumed that an explosion would disperse approximately 150 gallons of HLW solution into the cell in the form of a finely divided mist (a concentrator would have a volume of about 3000 cubic meters (m^3) and be installed in a highly shielded cell) and the mist would rain or plate out on the cell surfaces. Some droplets remaining in the air (10 milligrams/cubic meter (mg/$m^{3)}$) would be carried through the ventilation ducts to the high efficiency filters. Moisture separators upstream would knock out most of the mist. It was estimated that these actions would reduce the fraction of material released to 3.6 x 10^{-8}. 30.5 mg was estimated as the quantity of HLW solution leaving the final filter in aerosol form. The maximum offsite dose commitment to an individual was estimated as being 2.6 mrem (bone) for UO_2 fuel and 6.9 mrem (bone) for MOX.

For a 1000-m^3 plutonium concentrator cell volume, the postulated accident was estimated to release approximately 2.2 mg of plutonium. In addition to plutonium the radionuclide releases included americium-241 (Am-241), curium-242 (Cm-242), strontium-90 (Sr-90) and ruthenium-106 (Ru-106). By far the greatest source of radioactivity releases was calculated to be Ru (2000 millicuries (mCi)and 3400 mCi from UO_2 and MOX fuels, respectively), which was several orders of magnitude higher than that for the other radionuclides listed.

6.4.1.3 Safety Evaluation Report, Barnwell Nuclear Fuel Plant

In 1968, Allied-Gulf Nuclear Services filed a license application with the Atomic Energy Commission "…to construct and operate an irradiated nuclear fuel recovery plant…pursuant to Section 104 b. of the Atomic Energy Act of 1954, as amended. The plant was designed to process 1500 metric tons of uranium (MTU) every year using spent fuel that that on average would have a burn up of less than 40,000 megawatt-days per MTU (MWd/MTU) at 50 megawatts/MTU (MW/MTU) (AEC, 1970). Prior to reprocessing, the fuel was to be aged at least 90 days and normally aged 160 days after reactor discharge. A DBA approach was used.

Part of the safety evaluation performed by the NRC staff for the BNFP (AEC, 1970) included an accident analysis. The staff stated that except for a nuclear criticality accident, upper-limit accidents in a fuel reprocessing plant would release TRU and fission product particulate rather than radioactive gases, and that these releases would largely be confined to the site. To evaluate whether the proposed site was acceptable relevant to the risks associated with postulated accidents in the BNFP, an upper-limit guideline that constitutes a degree of hazard comparable to the accident dose guidelines given in 10 CFR Part 100 was used--"An amount of radionuclides equal to the time-integrated inhalable concentrations for 50 years of exposure to the airborne concentration shown in Table II, Column I of 10 CFR Part 20" (note that this criterion is no longer part of 10 CFR Part 100). Based on this, it was calculated that the guideline value for the release of plutonium from the BNFP stack was limited to approximately 84 curies. From this, it was calculated that a person in the area of maximum ground level exposure (within the exclusion area about 400 m from the stack) could receive a bone dose lifetime commitment of about 150 rem during the time of the release. Persons beyond the site boundary could receive no more than 55 rem bone dose lifetime commitment. Similar guideline values were established for other radionuclides, but it was determined that in the event of an upper limit accident, the TRU radionuclides would become the limiting guideline values.

In evaluating the site, the NRC staff postulated major accidents to represent the upper-limit accidents that could occur in the BNFP. For each postulated accident simultaneous failure of process safety features and the worse probable consequence was assumed. These were as follows:

- An explosion would disperse solution containing soluble radionuclides into the cell's atmosphere. Radionuclides up to the amount involved in the accident or that contained in a quantity of solution equivalent to a heavy mist (100 mg solution/m^3) in one cell volume of air (whichever is limiting), would be exhausted to the cell's ventilation system. This assumption is conservative since air containing a heavy mist would retain only about 10 percent of such particles after impinging against a wall or baffle.

- All of the iodine and 0.1 percent of the ruthenium associated with the contents of a vessel or stream that is involved in the accident would be exhausted to the cell's ventilation system.

- A fire would release smoke contaminated with about 1 percent of the fission product and TRU radionuclides contained in the burning organic solvent. This assumption was based upon measurements made at the Savannah River Plant and is conservative relevant to actual experience with the disposal of spent organic solvent by burning in open pits.

- The final filters would retain their integrity and efficiency during and after the accident. Krypton, xenon, iodine and volatilized ruthenium radionuclides pass through the filters without being removed. The final filters would remove 99 percent of particulate in the form of smoke or aerosol. This assumption was also conservative based upon experience with absolute filters operating at their rated flow which demonstrated better than 99.95 percent efficiency for removing particles greater than 0.3 micron.

- The accident occurs during meteorological conditions that could result in a puff release (of Q curies[4]) traveling at a rate of 1 m/sec. On this basis, a person who is 400 m downwind from the stack could receive the maximum total integrated dose. Again, this assumption was conservative. For a person to receive a maximum exposure they would have to be at ground level during the entire time the accidental release occurred. The area of maximum ground level concentration is within the exclusion area of the site, which upon warning would be evacuated.

For a criticality accident in the dissolver, 10^{19} fissions occurring was considered prior to sufficient liquid or chopped fuel being ejected from the dissolver to render the system subcritical. All radioactive gases were assumed to be released into the process cell, thus bypassing the off-gas systems and subsequently are released to the atmosphere through the stack.

For fires, two hypothetical accidents were chosen as being representative of an upper-limit accident in the BNFP. Though fire detectors at the plant would likely respond with a blanket of

[4] "Q" represents an undetermined number.

high density foam to put out the fire within 5 minutes, for the staff evaluations it was assumed that the fire would burn for 30 minutes and would be extinguished by oxygen depletion caused by plugging of the cell filter.

The first fire was postulated to occur due to a leak in the High Activity Product (HAP) stream, which is the organic solvent stream leaving the highly active (HA) contactor. This stream contains the largest amount of plutonium per unit of time in an organic stream during normal operation and has the highest fission product content during the neptunium accumulation cycle. A leak in the pipe leads to ignition of the organic solvent that is spilled in the pan liner. In the event of such as accident, it was calculated that 1 curie (Ci) of plutonium could be released from the stack.

The second fire was presumed to occur in the 3B stripper, which strips plutonium from the organic phase into the aqueous phase. H_2 gas is generated in the 3B plutonium stripper, but is purged to the vessel offgas (VOG) system by nitrogen gas which is monitored by flow rate instruments with alarms. The operating temperature is below 50^{o}C, which is far below the auto-ignition temperature for a hydrogen-air mixture. The accident postulated that air or oxygen into the system, and failure of the electrical insulation to prevent current leakage; i.e., H_2 is ignited and an explosion occurs. It was also postulated that the entire contents of the vessel is expelled via a rupture caused by the explosion and that the solvent stream (3AP) is ignited by the explosion. It was also assumed that for some unknown reason, the organic solvent stream and related process streams to the 3A column do not stop and so the organic solvent stream continues to flow after the accident. It was calculated that about 150 Ci of plutonium would be dispersed into the cell air by the explosion and about 150 Ci of plutonium would be in the smoke going to the cell's filter. This could result in a release of about 3 Ci of plutonium from the stack.

Red oil explosions in both the high level and low level waste concentrators were postulated. In the case of the HLW concentrator, an abnormal condition was assumed with a plutonium concentration in the concentrator equivalent to a 5 percent product loss rate. Based on this and assumptions made regarding upper-value accidents, it was calculated that an explosion may release from the stack 2400 Ci ruthenium-106, 3.2 Ci zirconium-95, 0.8 Ci strontium-89, 0.8 Ci strontium-90, 1.7 Ci cesium-134, 1.1 Ci cesium-137, 8.9 Ci cerium-144, 0.5 Ci americium-curium, 0.08 Ci plutonium, and other lesser radonuclides. Of these, the Ru-106 and Am-Cm radionuclides were identified as the predominant hazard. In the case of the low level waste concentrator, the potential release due to an explosion was considerably less. Through the stack might be released 33 Ci Ru-106, 35 mCi Pu, and other lesser radionuclides.

6.4.1.4 NUREG-1140 – A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees

NUREG-1140 (NRC, 1991), contains a review of accidents that could occur at fuel cycle facilities, including spent fuel reprocessing facilities, and the implications for emergency planning requirements. The document concluded that the releases during these accidents would not result in a maximum offsite individual dose commitment that exceeded EPA's Protective Action Guidelines (PAGs). This was primarily attributed to a lack of strong driving forces and extensive containment systems. The overall conclusion from the regulatory analysis was that accidents at fuel cycle facilities and other radioactive materials licensees (reprocessing plants included) pose a small risk to the public. It concluded that serious accidents would be infrequent and would generally involve relatively small radiation doses to few people located in small areas.

NUREG-1140 considered an analysis of three major accident scenarios at reprocessing facilities, taken from the "Generic Environmental Statement on the Use of Recycled Plutonium in Mixed Oxide Fuel in Light-Water Reactors" (NRC, 1976): (1) criticality, (2) HLW concentrator or calciner explosion, and (3) Pu product concentrator explosions. The analysis considered the dispersal of 150 gallons of HLW solution from a waste concentrator explosion and assumed the same concentration of aerosol from an explosion in the plutonium concentrator. However, NUREG–1140 did not include details of the analyses, except for the following: the analyses assume the filtration systems are not affected by the explosions and use a reduction in the fraction of material released to 3.6×10^{-8}. It estimated the material leaving the final filter at 30.5 mg of HLW solution (as an aerosol). It estimated the maximum offsite bone dose commitment that could result from this hypothetical accident to an individual at about 2.6 mrem for uranium oxide fuel.

Current NRC guidance in the accident analysis handbook, NUREG/CR-6410 (SAIC, 1998) indicates reduced performance of high-efficiency particulate air (HEPA) filters because of the effects of accidents and mentions a range of 95 to 99 percent (as compared to 99.95 percent removal when new and undamaged). Guidance used for the review of the MFFF, NUREG-1821 (NRC, 2005b) limits damaged HEPA filter performance to the 99- to 99.9-percent range, depending on the number of HEPA filter banks in series. Following this guidance and applying an efficiency of 99 percent for degraded HEPA filter performance, and assuming no plating out of the aerosol in the cell, the resultant offsite dose would be 7.2×10^{6} mrem (7,200 rem). If the accident was sufficiently energetic to completely degrade HEPA filter performance or to create an unfiltered release pathway (e.g., from a potential hydrogen explosion) in which all the material was released (i.e., assuming a 100 percent failure of the filter systems and no plating out), the result would be a dose of 7.2×10^{10} mrem (72 million rem). Either result is greater than the 2.6 mrem cited in NUREG–1140 and exceeds EPA's PAG; thus, the potential for an event classified as a general emergency exists for potential accidents at reprocessing facilities.

NUREG-1140 did not use higher burnup fuel with correspondingly greater radiotoxic inventories per unit mass. The analysis uses a burnup of 33,000 megawatt-days/metric ton of initial heavy metal (MWD/MTIHM), which is approximately half of current day burnups and, therefore, underestimates the concentration of Pu-238 by about 75 percent. Pu-238 is the dominant contributor to inhalation dose. The NRC staff estimated an approximately 50-percent increase in the doses cited above if the event occurred with current burnups of about 60,000 MWD/MTIHM. For SNF storage, the analysis only looks at the doses from Kr-85 and I-129, caused by a breach of the fuel rod plenum(s). There is no analysis for disruptive events, such as fires and explosions that can damage and potentially turn fuel constituents to aerosols (e.g., Cs, Pu, Am, and Cm isotopes would be released). There is no mention of a possible significant inventory (1,000+ MTIHM) of SNF being stored in a wet pool at a reprocessing facility, much larger than the small number of assemblies used in NUREG-1140. There is also no mention of the other events that have occurred at reprocessing facilities (e.g., loss of filters, explosions, and fires blowing out cells and glove boxes) and waste accidents and analyses (e.g., Kyshtym and Tomsk in Russia, and the Atomic Energy Commission/DOE HLW tanks).

6.4.2 Potential Accidents and Analyses under the Recommended Case (Potential Hybrid ISA-PRA Accident Categories and Examples)

For the recommended case under the proposed 10 CFR Part 7X, potential accident sequences are placed into the seven top-level categories listed below:

- Confinement events
- Fire events
- Load-handling events
- Explosion events
- Criticality events
- Chemical events
- Direct overexposure events

Each accident category is described in the sections that follow. The accident categorization follows an approach modeled after that in the NRC's NUREG-1821, "Final Safety Evaluation Report on the Construction Authorization Request for the Mixed Oxide Fuel Fabrication Facility at the Savannah River Site, South Carolina" (NRC, 2005b), modified to factor in reprocessing facility hazards and characteristics.

Although NUREG-1821 is for the MFFF, that facility includes a modified PUREX process and the MOX fuel fabrication process involves the handling and processing of nuclear fuel grade uranium and plutonium, making this a reasonable analog for potential accidents in a PUREX reprocessing facility. Information below is taken largely from NUREG-1821.

6.4.2.1 Confinement Events

Confinement of radioactive material at reprocessing facilities would be provided by static confinement boundaries in conjunction with ventilation systems and sealed confinement barriers (e.g., containers and fuel rods). Multiple separate events with potentially significant consequences are possible. These events can be assigned to the following 12 groups, each of which might have different prevention or mitigation strategies:

- Overtemperature
- Corrosion
- Glovebox breaches or backflows
- Leaks in the aqueous polishing (AP) process vessels or pipes
- Backflow from a process vessel through utility lines
- Rod-handling operations
- Breaches in containers outside of gloveboxes as a result of handling

- Over- or under-pressurization of glovebox
- Excess temperature caused by radioactive decay
- Glovebox dynamic exhaust failure
- Process fluid line leak in a C3 area outside a glovebox
- Sintering furnace confinement boundary failure

These 12 groups are discussed below:

6.4.2.1.1 Overtemperature (Confinement)

Reprocessing facilities would handle irradiated materials that can be self-heating. Major areas of potential concern include SNF storage areas, dissolver and accountability tankage, HLW areas, and MOX (liquid and powder) handling areas. Without adequate cooling, the radioactive materials in these areas can exceed the design temperatures of their confinement systems and release radioactive materials. An example would be a tank containing liquid HLW that starts to boil. The boiling materials would overwhelm the filtration systems or, in a worst-case scenario, heat the materials to an explosive endpoint that would break confinement systems. The material at risk is the maximum inventory of radioactive material in the tank. Such an event could be caused by control system failure, electrical isolation failure, or loss of cooling to process equipment. Such an event would likely correspond to the VHCE category in the proposed 10 CFR Part 7X for facility workers, site workers, individuals (or individual) outside the controlled area (IOC), the environment, contamination, and/or economic impact. Potential controls would have to protect potential receptors through a strategy of prevention and mitigation, and could include redundant control and cooling systems, and more robust filters. Defense-in-depth and "as low as reasonably practicable" (ALARP) features might include the different ventilation systems, cell structures, and operator actions.

Other potential accident scenarios in this category might occur in association with tankage containing dissolver solutions, first cycle columns and vessels, and plutonium and MOX containing areas. It is anticipated that there would be many potential scenarios in this category given the large number of vessels in a reprocessing facility containing highly radioactive materials. There could be over 50 such vessels and containers.

6.4.2.1.2 Corrosion (Confinement)

The corrosion event group is defined as catastrophic failure of a primary confinement boundary, such as piping, gloveboxes, ductwork, filters, or even cell liners and walls, postulated to result from corrosion. Loss-of-confinement events caused by corrosion within process cells are discussed in Section 6.4.2.1.4 as leaks of process vessels or pipes within process cells event group. Loss-of-confinement events caused by corrosion of pipes containing process fluids within C3 areas not enclosed within a glovebox are discussed in Section 6.4.2.1.11 as process fluid leaks in C3 areas outside of glove box event group.

Typical events might include sampling handling accidents, with lines, containers, pneumatic line sample transfers, etc. These sequences would likely exceed the VHCE definition for at least the facility worker. The material at risk would be the maximum inventory in the sampling line or area. Preventative and mitigative features could be applied as safety controls, such as corrosion monitoring programs (e.g., maintenance and surveillance to detect and limit corrosion prior to failures) and confinement ventilation systems. Ventilation systems can also provide defense-in-depth. The potential number of these types of event sequences depends greatly upon the specific design.

6.4.2.1.3 Glovebox Breaches or Backflows (Confinement)

A typical event for small breaches in a glovebox confinement boundary or backflow in the confinement events accident category might involve backflow through the interfacing gas line (e.g., nitrogen, helium) to the interfacing system, followed by the opening of this interfacing system during a maintenance operation. The material at risk would be the maximum inventory of radioactive material in a glovebox, such as MOX powder or first or second cycle solutions (i.e., a sampling glovebox (confinement)). Potential causes would include loss of gas pressure or flow through a supply line. These scenarios would most likely exceed the VHCE thresholds, at least for the facility worker. Protection could involve both prevention (e.g., high quality gas supplies and components) and mitigation, such as the glovebox confinement system; the latter maintains a negative glovebox pressure differential between the glovebox and the interfacing systems and would also maintain a minimum inward flow through small glovebox breaches.

6.4.2.1.4 Leaks in the AP Process Vessels or Pipes (Confinement)

Leaks in process vessels or pipes within process cells in the confinement events accident category could be caused by corrosion and corrosion/erosion phenomena. Many of the vessels in the dissolution, first cycle extraction, and waste areas have sufficient inventories and radionuclide characteristics to render such leaks as VHCEs for all receptors unless they are prevented or mitigated by safety controls. The material at risk is usually the maximum inventory of radioactive materials in the affected equipment. Potential safety controls could differ by the receptor, but might include vessel integrity, cell liner integrity, cell integrity, detection and sump capability, ventilation systems, and filters. Defense-in-depth and ALARP features might include other ventilation systems, cell structures, and operator actions.

It is anticipated that there would be many potential scenarios in this category given the large number of vessels in a reprocessing facility containing highly radioactive materials. There would be over 50 such vessels and containers.

6.4.2.1.5 Backflow from a Process Vessel through Utility Lines (Confinement)

Reprocessing facilities contain many lines that feed utilities (e.g., air, water) or reagents (e.g., nitric acid) into the process and cell areas. These lines usually include pots, liquid seals, and check valve devices to prevent reverse flow from the process and cell areas, such as in the dissolution, waste, separations, and plutonium/MOX areas of the facility. However, backflow through the line from an accident can result in VHCE scenarios to a facility worker unless safety controls are implemented. Impacts to other receptors would require further evaluation. A typical event would involve backflow from a process vessel through the utility lines confinement barriers into the facility worker (operator) occupied area, due to the loss of controls, overpressure, or even maintenance activities. The material at risk could be significant, up to the maximum radioactive material in the initial pot or even the vessel itself, depending upon the specific design. Potential prevention and mitigation strategies include the backflow prevention devices (e.g., liquid seals, pots, check valves), use of gloveboxes or other confinement around the line connections, and ventilation systems. One of the ventilation systems could also function as a defense-in-depth feature. There are many potential vessels in this category.

6.4.2.1.6 Rod-Handling Operations (Confinement)

MOX fuel rods contain plutonium isotopes that have very high dose conversion factors. The rod and assembly handling operations at the facility represent a potential confinement scenario in the events accident category. This scenario might involve the fracture of one or more fuel rods while utilizing fuel rod handling equipment, thus resulting in a breach of confinement and dispersal of radiological materials from the broken fuel rod itself. The total material at risk might be the maximum inventory of radioactive material in a tray of fuel rods. Human error or equipment failure are potential causes of the scenario.

The consequences of this event would likely exceed very high consequences for the facility worker; the consequences for other receptors would require more specific evaluations. A strategy of prevention and mitigation would identify safety controls; likely safety controls would include maintaining the primary confinement (the fuel rod cladding, e.g., via quality assurance (QA) and other rod quality controls (QCs)), rod material handling controls, materials handling equipment and controls, and facility worker actions to control exposures. While this release could occur with little or no warning, these controls would limit the initial release and include immediate worker responses to mitigate the consequences. The ventilation systems provide additional protection and defense-in-depth. There might be several rod loading areas with several scenarios each.

6.4.2.1.7 Breaches in Containers Outside of Gloveboxes as a Result of Handling (Confinement)

Facility movements would likely use some types of transfer containers for intra-plant movement of radioactive materials, such as MOX powders, wastes (HLW, intermediate-level waste (ILW), Greater-Than-Class C (GTCC) waste, etc.). Some of these, such as MOX powders, would be moved in sufficient quantities and forms that a VHCE could occur if the container is breached, e.g., outside of gloveboxes but in a glovebox room. Specific design information would be needed to determine if one or more containers could be affected and fail simultaneously. The most likely affected receptor is the facility worker. Specific designs and analyses would be needed to determine the impacts upon other receptors. Potential controls could include certification of canister designs to meet the design basis accidents without breaching, administrative handling controls, and the room and hall confinement/ventilation systems. The determination of the number of sequences requires a specific design.

6.4.2.1.8 Over- or Under-pressurization of Glovebox (Confinement)

The powder processing areas of a reprocessing facility would likely make extensive use of gloveboxes. Gloveboxes use negative pressure to maintain confinement. In contrast, over-pressurization could cause failure of the glovebox confinement and disperse radioactive materials. Gloveboxes handling MOX powders would have sufficient inventories and dose conversion factors to produce VHCEs for all receptors. Potential causes of this event have been identified as the rupture of a high-flow or high-pressure supply line or a clogged outlet HEPA filter.

Preventative controls might include glovebox pressure controls, which would maintain glovebox pressure within design limits. For a slow pressurization event, a mitigation strategy could be used, such as facility worker actions and safety control systems to warn operators of glovebox pressure discrepancies before exceeding differential pressure limits. The glovebox and room ventilation systems might be identified as the safety controls for other receptors, such as site workers, the public, and the environment. The outside hall confinement ventilation system would provide defense in depth. The facility would have many gloveboxes in which such an event could occur.

6.4.2.1.9 Excess Temperature Caused by Radioactive Decay (Confinement)

Thermal calculations on specific materials and designs would be needed to evaluate the effects of temperature on confinement structural materials, such as containers. As a first approximation, containers confining high heat generation materials, such as SNF, MOX powder, and HLW glass, have the potential to overheat and cause failure of their confinement systems, potentially causing releases and, thus, become VHCEs. Potential controls include cooling systems, such as the area’s heating, ventilation, and air conditioning (HVAC) system. The determination of the number of sequences requires a specific design.

6.4.2.1.10 Glovebox Dynamic Exhaust Failure (Confinement)

Gloveboxes would be under continuous negative pressure. Failure of the negative pressure system (sometimes called the dynamic exhaust) could result in a loss of negative pressure or a flow perturbation involving the dynamic confinement system (sometimes called C4), resulting in a ventilation airflow reversal into a glovebox room area (sometimes designated a C3 area). The material at risk could be the maximum inventory of airborne radioactive material and fine powders in all connected gloveboxes. Potential causes of this event are loss of normal control system, loss of all power, or mechanical failure of the ventilation system. As a first approximation, this would likely be characterized as a VHCE for all receptors. Preventative strategies could be applied, such as using the ventilation systems as safety controls. The determination of the number of sequences requires a specific design.

6.4.2.1.11 Process Fluid Line Leak in a C3 Area Outside a Glovebox (Confinement)

This type of event is postulated to result from a leak from a line carrying a process fluid in a C3 (room) area outside of a glovebox or process cell caused by corrosive chemicals or mechanical failure of the piping. It primarily applies to second cycle and MOX scrap recovery areas, and the material at risk would likely be the maximum inventory of radiological material in a vessel or interconnected vessels. This would likely be a VHCE to all potential receptors. A preventative strategy using double walled pipes and the ventilation systems as the safety controls would likely address the event sequences. There are numerous tanks and vessels in these areas.

6.4.2.1.12 Sintering Furnace Confinement Boundary Failure (Confinement)

In most modern reprocessing facilities, the sintering furnace is in a room area and not a glovebox. Only the entry and removal stations are usually located in gloveboxes. Thus, the sintering furnace is the confinement boundary. This boundary could be breached by several scenarios, such as a slow leak through the seals or a rapid over-pressurization event. These events could be caused by failure of the control system for the hydrogen/argon supply line, a failure in the sintering furnace exhaust system, or a sintering furnace seal failure. The material at risk would be the maximum inventory of radiological material in a sintering furnace.

The safety review would have to consider and evaluate whether there are any scenarios that could involve two or more of the furnaces, e.g., via a common-mode failure or interconnections in an actual design. For one furnace, the unmitigated event sequences would most likely exceed the VHCE limits for all receptors due to the quantity of MOX involved and the high dose conversion factors involved with reactor-grade plutonium. Preventative strategies for rapid over-pressurization might use combinations of pressure controls, temperature controls, and gas flow controls, and confinement by the sintering furnace shell; the latter could rely on specific features, including materials of construction, American Society of Mechanical Engineers (ASME) QC requirements, seal designs, cooling water designs, etc. Sintering room and glovebox ventilation systems provide additional controls and defense-in-depth.

6.4.2.2 Fire Events

The potential consequences of fire events at the facility might include the following:

- destruction of confinement barriers
- destruction of civil structures
- destruction of equipment contributing to dynamic confinement
- failure or damage to utility equipment
- loss of criticality controls
- loss of other SSCs with safety functions

All of the above can lead to the release of nuclear and chemical materials to the environment.

Potential causes for fire events within the facility might include the following:

- short circuits or equivalent event involving electrical equipment
- ignition or combustion of fixed or transient combustibles
- equipment that operates at high temperatures

- ignition of a solvent or other flammable/reactive chemical

Thirty-five separate events with potentially significant consequences were analyzed to determine the bounding consequences from a potential fire event. These events were assigned to 13 groups as follows with a unique prevention or mitigation strategy:

- AP process cells
- AP/mixed oxide process (MP) C3 glovebox area
- C1 and C2 areas:
    - 3013 canister
    - 3013 transport cask
    - Fuel rods
    - MOX fuel transport cask
    - Waste container
    - Transfer container
    - Final C4 HEPA filter
- Outside MFFF building
- Facility-wide systems
- Facility
- AP electrolyzer

These 13 groups are discussed below.

6.4.2.2.1 AP Process Cells (Fire)

The bounding event for the AP process cells events group in the fire events accident category was determined to be a fire in the cell containing the liquid waste reception unit tanks. The material at risk was taken to be the maximum inventory of radioactive material in the cell containing the tanks. A fire was postulated to occur in the process cell and consequences were evaluated. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to protect these receptors through a strategy of prevention. The principal systems, structures, and components (PSSCs) for protection of the facility worker were the process cell fire prevention features, the purpose of which is to ensure that fires in the process cells are highly unlikely. The process cell fire prevention features consist of the following:

- elimination of ignition sources, including electrical equipment and static electricity
- fire barriers to protect process cell areas
- elimination of all combustible materials from process cells containing aqueous solutions
- elimination of combustibles outside of process equipment in cells containing solvents
- maintenance of temperatures at levels to prevent creation of flammable vapors

The process cell fire prevention features were also identified as the PSSC for protection of the environment, site worker, and IOC. In addition, the process cell ventilation system's passive boundary and the C2 confinement system's passive boundary provide defense-in-depth protection to mitigate the potential consequences to the environment, site worker, and IOC. Based on deterministic criteria and the descriptions of types of control (enhanced administrative control with active and passive features) in Table A-5 of NUREG-1718, "Standard Review Plan for the Review of an Application for a Mixed Oxide (MOX) Fuel Fabrication Facility" (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.2 AP/MP C3 Glovebox Area (Fire)

The bounding event for a fire in the AP/MP C3 glovebox area in the fire events accident category was a fire within the plutonium dioxide buffer storage area. The material at risk was the maximum inventory of radioactive material within the fire area. The specific cause of a fire in this area was not addressed, but the bounding event in this event group was identified as a fire originating in a glovebox. This was determined be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to protect potentially affected workers, IOC, and the environment through a strategy of mitigation. The PSSCs identified for protection of the facility worker were facility worker actions and facility worker controls. The PSSCs identified for protection of the environment, site worker, and IOC were the C3 confinement system, the active portion of the C4 confinement system, and fire barriers. In addition, combustible loading controls is also identified as a PSSC for protection of the environment, site worker, and IOC for fires involving storage gloveboxes. The primary protection of the worker would be early detection of the fire and the ability to evacuate the area before a release.

Although not credited by the accident analysis, there would also be a fire suppression system in areas with dispersible radioactive material. This suppression system would be classified as a PSSC. Consideration of the warning time available from a fire before a breech in containment allows facility worker action to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements with regard to the facility worker. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (active engineered control (AEC), enhanced administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.3 C1 and C2 Areas: 3013 Canister (Fire)

The bounding event for a fire affecting a 3013 canister event group in the C2 area is a fire in the 3013 storage area. The material at risk for this fire is the maximum inventory of radioactive material in the fire area. The cause of the fire was ignition of transient combustibles. This was determined this to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to protect the facility worker, environment, site worker, and IOC through a strategy of prevention. The PSSC identified for protection of the facility worker, environment, site worker, and IOC is combustible loading controls, which are intended to limit the quantity of combustibles in a fire area containing 3013 canisters to ensure that the canisters are not adversely impacted by a fire. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (enhanced administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.4 C1 and C2 Areas: 3013 Transport Cask (Fire)

The bounding event for a fire affecting a 3013 transport cask in the C1 or C2 area was determined to be a fire in the truck bay involving transport packages resulting in an energetic breach of the containers and the dispersal of radioactive materials. The type of fire postulated would be a fuel fire involving a truck. The material at risk was determined to be the maximum inventory in the transport packages. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to protect the facility worker, environment, site worker, and IOC through a strategy of prevention. The PSSCs identified for protection of the facility worker, environment, site worker, and IOC are the 3013 transport cask, which will withstand the design basis fire without breaching, and combustible loading controls, which will limit the quantity of combustibles in a fire area containing 3013 transport casks to ensure that the cask design basis fire is not exceeded. In addition to the identified PSSCs, there would also be a fire suppression system that is considered an additional protective feature. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (passive engineered control (PEC) and enhanced administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.5 C1 and C2 Areas: Fuel Rods (Fire)

The bounding event for a fire affecting fuel rods in the fire event accident category is a fire in the fuel assembly storage area. The material at risk for this fire is the maximum inventory of radioactive materials in the assembly storage area. Combustible loading in this area is low, but the fire is still assumed to involve all of the radioactive materials in the storage area. The source of the fire is considered to be electrical equipment and transient combustibles. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, the environment, site worker, and IOC.

The applicant proposed to protect the potential receptors through a strategy of prevention. The PSSC identified for protection of these receptors is combustible loading controls which will limit the quantity of combustibles in a fire area containing fuel rods to ensure that the fuel rods are not adversely impacted by a fire. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (enhanced administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.6 C1 and C2 Areas: MOX Fuel Transport Cask (Fire)

The bounding event for a fire affecting the MOX fuel transport cask in the fire event accident scenario was determined to be a fire in the fuel assembly truck bay. The source of the fire was considered to be electrical equipment and transient combustibles. The material at risk was the radioactive material in the transport casks. This was determined this to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to protect potential receptors through a strategy of prevention. The PSSCs identified for protection of the facility worker, environment, site worker, and IOC are the MOX fuel transport cask, which will withstand the design basis fire without breaching, and combustible loading controls, which are intended to limit the quantity of combustibles in a fire area containing MOX fuel transport casks to ensure that the cask design basis fire is not exceeded. In addition to the identified PSSCs, there would also be a fire suppression system that is considered an additional protective feature. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (PEC and enhanced administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.7 C1 and C2 Areas: Waste Container (Fire)

The bounding event for a fire affecting a waste container in the C1, C2, or C3 area event group in the fire event accident category was determined to be a fire located in the assembly packaging area. The material at risk was the maximum inventory of radioactive material in the waste container. The source of the fire was considered to be electrical equipment and transient combustibles. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, but a below the 10 CFR 70.61(c) threshold consequence event for the environment, site worker, and IOC.

The applicant proposed to limit the dose to the facility worker using a strategy of mitigation. The PSSC identified for protection of the facility worker is facility worker action to ensure that facility workers take proper actions to limit dose. No PSSCs were identified as being necessary to adequately protect the environment, site worker, and IOC. Based on the nature of this event (mitigated by rapid detection of fire and immediate worker responses), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.8 C1 and C2 Areas: Transfer Container (Fire)

The bounding event for a fire affecting a transfer cask within the C1, C2, or C3 areas event group in the fire event accident category was determined to be a fire in the air locks, corridors, stairways, safe areas, or liquid waste reception areas. The material at risk was the maximum inventory in a transfer container. The source of the fire was identified as electrical equipment, transient combustibles, or a HEPA filter. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, and site worker, but a below the 10 CFR 70.61(c) threshold consequence event for the IOC.

The applicant proposed to limit dose to the facility worker, environment, and site worker using a strategy of prevention. The PSSC identified for protection of the facility worker, environment, and the IOC is combustible loading controls, which limit the quantity of combustibles in a fire area containing transfer containers to ensure that the containers are not adversely impacted by a fire. No PSSCs were identified by the applicant as being necessary to adequately protect the site worker. Based on the nature of this event (prevented by an enhanced administrative control), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.9 C1 and C2 Areas: Final C4 HEPA Filter (Fire)

The bounding event for a fire affecting the final C4 HEPA filter in the fire event accident category is a fire which breaches the HEPA filter housing and allows material from the HEPA filters to pass directly to the stack. The material at risk for this event is based on a conservative estimate of material present on the C4 HEPA filters. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to limit dose to the facility worker, environment, site worker, and IOC using a strategy of prevention. The PSSC identified for protection of the facility workers, environment, site worker, and IOC are combustible loading controls. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (enhanced administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.10 Outside MFFF Building (Fire)

The bounding event for a fire originating outside of the MFFF building event group in the fire event accident category was determined to be a fire involving diesel fuel storage, gasoline storage, or the reagents processing building, such that the MFFF building structure is damaged and radioactive material is released. The material at risk was the maximum inventory of radioactive material in the MFFF, which is susceptible to the effects of external fires. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified to protect all receptors are the MFFF building structure, which is designed to maintain structural integrity and prevent damage to internal PSSCs from external fires, the emergency diesel generator building structure, which is designed to maintain structural integrity and prevent damage to internal PSSCs from fires external to the structure, the emergency control room air conditioning system, which will ensure habitable conditions for operators, and the waste transfer line, which will prevent damage to the line from external fires. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (PECs and an AEC) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.11 Facility-wide Systems (Fire)

The bounding event for a fire affecting facility-wide systems (fires involving systems that cross fire areas) in the fire event accident category was determined to be a fire involving the pneumatic pipe automatic transfer system which results in a breach of confinement and the dispersal of radioactive material. The material at risk was the maximum inventory of radioactive material in the pneumatic pipe automatic transfer system. The fire was postulated to be caused by electrical equipment and transient combustibles. This was determined this to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker and the environment, but a below the 10 CFR 70.61(c) threshold consequence event for the site worker and IOC.

The applicant proposed to limit the dose to the facility worker using a strategy of mitigation. The PSSCs identified for protection of facility workers are facility worker actions and combustible loading controls. The primary protection of the worker will be early detection of the fire and evacuation of the area before a release. The PSSC identified for protection of the environment is combustible loading controls. No PSSCs were identified by the applicant as being necessary to adequately protect the site worker and IOC. Based on the nature of this event (mitigated by enhanced administrative controls and immediate worker responses), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.12 Facility (Fire)

The bounding event for a facility fire which involves more than one fire area in the fire event accident scenario was determined to be a fire in all process units and support units with radioactive materials present. The source term is the maximum inventory in the facility susceptible to a facility-wide fire. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, and IOC.

The applicant proposed to meet the performance requirements using a strategy of mitigation and prevention. The PSSCs identified for protection of the facility worker are worker actions and fire barriers that would contain the fires within the fire area. The PSSC identified for protection of the environment, site worker, and IOC is fire barriers. In addition to the identified PSSCs, there would also be a fire suppression system designated as a PSSC where dispersible radioactive material is present. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (PEC) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.2.13 AP Electrolyzer (Fire)

The bounding event for a titanium fire in the AP electrolyzer was determined to be the energetic breach of the AP electrolyzer and the dispersal of radioactive materials. The material at risk was the maximum inventory in the AP dissolution units. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified for the protection of the facility worker, environment, site worker, and IOC are maintenance activity controls, the process safety control subsystem, and specified electrolyzer components, such as the electrolyzer structure, sintered silicon nitride barrier, guide sleeves, and polytetrafluorethylene (PTFE) insulator. The safety function of the maintenance activity controls is to isolate power from the electrolyzer when the electrolyzer is drained. The safety function of the process control subsystem is to monitor the electrolyzer for faults that could result in arcing or other imparting of electrical energy with the risk of titanium fire. The safety function of the specified electrolyzer components is to provide physical separation and electrical insulation between the electrolyzer components and structural integrity and stability to the electrolyzer system. The C3 confinement system, the C4 confinement system, and the fire suppression and detection system provide defense in depth protection to mitigate potential consequences to the environment, site worker, and IOC. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (AECs) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.3 Load Handling Events

Load handling events may occur during the operation of load-handling or lifting equipment during normal operations or maintenance activities. Load-handling events may occur because of the failure of handling equipment to lift or support the load, failure to follow designated load paths, or toppling of loads. Consequences of load-handling events include possible damage to handled loads, resulting in dispersal of radioactive or chemical materials, possible damage to nearby equipment or structures, resulting in a loss of confinement and/or a loss of subcritical conditions, and possible damage to process equipment or structures relied on for safety.

Twenty-eight separate events with potentially significant consequences were analyzed to determine the bounding consequences from a potential load-handling event. These events were assigned to 12 groups as follows with a unique prevention or mitigation strategy:

- AP process cells
- AP/MP C3 glovebox area
- C1 and C2 areas:
    - 3013 canister in C2 confinement area
    - 3013 transport cask
    - Fuel rods in C2 confinement area
    - MOX fuel transport cask
    - Waste container
    - Transfer container
    - Final C4 HEPA filter
- C4 confinement
- Outside MFFF building
- Facility-wide systems

These 12 groups are discussed below.

C.4.2.3.1 AP Process Cells (Load Handling)

The bounding event for load-handling events in the AP process cells event group in the load handling event accident category was determined to be an event in the cell containing the liquid waste reception unit. The material at risk was the maximum inventory of radioactive material in the AP process cell containing the liquid waste reception unit. The load-handling event is postulated to result in a breach of the americium reception tank and subsequent release of americium in solution because of vessels in the process cell being impacted by a lifting device or a lifted load. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site workers, and IOC.

The applicant proposed to meet the performance requirements using a strategy of mitigation. The PSSCs for the protection of facility workers are the process cells which contain fluid leaks using drip trays and the process cell entry controls which will prevent entry during normal conditions and assure that worker dose limits are not exceeded during maintenance operations. The PSSC for protection of the environment, site worker, and IOC is the process cell exhaust system. The safety function of the process cell exhaust system is to ensure that a negative pressure exists between the process cell areas and the C2 areas, as well as to ensure that the process cell exhaust system is effectively filtered. The C2 confinement system's passive boundary provides defense-in-depth protection for the environment, site worker, and IOC. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (administrative control, AECs, and PECs) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

C.4.2.3.2 AP/MP C3 Glovebox (Load Handling)

The bounding event for load-handling events in the AP/MP C3 glovebox area event group in the load-handling accident category was determined to be an event which occurs within the gloveboxes that contain jar storage and handling of the MOX powder workshop from a breach of the glovebox. The material at risk was the maximum inventory of radioactive material in the glovebox. The breach of the glovebox is from a lifting device or a lifted load. This was determined this to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention and mitigation. The PSSCs for protection of the facility worker and the environment are materials-handling controls, which are intended to prevent impacts to the glovebox during normal operations from loads outside or inside the glovebox that could exceed the glovebox design basis, materials-handling equipment, which is engineered to prevent impacts to the glovebox, the glovebox, which maintains confinement integrity for design basis impacts, and facility worker controls (facility worker during maintenance operations). An additional safety function of the materials-handling controls is to prevent potential over-pressurization of the reusable plutonium dioxide cans caused by radiolysis or oxidation of plutonium (III) oxalate and its subsequent impact to the glovebox. The PSSC for protection of the site worker and IOC is the C3 confinement system. The C2 confinement system also provides defense-in-depth protection for the site worker and IOC. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (AEC, PEC, and administrative controls) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

C.4.2.3.3 3013 Canister in C2 Confinement Area (Load Handling)

The bounding event for the 3013 canister event group (C2 area) in the load-handling accident category was the drop of one 3013 container onto another 3013 container, each containing unpolished plutonium dioxide in powder form. The material at risk was the amount of radioactive material in two 3013 canisters. The cause of the event would likely be human error or equipment failure during a hoisting operation. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified for protection of the facility worker, environment, site worker, and IOC are the 3013 canister and materials-handling controls. The C2 confinement system's passive boundary provides defense-in-depth for the environment, site worker, and IOC. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (administrative control and PEC) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

C.4.2.3.4 3013 Transport Cask (Load Handling)

The bounding event for the 3013 transport cask event group (C1 or C2 area) in the load handling accident category was the drop of a 3013 transport cask containing unpolished plutonium dioxide in powdered form onto another 3013 transport cask. The material at risk was the maximum inventory of radioactive material in two 3013 transport canisters. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The staff independently evaluated this accident sequence and agrees to its categorization. The PSSCs identified for protection of the facility worker, environment, site worker, and IOC are the 3013 transport cask and materials-handling controls. The C2 confinement system's passive boundary provides defense-in-depth for the site worker, IOC, and the environment. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (PEC and administrative controls) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

C.4.2.3.5 Fuel Rods in C2 Confinement Area (Load Handling)

The bounding event for the fuel rods in the C2 area event group in the load-handling accident category was the drop of a strongback containing three fuel assemblies containing MOX (6 percent). The material at risk was the maximum inventory of three fuel rod assemblies. The cause of this event would probably be human error or equipment failure. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, but a below the 10 CFR 70.61(c) threshold consequence event for the environment, site worker, and IOC.

The applicant proposed to use a strategy of mitigation to protect the facility worker. The PSSC identified for protection of the facility worker is facility worker actions. No PSSCs were identified by the applicant as being necessary to adequately protect the environment, site worker, and IOC. However, the C2 confinement system passive boundary provides defense-in-depth for the environment, site worker, and IOC. Because a release could occur without warning, the applicant provided dose calculations which were reviewed onsite by the staff and found to be acceptable. Based on the nature of this event (limited initial release and immediate worker response), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

C.4.2.3.6 MOX Fuel Transport Cask (Load Handling)

The bounding event for the MOX fuel transport cask event group (C1 or C2 areas) in the load handling accident category was determined to be the drop of one MOX fuel transport cask containing up to three MOX fuel assemblies. The cause of this event would probably be human error or equipment failure. The material at risk was determined to be the maximum inventory of one fuel assembly transport package. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker and the environment, but a below the 10 CFR 70.61(c) threshold consequence event for the site worker and IOC.

The applicant proposed to meet the performance requirements of 10 CFR 70.61 for the facility worker and the environment using a strategy of prevention. The PSSCs identified for protection of the facility worker and the environment are the MOX fuel transport cask and materials-handling controls. No PSSCs were identified by the applicant as being necessary to adequately protect the site worker and IOC. However, the MOX fuel transport cask provides defense-in-depth protection for the site worker and IOC. Based on the nature of this event (prevented by a PEC and administrative controls), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

C.4.2.3.7 Waste Container (Load Handling)

The bounding event for the waste container event group (C1, C2, or C3 area) in the load handling accident category is a damaged waste drum in the assembly packaging (truck bay) area caused by human error or equipment failure. The material at risk was determined to be the maximum inventory of radiological material in a waste container. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, but a below the 10 CFR 70.61(c) threshold consequence event for the environment, site worker, and IOC.

The applicant proposed to meet the performance requirements of 10 CFR 70.61 for the facility worker using a strategy of mitigation. The PSSCs identified for protection of the facility worker are worker actions. No PSSCs were identified by the applicant as being necessary to adequately protect the environment, site worker, and IOC. For drops in the C2 area, the C2 confinement passive boundary provides defense-in-depth protection for the environment, site worker, and IOC. However, because a release could occur without warning, the applicant provided dose calculations which were reviewed on site and found to be acceptable. Based on the nature of this event (mitigated by limited initial release and immediate worker responses), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.3.8 Transfer Container (Load Handling)

The bounding event for the transfer container event group (C2 area) in the load-handling accident category was the drop of a transfer container containing a HEPA filter with plutonium dioxide in powdered form. The material at risk was determined to be the maximum inventory in a HEPA filter. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified for protection of the facility worker, environment, site worker, and IOC are the transfer container and materials-handling controls. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (PEC and administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.3.9 Final C4 HEPA Filter (Load Handling)

The bounding event in the final C4 HEPA filter event group in the load-handling accident category was determined to be the impacting of the final C4 filters by a load that breaches the HEPA filter housing and allows material from the HEPA filters to pass directly to the stack. The cause of this event would probably be human error or equipment failure around the ventilation system. The material at risk was determined to be the radiological material contained in the HVAC system and filters. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements of 10 CFR 70.61 for the facility worker, environment, site worker, and IOC using a strategy of prevention. Materials-handling controls were identified as the PSSC for protection of these receptors. In addition, the applicant stated that in the current design and operations, there are no cranes or heavy equipment in the vicinity of the C4 final filters that could cause a load-handling event. Thus, there are no credible load handling events during normal operations. During maintenance operations, maintenance will only be performed on out-of-service trains, which will prevent a release to the stack. The C2 confinement system’s passive boundary provides defense-in-depth protection for the environment, site workers, and IOC for load-handling events that occur in the C2 areas where the final C4 filters are located. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (enhanced administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.3.10 C4 Confinement (Load Handling)

The bounding event in the C4 confinement event group in the load-handling accident category was determined to be a spill of unpolished plutonium powder that occurs inside the glovebox, but does not result in a breach of the glovebox. The cause of this event would probably be human error or equipment failure during load-handling operations inside the glovebox. The material at risk would be the maximum inventory in the glovebox. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements of 10 CFR 70.61 for the facility worker, environment, site worker, and IOC using a strategy of mitigation. The C4 confinement system is identified as the PSSC for protection of the facility worker, environment, site worker, and IOC. The safety functions of the C4 confinement system in this event are to ensure that the C4 exhaust is effectively filtered and to maintain a negative glovebox differential pressure between the glovebox and the interfacing systems. The C3 confinement system provides defense-in-depth protection for the environment, site worker, and IOC. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (high dependability AEC) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.3.2.11 Outside MFFF Buildings (Load Handling)

The bounding event in the load-handling event category outside the MOX fuel fabrication building is an event involving the waste transfer line. The cause of this event would probably be human error or equipment failure. The material at risk was determined to be the maximum inventory in the waste tank. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSC identified for protection of the facility worker, environment, site worker, and IOC is the waste transfer line which is double walled and buried. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (robust PECs) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.3.2.12 Facility Wide (Load Handling)

The bounding event in the load handling event category for the facility-wide event class is the breach of the facility structure from a heavy load resulting in a breach of primary confinement or in a breach of a container holding nuclear materials. The cause of this event would probably be human error or equipment failure. The material at risk was determined to be the maximum inventory in a container or primary confinement. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified for protection of the facility worker, environment, site worker, and IOC are the MOX fuel fabrication building structure, which is designed to withstand the effects of load drops that could potentially impact radiological material, and materials-handling controls that would prevent load-handling events that could breach primary confinements. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (PEC and administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.4 Explosion Events

Explosions are postulated to occur inside a reprocessing facility from process operations and upsets, outside the buildings from nearby support facilities and the storage of chemicals on the facility site, and from laboratory operations. The following are considered to be the major consequences of explosions:

- release of radioactive materials or chemicals to the environment
- damage to a confinement boundary
- damage to equipment contributing to dynamic confinement
- loss of subcritical conditions
- damage to civil structures
- damage to other SSCs with safety functions

All of the above may result in the release of nuclear materials or chemicals to the environment.

Many separate scenarios with potentially significant consequences exceeding the proposed 10 CFR Part 7X performance criteria are possible. These events can be further differentiated into the following categories:

- Hydrogen explosion (process)
- Steam over-pressure explosion
- Radiolysis induced explosion
- HAN explosion
- Hydrogen peroxide explosion
- Solvent explosion
- TBP-nitrate (red oil) explosion
- Process vessel over-pressurization explosion
- Pressure vessel over pressurization explosion
- Hydrazoic acid explosion
- Metal azide explosion
- Plutonium process-specific explosion (e.g., oxalate, electrolysis, etc., if used)
- Electrolysis-related explosion
- Laboratory explosion
- Outside explosion

These 15 groups are discussed below:

6.4.2.4.1 Hydrogen Explosion (Process)

H_2 is used as a process reagent in the MOX fuel fabrication area, primarily in the sintering furnace and sintering furnace room areas. H_2 (usually in an argon cover gas) provides the reducing conditions to assist with the chemical formation of the dense MOX pellets. H_2 also protects the furnace electrodes from failing and burning. Potential scenarios include excessive H_2 in the furnace, H_2 leakage out, air in-leakage (through the feed or exit ports on the furnace, or at seals), or slow H_2 accumulation in the room. The sintering furnace has sufficiently high quantities of reactor-grade plutonium in the MOX green pellets well above those needed to exceed the proposed VHCE thresholds of the proposed 10 CFR Part 7X for all receptors. Potential preventive control strategies might use process control systems to monitor and control H_2 concentrations and quantities, H_2 and oxygen monitors, inerting of the gloveboxes around the sintering furnaces, and use of the ventilation systems to dilute H_2 below explosive limits.

6.4.2.4.2 Steam Over-pressure Explosion

Steam explosions can occur where liquid water is confined and can be suddenly exposed to high temperatures that cause it to flash rapidly to steam. These depend on the specific processes and the designs used. However, steam explosions are typically a concern around furnaces, such as the uranium nitrate calcining furnaces, MOX sintering furnaces, vitrification calciners, and vitrification melters. Potential scenarios include unexpected carryover of liquids from upstream equipment (e.g., tanks, humidifiers), ceramic insulation failure, and cooling water leaks and accumulation in the heated equipment. For equipment handling the reprocessed uranium, the inventory is likely sufficient to exceed the VHCE threshold for the worker only. For equipment handling MOX and HLW, the VHCE thresholds would likely be exceeded for all receptors. Potential preventive controls include process controls to detect and isolate leaks and temperature hot spots before sufficient accumulation has occurred.

6.4.2.4.3 Radiolysis Induced Explosion

The intense radiation fields generate flammable gases from water and solvents; determining the rate of generation can be a complex calculation with many uncertainties. H_2 is the main concern of radiolysis. Essentially any vessel in the dissolution, HLW, and first cycle areas will have sufficient radioactive inventory for reasonable radiolysis rates and the potential for very high consequence scenarios for all receptors. Some vessels in the MOX areas may be able to have radiolysis rates and very high consequences to at least one receptor. Potentially, there are several hundred scenarios. Potential preventive controls include dilution air flow, inerting (selective or total), and off-gas systems.

6.4.2.4.4 HAN Explosion

The hydroxylamine nitrate (HAN) reagent is used for plutonium valence state changes in the first and second cycles of the PUREX process. HAN also follows aqueous streams into other areas of the process, such as waste processing areas. However, HAN is a reactive reagent, can form reactive intermediates (e.g., hydrazoic acid and azides), and can undergo rapid decomposition under potentially explosive conditions. HAN explosions that could potentially occur within the reprocessing facility may be characterized by one of the following two cases:

- process vessels containing HAN and hydrazine nitrate without NO_x addition
- process vessels containing HAN and hydrazine nitrate with NO_x addition

In the first and second cycles, and in waste processing areas, the materials at risk and radiological characteristics for many vessels and areas are such that the proposed VHCE thresholds would be exceeded for all receptors. Thus, safety controls would be needed. Preventive controls might include process controls on temperature and pH, and controls on the chemicals and their concentrations (e.g., HAN, nitric acid, metals, impurities, hydrazoic acid, and hydrazine and hydrazine nitrate) within a safe envelope that precludes explosions.

6.4.2.4.5 Hydrogen Peroxide Explosion

Some PUREX process variations use hydrogen peroxide to make valence state changes or destroy undesirable side products before they can have deleterious effects. Hydrogen peroxide is also a reactive chemical that can rapidly decompose and cause explosions that could result in the failure of associated tanks and piping, and the release of radioactive materials. Hydrogen peroxide would be used in the dissolver and extraction areas, involving very radioactive solutions. Consequently, potential scenarios would likely exceed the VHCE threshold for one or more receptors. Specific designs would be necessary to accurately estimate the number and consequences of potential scenarios. Preventive safety strategies would likely be used, such as chemical concentration controls (chemical analyses), vessel venting systems, and cell integrity.

6.4.2.4.6 Solvent Explosion

Solvents are used in the first and second solvent extraction cycles. Solvents are flammable and vapors can form explosive concentrations above certain temperatures. The temperature limits can be based upon flashpoints or percentage of Lower Flammability Limits (LFLs) and Lower Explosive Limits (LELs); National Fire Protection Association (NFPA) codes recommend 25 percent of the LFL/LEL as the concentration limit that provides sufficient margin for unknowns, uncertainties, geometry variations, and corrective actions. Radionuclide concentrations and dose conversion factors in the first cycle and the second cycle for MOX purification are sufficiently high for solvent explosions to exceed VHCE thresholds for all receptors; the radionuclides in the second cycle uranium purification cycle may be sufficient to exceed the VHCE threshold for at least one or more receptors (e.g., the facility and site workers). Given the large number of vessels in these areas of the first and second solvent extraction cycles where solvent s and solvent vapors can form (~100) and 5 to 10 initiators per vessel (e.g., overheating, frictional heating, chemical reaction heating, ambient (other) heating, loss of cooling), there could be about 1,000 VHCEs. Preventive safety strategies would be used, such as active safety cooling systems, chemical/analysis controls, vessel venting, fire prevention controls etc.

6.4.2.4.7 TBP-Nitrate (Red Oil) Explosion

The PUREX solvent contains a diluent (usually a dodecane analog) and TBP. Other chemicals are added as needed for valence and phase adjustments. TBP slowly reacts in the nitric acid environment to form intermediates, including nitrated intermediates. Radiation exacerbates the degradation reactions. These intermediates are collectively referred to as red oil. Red oil can cause explosions under certain situations, and multiple events have been reported over the past 60 years.

The bounding event in the TBP-nitrate (red oil) explosion class is a process-related chemical explosion involving red oil formation in the AP boiler, vessel, or tank and results in a loss of confinement and dispersal of nuclear materials. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified for prevention of this event are the process safety control subsystem, chemical safety control, and off-gas treatment system. The purpose of the process safety control subsystem is to ensure that the evaporator process temperature is maintained within safe limits and to control the residence time of organics in the presence of oxidizers, radiation fields, and high temperatures. The chemical safety control ensures that quantities of organics are limited from entering process vessels containing oxidizing agents and at potentially high temperatures and ensures that a diluent is used that is not very susceptible to either nitration or radiolysis. The off-gas treatment system provides an exhaust path for the removal of gases in process vessels. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (PECs, AECs, and administrative controls) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.4.8 Process Vessel Over-pressurization Explosion

The bounding events in AP vessel over-pressurization explosion class were determined to be the over-pressurization of AP tanks, vessels, and piping postulated to result from increases in the temperature of exothermic chemical reactions of solutions into tanks or vessels within the facility. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified for prevention of this event are the fluid transport systems, which will insure that vessels, tanks, and piping are designed to prevent process deviations from creating over-pressurization events, the off-gas treatment system, which will provide an exhaust path for the removal of gases in process vessels, and chemical safety controls to ensure control of the chemical makeup of the reagents and ensure segregation/separation of vessels/components from incompatible chemicals. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (PECs, AECs, and administrative controls) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.4.9 Pressure Vessel Over-pressurization Explosion

The bounding event in the pressure vessel over-pressurization explosion class is an explosion related to the over-pressurization of gas bottles, tanks, or receivers which could impact primary confinements and result in a release of radioactive material. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified for prevention of this event are the pressure vessel controls, which ensure that primary confinement is protected from the impact of pressure vessel failures. Pressure vessels would be located away from PSSCs or otherwise protected so that a failure of any vessel would have no impact on the ability of the PSSC to perform its safety function. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (PECs and administrative controls) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.4.10 Hydrazoic Acid Explosion

The bounding event in the hydrazoic acid explosion sequence was a process-related chemical explosion involving HAN/nitric acid in the AP vessels, tanks, and piping (in AP process cells or gloveboxes) which results in a breach of the AP vessels, tanks, and piping. The material at risk was the maximum inventory of radiological material in AP vessels, tanks, and piping. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, and individuals outside the controlled area boundary.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified for protection of the facility worker, environment, site worker, and IOC are the chemical safety control and the process safety control subsystem. The function of the chemical safety control is to (1) assure that the proper concentration of hydrazine nitrate is introduced to the system, limiting the quantity of hydrazoic acid produced, and (2) ensure that hydrazoic acid is not accumulated in the process or propagated into the acid recovery and oxalic mother liquors recovery units by either taking representative samples in upstream units or by crediting the neutralization process within the solvent recovery unit. The safety function of the process safety control subsystem is to limit the temperature of the solution, thereby limiting the evaporation rate and resulting vapor pressure of hydrazoic acid so that an explosive concentration of hydrazoic acid does not occur. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (enhanced administrative control and AEC) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.4.11 Metal Azide Explosion

The bounding event in the metal azide explosion category was a process-related chemical explosion involving an azide (other than hydrazoic acid) in an AP boiler, vessel, or tank (in an

AP cell or glovebox) that results in an energetic breach of the AP boiler, vessel, or tank. The material at risk was the maximum inventory of radiological material in AP vessels, tanks, and piping. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified for protection of the receptors are the chemical safety control and the process safety control subsystem. The safety functions of the chemical safety control are to (1) ensure that metal azides are not added to high temperature process equipment, and (2) ensure that the sodium azide has been destroyed before transfer of the alkaline waste into the acidic high alpha waste of the waste recovery unit. The safety function of the process safety control subsystem is to ensure that metal azides are not exposed to temperatures that would supply sufficient energy to overcome the activation energy needed to initiate the energetic azide decomposition and limit and control conditions under which dryout can occur. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (AEC and enhanced administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.4.12 Plutonium Process-Specific Explosion

The bounding event for the plutonium (VI) oxalate explosion category was a process-related chemical explosion involving plutonium (VI) in the calcining furnace results in an energetic breach of the furnace and glovebox and the dispersal of radiological materials. The material at risk was the maximum inventory of radiological material in the AP vessels, tanks, and piping. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSC identified for protection of the facility worker, site worker, environment, and IOC is the chemical safety control. The safety function of the chemical safety control is to perform a measurement of the valence of the plutonium before the addition of oxalic acid to the oxalic precipitation and oxidation unit to ensure that plutonium (IV) cannot be formed. In addition, the design basis for the calciner will assure that the rapid decomposition of any plutonium (VI) oxalate that may enter the calciner will not challenge the calciner vessel’s integrity. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (enhanced administrative control) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.4.13 Electrolysis-Related Explosion

The bounding event for the electrolysis-related explosion category was the explosion of hydrogen in the vapor space of the electrolyzer. The material at risk was the maximum inventory of radiological material in the AP vessels, tanks, and piping. This was determined to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention. The PSSCs identified for protection of the facility worker, environment, site worker, and IOC are the process safety control subsystem and specified electrolyzer components, such as the electrolyzer structure, sintered silicon nitride barrier, and PTFE insulator. The function of the process safety control subsystem is to ensure that the normality of the acid is sufficiently high to ensure that the off-gas is not flammable and to limit excessive generation of hydrogen. The process safety control subsystem also has the function of monitoring the electrolyzer for electrical faults that could result in arcing or other imparting of electrical energy with the risk of a titanium fire and hydrogen explosion. The safety function of the specified electrolyzer components is to provide physical separation and electrical insulation between the electrolyzer components and structural integrity and stability to the electrolyzer system. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (AECs) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.4.14 Laboratory Explosion

The bounding event for the laboratory explosion class is an explosion within the MFFF laboratory involving flammable, explosive, or reactive chemicals which results in a dispersal of radiological material. The radiological material assumed to be dispersed is the maximum inventory in the laboratory. This was determined this to be an above the 10 CFR 70.61(c) threshold consequence event for the facility worker, environment, site worker, and IOC.

The applicant proposed opted to meet the performance requirements using a strategy of prevention and mitigation. The PSSCs for protection of the facility worker are the chemical safety control, laboratory material controls, and facility worker actions. The function of the chemical safety control is to ensure control of the chemical makeup of the reagents and ensure segregation/separation of vessels/components from incompatible chemicals. The safety function of the laboratory material controls is to minimize quantities of hazardous chemicals in the laboratory and to minimize quantities of radioactive materials in the laboratory. The function of facility worker actions is to ensure that facility workers take proper actions to limit radiological/chemical exposure. The PSSC identified for protection of the environment, site worker, and IOC is the C3 confinement system which provides filtration to mitigate dispersions from the C3 areas. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (enhanced administrative controls and AEC) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.4.15 Outside Explosion

The bounding events for the outside explosion class were determined to be explosions in the reagent processing building, gas storage area, emergency diesel generator building, standby diesel generator building, and the access control building. This was determined to have the potential of being an above the 10 CFR 70.61(c) threshold consequence for the facility worker, environment, site worker, and IOC.

The applicant proposed to meet the performance requirements using a strategy of prevention of a release. The PSSCs identified are the waste transfer line, which is designed to prevent damage to the line during an explosion, the MOX fuel fabrication building structure, which is designed to maintain structural integrity and prevent damage to internal PSSCs from explosions external to the structure, and the emergency diesel generator building structure, which is designed to maintain structural integrity and prevent damage to internal PSSCs from explosions external to the structure. Also identified as a PSSC is the hazardous material delivery controls which ensure that the quantity of delivered hazardous material and its proximity to the fuel fabrication building structure, emergency generator building structure, and the waste transfer line are controlled to within the bounds of the values used to demonstrate that the consequences of outside explosions are acceptable. Based on deterministic criteria and the NUREG-1718 Table A-5 descriptions (robust PECs and administrative controls) (NRC, 2000), the staff considered this to be an acceptable strategy for meeting the 10 CFR 70.61 performance requirements.

6.4.2.5 Criticality Events

A criticality event is characterized by a self-sustaining fission chain reaction and can potentially release a large amount of energy over a short period of time. When fissionable materials, such as U-235 or Pu-239 are present in sufficient quantities, a self-sustaining fission chain reaction may be attained depending on the size and shape of the fissionable materials, the nature of solvents or diluent, and the proximity of potential reflectors. The most immediate potential consequences from a criticality event are direct radiation exposure to the facility worker. Distance from the event normally protects persons beyond the controlled area boundary. Depending on the location, reprocessing facilities incorporate shielding materials, and these may reduce potential doses.

Criticality accidents may be caused by violation of safety limits such as the following:

- geometry control
- mass control
- density control
- isotopic control
- reflection control
- moderation control
- concentration control
- interaction control
- neutron absorber control
- volume control
- heterogeneity control
- process variable control

The proposed 10 CFR Part 7X uses a similar approach to criticality sequences as 10 CFR Part 70; namely, use a double contingency approach to prevent criticality, whether or not shielding is present to protect the facility worker. Therefore, a potential licensee for a reprocessing facility would use a strategy of prevention. The licensee would identify potential criticality scenarios and potential safety controls, perhaps under an umbrella heading called “criticality control,” that would encompass one or more of the control approaches identified above. The number of potential criticality scenarios would be anticipated to be much larger at a reprocessing facility, perhaps even an order of magnitude larger (say, in the thousands), as compared to 10 CFR Part 70 LEU fuel cycle facilities due to the larger quantities of fissile material present and larger number of processing operations.

6.4.2.6 Chemical Events

As noted in Section 6.2.2, the NRC has established an MOU with OSHA covering the three areas of chemical safety that the NRC regulates at its licensees.

Chemical effects have the potential to make a facility uninhabitable for the operating personnel for some period of time. The proposed 10 CFR Part 7X includes a general design criteria for habitability within the facility.

Chemical effects can occur from three discrete areas of a reprocessing facility:

- Chemical storage areas
- Chemical delivery areas and routes
- Chemical process use areas

6.4.2.6.1 Chemical Storage Areas

A reprocessing facility would have a chemical storage area for bulk storage, prior to use of the chemicals. This area would likely include some operations, such as QA/QC analyses, blending, and dilution. These chemicals would be stored at or near ambient temperatures. Chemicals like nitric acid would be at ambient pressure, while others, such as nitrogen tetroxide, ammonia, and chlorine, would be self-pressurized (i.e., by their vapor pressure at near-ambient temperatures). The self-pressurized chemicals can have the greatest deleterious effects for the longest distances, sometimes for several miles.

A release of these types of chemicals would likely impact radiological safety by one or more of the following:

- Impede facility workers performing their work duties in radiological areas (e.g., the time is increased for a specific task, resulting in an increased dose in the presence of the chemical vapor as compared to normal conditions).

- Hinder or prevent staff movements within radiological areas, including egress. Again, the time is increased due to the chemical vapor or fog, irritant effects, coughing, lacrimation etc. This increases stay time and dose, or results in additional contamination (e.g., from floor contact, mishandling accidents etc.)

- Damage or mislead instruments and equipment, resulting in fault and unanalyzed conditions, and potentially introducing additional accident scenarios affecting the safety of licensed materials. For example, NO_x attacks and disables electronic and electrical devices, and filters; ammonia attacks copper contacts and electrical devices.

- Directly and indirectly affects safety and security of licensed radioactive materials by impeding observations, creating confusion, and potentially disabling protective forces and devices.

- Impeding emergency preparedness and response.

These events are regulated by the NRC. Most of the radiological dose effects would be experienced by the workers (facility and site) and would likely be below the proposed performance requirement thresholds of the proposed 10 CFR Part 7X. However, the chemical consequences would likely exceed the VHCE thresholds for workers and the public.

In summary, the main chemicals of concern from the chemical storage areas would likely be nitric acid, nitrogen tetroxide, ammonia, and chlorine, and these have the potential to produce VHCEs for workers and the public.. Preventative and mitigative strategies would be needed, using controls such as water fogging and deluge systems, HVAC detectors and intake dampers, bottled air systems, safe havens, and scrubbers.

Typical scenarios might include the following:

- bulk container failure
- connecting piping/header failure
- incorrect valve lineup/failure
- fill valve failure/stuck open
- vent-line failure
- multiple container failure
- relief valve failure
- storage system over-pressurization (e.g., from utility gases or reactions)
- storage container over-heating
- mixing of inappropriate/incompatible chemicals

6.4.2.6.2 Chemical Delivery Areas and Routes

Bulk chemicals would be routinely delivered to a reprocessing facility, most likely by road transportation. Some would be by tanker trucks and some by truck-carried cylinders and containers. These present similar chemical hazards as at the bulk chemical storage area and can produce VHCEs to workers and members of the public. They can also introduce transportation and delivery style accidents as initiating events (e.g., crash, fire, hose breaks, valve breaks, misalignment, backflow). Preventative and mitigative strategies would be needed, using controls such as water fogging and deluge systems, HVAC detectors and intake dampers, bottled air systems, safe havens, and scrubbers.

6.4.2.6.3 Chemical Process Use Areas

Chemicals are used throughout a reprocessing facility as part of plant operations. Once inside the facility, they are regulated by the NRC because they constitute hazardous chemicals produced from radioactive materials or they affect the safety and safeguards of radioactive materials. Potential examples include:

- NO_x and nitric acid from nitric acid additions, reactions, and releases, and denitration reactions, which has the potential to impact the workers (very high consequences) and the public (at least high consequences).

- Nitrogen tetroxide and NO_x from nitrogen tetroxide use for oxidation state manipulation, hydrazine scavenging, etc., which has the potential for very high consequences to all receptors.

- Hydrazine, is used to maintain reducing chemistry in plutonium and TRU solutions, working in tandem with HAN, which has the potential for very high consequences to facility and site workers.

- Ammonia (may or may not be used in the processing of the uranium and MOX, which if used for co-precipitation and ammonium diuranate (ADU)-like processing, has the potential for very high consequences to all receptors.

Potential scenarios might include:

- overaddition (stuck valve, failed valve)
- single line failure (a potential for this to occur at multiple locations)
- misalignment
- scrubbers non-functional

In addition, recovered uranium oxide(s) may be present in sufficient quantities that a fire or other energetic condition could exceed chemical performance requirements in 10 CFR Part 7X. The fire could be exacerbated depending upon the uranium oxide form; slightly reduced forms and powders closer to the dioxide chemistry tend to participate more in fires via the burnback phenomena (reference). Note that doses from uranium oxide(s) release would depend on the purity of the material with respect to traces of TRU and fission product isotopes; and with a PUREX process, it is unlikely that uranium oxide doses would be sufficiently high to exceed any of the potential dose performance requirements in 10 CFR Part 7X. Areas containing uranium could require safety controls such as combustible loading control and avoidance of ignition sources.

6.4.2.7 Direct Overexposure Events

A reprocessing facility handles highly radioactive materials. This introduces the potential for overexposure events, such as when handling the following:

- SNF, as assemblies, cask unloading, SNF pool movements
- HLW, as liquid transfers and canister movements
- HEPA and other filter changeouts
- Resin and absorbent areas, and changeouts

Potential scenarios might include the following:

- backflow of highly radioactive materials into unshielded areas
- carryover (e.g., from evaporators; forward flow) of highly radioactive materials into unshielded areas
- SNF cask not fully emptied
- shielding misplacement
- cask malclosure
- loaded HLW can misplacement (e.g., with unused/empties)
- shield door interlock failure
- HLW can shield cask misalignment
- HLW can shield cask closure malfunction

All of these events would be VHCEs to the facility worker, although it is unlikely they would trip the proposed 10 CFR Part 7X performance requirements for other receptors.

6.5 References

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