Department of Energy
Idaho Operations Office
1955 Fremont Avenue
Idaho Falls, ID 83415

October 31, 2018

Dear Citizen:

Pursuant to 10 CFR 1021.321, the U.S. Department of Energy (DOE) has prepared the *Draft Environmental Assessment for the Use of DOE-Owned High Assay Low-Enriched Uranium Stored at INL.* The draft environmental assessment provides DOE's analysis of potential environmental impacts for the use of DOE-owned high assay low-enriched uranium (HALEU) currently stored at Idaho National Laboratory. The proposed use of this HALEU would involve fabrication of advanced reactor fuel in support of nuclear energy. DOE prepared this draft environmental assessment to determine whether an environmental impact statement should be prepared for this action, or that no further National Environmental Policy Act (NEPA) documentation is required.

The draft environmental assessment and existing NEPA documents referenced in the draft environmental assessment are available at the following web link: http://www.id.energy.gov/insideNEID/PublicInvolvement.htm.

The draft environmental assessment has been issued for a 30-day public comment period. Comments received after the 30-day public comment period will be considered to the extent practicable. Comments are due to DOE on or before November 30, 2018. Comments can be submitted to Dave Herrin, U.S. Department of Energy, Idaho Operations Office, 1955 Fremont Avenue, Idaho Falls, Idaho, 83415-1222 or by email at haleu@id.doe.gov.

Sincerely,

Richard B. Provencher
Manager

DOE/EA-2087

U.S. Department of Energy
Idaho Operations Office

Environmental Assessment for Use of DOE-Owned High-Assay Low-Enriched Uranium Stored at Idaho National Laboratory

Draft

October 2018

Idaho National Laboratory

DOE/EA-2087

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U.S. Department of Energy
DOE Idaho Operations Office

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ACRONYMS

APAD	air permitting applicability determination
ATC	approval to construct
ATR	Advanced Test Reactor
CAA	Clean Air Act
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy – Idaho Operations Office
EA	environmental assessment
ECAR	engineering calculations and analysis report
ED	effective dose
EIS	environmental impact statement
EMT	electrometallurgical treatment
EO	Executive Order
EPA	U.S. Environmental Protection Agency
FCF	Fuel Conditioning Facility
FR	Federal Register
GHG	greenhouse gas
HALEU	High-Assay Low-Enriched Uranium
HEPA	High Efficiency Particulate Air
HM	Heavy Metal
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
LCF	latent cancer fatality
LLW	low-level waste
MEI	maximally exposed individual
MOA	memorandum of agreement
MFC	Materials and Fuels Complex
MLLW	mixed low-level waste
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NRC	U.S. Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NSR	New Source Review
PEC	Plutonium-239 equivalent curies
PRGs	preliminary remediation goals
ppm	parts per million
PTC	permit to construct
REM	roentgen equivalent man
ROD	record of decision
RSAC	Radiological Safety Analysis Computer Program
SHPO	State Historic Preservation Office
TED	total effective dose
USC	U.S. Code

HELPFUL INFORMATION FOR THE READER

Scientific Notation

This document uses scientific notation to express numbers that are very small or very large. A number with a negative exponent, such as 1.3×10^{-6} is a very small number. To convert this small number to the more commonly used decimal notation, move the decimal point left by the number of places equal to the exponent, in this case 6. The number thus becomes 0.0000013. For large number, those with a positive exponent, move the decimal point to the right by the number of places equal to the exponent. For instance, the number 1,300,000 becomes 1.3×10^{6}.

Units

This document uses English units with conversion to metric units given below. Occasionally, metric units are used if metric is the common usage (i.e., when discussing waste volumes or when commonly used in formulas or equations).

cal/g	calories per gram	J/g	joule per gram	mrem	millirem
cfm	cubic feet per minute	km	kilometers	MT	metric ton
cm	centimeters	kW	kilowatt	rem	roentgen-equivalent–man
ft	foot (feet)	m	meter	pCi/g	picocurie per gram
GSF	gross square ft	mi	mile	T	ton(s)
in.	inch	mi^2	square mi	yr	year

Conversions

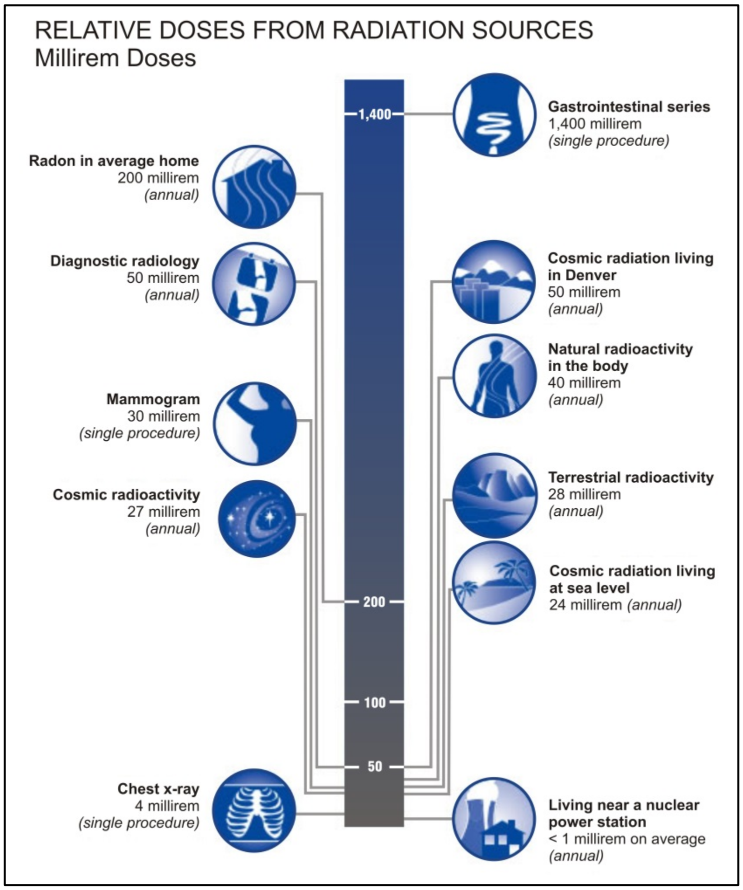
English to Metric			Metric to English		
To Convert	**Multiply By**	**To Obtain**	**To Convert**	**Multiply By**	**To Obtain**
acres	4.047×10^{-1}	hectares	hectares	2.471	acres
ft/sec	3.048×10^{1}	cm/sec	cm/sec	3.281×10^{-2}	ft/sec
ft	3.048×10^{-1}	m	m	3.28084	feet
gallons	3.785	liters	liters	2.641×10^{-1}	gallons
mi	1.609334	km	km	6.214×10^{-1}	mi
square mi	2.590	square km	square km	3.861×10^{-1}	square mi
T	9.08×10^{-1}	MT	MT	1.1013	T
yards	9.144×10^{-1}	m	m	1.093613	yards

Understanding Small and Large Numbers

Number	Power	Name
1,000,000,000,000,000	$= 10^{15}$	quadrillion
1,000,000,000,000	$= 10^{12}$	trillion
1,000,000,000	$= 10^{9}$	billion
1,000,000	$= 10^{6}$	million
1,000	$= 10^{3}$	thousand
10	$= 10^{1}$	ten
0.1	$= 10^{-1}$	tenth
0.01	$= 10^{-2}$	hundredth
0.001	$= 10^{-3}$	thousandth
0.000 001	$= 10^{-6}$	millionth
0.000 000 001	$= 10^{-9}$	billionth
0.000 000 000 001	$= 10^{-12}$	trillionth
0.000 000 000 000 001	$= 10^{-15}$	quadrillionth

Understanding Dose (Millirem Doses) and Latent Cancer Fatality

Relative Doses[1]



A dose is the amount of radiation energy absorbed by the body. The United States unit of measurement for radiation dose is the *rem* (*Roentgen Equivalent Man*). In the U.S., doses are most commonly reported in millirem (mrem). A millirem is one thousandth of a rem (1000 mrem = 1 rem). The **inset diagram** compares radiation doses from common radiation sources, both natural and man-made. Use this information to help understand and compare dose information described in this document.

Latent Cancer Fatality calculations

The consequence of a dose to an individual is expressed as the probability that the individual would incur fatal cancer from the exposure. Based on a dose-to-risk conversion factor of 0.00041 *latent cancer fatality* (LCF) per *person-rem*), and assuming the linear no-threshold model, an exposed worker receiving a dose of 1 rem would have an estimated lifetime probability of radiation-induced fatal cancer of 0.00041 or 1 chance in 2,400. Equivalently, out of a population of 2,400 exposed persons, one individual would be expected to get cancer.

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[1] From http://www.epa.gov/radiation/understand/perspective.html

GLOSSARY

Note: *Terms in this Glossary are italicized in the text.*

Attainment area: An area considered to have air quality as good as or better than the *National Ambient Air Quality Standards* as defined in the Clean Air Act. An area may be an attainment area for one pollutant and a *nonattainment area* for others.

Carbothermic Reduction: A process used to produce uranium carbide or uranium nitride from uranium oxide (UO_2) powder. UO_2 powder and carbon powder are mixed together in the desired ratio and heated in a vacuum to roughly 1700°C, to form uranium carbide powder and CO_2 gas. If a uranium nitride compound is desired, the uranium carbide powder is subsequently heated under flowing nitrogen (with 6% hydrogen) to produce uranium nitride powder and methane gas.

Cladding: The outer layer of a *nuclear fuel* rod, which is located between the coolant or test environment and *nuclear fuel*. Cladding prevents radioactive elements from escaping the fuel into the coolant or test environment and contaminating it.

Clean Air Act (CAA): The Federal CAA is the basis for the national air pollution control effort. Basic elements of the act include *National Ambient Air Quality Standards* for major air pollutants, hazardous air pollutants, state attainment plans, motor vehicle emission standards, stationary source emission standards and permits, acid rain control measures, stratospheric ozone protection, and enforcement provisions.

Cultural resource: A broad term for buildings, structures, sites, districts, or objects of significance in American history, architecture, archaeology, engineering, or culture which are identifiable through field inventory, historical documentation, or oral evidence. Cultural resources may be, but are not necessarily, eligible for nomination to the National Register of Historic Places (NRHP) (see entry for *historic property*).

Dose consequences: The dose is the consequence of a person exposed to ionizing radiation. The increased chance of a person getting a cancer, as a result of exposure to a dose, is a risk-based consequence. If the dose is high enough, there is a chance the dose would result in a LCF. Collectively, dose, chance of getting a cancer, and risk of a LCF occurrence is the dose consequence.

Effective dose (ED): The sum of the products of the dose equivalent received by specified tissues of the body and a tissue-specific-weighting factor. This sum is a risk-equivalent value and used to estimate the health-effects risk of the exposed individual. The tissue-specific-weighting factor is the fraction of the total health risk resulting from uniform whole-body irradiation contributed by that particular tissue.

The effective dose, or ED, includes the committed ED from internal radionuclides deposition and the doses from penetrating radiation sources external to the body. The ED is expressed in units of rem. The U.S. Environmental Protection Agency (EPA) regulations in 40 Code of Federal Regulations (CFR) Part 61, Subpart H specify that estimates of radiological dose to a *member of the public* be reported in terms of effective dose equivalent or total ED equivalent, consistent with an older methodology described in International Commission on Radiological Protection (ICRP) Publication 26 (ICRP 1977) and ICRP Publication 30 (ICRP 1979–1988).

Fast-Spectrum Reactor: Nuclear reactor with minimal slowing down (moderation) of fission neutrons to lower energies. Such reactors use coolants other than water, which slows down neutrons, and those coolants provide some safety advantages. Fast-spectrum reactor also have advantages for managing the long-term fuel cycle and reducing long-lived constituents of high-level waste.

Fuel rod: Individual units of coated or clad *nuclear fuel*.

Glovebox: A controlled environment work enclosure, of rigid construction, that serves as a primary barrier from the work area. Operations are performed through sealed glove openings to protect the worker, the work environment and the product.

HALEU*:* High Assay Low Enriched (U^{235} content ranges from >5% to <20%) Uranium. The term may be further broken out into the following:

> HALEU *feedstock:* The nuclear material that has been processed by Fuel Conditioning Facility (FCF) and is being used as feedstock for the fuel fabrication process described in this document.
>
> HALEU *fuel:* The final fuel produced using the HALEU feedstock.

Hazard Category 2 nuclear facility: A nuclear facility that is allowed a significant quantity of special nuclear material as defined in DOE-STD-1027-92 (1997 Change notice).

Historic property: Any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the NRHP.

Hot cell: Shielded containment chambers used to protect workers from radiation by creating a safe containment area in which workers can control and manipulate the equipment required.

Hydride-dehydride: A process used to make ceramic powder from metal uranium. The first step exposes uranium metal to flowing hydrogen gas at elevated temperature (roughly 230°C) to form uranium hydride, which breaks up the bulk metal into a powder. The second step exposes the uranium hydride powder to a vacuum at increased temperature (e.g., 400°C), which decomposes the uranium hydride into metal powder and hydrogen gas. The metal powder can then be exposed to nitrogen to form uranium nitride.

Latent cancer fatality (LCF): Based on the *Linear no-threshold model*, the value reported as an LCF is the risk that a death results from a dose sustained. (See Helpful Information for the Reader).

Linear no-threshold model: The hypothesized model that assumes that additional cancer risk to persons exposed to ionizing radiation is linear and proportional with respect to the absorbed dose, and becomes zero only at zero dose.

National Ambient Air Quality Standards: Standards established by the EPA under authority of the *CAA* that apply to outdoor air throughout the country. Primary standards protect human health with an adequate margin of safety, including sensitive populations (such as children, the elderly, and individuals suffering from respiratory disease). Secondary standards protect public welfare from any known or anticipated adverse effects of a pollutant.

National Emissions Standards for Hazardous Air Pollutants (NESHAPs): The *CAA* requires the EPA to regulate airborne emissions of hazardous air pollutants (including radionuclides) from a specific list of industrial sources called "source categories." Each “source category” that emits radionuclides in significant quantities must meet technology requirements to control hazardous air pollutants and is required to meet specific regulatory limits.

New Source Review (NSR): EPA’s permitting program that protects air quality when factories, industrial boilers and power plants are newly built or modified. NSR permitting also assures that new or modified industries are as clean as possible, and advances in pollution control occur concurrently with industrial expansion.

Nitride-denitride: A process used to make uranium nitride powder from metal uranium powder. The first step exposes uranium metal powder to flowing nitrogen gas as the temperature is raised to 800°C, forming U_2N_3, and UN. The second step increases the temperature to over 1100°C without nitrogen flow to decompose the U_2N_3 powder to UN powder, which is the compound used in uranium nitride fuel.

Nonattainment NSR area: The *CAA* and its amendments in 1990 define a nonattainment area as a locality where air pollution levels persistently exceed *National Ambient Air Quality Standards* or that contribute to ambient air quality in a nearby area that fails to meet those standards. The EPA classifies nonattainment areas based on the severity of the violation and the air quality standard they exceed. EPA designations of nonattainment areas are based on violations of national air quality standards for oxides of nitrogen, carbon monoxide, lead, ozone (1-hr), particulate matter (PM-10/PM-2.5), and sulfur oxides.

Nuclear fuel: Coated or clad nuclear material designed and fabricated to be used to power nuclear systems.

Person-rem: A person-rem is a collective radiation dose applied to populations or groups of individuals and is the product of the average dose per person (expressed in rem) times the number of people exposed or the population affected.

Receptor: Any element in the environment (typically human or ecological) which is subject to impacts, usually from exposure to hazardous conditions or substances.

> *Member of the public (public receptor location or hypothetical member of the public)*: Location where a member of the public could be when the activity is taking place. "Public receptor locations" correspond to the location of either an actual or a hypothetical person. These receptor locations are used because they correspond to those where the highest dose to a member of the public could occur.

> *Facility worker:* Person working inside a facility when the activity is taking place. These workers could be protected by technical safety requirements, administrative procedures, and personal protective equipment that minimize dose in event of an accident occurring inside a facility. However, doses given in this document do not credit these protective measures.

> *Collocated worker:* Hypothetical person working outside of the facility where the activity is occurring. These workers are less likely to be protected by technical safety requirements, administrative procedures, or personal protective equipment when an accident occurs. The doses calculated for collocated workers do not credit any protective measures that could be put in place.

> *Crewmember*: The driver and passenger of a transportation vehicle.

Residual Fission Products: Fission products (elements/isotopes produced during irradiation) that remain in the *HALEU* feedstock.

Roentgen Equivalent Man (REM): The United States unit of measurement, REM, is the unit used to express *effective dose (ED)*. REM measures the biologic effects of ionizing radiation. A millirem (mrem) is one thousandth of a rem (0.001 rem), often used to express dosages commonly encountered from medical imaging (X-rays) or natural background sources.

Subassembly: A grouping of *fuel rods* configured by reactor requirements.

Vadose zone: A subsurface zone of soil or rock containing fluid under pressure that is less than that of the atmosphere. Pore spaces in the vadose zone are partly filled with water and partly filled with air. The vadose zone is limited by the land surface above and by the water table below.

Thermal-Spectrum Reactor: Nuclear reactor with fission neutrons slowed down (moderated) to energies comparable to the thermal vibrational energy of atoms in the reactor structural materials and fuel. This reactor type includes light water reactors, which are used in the U.S. and elsewhere for producing electricity, heavy water reactors, and gas-cooled reactors.

Transuranic waste (TRU): Transuranic waste is, as stated by U.S. regulations and independent of state or origin, waste which has been contaminated with alpha emitting transuranic radionuclides possessing half-lives greater than 20 years and in concentrations greater than 100 nCi/g (3.7 MBq/kg).

Environmental Assessment for Use of DOE-Owned High-Assay Low-Enriched Uranium Stored at Idaho National Laboratory

1 INTRODUCTION

1.1 Purpose and Need for Agency Action

The U. S. Department of Energy (DOE) proposes to make about 10 Metric Tons (MT) of High-Assay Low-Enriched Uranium (*HALEU*[2]) produced through the electrometallurgical treatment (EMT) process, and other small quantities of HALEU stored at Idaho National Laboratory (INL) available for research development & demonstration in support of the commercial nuclear industry and government agencies, including use in advanced reactors. HALEU is a term applied to uranium that is enriched in the uranium-235 (U-235) isotope to a value that is 5% to 20% of the total uranium. Private sector advanced nuclear reactor designs and advanced *nuclear fuel* designs call for use of HALEU, but currently no commercial facility manufactures HALEU.

DOE proposes to expand the fuel fabrication capability at INL to produce up to 10 MT of *HALEU fuel* at INL to meet near term needs. The production requires expansion of the fuel fabrication capability, including the purchase of new equipment and use of facilities at INL's Materials and Fuels Complex (MFC) and the Idaho Nuclear Technology and Engineering Center (INTEC). DOE would address decisions on the construction and operation of a reactor using the HALEU fuel in future National Environmental Policy Act (NEPA) documents.

The electrometallurgical treatment process in operation at the INL converts sodium-bonded spent nuclear fuel into waste forms suitable for disposal as high-level waste and a HALEU product that is unsuitable for diversion to nuclear weapons but could be either reused in fuel or disposed of as waste. The Final Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel (DOE/EIS-0306, 2000) discussed the EMT process, but did not make a decision on the disposition or use of the HALEU product from the EMT process. This Environmental Assessment addresses the HALEU product as *HALEU* feedstock in production of HALEU fuel*.*

1.2 Background

The primary mission of the DOE Office of Nuclear Energy is to advance nuclear power as a resource capable of meeting the Nation's energy, environmental, and national security needs by resolving technical, cost, safety, security barriers, and proliferation concerns through research and development and demonstration. DOE has been exploring how to support deploying advanced reactor technology by the domestic (United States) nuclear industry and the industry interest in using *HALEU fuel*. *HALEU* consists of uranium enriched in the isotope U-235 between 5 and 20 percent. U-235 is an isotope of uranium that drives the nuclear reaction. Commercial reactors use fuel is typically enriched between 3 and 5 percent. The higher U-235 enrichment in HALEU reactor fuel allows advanced reactors to operate longer before refueling. Public and private interest in advanced reactor technology is considerable because of the technologies potential to supply transportable, reliable, and affordable power.

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[2] The Glossary defines *Italicized* terms.

DOE’s support of advanced reactor development may include making available about 10 MT of HALEU feedstock for use as fuel by the commercial nuclear industry and government agencies for advanced reactor research, development, and demonstration activities. Other applications using HALEU may be of interest to the commercial industry.

Most of the available HALEU at INL is a product of the EMT of sodium-bonded spent nuclear fuel (SNF) that occurs in the Fuel Conditioning Facility (FCF) at the MFC at INL. DOE’s Sodium Bonded Environmental Impact Statement (EIS) discusses the EMT process (DOE/EIS-0306, 2000). The EMT process involves dissolving SNF rods in molten salt and extracting uranium and transuranic elements through electrolysis, then processing in a metal casting furnace to produce low-enriched uranium ingots. The 2000 Record of Decision (ROD) for DOE/EIS-0306 did not make a decision on the disposition of the uranium ingots, instead deciding to store the ingots and deferring a decision on disposition to a separate NEPA review.

2 ALTERNATIVES

The Council on Environmental Quality's NEPA regulations require agencies to identify and assess reasonable alternatives (40 CFR 1500.2[e]) when proposing new activities. In line with this requirement, DOE has reviewed and analyzed two reasonable alternatives, plus a second "No Action" alternative, in this environmental assessment (EA).

INL is the only location considered for the proposed action alternatives and for the no-action alternative because DOE is producing and storing the FCF *HALEU feedstock* at INL facilities. INL has the available facilities and process knowledge needed to carry out the proposed or no-action alternatives. Finally, the proposed action is consistent with INL's mission as the DOE's lead laboratory for nuclear energy.

DOE identified the following alternatives for analysis in this EA:

Alternative 1: Proposed Action – Use of DOE-Owned High-Assay Low-Enriched Uranium Stored at Idaho National Laboratory

- Alternative 1a: Conduct activities only at MFC
- Alternative 1b: Conduct activities at MFC and INTEC

Alternative 2: No action.

2.1 Alternative 1: Proposed Action -- Use of DOE-Owned High-Assay Low-Enriched Uranium Stored at Idaho National Laboratory

The proposed alternative calls for equipping two INL facilities at MFC or one at MFC and one at INTEC to fabricate each of two fuel types from FCF *HALEU feedstock* using associated fuel fabrication processes. Specifically, INL proposes a **ceramic fuel fabrication process** and a **metallic fuel fabrication process** installed and operated within two respective INL buildings. INL has not determined which buildings would house each of the two fabrication processes. This EA evaluates the potential impacts from developing a ceramic *HALEU fuel* fabrication operation and a metallic HALEU fuel fabrication operation at the INL. The buildings would be distinct only by the volume of air contained and in location for possible emissions.

The EA identifies only two variants to the proposed action: 1) two buildings located at MFC, and 2) one building at MFC and one building at INTEC. There is no distinction in potential emissions from the two MFC buildings, so the only variant that bears on the environmental impacts is whether one of the buildings is at INTEC.

The 2000 Record of Decision did not make a decision on the disposition and use of the HALEU feedstock from the EMT process. DOE now proposes to make 10 MT of HALEU feedstock produced through the EMT process, and other small quantities of HALEU feedstock stored at INL, available to support early-stage demonstration by the commercial nuclear industry and government agencies. The processes need to clean the material of impurities to be useable in industry applications. Uses of the material involve research and development activities and use as *nuclear fuel*, including for use in advanced reactors.

2.1.1 Proposed Processes

The two types of fuels considered in this document are, in general, metallic and ceramic fuels. Ceramic fuels are compounds in which a metal (uranium, in this case) is chemically combined with a non-metal, such as oxygen or nitrogen to form uranium oxide (UO_2) or uranium nitride (UN), respectively. Metallic fuels are made of uranium alloyed with other elements (typically zirconium) so the fuel retains a metallic form. Most advanced reactor designs call for use of one of these two types of fuel. Metallic fuels typically have been used in f*ast-spectrum reactors* with liquid metal coolants, while ceramic fuels have been used in both fast- and *thermal-spectrum reactors*. Ceramic fuel fabrication is usually performed by synthesizing the ceramic compounds in powder form followed by pressing and sintering of the powders into solid pellets. Metallic fuel fabrication usually begins with melting the fuel constituents together to form an alloy, following which the alloy is immediately, or after solidification and reheating, cast or otherwise shaped to the specific form desired by the specific reactor design. Although the specific steps and details for these fabrication processes vary for specific fuel designs, the processes can be described generically but with enough detail to allow evaluation of bounding environmental impacts. Some design specifics that bear on fabrication details include the means of thermally bonding the fuel material to the enclosing *cladding*; e.g., some fuel designs use a liquid metal (such as sodium, which is solid at room temperature but liquid at operating reactor temperatures) in the annular space between fuel and cladding, while other fuel designs might use helium in that gap or even eliminate the gap by pressing fuel and cladding together for a mechanical bond. Those details have little impact on the extent of environmental impact, so the fabrication processes for metallic and ceramic fuels are described generically in the following subsections.

The processes described below are based on the following assumptions:

- *HALEU feedstock* is obtained from Experimental Breeder Reactor-II (EBR-II) fuel processing with the intended U-235 enrichment, contaminated with about 100 ppm transuranic contaminants
- *Residual fission products* have been removed such that the feedstock can be handled without extensive shielding (i.e., without requiring shielding walls as in *hot cells*, although containment of low-activity contamination would require *gloveboxes*)
- The typical batch sizes that would be processed through fuel fabrication would be roughly 30-50 Kg HALEU feedstock/batch, although this would be limited by criticality safety considerations
- The quantities of fuel assumed to be fabricated would likely require the process be operated within a double-high efficiency particulate air (HEPA) -filtered, *Hazard Category 2 nuclear facility*. The total target throughput of a fuel fabrication process, either ceramic or metallic, would not exceed 2500 kg HM/year. The process lines would be in separate facilities, the total throughput of the two combined facilities would not exceed 5000 kg/year.

2.1.1.1 Metallic Fuel Process

Typical metallic fuel fabrication processes consist of the following 6 stages: 1) receipt of *HALEU feedstock*; 2) alloy production; 3) fuel casting or forming; 4) final mechanical processing (shearing to length, machining, forming, etc.); 5) encapsulation into *cladding* to form *fuel rods*; and 6) final inspections. Any steps involving fuel before being hermetically sealed within a cladding tube would be performed in engineered enclosures (typically *gloveboxes*). These stages are discussed in further detail below.

HALEU **Receiving/Cleaning/Casting:**Because the HALEU feedstock is coming from the FCF used fuel treatment process, an initial cleaning step may be necessary. In most cases, this could be a simple external decontamination of the as-received ingots to minimize contamination spread to the *gloveboxes*. In some cases, depending on the condition of the HALEU feedstock, a mechanical or chemical cleaning may be necessary to remove oxide or slag layers. During the cleaning process, waste products would be generated. Following cleaning, the HALEU feedstock is ready for casting. Casting and alloying can be a one- or two-step process. In a single-step process, the HALEU feedstock and other alloying components, such as zirconium, are loaded into a crucible. The crucibles are usually coated with a non-reactive ceramic (typically yttrium oxide). The loaded crucible is placed into a furnace and heated, usually to about 1500°C and held for about 1-2 hours to melt and mix the constituents into a homogeneous alloy. The exact casting temperature used depends on alloy composition and specific process needs. The molten alloy is then poured or injected into a mold of specific shape. In a two-step process, the material is melted and poured into an interim shape, usually sized for convenient handling. The first casting step results in chemical homogeneity and allows inspection for the proper chemical composition. During the second casting step, the product is melted again and cast into the desired final fuel form. Casting operations with molten uranium alloys form an oxide slag or dross. This dross is a waste stream that requires disposal or, preferably, eventual recycle into a new casting batch. Crucibles generally can be re-used for 10-20 cycles; however, the non-reactive coating must be removed and re-applied after each casting process. In the past, single-use quartz molds have been used for solidifying the cast metal into the desired shape, and those molds could be used only a single time before being disposed as waste. Developments in recent years may allow use of re-useable fuel molds, which would reduce the amount of casting process waste.

Mechanical Processing: Industry and research institutions/organizations have communicated interest in a number of metallic fuel forms. Some fuel forms can be geometrically complex, while others may be simple right cylinders. Depending on the final fuel form, mechanical processing of fuel to final shape may be as simple as cutting or shearing a fuel slug to final length. However, more-complicated processes of machining, extrusion, drawing, or other forming methods might be needed. If the fuel is a traditional rod-type form, a simple shearing process is usually all that is required. In this case little to no additional waste is produced during this step, other than the end trimmings from the fuel slugs, which can typically be recycled into a subsequent casting batch. If machining is required, machine chips would be produced which may be recycled or disposed, depending on available recycle processes. Given the low availability and intrinsic high value in HALEU, recycling of such machining scrap material would be warranted. Additional fuel processing may include hot forming activities, such as extrusion, in which the fuel is heated to 600-900°C and forced through a die. This could be followed by another cleaning step to remove potential lubricants or surface oxides. Further mechanical processing and heat treatments, (500-850°C for less than 60 minutes) may also be needed to obtain the necessary physical and microstructural characteristics. Some additional waste would be generated from any forming activity (e.g. leading and following blocks for extrusion).

Encapsulation: After the fuel has been formed and inspected it is ready for encapsulation into a *cladding* tube, which forms a *fuel rod* or fuel element. The cladding tubes would be brought into the facility from an off-site vendor. Cladding tubes are generally either a stainless steel, such as 316SS or 421SS, a high-alloy steel, such as a 9Cr-1Mo steel, or an alloy of zirconium. In the case of a liquid-metal bonded fuel, the cladding tubes may be pre-loaded with the bond metal (e.g. sodium) by the supplier or this operation can be completed in the fuel fabrication facility.

Fuel slugs may be loaded either vertically or horizontally into *cladding* tubes that are closed on one end. After the cladding tube is properly loaded, the open end is closed with an end plug that is welded into place. At this point the fuel is encapsulated and can be removed from the *glovebox* if further processing is required. Further processing may include heat treating welds, heating the liquid metal bond material, slight deformations of the cladding tube, or wire wrapping of the *fuel rods* for proper spacing in the reactor. Heat treating welds, if necessary, is generally done at temperatures lower than 800°C for less than 30 minutes. If the metal bond material must be heated, the final temperature would depend on the properties of the metallic bond material, in the case of sodium, the sealed tube is heated to about 500°C for up to 1 hour. The seal-welded fuel rods are inspected to verify closure, final dimensions, and other attributes, and then released for later assembly into fuel subassemblies.

2.1.1.2 Ceramic Fuels Process

The fabrication of fuels from three representative ceramic compounds is briefly outlined here: uranium oxide, uranium nitride and uranium silicide (other compound/ceramic fuels could also be fabricated with limited changes to the production line).

HALEU **Receiving and Cleaning**: Because the *HALEU feedstock* is coming from the FCF used fuel treatment process, an initial cleaning step may be necessary. In most cases this could be a simple external decontamination of the as-received ingots to minimize contamination spread to the *gloveboxes*. In some cases, depending on the condition of the HALEU feedstock, a mechanical or chemical cleaning may be necessary to remove oxide or slag layers. During the cleaning process, waste products would be generated.

Powder Production: Powder production could occur by three processes:

1. Uranium oxide would be produced by the reaction of uranium metal directly with oxygen through a process known as roasting. This involves a controlled atmosphere furnace with an agitation system to separate the oxidized material as it reacts. The oxidized powder would be a mix of oxidation states and would undergo another furnace run in a reducing atmosphere to transform the material into UO_2. The resultant material would undergo a granulation step to form it into powder that would be compatible with the rotary press that produces the pellets.

2. Uranium silicide is made by first alloying silicon with the FCF metallic HALEU feedstock. Preferential loss of silicon during initial melting is minimized by using an arc-melting furnace to produce the uranium silicon alloy. After more 'homogenization melts', the ingot is mechanically broken up and ball-milled to reduce the material particle size to the proper powder size. The milling media is periodically replace and disposed as waste.

3. Uranium nitride is produced through a *hydride-dehydride/nitride-denitride* process (i.e., forming uranium hydride, then decomposing the hydride to form powder that is then nitrided to form uranium nitride).This process is done by heating the bulk uranium in a hydrogen atmosphere (the optimal temperature is 225°C) until the uranium has reacted with hydrogen followed by introduction of vacuum (still at temperature) until the material has turned into a fine powder. The process is repeated with nitrogen (the denitriding step reduces the material from U_2N_3 to the required UN).

Pellet Production: Following powder manufacture, fuel pellets are formed using an industry standard pelletizing process. Each powder requires optimizing parameters, with variables such as binder, die lubrication and pressing parameters evaluated. The residual contaminants expected to be present in the HALEU feedstock requires that the powder and pelletizing operations be performed within containment *gloveboxes*. Depending on the characteristics and chemical reactivity of the powder, the pelletizing process might need to be contained in inert atmosphere *gloveboxes* (for example, uranium silicide powder is potentially pyrophoric and must be handled away from atmospheric air).

The prepared fuel powder is fed into a rotary die where the material is pressed at room temperature to form "green" pellets (i.e., pellets that have been pressed from powder but not yet sintered into non-friable pellets). Green pellets are later heated in a sintering furnace (at temperatures ranging from 1450 to 2000°C). The atmosphere of the furnace needs to vary depending on the material: silicide fuel requires an inert atmosphere while oxide and nitride need a reducing atmosphere, such as dry argon with a small amount of hydrogen.

Following sintering, pellets are ground to final diameter using centerless grinders (the desired length and end chamfer are imparted during pelletizing). Following quality inspection, the pellets are ready to be encapsulated into *fuel rods*.

Encapsulation: Fuel pellets approved by inspection are laid out in channeled trays in single columns. After the proper number of pellets are arranged into columns, the pellet columns are pushed horizontally into a horizontal *cladding* tube that is sealed on one end. The cladding tubes would be brought into the facility from an off-site vendor. Cladding tubes are generally either a stainless steel, such as 316SS or 421SS, a high-alloy steel, such as a 9Cr-1Mo steel, or an alloy of zirconium. After the cladding tube is properly loaded, the open end is closed with an end plug that is welded into place. The seal-welded *fuel rods* are inspected to verify closure, final dimensions, and other attributes, and then released for later assembly into fuel subassemblies.

2.2 Alternative 2 - No Action

Under the No Action Alternative, DOE would continue to electrometallurgically treat the EBR–II spent nuclear fuel (about 25 metric tons) and miscellaneous small lots of sodium bonded spent nuclear fuel, as decided in the ROD for the Treatment and Management of Sodium Bonded Spent Nuclear Fuel (FR Vol. 65, No. 182, September 19, 2000 pp. 56565-56570) and addressed in DOE's Sodium-Bonded EIS (DOE/EIS-306, 2000). DOE would continue to treat the fuel at MFC, blend with depleted uranium, if needed, to reduce the enrichment levels, and cast into ingots to store until deciding on appropriate disposition made through a separate NEPA review.

3 AFFECTED ENVIRONMENT

3.1 Idaho National Laboratory, Idaho

3.1.1 General Description of INL Site and Surrounding Area

The INL Site consists of several complexes, each taking up less than 2 square miles, located across an 890 square miles expanse of otherwise undeveloped, cool desert terrain. DOE controls the INL Site land, which is located in southeastern Idaho and includes portions of five Idaho counties: Butte, Bingham, Bonneville, Clark, and Jefferson. Population centers in the region include the cities (>10,000 people) of Idaho Falls, Pocatello, Rexburg, and Blackfoot, located further than 30 miles to the east and south; several smaller cities/communities (<10,000 people), including Arco, Howe, Mud Lake, Fort Hall Indian Reservation, and Atomic City, located around the site less than 30 miles away. Craters of the Moon National Monument is less than 20 miles to the west of the western INL boundary; Yellowstone and Grand Teton National Parks and the city of Jackson, Wyoming are located more than 70 miles northeast of the closest INL boundaries. (see **Figure 1**)

Figure 1. Figure shows the INL Site and the surrounding region with two insets showing locations of MFC and INTEC.

Populations potentially affected by INL Site activities include INL Site employees, ranchers who graze livestock in areas on or near the INL Site, hunters on or near the INL Site, residential populations in neighboring communities, travelers along U.S. Highway 20/26, and visitors at the Experimental Breeder Reactor I National Historic Landmark. There are no permanent residents on the INL Site.

The five Idaho counties that are part of the INL Site are in an *attainment area* or are unclassified for *National Ambient Air Quality Standards* status under the *Clean Air Act*. The nearest *new source review* (*NSR) nonattainment area* is located about 50 miles south of INL in Power and Bannock counties. INL is classified under the NSR minor source permit regulations as a Class II area—an area with reasonable or moderately good air quality.

Surface waters on the INL Site include the Big Lost River and Birch Creek. Both streams carry water on an irregular basis, with the majority of the flow diverted for irrigation before entering INL. The Snake River Plain Aquifer, which lies between 220 ft (at the north end of the Site) to 610 ft (at the south end of the Site) below the surface of the Site. The geology above the Snake River Plain Aquifer—the *vadose zone*—is generally comprised of basalt (95%), with a layer of soil or sediment on top of the basalt, and thin layers of sediments (1 to 20 ft intervals) between basalt flows. The Snake River Plain Aquifer has similar geology as the overlying *vadose zone* and is generally 250 to 900 ft thick.

Predominant natural vegetation of the INL Site consists of a shrub overstory with a perennial grass and forb understory. The most common shrub is Wyoming big sagebrush, although basin big sagebrush may dominate or co-dominate in areas with deep or sandy soils. Other common shrubs include green rabbitbrush, winterfat, spiny hopsage, gray horsebrush, gray rabbitbrush, and prickly phlox. The grass and forb understory consists of native grasses, thick-spiked wheatgrass, Indian ricegrass, bottlebrush squirreltail, needle-and-thread grass, Nevada bluegrass, and bluebunch wheatgrass and native forbs (i.e., tapertip hawksbeard, Hood's phlox, hoary false yarrow, paintbrush, globe-mallow, buckwheat, lupine, milkvetches, and mustards). Steep slopes and rises associated with buttes, bluffs and foothills may be dominated or co-dominated by Utah juniper. Part of the INL Site has been designated as the Sagebrush Steppe Ecosystem Reserve, which is managed to allow research opportunities and preserve sagebrush steppe habitat. The INL site is also designated as a National Environmental Research Park.

A total of 219 vertebrate species have been recorded as occurring at the INL Site. These wildlife species include amphibians, reptiles, rodents, carnivores, bats, big game and birds. Several of these species are sagebrush-obligate species, meaning that they rely upon sagebrush for survival. These species include sage sparrow, Brewer's sparrow, sage thrasher, northern sagebrush lizard, greater sage-grouse, and pygmy rabbit.

The INL Site also contains important breeding and nesting habitat for many species of raptors and songbirds. Most avian species occupying the INL Site use both sagebrush and grassland habitats from a few days for feeding and resting during migration to several months for breeding and raising young. Many bird species use specific habitats for foraging and reproduction. Species that primarily use sagebrush include greater sage-grouse, sage sparrow, Brewer's sparrow, sage thrasher, and loggerhead shrike. Species that occur mainly in grassland habitats include horned lark, western meadowlark, vesper sparrow, and grasshopper sparrow. Other common bird species at the INL Site include the following: rock wren, common nighthawk, red-tailed hawk, rough-legged hawk, prairie falcon, ferruginous hawk, golden eagle, and common raven. Although most raptors range widely across the INL Site for foraging, nesting habitat and structures are a limiting factor in population abundance and species diversity.

No resident species on the INL Site are listed as endangered or threatened under the Endangered Species Act. North American wolverine (*Gulo gulo luscus*) has not been documented at the INL Site, but may pass through it. Yellow-billed cuckoo (*Coccyzus americanus*) is known to breed in river valleys in southern Idaho (Federal Register, Vol. 79 No. 192, October 3, 2014), but has only been observed once near the INL Site at Atomic City. The INL Site has no designated critical habitat. Several species identified as Birds of Conservation Concern under the Migratory Bird Treaty Act or as Species of Greatest Conservation Need under state of Idaho regulations do occur on the INL Site, including bald eagle, Brewer's sparrow, burrowing owl, common nighthawk, golden eagle, grasshopper sparrow, greater sage-grouse, long-billed curlew, ferruginous hawk, Franklin's gull, loggerhead shrike, peregrine falcon, sage thrasher, sagebrush sparrow, short-eared owl, pygmy rabbit, hoary bat, little brown myotis, Townsend's big-eared bat, silver-haired bat, and western small-footed myotis. In 2010, a status review of little brown myotis was prepared and determined that emergency listing under the Endangered Species Act was warranted. The U.S. Fish and Wildlife Service has not made a final determination on listing of little brown myotis.

Several wildlife species that were delisted but continue to be monitored are present on the INL Site. Bald eagle (*Haliaeetus leucocephalus*) was delisted in 2007, but is still protected under the Bald and Golden Eagle Protection Act. The Bald Eagle often winters in the Little Lost River Valley just north of the INL Site and some eagles' winter on the INL Site. American peregrine falcon (*Falco peregrinus*), delisted in 2009, has been observed infrequently on the northern part of the INL Site.

The cultural landscape of the INL represents nearly 13,500 years of human occupation and land use. Historic properties (those properties either listed or eligible for listing on the National Register of Historic Places [NRHP]) present within INL boundaries include both archaeological sites, and resources associated with the built environment. Archaeological sites encompass Native American habitation, and late 19th and early 20th century Euro-American sites associated with mining, canal and railroad construction, emigration and homesteading, agriculture, and ranching. Resources within the built environment consist of modern roads, railroad tracks, irrigation canals, and transmission and telephone lines, along with buildings and landscape features associated with the Arco Naval Proving Ground (NPG) and nuclear energy research at INL between 1949 and 1970, including the MFC and the INTEC. Additionally, the INL site contains numerous areas and natural resources of traditional cultural importance to the Shoshone-Bannock Tribes.

Two NRHP listed historic properties occur on the INL:

- Aviator's Cave is listed under Criterion D for archaeological potential, and cultural significance to the Shoshone-Bannock Tribes; and
- Experimental Breeder Reactor one (EBR-I) is listed under Criterion A for its association with events that have made a significant contribution to the broad patterns of American history, and Criterion C for distinctive characteristics of a method of construction.

3.1.2 MFC Area (Area Potentially Affected by Alternative 1a and 1b)

MFC, which is located about 38 miles west of Idaho Falls in Bingham County in the southeastern corner of INL. MFC is about 100 acres (inside the MFC fence) and about 2.7 mi (4.3 km) from the southern INL Site boundary. MFC is engaged in advanced nuclear power research and development, spent fuel and waste treatment technologies, national security programs, and projects to support space exploration. Formerly the Argonne National Laboratory-West (ANL-W), the MFC was established in 1949. For the next half-century, its primary mission was to take nuclear reactor power stations through the steps from design to demonstration.

3.1.3 INTEC Area (Area Potentially Affected By Alternative 1b)

INTEC is located in the southcentral portion of the INL Site in Butte County, between INL's ATR Complex and Critical Infrastructure Test Range Complex areas, and just south of the Big Lost River. INTEC is about 210 acres (inside the INTEC fence) and about 13.7 km (8.5 mi) from the southern INL Site boundary.

INTEC was a one-of-a-kind facility built in the early 1950s for reprocessing government-owned *nuclear fuels* from research and defense (primarily naval) reactors. Through April 1992, INTEC recovered uranium from the spent nuclear fuels for reuse. The current missions at INTEC include safe and secure storage and handling of spent nuclear fuel, special nuclear material, and waste by-products; waste treatment; and dismantle and demolition of facilities that are no longer needed.

4 ENVIRONMENTAL CONSEQUENCES

The following sections evaluate direct, indirect, and cumulative environmental impacts that are likely to occur from the alternatives described in Section 2. Section 4.1 discusses the environmental impacts associated with Alternative 1. Section 4.2 discusses the environmental impacts associated with 'no action.' Each section discusses cause and effect relationships, including cumulative impacts, of the proposed actions on INL's natural, biological, and *cultural resources*; mitigative measures needed to lessen impacts; and those permits and regulations required to protect the resources.

During the EA scoping meeting, resource personnel identified that the proposed action could potentially affect air, biological and *cultural resources* and waste generation and management. This document evaluates impacts from construction/modification impacts to air, cultural and waste management (Section 4.1.1); normal operations to air, waste generation and management, and biological resources (Section 4.1.2); Accidents (Section 4.1.3); Transportation (Section 4.1.4); Destructive Acts (Section 4.1.5), and Cumulative Impacts (Section 4.1.6).

DOE uses engineered and administrative controls to make work safe and to reduce the potential for environmental consequences of its operations.

4.1 Alternative 1 - Proposed Action: Use of DOE-Owned High-Assay Low-Enriched Uranium Stored at Idaho National Laboratory

4.1.1 Construction/Modification

The proposed action would result in facility modifications that involve construction activities that include modifying facilities to support fuel-fabricating processes to separate the proposed processes (e.g., physical changes to buildings, ventilation separation, and so forth). These activities could affect air and *cultural resources* and waste generation and management.

Air –

The proposed action would likely result in fugitive dust and emissions. Before commencing any construction or modification, facility environmental personnel would complete an air permitting applicability determination (APAD). If an approval to construct (ATC) from EPA or a permit to construct (PTC) from the Idaho Department of Environmental Quality (DEQ) is required, an ATC or PTC would be obtained before commencing construction or modification. Construction and modification activities are not expected to release radiological contamination. However, activities could disturb materials containing asbestos; therefore, properly trained personnel would perform work on asbestos containing building materials.

Cultural –

The proposed action would not disturb areas outside facility areas, but could impact historic properties at MFC or INTEC. DOE has chosen to defer Section 106, per 36 CFR 800.14(b)(1)(ii), until after a NEPA decision has been made. As such, neither the Area of Potential Effect (APE), potential impacts (either direct or cumulative), nor potential mitigation about historic properties have been identified.

INL has not determined which buildings at either MFC or INTEC would be used under the proposed action; as such, DOE will not evaluate impacts to historic properties before making the NEPA decision, resulting in deferring Section 106 as per 36 CFR 800.14(b)(1)(ii).

DOE negotiated a process for deferring Section 106 under the proposed action for Alternative 1, with the Idaho State Historic Preservation Office (SHPO). The following process was outlined in a letter from DOE to the Idaho SHPO on October 10, 2018:

1) The Idaho SHPO will be allowed the opportunity to review the language in the EA regarding deferment of Section 106 once the document has been made available for public comment, as per 36 CFR 800.8(c)(2)(i);
2) DOE will prepare a Memorandum of Agreement (MOA) outlining how the Section 106 process will be completed, once determinations are made regarding the specific buildings involved in the undertaking.
3) The MOA will be signed prior to making the NEPA decision. The NEPA decision will include stipulations for completing the Section 106 process.

Waste Management –

Modifying buildings at MFC and INTEC for the new fuel fabrication facilities would generate waste. The modifications for fuel fabrication would generate non-radioactive electronic waste, scrap metal, and other construction-related debris. Construction debris, electronic waste, and scrap metal would be recycled to the extent possible. Activities could require disposal of construction debris, concrete, coolants, and hydraulic/lubricating fluids. These wastes could be recycled or disposed at on-site facilities or sent off-site. These modifications could also generate radioactive waste. Constructing and modifying activities would likely generate mixed low-level waste (MLLW) (waste that is both radioactive and hazardous).

Based upon estimates supplied by MFC Engineering the amount of waste generated to refurbish a radiological facility would be about 218 m^3. During FY 2018, INL sent 934-m^3 low-level waste (LLW) to off-site facilities for disposal. INL would accumulate and store any waste generated per Federal and state regulations, and if required, treat and disposed at an off-site permitted/licensed facility.

4.1.2 Normal Operations Activities

Normal activities involved in the processing of *HALEU* include those described in Section 2.1.3 (e.g., cleaning, casting/alloying, cutting/shearing, machining/extruding/drawing, welding, dissolving, calcining/drying, pelleting, sintering, and grinding). Processes would use engineered and administrative controls to enhance safety and minimize the potential for environmental consequences. The only anticipated releases would be to the atmosphere.

Helpful Information for the Reader

When reviewing the impact of toxic and radiological releases to the air from normal operation, transportation, and accidents it may be useful to refer back to the section on 'Helpful Information' (page vi) for discussion on Scientific Notation, English/Metric Units, Understanding Small and Large Numbers, and Understanding Dose and Latent Cancer Fatalities.

4.1.2.1 Releases to the Air

Toxic Emissions—Nonradiological emissions would be minimal during operational stages. Welding emissions during *cladding* operations as well as hazardous and toxic air emissions from processing would from experience be expect to be below State of Idaho's toxic regulations. Ceramic fuels processing may involve using hydrochloric acid, hydrogen peroxide, and nitric acid. An acid scrubber system would be required to keep emissions below State of Idaho toxic limits. During encapsulation phase, some minor welding is performed to seal cladding tubes. These welding emissions are minor (an estimated 5.5 grams of chromium and 4.2 grams of nickel fume may be generated per batch based on the amount of welding rod used). Cleaning for external contamination may use small amounts of nitric acid (about 2 liters per batch). The APAD would quantify these emissions.

Radiological Impacts of Atmospheric Releases— During normal operations, radioactive particulate matter and gaseous emissions are possible. Based on the proposed processing operations, the potential for release of particulate contamination, and gaseous/vapor-phase radionuclides is greatest when the fuel is heated during the casting phase. During processing operations, the amount of radioactive material released during heating operations is assumed the same for each alternative. Operations planned for Alternatives 1a and 1b involve heating with equivalent cleanup efficiencies, i.e., two stages of HEPA filtration each with at least 99.97% removal of airborne material with a particulate size of 0.3 µm or greater. For the APAD evaluation HEPA filtration is not credited for gaseous/vapor phase radionuclides.

Each of the two facilities could process a maximum 2,500 kg of *HALEU feedstock* annually. The average radionuclide composition in the HALEU feedstock (TEV-3537) was used to determine the activity inventory in 2,500 kg as shown in **Table 1**.

Potential emissions were conservatively estimated using the maximum amount of feedstock material to be processed annually and appropriate emission factors based on the physical state of the material. Because the material could undergo heating, an alternative to the method in 40 CFR 61 Appendix D, approved for use at INL by EPA Region 10 (see letter from Donald Dossett [EPA Region 10] to Tim Safford (U. S. Department of Energy – Idaho Operations Office [DOE-ID] Oct 19, 2017 [CCN 241475]) was used to determine the emission factors for radioactive solid materials with high melting and boiling points. These emission factors are:

- 1 for radioactive solid materials heated to temperatures greater than or equal to 90% of the boiling or subliming point;
- 1E-03 for radioactive solid materials heated to temperatures greater than or equal to their melting point but less than 90% of their boiling or subliming point; and
- 1E-06 for radioactive solid materials heated to temperatures above ambient temperature but less than their melting point.

Table 1 shows the emission factors and potential radionuclide emissions for 2,500 kg of *HALEU feedstock* material assuming the material is heated to a temperature of 2000 C, which equals or exceeds the maximum predicted temperature of both the metallic and ceramic processes. In this case, the emission potential is the product of the inventory and the emission factor and represents the amount that could potentially be released from the facility annually. It was assumed that the most likely manner for emissions to exit the processing facilities during normal operations would be from a stack similar to the stacks at the Fuel Manufacturing Facility or Irradiated Materials Characterization Laboratory at MFC. These stacks are about 15 m high with an exit diameter of 0.6 m.

Table 1. Radionuclide inventory in 2,500 kg *HALEU feedstock* material and unabated estimated annual potential to emit per processing facility.

Radionuclide[a]	Inventory in 2,500 kg[b] (Ci)	Emission Factor (at 2000 C)	Emission Potential per Facility[b] (Ci/yr)
Mn-54	5.89E-02	1	5.89E-02
Co-60	7.86E-02	0.001	7.86E-05
Sr-90	5.40E+00	1	5.40E+00
Tc-99	6.41E-03	0.000001	6.41E-09
Sb-125	2.67E-01	1	2.67E-01
Cs-134	8.06E-02	1	8.06E-02
Cs-135	7.68E-03	1	7.68E-03
Cs-137	1.74E+00	1	1.74E+00
Ce-144	5.34E-01	0.001	5.34E-04
Eu-154	1.49E-01	1	1.49E-01
Eu-155	2.67E-01	1	2.67E-01
Np-237	3.02E-02	0.001	3.02E-05
Pu-239	1.30E+01	0.001	1.30E-02
Pu-240	1.27E+00	0.001	1.27E-03
Am-241	5.25E-01	1	5.25E-01
U-234	2.48E+01	0.001	2.48E-02
U-235	1.04E+00	0.001	1.04E-03
U-236	8.38E-01	0.001	8.38E-04
U-238	6.68E-01	0.001	6.68E-04
U-232	2.77E-01	0.001	2.77E-04
U-233	7.67E-03	0.001	7.67E-06
U-237	7.67E-03	0.001	4.49E-05

a. Includes nuclides whose concentrations were measured by analysis or determined by modeling; other nuclides, including radioactive decay products, may be present at very low concentrations but does not change the conclusions of the analyses presented in the EA.

b. Alternative 1a assumes two processing facilities at MFC that would each process 2,500 kg annually for a total of 5,000 kg processed annually at MFC. Alternative 1b assumes one processing facility at MFC and one processing facility at INTEC that would each process 2,500 kg annually. Thus the emission rates are per facility.

Public Receptor

The CAP88-PC computer code was used to model atmospheric transport of the emissions and calculate the potential *effective dose (ED)* at the following public *receptor* locations for Alternatives 1a and 1b (see **Figure 2**) (ECAR-4321).

1. INL Site boundary nearest MFC: Located 5 km from MFC and 400 m north of the INL East entrance on Highway 20, which is accessible to the public, but there are no permanent residents (hypothetical receptor). Regulatory dose limits do not apply to this location. Doses are presented only for reference.
2. INL Site boundary nearest INTEC: Located about 14 km directly south of the INTEC entrance and 10 km west of Atomic City. The distance to INL's Site boundary northwest of INTEC is about the same distance, but the dose at the south receptor is higher. This location is accessible to the public, but there are no permanent residents. Regulatory dose limits do not apply to this location. Doses are presented only for reference.

3. Permanent resident nearest MFC: This is a farmhouse located 9 km from MFC and 3.1 km south of Highway 20, 3 km from INL's East entrance. Regulatory dose limits apply at this location.
4. Atomic City: This town of population 29 (2010 census) is located about 2 km east of INL's South entrance on Highway 26. The residence nearest INTEC is located in Atomic City. Atomic City is about 21 km SSW of MFC and 17 km SE of INTEC. Regulatory dose limits apply at this location.
5. Frenchman's Cabin: This location is about 2 km south of the southern INL boundary near Big Southern Butte. This location is used to show INL Site compliance with 40 CFR 61, Subpart H – *National Emissions Standards for Hazardous Air Pollutants (NESHAPs)* Other Than *Radon From Department of Energy Facilities,* and is the location of the maximally exposed individual (MEI). The site may be inhabited during portions of the year. Regulatory dose limits do apply to this location because of the potential for occupation during a portion of the year.

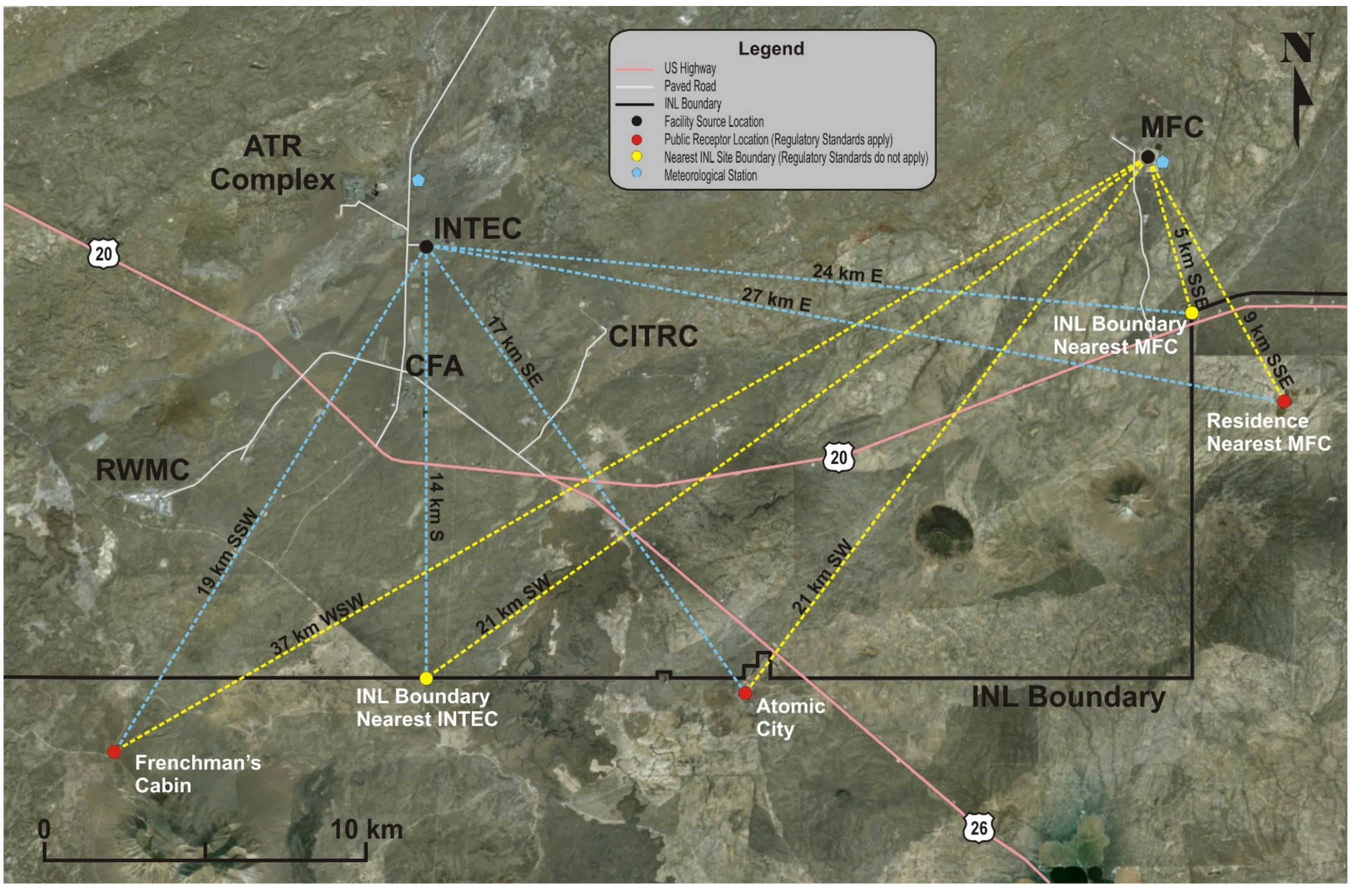

Figure 2. Actual and hypothetical public *receptor* locations for the air pathway analysis showing distance and direction from MFC and INTEC. Regulatory dose limits do not apply to the nearest boundary locations.

Table 2 shows the calculated potential EDs for public receptor locations from normal operations (ECAR-4321). For each alternative, the doses are well below the 10 mrem/year federal standard set by 40 CFR 61, Subpart H for public exposures. Cumulative doses from all INL sources would also be well below the 10 mrem/year dose standard at the INL MEI location (see Section 4.1.7).

Table 2. Public air pathway potential dose estimates from normal operations (unmitigated dose).

Potential *Receptor* Location	Alternative 1a Total ED (mrem/year)	Alternative 1b Total ED (mrem/year)
INL Site Boundary Nearest MFC (hypothetical receptor)[a]	5.4[d]	3.1[d]
INL Site Boundary Nearest INTEC (hypothetical receptor)[a]	NA[b]	2.2
Residence Nearest MFC	2.4[e]	1.5
Atomic City[c]	1.9	1.5
Frenchman's Cabin (INL Site NESHAP MEI)	0.74	1.6[e]

a. INL Site boundary locations between the two boundary locations were not evaluated, but the dose at other boundary locations is likely bounded by these values.
b. Location not applicable to Alternative 1a since there are no emissions from INTEC.
c. The Residence nearest INTEC is located at Atomic City.
d. Highest potential dose at a publicly accessible location, but no permanent resident (hypothetical receptor). Regulatory dose limits do not apply to these locations. Doses are presented only for reference.
e. Highest potential dose at a location with a residence, school, business or office.

Collocated Worker Receptor

Collocated worker potential doses were calculated at 100 m from the source stack in the direction of maximum dose using the same atmospheric transport and dose model used for public dose calculations. However, worker dose estimates do not include the ingestion pathway because workers do not consume contaminated food products, and the inhalation and external doses were scaled to account for the reduced time workers would be onsite.

Table 3 shows the calculated EDs for *collocated workers* from normal operations (ECAR-4321). For Alternative 1b, doses are presented for both MFC and INTEC with the difference attributed to the different meteorological conditions. For each alternative, the doses are well below the 5,000 mrem/yr federal occupational dose limit for general employees (10 CFR 835.202).

Table 3. *Collocated worker* potential doses from operational radionuclide emissions (unmitigated dose).

Alternative	Facility	Feedstock Material Processed Annually	Total ED[a] (mrem/yr)
1a	MFC	5,000 kg	48
1b	MFC	2,500 kg	24
	INTEC	2,500 kg	33

a. Dose at 100m from stack in direction of maximum dose.

Surface Soil Exposure Pathway

Estimated potential doses to public *receptors* (**Table 2**) and *collocated workers* (**Table 3**) from atmospheric emissions include impacts from air immersion, inhalation of contaminated air, ingestion of contaminated food products and direct radiation from ground deposition. Additional impacts from incidental ingestion of contaminated soil and inhalation of fugitive dust (particulate matter) were assessed by calculating soil concentrations due to build-up of particulate deposition, and comparing them to EPA preliminary remediation goals (PRGs) (ECAR-4321). PRGs are risk-based soil concentrations derived from standardized equations combining exposure information assumptions with EPA toxicity data. They are soil concentrations that would not likely result in adverse health impacts under reasonable maximum exposure conditions for long-term/chronic exposures.

Table 4 contains estimated soil concentrations calculated from maximum deposition rates calculated by the atmospheric transport model. For both MFC and INTEC, maximum deposition occurs 200 m from the stack in the NE direction. For both MFC and INTEC, this distance would likely be the shortest distance from a production facility to a location outside the facility fence. The soil concentrations from these deposition rates were also used to determine impacts to biota (see Section 4.1.2.3). There are no permanent human *receptors* at these locations and the soil concentrations are much greater than concentrations at actual public receptor locations farther from the facilities. Thus, impacts to public receptors are bounded by use of these concentrations.

Table 4. Comparison of maximum radionuclide soil concentrations to EPA PRGs.

Radionuclide	Maximum Soil Concentration outside MFC (pCi/g)[a]	Maximum Soil Concentration outside INTEC (pCi/g)[b]	EPA Total PRG for Soil Ingestion and Inhalation[c]	Ratio of MFC Maximum Soil Concentration to EPA PRG	Ratio of INTEC Maximum Soil Concentration to EPA PRG
Mn-54	2.16E-02	1.49E-02	3.8E+03	5.69E-06	3.92E-06
Co-60	5.06E-05	3.49E-05	8.3E+01	6.09E-07	4.20E-07
Sr-90	3.89E+00	2.68E+00	8.9E+00	4.37E-01	3.01E-01
Tc-99	3.46E-09	2.39E-09	1.2E+02	2.89E-11	1.99E-11
Sb-125	1.56E-01	1.07E-01	5.4E+02	2.88E-04	1.98E-04
Cs-134	4.35E-02	3.00E-02	1.4E+02	3.11E-04	2.14E-04
Cs-135	5.69E-03	3.92E-03	9.6E+01	5.93E-05	4.09E-05
Cs-137	1.26E+00	8.72E-01	2.8E+01	4.51E-02	3.11E-02
Ce-144	1.85E-04	1.27E-04	2.2E+02	8.41E-07	5.79E-07
Eu-154	1.02E-01	7.03E-02	8.4E+01	1.21E-03	8.38E-04
Eu-155	1.72E-01	1.18E-01	6.7E+02	2.57E-04	1.76E-04
Np-237	2.22E-05	1.53E-05	6.2E+00	3.60E-06	2.48E-06
Pu-239	9.64E-03	6.64E-03	3.8E+00	2.54E-03	1.75E-03
Pu-240	9.42E-04	6.49E-04	3.8E+00	2.48E-04	1.71E-04
Am-241	3.88E-01	2.68E-01	4.8E+00	8.09E-02	5.58E-02
U-234	1.81E-02	1.25E-02	5.9E+00	3.08E-03	2.13E-03
U-235	7.61E-04	5.24E-04	5.7E+00	1.33E-04	9.19E-05
U-236	6.13E-04	4.23E-04	6.3E+00	9.77E-05	6.74E-05
U-238	4.88E-04	3.37E-04	4.4E+00	1.10E-04	7.59E-05
U-232	2.01E-04	1.38E-04	1.9E+00	1.08E-04	7.41E-05
U-233	5.62E-06	3.87E-06	5.8E+00	9.70E-07	6.69E-07
U-237	4.44E-07	3.06E-07	6.5E+04	6.83E-12	4.71E-12
			Sum of Ratios[d]	0.57	0.39

a. Soil concentrations near MFC based on annual emission rate of 5,000 kg (2,500 kg per facility). Facilities are assumed collocated.

b. Soil concentrations near INTEC based on annual emission rate of 2,500 kg.

c. PRGs are based on a target risk of 1E-06. PRG is the total PRG for the soil ingestion and inhalation of fugitive dust exposure pathways.

d. Sum of Ratios less than 1 indicates concentrations would not result in adverse human health impacts. The lifetime cancer risk is less than one in one million.

The results in **Table 4** indicate maximum radionuclide soil concentrations are less than EPA PRGs. Sum of ratios values less than one is evidence that contaminated soils would not result in adverse human health impacts.

4.1.2.2 Waste Generation and Management

Routine maintenance and operations would generate a variety of waste streams, including both radioactive and non-radioactive wastes. Non-radioactive wastes would include trash and waste found at any industrial facility, including common trash, wastewater, hydraulic and lubricating fluids, scrap metal, and possibly small amounts of hazardous waste (e.g., electronic circuit boards, solvent contaminated wipes).

Common trash would be disposed at the on-site industrial waste landfill. Hazardous waste/mixed waste would be accumulated and stored per federal and state regulations, treated and disposed at an off-site permitted/licensed facility. Solid LLW may include scrap metal, HEPA filters, used personal protective equipment, wipes, rags, and decontamination fluids. Solid LLW would be sent to an off-INL disposal facility permitted/licensed to accept LLW. Liquid LLW would be solidified and sent to an off-site disposal facility permitted/licensed to accept LLW. The volume of various LLW generated during routine operations are expected to be less than 20 m^3 per year (based on FY2018 generation rates at MFC); the additional LLW disposal from the proposed action is less than a 2.5% increase in the volume sent to off-site disposal facilities each year.

Cleaning for external contamination may use small amounts of nitric acid (about 2 liters per batch. During ceramic fuels processing using hydrochloric acid, hydrogen peroxide, and nitric acid would generate a MLLW. MLLW when generated, would be accumulated and stored per federal and state regulations, treated if required, and disposed at an off-site permitted/licensed facility. Based on past operations of the FCF and the *HALEU feedstock,* less than 1 m^3 of *transuranic waste* may be generated.

The environmental impacts associated with disposal and transportation of LLW are addressed in the Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (DOE 1997a), the EA for the Replacement Capability for Disposal of Remote-Handled Low-Level Radioactive Waste Generated at the DOE's Idaho Site (DOE 2011b), and the Final Site-Wide Environmental Impact Statement for the Continued Operation of the DOE/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada (DOE 2013a).

Handling and Examinations in Other MFC Facilities—

Fuel fabrication would result in waste generation at other facilities at MFC where the fuel can be analyzed. The materials and fuel specimens proposed for analysis would not be appreciably different from current testing.

Based on INL's FY2018 LLW generation rate of 934 m^3, the increase in LLW generation would represent less than 2.5% of the volume generated at INL each year. MLLW may also be generated during these operations. If MLLW were generated, it would be accumulated and stored per Federal and state regulations, treated if required, and disposed at an off-site permitted/licensed facility. The proposed processes should generate less than 1 m^3 of *transuranic waste*. The environmental impacts associated with disposal of transuranic waste are addressed in the Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement (DOE 1997b).

4.1.2.3 Biological Resources

The RESRAD-BIOTA (Version 1.8) computer code (http://resrad.evs.anl.gov/codes/resrad-biota/) was used to model radiation exposures to terrestrial biota resulting from soil contaminated by airborne releases from the *HALEU* processing facilities at INTEC and/or MFC. The Level 1 analysis in RESRAD-BIOTA to provides generic limiting concentrations of radionuclides in environmental media, termed Biota Concentration Guides (BCG). Each biota concentration guide is the environmental concentrations of a given radionuclide in soil or water. The contaminated soil subsequently results in contamination in air and in different food sources used by biota. Both external radiation and internal radiation are considered in the dose assessment.

For the HALEU analysis, soil concentrations resulting from emissions under Alternatives 1a (MFC – 5000 kg feed processed per year for two years) and 1b (MFC and INTEC -2500kg per each facility processed per year for two years) were evaluated. The maximum radionuclide concentrations in soil resulting from deposition under each scenario were evaluated for dose to terrestrial biota.

The potential radionuclide concentrations in surface soils around the INTEC and MFC were estimated using radionuclide-specific deposition rates modeled by the CAP88-PC computer code, as discussed in Section 4.1.2.1. The locations at which the maximum deposition rates were estimated to occur were identified at 200 m northeast of MFC and 200 m northeast of INTEC. The concentrations of radionuclides in the soil at these locations were calculated using an algorithm which includes the deposition rate, radioactive decay and leaching of dissolved materials down through the soil via water infiltration (VFS-ID-ESER-NEPA-044). The calculated concentrations of radionuclides at the locations of maximum deposition are shown in Tables 5 and 6.

A Level 1 screening analysis was preformed using the maximum soil concentrations for each alternative scenario [MFC for Alternative 1a (Table 5) and INTEC for Alternative 1b (Table 6)]. Because RESRAD-BIOTA does not offer Mn-54, Pu-240, U-232, U-236, and U-237 as input choices, these radionuclides were handled as follows: 1) Mn-54 was summed with Co-60; 2) Pu-240 was summed with Pu-239; 3) U-236 was summed with U-238; 4) U-232 was entered as Th-228 (a daughter in the decay series); and 5) U-237 was eliminated. The Level 1 screening analysis represents the most conservative estimate of impacts of contaminants in soil on terrestrial biota accessing the soil. The bases for these decisions are discussed in VFS-ID-ESER-NEPA-044.

The results of the analyses show that for each alternative terrestrial animals are the limiting species and the soil concentration/BCG ratios do not cumulatively exceed 1. This shows that the limits established for protection of terrestrial biota would not be exceeded for either alternative.

Table 5. Results of Level 1 RESRAD-BIOTA analysis of proposed *HALEU* releases at MFC (Alternative 1a). Terrestrial animals are the limiting organism.

Terrestrial BCG Report for Level 1 **Title:** HALEU - MFC					
(Summed) Total Ratio for Limiting Organism: 2.38E-01 **(Summed) Soil Ratio for Limiting Organism:** 2.38E-01					
	Terrestrial Animal				
	Soil				**TOTAL**
Nuclide[a]	**Concentration (pCi/g)**	**BCG (pCi/g)**	**Ratio**	**Limiting Organism**	**Ratio**
Am-241	0.388	3.89E+03	9.96E-05	Yes	9.96E-05
Ce-144	0.000185	1.44E+03	1.28E-07	Yes	1.28E-07
Co-60	0.0217	6.92E+02	3.14E-05	Yes	3.14E-05
Cs-134	0.0435	1.13E+01	3.85E-03	Yes	3.85E-03
Cs-135	0.00569	2.62E+02	2.17E-05	Yes	2.17E-05
Cs-137	1.26	2.08E+01	6.07E-02	Yes	6.07E-02
Eu-154	0.102	1.29E+03	7.90E-05	Yes	7.90E-05
Eu-155	0.172	1.58E+04	1.09E-05	Yes	1.09E-05
Np-237	0.0000222	3.86E+03	5.75E-09	Yes	5.75E-09
Pu-239	0.0106	6.11E+03	1.73E-06	Yes	1.73E-06
Sb-125	0.156	3.52E+03	4.43E-05	Yes	4.43E-05
Sr-90	3.89	2.25E+01	1.73E-01	Yes	1.73E-01
Tc-99	0.00000000346	4.49E+03	7.70E-13	Yes	7.70E-13
Th-228	0.000201	5.30E+02	3.79E-07	Yes	3.79E-07
U-233	0.00000562	4.83E+03	1.16E-09	Yes	1.16E-09
U-234	0.0181	5.13E+03	3.53E-06	Yes	3.53E-06
U-235	0.000761	2.77E+03	2.75E-07	Yes	2.75E-07
U-238	0.0011	1.58E+03	6.97E-07	Yes	6.97E-07
Summed	-	-	**2.38E-01**	-	**2.38E-01**
	Terrestrial Plant				
	Soil				**TOTAL**
Nuclide[a]	**Concentration (pCi/g)**	**BCG (pCi/g)**	**Ratio**	**Limiting Organism**	**Ratio**
Am-241	0.00131	1.57E+04	8.33E-08	No	8.33E-08
Ce-144	0.000185	1.39E+04	1.33E-08	No	1.33E-08
Co-60	0.0217	6.13E+03	3.54E-06	No	3.54E-06
Cs-134	0.0435	1.09E+03	4.00E-05	No	4.00E-05
Cs-135	0.00569	2.81E+04	2.02E-07	No	2.02E-07
Cs-137	1.26	2.21E+03	5.71E-04	No	5.71E-04
Eu-154	0.102	1.25E+04	8.18E-06	No	8.18E-06
Eu-155	0.172	1.53E+05	1.13E-06	No	1.13E-06
Np-237	0.0000222	8.15E+03	2.73E-09	No	2.73E-09
Pu-239	0.0106	1.27E+04	8.36E-07	No	8.36E-07
Sb-125	0.156	3.49E+04	4.47E-06	No	4.47E-06
Sr-90	3.89	3.58E+03	1.09E-03	No	1.09E-03
Tc-99	0.00000000346	2.19E+04	1.58E-13	No	1.58E-13
Th-228	0.000201	6.42E+03	3.13E-08	No	3.13E-08
U-233	0.00000562	5.23E+04	1.07E-10	No	1.07E-10
U-234	0.0181	5.16E+04	3.51E-07	No	3.51E-07
U-235	0.000761	2.74E+04	2.77E-08	No	2.77E-08
U-238	0.0011	1.57E+04	7.00E-08	No	7.00E-08
Summed	-	-	**1.74E-03**	-	**1.74E-03**

Table 6. Results of Level 1 RESRAD-BIOTA analysis of proposed *HALEU* releases at INTEC (Alternative 1b). Terrestrial animals are the limiting organism.

Terrestrial BCG Report for Level 1
Title: HALEU - INTEC

(Summed) Total Ratio for Limiting Organism: 1.64E-01
(Summed) Soil Ratio for Limiting Organism: 1.64E-01

	Terrestrial Animal				
	Soil				TOTAL
Nuclide[a]	**Concentration (pCi/g)**	**BCG (pCi/g)**	**Ratio**	**Limiting Organism**	**Ratio**
Am-241	0.268	3.89E+03	6.88E-05	Yes	6.88E-05
Ce-144	0.000127	1.44E+03	8.81E-08	Yes	8.81E-08
Co-60	0.0149	6.92E+02	2.15E-05	Yes	2.15E-05
Cs-134	0.03	1.13E+01	2.66E-03	Yes	2.66E-03
Cs-135	0.00292	2.62E+02	1.12E-05	Yes	1.12E-05
Cs-137	0.872	2.08E+01	4.20E-02	Yes	4.20E-02
Eu-154	0.0703	1.29E+03	5.45E-05	Yes	5.45E-05
Eu-155	0.0118	1.58E+04	7.45E-07	Yes	7.45E-07
Np-237	0.0000153	3.86E+03	3.96E-09	Yes	3.96E-09
Pu-239	0.00729	6.11E+03	1.19E-06	Yes	1.19E-06
Sb-125	0.107	3.52E+03	3.04E-05	Yes	3.04E-05
Sr-90	2.68	2.25E+01	1.19E-01	Yes	1.19E-01
Tc-99	0.00000000239	4.49E+03	5.32E-13	Yes	5.32E-13
Th-228	0.000138	5.30E+02	2.60E-07	Yes	2.60E-07
U-233	0.00000387	4.83E+03	8.02E-10	Yes	8.02E-10
U-234	0.0125	5.13E+03	2.44E-06	Yes	2.44E-06
U-235	0.000524	2.77E+03	1.89E-07	Yes	1.89E-07
U-238	0.00076	1.58E+03	4.82E-07	Yes	4.82E-07
Summed	-	-	**1.64E-01**	-	**1.64E-01**
	Terrestrial Plant				
	Soil				**TOTAL**
Nuclide	**Concentration (pCi/g)**	**BCG (pCi/g)**	**Ratio**	**Limiting Organism**	**Ratio**
Am-241	0.268	2.15E+04	1.24E-05	No	1.24E-05
Ce-144	0.000127	1.39E+04	9.12E-09	No	9.12E-09
Co-60	0.0149	6.13E+03	2.43E-06	No	2.43E-06
Cs-134	0.03	1.09E+03	2.76E-05	No	2.76E-05
Cs-135	0.00292	2.81E+04	1.04E-07	No	1.04E-07
Cs-137	0.872	2.21E+03	3.95E-04	No	3.95E-04
Eu-154	0.0703	1.25E+04	5.64E-06	No	5.64E-06
Eu-155	0.0118	1.53E+05	7.72E-08	No	7.72E-08
Np-237	0.0000153	8.15E+03	1.88E-09	No	1.88E-09
Pu-239	0.00729	1.27E+04	5.75E-07	No	5.75E-07
Sb-125	0.107	3.49E+04	3.07E-06	No	3.07E-06
Sr-90	2.68	3.58E+03	7.49E-04	No	7.49E-04
Tc-99	0.00000000239	2.19E+04	1.09E-13	No	1.09E-13
Th-228	0.000138	6.42E+03	2.15E-08	No	2.15E-08
U-233	0.00000387	5.23E+04	7.40E-11	No	7.40E-11
U-234	0.0125	5.16E+04	2.42E-07	No	2.42E-07
U-235	0.000524	2.74E+04	1.91E-08	No	1.91E-08
U-238	0.00076	1.57E+04	4.83E-08	No	4.83E-08
Summed	-	-	**1.20E-03**	-	**1.20E-03**

4.1.3 Accident Consequences

Accident consequences for Alternative 1 (Proposed Action) were evaluated for events related to processing of *HALEU*. Accident types considered included thermal stress of fire on 50 kg uranium solids, spill or free-fall drop of molten metal, and accidents resulting in solid ingot free-fall drop or impact (ECAR-4310). The potential for nuclear criticality exists due to the quantity and form of material being processed. However, engineered and administrative controls would be incorporated into the facility and process operations to prevent and mitigate worker risk associated with this hazard.

DOE-Hdbk-3010-94 states that no significant airborne release is postulated from spill and impact of solid uranium, so those types of events are not addressed further. The handbook further states that release fractions for disturbed molten metal surface under dynamic conditions such as a spill or free-fall drop are higher than that for pieces or powder under thermal stress (fire). Therefore, the bounding and most severe postulated accident for the proposed action is a spill or free-fall drop of molten uranium during material processing. This accident could occur from an initiating event such as natural phenomena occurrence (i.e. severe seismic event), operator error, or from unspecified facility structural failures. The combined probability of initiating event and likelihood of equipment failure in this type of event of the magnitude to result in a material release during the molten phase of processing is judged to be no higher than a return frequency of 1E-02 to 1E-04 per year.

The needs of the proposed action are anticipated to be filled using more than one facility on the INL site. Dose consequence to the *facility worker* in an accident varies depending on the size of the room/building in which the accident occurs. Dose consequence to the public is dependent upon location of the activity and corresponding distance to the nearest site boundary where the public could be affected. Accident consequences in this document focus on molten material spill occurring at both the INTEC complex and MFC complex and use nominal values for building size and distance to the public.

To achieve the production requirements of the program, the two process lines could operate simultaneously and so for conservative analysis, double batch upsets are analyzed under accident conditions for airborne release.

Overview of Accident Analysis—

The accident analysis was conducted by using Radiological Safety Analysis Computer Program (RSAC) 7.2. RSAC 7.2 program is a radiological safety analysis tool that has been developed and used extensively at INL for calculating the doses to *facility worker*, *collocated workers*, and off-site public due to radiological releases. It has been independently verified and validated for these types of calculations.

Assumptions used for the accident analysis are as follows:

- Batch processing is 50 kg *HALEU feedstock*
- Potentially 2 batches simultaneously affected by accident
- HALEU feedstock is stored in closed containers when not in process and is therefore not considered material at risk during the analyzed accident
- Performance of HALEU in accidents (thermal stress, spill, drop, impact) follow that of uranium. The HALEU is >99% uranium. The other elements identified are homogeneously entrained throughout the uranium matrix on ppm and ppb scale

- This accident was analyzed as unmitigated with no credit taken for engineered controls or safety systems such as *glovebox* or ventilation systems
- Molten HALEU spills occur at a height of <4 m. Process equipment would be placed on the floor of the work area, and material would be molten only during processing
- A room/building volume of 1,700 m^3 was assumed for *facility worker* dose calculations
- The composition of HALEU feedstock is based upon the best available information. Specific values are shown in ECAR-4310 and calculated from the maximum concentrations postulated in TEV-3537
- The nearest INL boundary is located at about 5,000 m from MFC and 14,000 m from INTEC

Bounding Inhalation Dose Consequences—

The calculation of 100 kg molten *HALEU feedstock* was postulated to be involved in a spill under assumed conditions as described above and worst case environmental conditions. *Dose consequences* were analyzed for the *facility worker*, *collocated worker* at 100 m, and the public *receptor* located at 5,000 m and 14,000 m. The analysis and results are documented in ECAR-4310, Evaluation of the Inhalation Dose Consequences for the HALEU Environmental Assessment. RSAC-7.2 was used to quantify the doses of the postulated accidents. The program is used to calculate the doses from the release of radionuclides to the atmosphere and uses the parameters of source term, plume dispersion, breathing rate, dose conversion factor for each receptor, and dry deposition in determining an estimated committed *effective dose* for each downwind receptor location.

Source term is calculated by multiplying material at risk quantity by damage ratio, airborne release fraction, respirable fraction, and leak path factor. The methodology for dose estimates is detailed in ECAR-4310. The results from the RSAC consequence calculations are shown in **Table 7** below.

Radiologic Consequences—

Table 7. Summary of dose impacts for the highest consequence events for Alternative 1.

Receptor	Dose Total *Effective Dose* (TED)	*Latent Cancer Fatality* (LCF)[a]
Facility Worker (1,700 m^3 building)	8.81 (rem/min)[b]	1.03E-02[d]
Collocated Worker (100 m downwind)	997(mrem)[c]	4.09E-04
Offsite *Member of the Public (*5,000 m downwind)	29.4E(mrem)[c]	1.62E-05
Offsite *Member of the Public* (14,000 m downwind)	9.10(mrem)[c]	5.01E-06

a. conservatively estimated based on ICRP Publication 103 health effects

b. 50 yr TED rem per minute of exposure time. If smaller room volumes are used, process configuration and parameters would be adjusted to maintain worker dose below the calculated values

c. 50 yr TED millirem

d. Assumes a *facility worker* dose of 25 rem and LCF factor of 4.1 E-04 per rem

4.1.4 Impacts of Transportation

Transportation of *HALEU feedstock*, fuel alloy, and cast or clad fuel under the preferred alternative would occur between INL facilities on the route as shown in **Figure 3**, which is on roadways controlled by INL security. For transport between MFC and INTEC facilities on the INL site, an appropriate shipping container for each material would be used such as the Hot Fuel Examination Facility-5 cask.

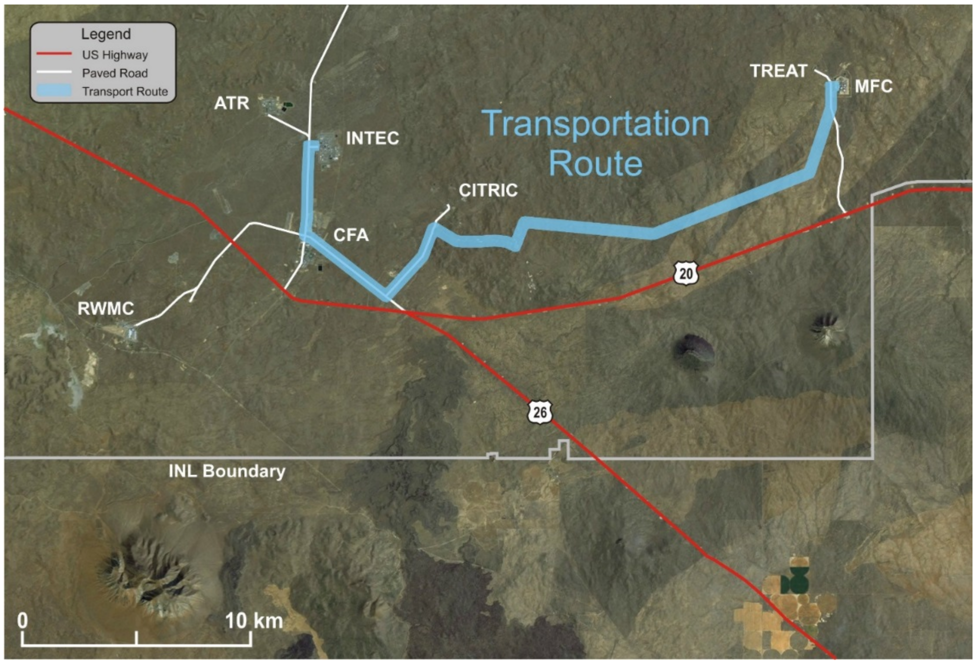

Figure 3. Transport route between INTEC and MFC.

The assessment of transportation accident consequences to workers and the public for on-site transport is addressed in DOE/EA-1772, “Environmental Assessment for the Multipurpose Haul Road Within Idaho National Laboratory.” *HALEU feedstock* would be transported in solid form; therefore, no significant airborne release is postulated from spill and impact of solid uranium. It is not credible that a shipment could become molten under plausible transportation accidents. As shown in the previous section, for double batch size quantities, the worst-case air release of molten material HALEU feedstock, the dose consequence is expected to be substantially less than that addressed in DOE/EA-1772 (Haul Road EA). Therefore, the consequence analysis of DOE/EA-1772 is appropriate and bounding for HALEU transportation. Safety during transportation is also assured using DOE-approved transport plans, which analyze reasonable and bounding accident scenarios.

4.1.5 Impacts of Intentional and Destructive Acts

DOE considered Impacts of intentional acts of destruction occurring at an INL facility or during transport on INL. INL’s protective force mitigates the potential for an act of sabotage occurring on site. INL routinely employs a variety of measures to mitigate the likelihood and consequences of intentional destructive acts. The DOE maintains a highly trained and equipped protective force intended to prevent attacks against and entry into the facilities. The protective force monitors and patrols site perimeters to prevent unauthorized entry.

Access to INL roads would be restricted during transport of radioactive materials. Security measures would be in place to mitigate the likelihood and consequences of sabotage. Transportation *crewmembers* would be screened for behavioral and substance abuse issues and would receive safety and security training. *Crewmembers* would conduct a thorough inspection of vehicles and loads before transport. During transport, *crewmembers* have a means of communication and immediately report suspicious activity encountered while in route.

Accident analyses for the preferred alternative are evaluated based on conservative assumptions using parameters resulting in the highest postulated dose to workers and public *receptors*, therefore, any acts of sabotage, should they occur, would be expected to result in consequences that would be bounded by the results of accident scenarios detailed above.

4.1.6 Sustainability

The only anticipated sources of greenhouse gas (GHG) emissions would be from a diesel backup generator. Emissions from the transport of nuclear material would also be included. BEA uses 100% renewable diesel fuel, which would result in ‘0’ metric tons carbon dioxide equivalent (MT CO2e) of anthropogenic GHG emissions. If 100% renewable diesel is not available, the total anthropogenic GHG emissions are estimated to be less than 0.5 MT CO2e, assuming heavy-duty vehicle burning 100% diesel and taking 20 one-way trips at 20 miles per trip.

4.1.7 Cumulative Impacts

DOE reviewed the resources at risk; geographic boundaries; past, present, and reasonably foreseeable future actions; and baseline information in determining the significance of cumulative impacts. The review was assessed for construction, transportation, normal operations, and potential impacts of accidents. Conclusions are as follows:

- Cumulative impacts to historic properties cannot be evaluated until Section 106 has been completed. Section 106 under the proposed action alternatives has been deferred; as such, cumulative impacts to historic properties would be evaluated under the MOA and associated stipulations identified in the NEPA decision for completion of Section 106. (see Section 4.1.1)

- The proposed action would not create new facility or building footprint; therefor, there would be no or negligible cumulative impacts to biological resources. There may be low short-term impact to INL's ecological resources. (see Section 4.1.2.3)
- During normal operations, cumulative radiologic, waste generating, or sustainability impacts would be minimal. Radiologic releases during normal operations would not result in adverse health impacts. Additional waste volumes would be small compared to current disposal volumes at INL. Additional GHG emissions would be negligible compared to INL Site-wide amounts (see Section 4.1.6).

The maximum total annual estimated dose from atmospheric emissions to a maximally exposed off-site individual reported for INL compliance in year 2017 is 0.008 mrem (DOE ID 2018). Inclusion of the conservatively estimated maximum annual dose contribution from *HALEU fuel* production of 1.6 mrem (Alternative 1b) would result in a total annual estimated dose at Frenchman's Cabin of 1.61 mrem. The estimated annual dose of 0.74 mrem (Alternative 1a) would result in a total annual dose estimate of 0.75 mrem. Although the Alternative 1a and 1b doses from HALEU fuel production are much larger than the dose from current emissions, the doses from HALEU fuel production are based on conservative emission estimates that take no credit for mitigation. The actual emissions and doses are expected to be much less.

There are several proposed projects at the INL Site that DOE considers reasonably foreseeable that would include radiological emissions that could contribute to cumulative impacts. Those that DOE reviewed include:

- DOE Idaho Spent Fuel Facility
- Remote-Handled LLW Disposal Facility
- Plutonium-238 Production for Radioisotope Power Systems
- Recapitalization of Infrastructure Supporting Naval Spent Nuclear Fuel Handling
- Resumption of Transient Testing using the TREAT facility
- Radiological Response Training Ranges
- National Security Test Range

Table 8 presents the estimated dose from each reasonably foreseeable project to a maximally exposed individual. Most are screening-level dose estimates which means the analysis used conservative assumptions (e.g. no mitigation) to bound the dose estimate. In addition, some projects estimate dose at the nearest off-site public *receptor* location which may be several miles from Frenchman's Cabin. For example, the location of the public receptor dose presented for the National Security Test Range is near the INL Site northeast boundary, more than 38 miles from the INL MEI location at Frenchman's Cabin. If the doses for each project are conservatively assumed to occur at Frenchman's Cabin (which they do not), the total dose from reasonably foreseeable projects, including *HALEU fuel* production, is 1.67 mrem/yr. If combined with the current maximum total annual estimated dose reported for INL compliance (0.008 mrem in 2017), the dose from current and reasonably foreseeable future actions on the INL Site would be 1.68 mrem as indicated in **Table 8**. Although the actual dose is expected to be much less, this estimated dose is still much lower than the 10 mrem annual dose standard.

The potential additive impacts from implementing Alternative 1a or 1b for HALEU fuel production are determined to be collectively small and would have little impact to reasonably foreseeable future actions or current operations.

Table 8 Estimated annual air pathway dose (mrem) from normal operations to the maximally exposed off-site individual from the above proposed projects, including the estimated dose from *HALEU fuel* production.

Reasonably Foreseeable Future Action	Estimated Annual Air Pathway Dose (mrem)
DOE Idaho Spent Fuel Facility (NRC 2004)	0.000063[a]
New DOE Remote-Handled LLW Disposal Facility (DOE/ID 2018)	0.0074[a]
Plutonium-238 Production for Radioisotope Power Systems (DOE/EIS 2013)	0.00000026[b]
Recapitalization of Infrastructure Supporting Naval Spent Nuclear Fuel Handling (DOE/EIS 2016)	0.0006[c]
TREAT (DOE/EA 2014)	0.0011[a]
Radiological Response Training Range (North Test Range) (DOE/EA-2063 DRAFT)	0.034[d]
Radiological Response Training Range (South Test Range) (DOE/EA-2063 DRAFT)	0.00024[a]
National Security Test Range (DOE/EA-2063 DRAFT)	0.03[e]
HALEU fuel Production	1.6[a,f]
Total of Reasonably Foreseeable Future Actions on the INL Site	1.67[g]
Current (2017) Annual Estimated INL Emissions (INL 2018)	0.008[h]
Total of Current and Reasonably Foreseeable Future Actions on the INL Site	1.68[i]

a. Dose calculated at Frenchman's Cabin, typically INL's MEI for annual NESHAP evaluation.
b. *Receptor* location is not clear. Conservatively assumed at Frenchman's Cabin.
c. Dose calculated at INL boundary northwest of Navel Reactor Facility (NRF). Dose at Frenchman' Cabin likely much lower.
d. Dose calculated at INL boundary northeast of Specific Manufacturing Capability (SMC). Dose at Frenchman's Cabin likely much lower.
e. Sum of doses from New Explosive Test Area and Radiological Training Pad calculated at separate locations northeast of MFC near Mud Lake. Dose at Frenchman's Cabin likely much lower.
f. Maximum dose from Alternative 1b (1.6 mrem/year) is presented. Alternative 1a dose is 0.74 mrem/year.
g. This total represents the air impact from reasonably foreseeable future actions and assumes they occur at Frenchman's Cabin.
h. Dose at MEI location (Frenchman's Cabin) from 2017 INL emissions (INL 2018). The 10-yr (2008-2017) average dose is 0.05 mrem/year.
i. This total represents air impact from current and reasonably foreseeable future actions at INL. It conservatively assumes the dose from each facility was calculated at the same location (Frenchman's Cabin) which they were not.

4.2 Alternative 2 - No Action

Under the No Action Alternative, blending uranium separated from sodium-bonded fuel through the electrometallurgical process with depleted uranium would continue at INL as analyzed in the Sodium Bonded

EIS. The Sodium Bonded EIS (DOE/EIS-306, July 2000) evaluated treating about 5 metric tons of heavy metal of sodium- bonded spent nuclear fuel per year. Appendix E, Section E.4.1, contains details on the process duration and the amount of blanket and driver spent nuclear fuel treated annually.

4.3 Summary of Environmental Impacts

Table 9 summarizes impacts of the proposed action for air, cultural and biological resources and waste generation and management.

Table 9. Summary of environmental impacts.[a]

Resource	Alternative #1: Proposed Action
	Impacts -- Construction
Constructions (Section 4.1.1)	• Project activities may generate fugitive dust as the result of construction or modification due to possible soil disturbance or excavation activities. • There is a possibility that materials containing asbestos could be disturbed. • INL has not determined which buildings at either MFC or INTEC would be used under the proposed action; as such, DOE would evaluate impacts to historic properties before making the NEPA decision, resulting in deferment of Section 106 as per 36 CFR 800.14(b)(1)(ii). • The modifications for fuel fabrication would generate non-radioactive electronic waste, scrap metal, and other construction-related debris. Construction debris, electronic waste, and scrap metal would be recycled to the extent possible.
	Impacts – Normal Operations
Non-Radiologic Atmospheric Impacts – chemical pollutants **(Section 4.1.2.1)**	• Nonradiological emissions would be minimal during operational stages.
Atmospheric Pathway **(Section 4.1.2.1**	• A conservative assessment of radionuclide releases during anticipated normal operations indicates cumulative doses from all INL sources would be well below the 10 mrem/year dose standard for a *member of the public* at the INL MEI location (see Section 4.1.7). Estimated doses to *collocated workers* would be well below the 5,000-mrem dose standard.
Waste Generation **(Section 4.1.2.2**	• The volume of various LLW generated during routine operations are expected to be less than 20 m^3 per year (based on past generation rates at MFC). The additional LLW disposal due to these operations would represent less than a 2.5% increase in the volume sent to off-site disposal facilities each year. • Less than 1 m^3 of *transuranic waste* is expected to be generated. • The materials and fuel specimens proposed for analysis would not be appreciably different from current testing.
Biological Resources **(Section 4.1.2.3)**	• Terrestrial animals are the limiting species and modeling shows that the soil concentration/BCG ratios do not cumulatively exceed 1 for terrestrial animals or plants, thus, the limits established for protection of terrestrial biota would not be exceeded for either alternative.
Impacts – Potential Accidents	
Accidents **(Section 4.1.3)**	• The committed dose to *facility workers* from the most severe postulated accident is conservatively estimated to be 8.81 rem/min of exposure time. Facility worker dose is further reduced by engineered and administrative controls and procedures and through the use of protective equipment. • Committed dose estimates for *collocated workers* would be 997 millirem and would result in 4.09E-04 (or 1 chance in 2400) *LCFs*. Estimated dose to the public at 5,000 m and 14,000 m would be 29.4 millirem and 9.1 millirem respectively with corresponding LCFs estimated at 1.62 E-05 (1 in 62,000) and 5.01E-6 (1 in 200,000). These consequences would likewise be reduced through the use of engineered and administrative controls applied.

Resource	Alternative #1: Proposed Action
Impacts -- Transportation	
Transportation **(Section 4.1.4)**	• *HALEU feedstock* would be transported in solid form; therefore, no significant airborne release is postulated from spill and impact of solid uranium. • The consequence analysis of DOE/EA-1772 is appropriate and bounding for *HALEU* transportation.
Intentional and Destructive Acts	
Destructive Acts **(Section 4.1.5)**	• INL routinely employs a variety of measures to mitigate the likelihood and consequences of intentional destructive acts.
a. Alternative #2 'No Action' results in no change to environmental impact from current operations.	

5 PERMITS AND REGULATORY REQUIREMENTS

Each alternative would be required to adhere to federal, state, and local regulations and obtain appropriate permits before constructing, modifying, or operating facilities, equipment, or processes. Below is a list of federal, state, and local regulations and permits that either of the alternatives may be required to adhere to or to obtain. The 'No Action' alternative complies with permits and applicable regulatory requirements. DOE would be responsible for identifying a comprehensive list of applicable regulations and permits for the selected actions. Activities that affect, or may affect, the safety of DOE nuclear facilities must also comply with the requirements of 10 CFR 830, *Nuclear Safety Management*.

Air

Radiologic air emissions from the INL must meet the EPA limit of 10 mrem/year for demonstration of compliance with "National Environmental Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" (40 CFR 61, Subpart H). In addition, because each processing facility would exceed the 0.1 mrem/yr limit, each facility may require an 'Application to Construct' under 40 CFR 61.96 and a state PTC under IDAPA 58.01.01.200 for a radiological source requiring a continuous stack monitor to be built per ANSI N13.1 (2011).

Emissions of hazardous air pollutants, criteria pollutants and state toxic air pollutants would be evaluated for compliance with Permit to Construct P-2015-0023, INL 'Permit to Construct' and Facility Emission Cap. If emissions are under the facility wide limits of Permit Condition 2.2 and comply with the Notice and Recordkeeping of Ambient Concentration Estimates of Permit Condition 2.6 no permit revision would be required. If the ambient concentration exceeds significant contribution levels of IDAPA 58.01.01.006.109, a separate PTC would be required.

Biological

In analyzing the potential ecological impacts of the action alternative for the proposed action, DOE has followed the requirements of the Endangered Species Act (16 USC §1531 et seq.) and has reviewed the most current lists for threatened and endangered plant and animal species. Other federal laws that could apply include: the Fish and Wildlife Coordination Act (16 USC § 661 et seq.), Bald and Golden Eagle Protection Act (16 USC § 668), and the Migratory Bird Treaty Act (16 USC § 715–715s).

Cultural

Cultural resources are managed at the INL Site according to a tailored approach outlined in INL's Cultural Resource Management Plan (DOE-ID 2016) and corresponding Programmatic Agreement executed among DOE, the Idaho SHPO, and the Advisory Council on Historic Preservation. Shoshone-Bannock tribal interests in INL resources and activities are addressed in an Agreement in Principle between DOE and the Shoshone-Bannock Tribes.

Section 106 of the National Historic Preservation Act (NHPA) directs any federal agency undertaking or licensing any activity, to "prior to the approval of the expenditure of any federal funds on the undertaking or prior to the issuance of any license, as the case may be, [to] take into account the effect of the undertaking on any district, site, building, structure or object that is included in or eligible for inclusion in the National Register." To assess the impact of such an undertaking, an agency must know whether any affected district, site, building, structure, or object is eligible for the NRHP. (Section 110 of the NHPA requires a federal agency to assume responsibility for historic properties it owns or controls. Historic properties must be identified, evaluated, documented, and nominated to the NRHP, if appropriate. Thus, Section 110 obliges an agency to preserve its historic properties and manage those properties in compliance with Section 106.

DOE has negotiated a following process for deferring Section 106 under the proposed action for Alternative 1 with the Idaho SHPO, per 36 CFR 800. l 4(b)(I)(ii). The following process was outlined in a letter from DOE to the Idaho SHPO on October 10, 2018:

1) 1) The Idaho SHPO will be allowed the opportunity to review the language in the EA regarding deferring Section 106 once the document has been made available for public comment, as per 36 CFR 800.8(c)(2)(i);

DOE will prepare a MOA outlining how the Section 106 process will be completed, once determinations are made regarding the specific buildings involved in the undertaking.

The MOA will be signed prior to the NEPA decision. The NEPA decision will include stipulations for completing the Section 106 process.

Sustainability

Executive Order 13834 "Efficient Federal Operations;" DOE's 2016 Strategic Sustainability Performance Plan; and DOE Order 436.1, "Departmental Sustainability" contains requirements and assign responsibilities for managing sustainability within DOE to carryout missions in a sustainable manner. These requirements also include provisions to institute wholesale cultural change to factor sustainability and GHG reductions into DOE decisions, and to achieve DOE's sustainability goals established in its Strategic Sustainability Performance Plan.

Per DOE's 2016 Strategic Sustainability Performance Plan Goal 2, alterations or renovations of buildings greater than 5,000 GSF must comply with the Guiding Principles. There are 26 Guiding Principles required for a building to meet compliance. Some are at no cost (e.g., non-smoking policy) and others require investments (e.g., water, gas, electricity meter installations). EO 13834 states that new construction and major renovations conform to applicable building energy efficiency requirements and sustainable design principles; consider building efficiency when renewing or entering into leases; practice using and optimizing space; and annually assess and report on building conformance to sustainability metrics. These requirements would be incorporated and addressed, where applicable.

Nuclear Safety

10 CFR 830 establishes requirements that must be implemented in a manner that gives reasonable assurance of adequate protection of workers, the public, and the environment from adverse consequences, taking into account the work to be performed and the associated hazards.

6 COORDINATION AND CONSULTATION DURING EA PREPARATION

Shoshone-Bannock Tribes
DOE briefed Shoshone-Bannock Tribes' staff on the HALEU EA and project on September 5 and October 24, 2018, and the Fort Hall Business Council on October 30, 2018.

INL Oversight Office

DOE briefed Kerry Martin (State of Idaho's INL Oversight Office Manager), her staff, and Mark Clough (Idaho DEQ) on the HALEU EA on October 16, 2018.

Idaho State Historic Preservation Office

DOE has negotiated a process for deferring Section 106 under the proposed action for Alternative 1 with the Idaho SHPO, per 36 CFR 800. l 4(b)(I)(ii).

Congressional
DOE briefed staff members of Sen Risch, Sen Crapo, and Congressman Simpson's on October 18, 2018.

7 REFERENCES

DOE-ID-10997, “Idaho National Laboratory Cultural Resource Management Plan”, U. S. Department of Energy – Idaho Operations Office, 2016.

DOE/EA-1772, “Environmental Assessment for the Multipurpose Haul road Within the Idaho National Laboratory Site”, August 2010.

DOE/EIS-306, “Final Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel, Volume 1”, U. S. Department of Energy, Office of Nuclear Energy, Science and Technology, Washington, DC , July 2000.

ECAR-4310, “Evaluation of the Inhalation Dose Consequences for the HALEU Environmental Assessment”, Revision 0, B. Christensen, October 2018.

ECAR-4321, “Evaluation of Impacts from Radiological Air Emissions for the HALEU Environmental Assessment”, Revision 0, A.J. Sondrup, October 2018.

ICRP-68, “Dose Coefficients for Intakes of Radionuclides by Workers,” International Commission on Radiological Protection”, 1994.

ICRP-72, “Age-dependent Doses from Intakes of Radionuclides,” International Commission on Radiological Protection, 1996.

TEV-3537, “Isotopic Characterization of HALEU from EBR-II Drive Fuel Processing”, Rev 0, D. Vaden, October 2018.

VFS-ID-ESER-NEPA-044, Analysis of Radiological Impacts to Terrestrial Biota in Support of Environmental Assessment for Use of DOE-Owned High-Assay Low-Enriched Uranium Stored at Idaho National Laboratory, Revision 0, Marilyn Case and Doulas Halford, Nuclear Solutions – Federal Services, October 2018.