

# **EA-1210; Lead Test Assembly Irradiation and Analysis Watts Bar Nuclear Plant, Tennessee and Hanford Site Richland, Washington**

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## Acronyms and Abbreviations

<b>ALARA</b>	as low as reasonably achievable
<b>ANL-W</b>	Argonne National Laboratory-West
<b>BWR</b>	boiling water reactor
<b>CFR</b>	<i>Code of Federal Regulations</i>
<b>CEDE</b>	committed effective dose equivalent
<b>CEQ</b>	Council on Environmental Quality
<b>Ci</b>	Curie (unit of radioactivity)
<b>CLWR</b>	Commercial Light Water Reactor
<b>DOE</b>	U.S. Department of Energy
<b>DOT</b>	U.S. Department of Transportation
<b>EA</b>	environmental assessment
<b>EDE</b>	effective dose equivalent
<b>EFPD</b>	effective full power days
<b>EIS</b>	Environmental Impact Statement
<b>FFTF</b>	Fast Flux Test Facility
<b>FONSI</b>	Finding of No Significant Impact
<b>FR</b>	<i>Federal Register</i>
<b>FSAR</b>	Final Safety Analysis Report
<b>HCRL</b>	Hanford Cultural Resources Laboratory
<b>HFEF</b>	Hot Fuels Examination Facility
<b>ICRP</b>	International Commission on Radiological Protection
<b>INEEL</b>	Idaho National Engineering and Environmental Laboratory
<b>kW</b>	kilowatt
<b>LCF</b>	latent cancer fatality
<b>LTA</b>	lead test assembly

<b>LWR</b>	light water reactor
<b>MEI</b>	maximally exposed individual
<b>MTF</b>	Memorandum-to-File
<b>MWe</b>	megawatt (electric)
<b>NDE</b>	nondestructive examination
<b>NEPA</b>	<i>National Environmental Policy Act of 1969</i>
<b>NRC</b>	U.S. Nuclear Regulatory Commission
<b>NTS</b>	Nevada Test Site
<b>ORR</b>	Oak Ridge Reservation
<b>PIE</b>	post-irradiation examination
<b>PWR</b>	pressurized water reactor
<b>R&amp;D</b>	research and development
<b>RCRA</b>	Resource Conservation and Recovery Act of 1976
<b>rem</b>	radiation equivalent man (unit of radiation dose equivalent)
<b>Sv</b>	Sievert (unit of radiation dose equivalent)
<b>TPBAR</b>	tritium-producing burnable absorber rod
<b>TSR PEIS</b>	(DOE) Programmatic EIS for Tritium Supply and Recycling
<b>TVA</b>	Tennessee Valley Authority
<b>WAC</b>	<i>Washington Administrative Code</i>
<b>WBN</b>	Watts Bar Nuclear Plant
<b>WDFW</b>	State of Washington Department of Fish and Wildlife

## Metric Conversion Chart

If you know	Multiply by	To get
<b>Length</b>		
centimeters	0.394	inches
meters	3.281	feet
square meters	10.764	square feet
kilometers	0.621	miles

Area		
hectares	2.471	acres
square kilometers	0.386	square miles
Mass (weight)		
kilograms	2.205	pounds
Volume		
liters	0.264	gallons
cubic meters	35.315	cubic feet
Radiological Units		
disintegrations per second	$2.7 \times 10^{-11}$	Curies
Sieverts	100	rem

From the *CRC Handbook of Chemistry and Physics*, Robert C. Weast, Ph.D., 70th Ed., 1989-1990, CRC Press, Inc., Boca Raton, Florida.

And

Eckerman, K. F., A. B. Wolbarst, and A. C. B. Richardson. 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*. Federal Guidance Report No. 11, EPA/520/1-88-020, Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C.

### Numerical (Scientific or Exponential) Notation

Numbers that are very small or very large are often expressed in scientific or exponential notation as a matter of convenience. For example, the number 0.000034 may be expressed as  $3.4 \times 10^{-5}$  or 3.4E-05 and 65,000 may be expressed as  $6.5 \times 10^4$  or 6.5E+04. Multiples or sub-multiples of the basic units are also used. A partial list of multiples and sub-multiples follows:

Name	Symbol	Value Multiplied by:		
atto	a	0.000000000000000001	or $1 \times 10^{-18}$	or 1E-18
femto	f	0.000000000000001	or $1 \times 10^{-15}$	or 1E-15
pico	p	0.000000000001	or $1 \times 10^{-12}$	or 1E-12
nano	n	0.000000001	or $1 \times 10^{-9}$	or 1E-09
micro	$\mu$	0.000001	or $1 \times 10^{-6}$	or 1E-06
milli	m	0.001	or $1 \times 10^{-3}$	or 1E-03
kilo	k	1,000	or $1 \times 10^3$	or 1E+03
mega	M	1,000,000	or $1 \times 10^6$	or 1E+06
giga	G	1,000,000,000	or $1 \times 10^9$	or 1E+09
tera	T	1,000,000,000,000	or $1 \times 10^{12}$	or 1E+12

The following symbols are occasionally used in conjunction with numerical expressions:

- < less than
- ≤ less than or equal to
- > greater than
- ≥ greater than or equal to

In this environmental assessment, numerical values that are less than 0.001 or greater than 9999 are generally expressed in exponential notation.

## **Preface**

This environmental assessment (EA) has been prepared to assess potential environmental impacts associated with a U.S. Department of Energy (DOE) Proposed Action to conduct a lead test assembly (LTA) program to confirm the viability of using a commercial light water reactor (CLWR) to produce tritium. The Proposed Action described in this EA supports DOE's Record of Decision for the *Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (TSR PEIS). This EA tiers from the TSR PEIS and covers only those activities necessary to conduct tests involving irradiation of tritium-producing burnable absorber rods (TPBARs) in a CLWR and post-irradiation examination (PIE) of the TPBARs. The Proposed Action would involve preparation and analysis activities at DOE facilities and irradiation of the TPBARs at a commercial nuclear power reactor. This confirmatory test draws on over 10 years of DOE research and development devoted to the safe and efficient production of tritium in CLWRs.

If the Proposed Action is found to be a major federal action that significantly affects the quality of the human environment, an environmental impact statement will be prepared. If the Proposed Action is not found to constitute a major federal action that significantly affects the quality of the environment, a Finding of No Significant Impact (FONSI) will be issued and the action will proceed. Criteria used to evaluate the significance can be found in the Code of Federal Regulations (CFR) at 40 CFR 1508.27.

This EA was prepared in compliance with the National Environmental Policy Act (NEPA) of 1969 (as amended), the Council on Environmental Quality (CEQ) regulations for Implementing the Procedural Provisions of NEPA (40 CFR 1500-1508), and the U.S. Department of Energy NEPA regulations (10 CFR 1021). The Tennessee Valley Authority (TVA) is participating with the DOE as a cooperating agency in the preparation of this EA, in accordance with its established procedures for implementing NEPA requirements. The following is a description of each section of this environmental assessment:

1.0 Purpose and Need for Agency Action provides a brief statement and background information concerning the issue the DOE is addressing with the Proposed Action.

2.0 Proposed Action contains a description of the Proposed Action.

3.0 Alternatives to the Proposed Action contains a description of alternative actions that meet DOE's defined purpose and need, as well as a description of a no-action alternative.

4.0 Affected Environment provides a brief description of the sites and associated environment in which the Proposed Action would occur.

5.0 Environmental Impacts identifies and describes the range of environmental impacts, beneficial and adverse, that might occur if the Proposed Action were implemented. Impacts of alternatives are also briefly discussed.

6.0 Permits and Regulatory Requirements identifies and describes regulatory requirements and permits that are applicable to the Proposed Action.

7.0 Agencies and Organizations Consulted identifies outside agencies that were or will be contacted as part of the process of preparing the environmental documentation .

# 1.0 Purpose and Need for Agency Action

The U.S. Department of Energy (DOE) needs to confirm the viability of using a commercial light water reactor (CLWR) as a potential source for maintaining the nation's supply of tritium. The Proposed Action discussed in this environmental assessment is a limited scale confirmatory test that would provide DOE with information needed to assess that option.

## Background

DOE's *Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (TSR PEIS), described the need for a new source of tritium for defense purposes as summarized in the following (DOE 1995a).

Since nuclear weapons were developed in 1945, a nuclear deterrent has been a cornerstone of the nation's defense policy and national security. Tritium is used to enhance the yield of current nuclear weapons and allows for the production of smaller or more powerful devices. The United States has based its strategic nuclear systems on designs that use tritium and therefore requires a reliable source of this material in order to maintain the nuclear weapons stockpile as required by law.

Tritium has a relatively short radioactive half-life of 12.3 years. Because of this relatively rapid radioactive decay, tritium must be replenished periodically in nuclear weapons to ensure that they will function as designed. Over the past 40 years, DOE has built and operated 14 reactors to produce tritium and other nuclear materials for weapons purposes. Today, none of these reactors is operational, and no tritium has been produced since 1988.

Until a new source of tritium is operational, DOE will continue to meet tritium requirements by recycling tritium from existing weapons as they are retired from the weapons stockpile. However, because tritium decays relatively rapidly, recycling can only meet tritium demands for a limited time. Current predictions of future stockpile scenarios indicate that recycled tritium will adequately support the nation's nuclear stockpile until approximately 2005. (At the time the TSR PEIS was published, a previous assessment of the need for new tritium had placed that date at 2011; the current target date of 2005 is based on a more recent analysis). The tritium supply and recycling facilities as proposed in the TSR PEIS would provide the capability to produce tritium safely and reliably in order to meet the nation's defense requirements well into the 21st century while also complying with environmental, safety, and health standards.

In the TSR PEIS, DOE proposed several alternatives to provide a new source of tritium for the nuclear weapons program (DOE 1995a). The TSR PEIS evaluated alternatives for the siting, construction, and operation of tritium supply technology and recycling facilities at each of five candidate sites: the Idaho National Engineering and Environmental Laboratory (INEEL) in Idaho, the Nevada Test Site (NTS) in Nevada, the Oak Ridge Reservation (ORR) in Tennessee, the Pantex Plant in Texas, and the Savannah River Site (SRS) in South Carolina.

The TSR PEIS included an analysis of the use of a light water reactor (LWR) as well as the use of an accelerator for production of tritium. As part of the LWR alternative, DOE considered the purchase of an operating or partially completed commercial power reactor, or purchasing irradiation services from an existing CLWR. A combination of the CLWR and accelerator alternatives (one option to serve as the primary tritium source with the other serving as the backup source) was selected in the TSR PEIS Record of Decision (60 FR 63877-63891). A decision is expected by the end of 1998 to determine which option will be the primary source for tritium and which will serve as the backup source.

This EA tiers from the TSR PEIS and covers only those activities necessary to conduct tests involving irradiation of tritium-producing burnable absorber rods (TPBARs) in a CLWR and post-irradiation examination (PIE) of the TPBARs. Aspects of the actual tritium production program or operations at the CLWR used to irradiate the TPBARs are, or would be, addressed by separate NEPA documentation. The commercial reactor proposed to perform the irradiation in this EA may or may not be the reactor selected for actual tritium production in the future. If the CLWR alternative is selected to be a primary or backup tritium source, the selection of the specific reactor(s) eventually used for the production mission would be addressed by a separate site-specific NEPA analysis.

## 2.0 Proposed Action

The Department of Energy's Proposed Action is described in the following sections.

### 2.1 Background

Irradiation of TPBARs in a CLWR is being evaluated as a reasonable alternative for meeting the need to replenish the supply of tritium for nuclear weapons. It is also being considered as a backup source, should the accelerator alternative be selected as the primary tritium source, in order to ensure that adequate supplies of tritium would be available. The TPBARs used in the proposed tests would both replace and function as a standard burnable absorber assembly in a CLWR. The function of the reactor, the absorber assembly and the TPBARs is described below.

The TPBARs have been designed for use in a pressurized water reactor (PWR) of the type developed commercially by Westinghouse. The LWRs used to generate electric power in the United States utilize both PWR and boiling water reactor (BWR) technologies. However, use of a BWR to produce tritium would require technology different from that involved in using a PWR of the design proposed for this test. Specifically, to produce tritium most BWR designs would require production of specially designed fuel or reconfiguration of the reactor core to accommodate separate tritium targets. As a result of these considerations, and because of the extensive research and development that has already occurred using PWR technology, the Proposed Action described in this EA involves the use of a PWR.

Commercial PWRs produce electricity by creating steam to drive a steam turbine generator. In a typical large PWR, heat is generated by nuclear fission in the reactor core and transferred to the turbine via steam produced in a heat exchanger. The side of the heat exchanger that is connected to the reactor vessel (referred to as the "primary" side) is isolated from the side that supplies steam to the turbine (the "secondary" side of the heat exchanger) so that water in contact with the reactor core is effectively contained within the reactor vessel and the primary side of the heat exchanger under normal operating conditions.

The reactor core contains fuel assemblies, coolant, a neutron moderator (a material that slows neutrons), and devices to control the nuclear fission reaction. In U.S. commercial power reactors, the fuel consists of uranium slightly enriched (less than 5%) in the fissile isotope uranium-235 (U-235), which is typically fabricated into fuel elements as a series of stacked pellets within a cylindrical metal cladding. A number of individual fuel elements are then bundled into a larger unit, referred to as a fuel assembly, for ease of handling during shipping and refueling.

Water provides both the coolant and neutron moderator functions in a LWR. The moderator in a reactor serves to reduce the energy of neutrons generated by the fission process. The lower energy neutrons are more readily absorbed by U-235 in the fuel to produce additional fissions, thereby sustaining a fission "chain reaction." The primary coolant circulates through the reactor core to remove heat and carry it to the heat exchanger, where the heat is transferred to the secondary coolant (also water in the case of commercial PWRs) which is converted to steam to drive the turbine generator.

The power level in the core of the reactor is regulated in part by devices that contain neutron-absorbing materials, typically cadmium or boron, which prevent neutrons from interacting with fuel to produce fission reactions. These materials are incorporated into "control rods" which can be inserted into spaces within or between the fuel assemblies to control the power level in that region of the core. The control rods are configured in such a way that the nuclear reaction is completely shut down when all of the control rods are fully inserted.

The power level in the region of new fuel assemblies can also be regulated by incorporating neutron absorbing materials directly into the fuel elements or assemblies, thereby maintaining a more uniform power density throughout the core and extending the useful life of the new fuel elements. The absorbers in the fuel assemblies consist of isotopes that readily absorb neutrons, and in the process are transformed into different isotopes that absorb neutrons less efficiently (hence, they are referred to as "burnable" absorbers). As the active fuel in the assembly is depleted, the neutron absorber in the assembly is also depleted. When a fuel assembly becomes sufficiently depleted of fissile material that it cannot sustain the required power level, it must be removed from the reactor and replaced by a new fuel

assembly. CLWRs typically replace part of their fuel on a rotating schedule every 12-18 months, a process referred to as the "refueling cycle."

The fuel assemblies in PWRs of the design proposed for the TPBAR irradiation consist of fuel element lattices that contain spaces in the lattice into which either burnable absorber rods or control rods may be inserted. If the fuel assemblies are to contain burnable absorbers, the absorber material is incorporated into separate rods that fit into the lattice openings. The absorber material used for many commercial PWRs consists of borosilicate glass encased in a stainless steel cladding. The absorber rods are attached to a hold-down plate that, in turn, fits into the top of the fuel assembly. The burnable absorber assemblies can be removed from the fuel assemblies after the fuel has been through one operating cycle. This fuel configuration is convenient for the proposed tests because the TPBARs can be incorporated into fuel assemblies in place of the conventional burnable absorber rods. The major difference between conventional PWR burnable absorber rods and the TPBARs would be the use of a lithium aluminate ceramic as a neutron absorber in place of the standard borosilicate glass. At the end of the operating cycle, the TPBAR assemblies could then be removed from the host fuel assemblies and shipped for examination without the need to transport or handle the irradiated fuel.

When a utility desires to implement design modifications in a commercial reactor that may affect fuel performance or other systems that provide reactivity control (such as substituting TPBARs for the conventional burnable absorber rods), a lead test assembly (LTA) program can be conducted to confirm specific expected behavior in a reactor. An LTA program usually consists of a limited number of assemblies of the proposed new design (typically an even number for symmetry), which are inserted into the reactor core at the beginning of an operating cycle in order to demonstrate satisfactory performance of the components. Such a program is appropriate for the use of TPBARs containing lithium in place of the standard boron neutron absorbers in a PWR burnable absorber assembly.

The Proposed Action expands upon more than ten years of DOE research and development activities associated with tritium production targets for LWRs. As part of this research, target irradiation, PIE, and safety testing has been performed entirely at DOE facilities. During the Proposed Action, the NRC would oversee activities that take place at its licensee facilities. The NRC is currently reviewing a technical report prepared by DOE to document the performance and safety basis for the TPBAR design (Erickson et al 1997), and is expected to issue a safety evaluation report with regard to the proposed tests prior to their commencement.

## **2.2 Description of the Proposed Action**

The Proposed Action would confirm the results of developmental testing conducted previously at DOE facilities and provide DOE with information regarding the actual performance of the TPBARs in a CLWR. It would also demonstrate that tritium production could be carried out within the normal operating and regulatory constraints associated with a commercial nuclear power facility, without affecting the plant's safety systems, production capacity, or normal operations. These activities would provide added confidence to the utilities and the NRC, which regulates commercial power reactors, that tritium production in a CLWR could meet national security needs in a technically straightforward, safe and cost effective manner.

Activities associated with the Proposed Action include replacing four conventional PWR burnable absorber assemblies with assemblies containing the TPBARs (referred to as TPBAR-LTAs) during the next refueling outage at the Watts Bar Nuclear plant (WBN), Unit 1 in southeastern Tennessee. The TPBARs would be shipped from the Hanford Site near Richland, Washington to the Westinghouse fuel fabrication facility in Columbia, South Carolina, for assembly into TPBAR-LTAs (see Figure 2.2). The TPBAR-LTAs would be inserted into four new fuel assemblies at Westinghouse. The fuel assemblies with the TPBAR-LTAs (hereafter referred to as "integrated assemblies") would then be shipped to WBN with the rest of the new fuel and stored until the next refueling outage, when they would be inserted into the reactor. A typical fuel reload would contain more than 1000 burnable absorber rods, of which 32 would be replaced by the TPBARs in the proposed test.

The TPBAR-LTAs would be irradiated for one complete operating cycle (approximately 18 months), following which they would be removed from the integrated assemblies and stored in the spent fuel pool. The fuel assemblies would be placed back in the reactor as part of the refueling process. The TPBAR-LTAs would be shipped to the Pacific

Northwest National Laboratory (PNNL) at Hanford for post-irradiation examination (PIE). Because the fuel assemblies from the integrated assemblies could be returned to the reactor core during refueling, no shipment or disposal of spent nuclear fuel would be required as part of the Proposed Action.

As part of the PIE activities at Hanford, the TPBARs would be removed from the remaining hardware. The TPBARs would then be subjected to non-destructive evaluation (NDE), including a visual inspection and gamma radiography. The TPBARs would also be punctured to collect and analyze any gases that accumulate during irradiation, and the penetrations would be sealed before the TPBARs are stored or processed further.

After the initial NDE at PNNL, the TPBARs may also be examined by neutron radiography at a facility yet to be determined. For the purposes of this analysis, neutron radiography was assumed to take place at the Hot Fuels Examination Facility (HFEF) located at the Argonne National Laboratory-West (ANL-W) near Idaho Falls, Idaho. Upon completion of the neutron radiography, the TPBARs would be returned to PNNL for destructive examination. For this evaluation, laboratory wastes that result from the destructive examinations, intact spent TPBARs, and residual equipment and materials that remain from cleaning out the facilities are assumed to be dispositioned as waste at the Hanford Site. The small quantities of radioactive waste that may be generated at other locations would be disposed with similar wastes from those facilities. Additional information about each phase of the Proposed Action is provided in the following sections. See Figure 2.1 for a graphical depiction of the Proposed Action.

### **2.2.1. Pre-Irradiation Transport and Assembly of TPBAR-LTAs**

Initially, the TPBARs would be shipped from the Hanford Site to the Westinghouse fuel fabrication facility for assembly into the TPBAR-LTAs. Prior to placement in the reactor, the TPBARs are not radioactive nor do they contain hazardous materials as defined by the Department of Transportation (DOT) in 49 CFR Part 171-178. (Figure 2.3 depicts transportation route options for the Proposed Action.)

Thirty-two TPBARs (plus a limited number of spares) would be required for the Proposed Action. General information regarding the TPBAR design is included in this section; Appendix A contains additional information. The exterior dimensions of the TPBAR are compatible with those of a standard Westinghouse burnable absorber rod - approximately 0.381 inch (1 cm) in diameter and 152 inches (390 cm) long. The TPBARs contain lithium aluminate absorber in the form of stacked cylindrical elements, a Zircaloy-4 liner, and a nickel-plated zirconium "getter" to trap and retain the tritium in a solid matrix. The getter is an effective mechanism to contain the tritium. In fact, it is extremely difficult to extract the tritium from the getter which requires very high temperatures for an extended period of time. The TPBAR cladding consists of Type 316 stainless steel with a wall thickness of 0.0225 inch (0.057 cm). The cladding also has an aluminum coating to minimize permeation of hydrogen. The TPBAR end plugs are of a standard Westinghouse design and are seal-welded in place.

At the Westinghouse fuel fabrication facility, 8 TPBARs and 16 thimble plugs would be attached to a hold-down assembly to make up a single TPBAR-LTA (which contains 24 possible burnable absorber rod locations). Figure 2.2 depicts the TPBAR-LTA. Each TPBAR-LTA would undergo a standard acceptance inspection before incorporating it into an integrated fuel assembly. Four TPBAR-LTAs would be prepared, each of which would be placed into one fuel assembly to provide the four integrated assemblies required for the LTA program. The integrated assemblies containing the TPBAR-LTAs would be loaded into standard unirradiated fuel shipping containers and transported to WBN. The shipments would likely utilize a commercial carrier authorized to transport radioactive materials of low-specific-activity.

### **2.2.2 Irradiation**

The integrated assemblies containing the TPBAR-LTAs would be received at WBN and transported through the truck bay door, into the truck bay, and through the truck bay overhead hatches to the refueling floor. The integrated assemblies and the rest of the new fuel would undergo a receiving inspection, following which they would be stored in preparation for loading into the reactor core during the refueling outage.

The TPBAR-LTAs would remain in the core for one operating cycle and would receive approximately 450 to 550

effective full power days (EFPD) of exposure. After one cycle of irradiation, during the next refueling outage, the integrated assemblies would be removed from the reactor core and transported under water to the spent fuel pool. The TPBAR-LTAs would then be removed from the integrated assemblies, and the fuel assemblies that held the TPBAR-LTAs would be reloaded into the reactor core with the new reload fuel.

### **2.2.3 Post-Irradiation Transportation**

Following the refueling, an NRC-certified Type B shipping cask would be shipped to WBN and transported to the spent fuel pool floor through the previously described path. No cool down period is necessary for transport of the TPBAR-LTAs; therefore, the shipment would likely occur after the refueling outage to minimize operational impacts on the WBN restart. The cask would be placed in the fuel cask loading area in the spent fuel pool, and one or two of the TPBAR-LTAs would be loaded into the cask under water. The loaded cask would be lifted out of the spent fuel pool and moved to the cask wash down area. The cask would be washed down, drained, decontaminated, transported to the truck bay, and loaded on a truck. Up to 4 exclusive use shipments would be used to transport the cask containing the irradiated TPBAR-LTAs to the 325 Building at Hanford.

### **2.2.4. Post-Irradiation Examination**

Post-irradiation examinations would be performed at the Hanford Site 325 Building and possibly at a neutron radiography facility to be identified in the future. PNNL would conduct all PIE activities other than the neutron radiography.

The 325 Building in the Hanford Site 300 Area houses a variety of laboratories, three hot cells and a cask unloading gallery in the rear of the cells. (See Figure 2.4) Some construction would be necessary in order to accept and unload the shipping cask at the 325 Building. The construction would consist of making a new penetration in the south wall of the "A" hot cell and installing an access door. Some additional modifications would be required to relocate a stairway inside the building but external to the hot cell. However, all of the planned construction activities would be performed inside the current building footprint, and no construction external to the building would be required.

After the cask is unloaded at the Hanford 325 Building, the TPBAR-LTAs would be moved to the "A" cell facility through the new access port. The TPBAR-LTAs would be disassembled inside the "A" cell, and all ancillary hardware (such as the hold down assembly, attachment nuts, and thimble plugs) would be packaged and dispositioned as low level radioactive waste. The TPBARs would undergo an initial non-destructive evaluation, including a visual inspection and gamma radiography. All of the TPBARs may then be punctured to collect and analyze any gases that accumulated during irradiation, and the penetrations would be resealed prior to storage or further handling.

If neutron radiography is to be performed, all of the TPBARs would be loaded into an NRC-certified Type B shipping cask and transported to the neutron radiography facility for additional non-destructive examination. The HFEF at ANL-W was analyzed as a representative location for this activity. The HFEF is used by DOE for neutron radiography on a variety of materials including components similar to the TPBARs. The HFEF can only radiograph a 9' 6" (2.9 m) length; thus each rod would be flipped end-to-end such that a radiograph of the full length of the rod can be obtained. Upon completion of neutron radiography, the TPBARs would be reloaded into the shipping cask and returned to Hanford.

The TPBARs would be stored in sealed containers within the 325 Building hot cell facility until they are removed for destructive examination. Destructive examination of the TPBARs involves 2 major activities:

- Sectioning the TPBARs into small pieces to examine structural changes in the cladding and internal components as a result of irradiation and
- Extracting tritium from the TPBARs to determine production and recovery levels.

For sectioning, at least one TPBAR from each TPBAR-LTA would be moved into the "B" cell facility and cut in preparation for examination. Helium, lithium, tritium, and protium assays would be performed on various sections from the TPBARs. Metallographic examinations would also be performed on various components including the

cladding. Extraction of tritium from the TPBARs involves puncturing and heating the TPBARs in a closed system to drive off tritium trapped in the solid components. The gases are then collected and analyzed to determine the quantity and chemical state of recovered tritium. In addition to the PIE tests, additional experiments to evaluate the permeability of the TPBAR cladding material to tritium would also be conducted using tritium from a commercial source. Examination of small samples from the TPBARs may take place in other laboratories within the 325 building or at another appropriate laboratory in the 300 Area. Depending on the results of the destructive examinations, additional TPBARs (up to all 32) may be selected for further examination.

### **2.2.5. Interim Storage and Waste Disposition**

Any TPBARs that are not subjected to destructive examination would be stored at Hanford until another use for them is identified or DOE decides to dispose of them. Prior to disposal, the tritium would be extracted from any remaining intact TPBARs and recovered for other purposes or packaged separately for disposal.

Preparation of the integrated assemblies at the Westinghouse fuel fabrication facility would not produce any radioactive or hazardous wastes in addition to those typically generated at the facility. Wastes associated with irradiation of the integrated assemblies at WBN would consist of low-level radioactive liquids and solids generated as the TPBAR-LTAs are removed from the spent fuel pool and packaged for shipment to Hanford. These wastes would be treated as appropriate and disposed of at an NRC-licensed commercial facility with wastes from routine operations at WBN.

Wastes produced during disassembly of the TPBAR-LTAs and NDE of the TPBARs at Hanford would consist of laboratory materials and protective clothing used to prevent possible spread of contamination during receipt, handling, and examination. Those wastes would be disposed of at Hanford in facilities appropriate to the waste type. Likewise, any radioactive waste generated by neutron radiography at ANL-W would consist of small quantities of laboratory materials used to survey the shipping cask for external contamination and disposable protective clothing such as gloves. Waste generated during activities at ANL-W would be managed onsite at the INEEL.

The quantities of low-level radioactive waste generated during destructive PIE of the TPBARs at Hanford would consist of cuttings and small sections of the cladding and internal components, laboratory materials used to control spread of contamination, and either solid molecular sieve or bubbler liquids used to trap the tritium contained in gaseous effluents from the sectioning and extraction processes. Smaller quantities of mixed low-level waste could be produced during liquid scintillation counting of tritium samples, and a small quantity of nonradioactive hazardous wastes would be produced during the laboratory activities as well. Additional radioactive wastes would result from decontamination of the hot cells and removal of unneeded equipment after the work is completed. All radioactive and hazardous wastes generated at Hanford would be disposed of either at the onsite burial grounds or in permitted commercial disposal facilities in accordance with applicable state and federal regulations. Mixed low-level wastes would be stored onsite in permitted facilities. Section 5.3 of this EA contains additional information concerning waste management.

## **3.0 Alternatives to the Proposed Action**

The Department has considered three alternatives to the Proposed Action, including: no action; irradiation at another reactor, with analysis at other DOE laboratories; and use of a private hot cell facility to analyze the irradiated TPBARs. Each alternative is discussed in this section.

### **3.1 No Action**

Under a no-action alternative, DOE would not conduct the LTA program or post-irradiation examinations. The final selection of either a CLWR or an accelerator as the nation's primary tritium source would be made without the benefit of the results of this proposed project. The no-action alternative is not consistent with the Department's purpose and need and therefore was not considered reasonable. However, evaluation of the No Action alternative is required by NEPA as a baseline against which to assess the impacts of the Proposed Action and alternatives.

### **3.2 Irradiation at Other Reactor/Analysis at Other DOE Laboratory**

DOE has considered the use of another commercial reactor to conduct the LTA program, as well as the use of other DOE laboratory facilities for examining the TPBARs. WBN was proposed for these tests because its refueling schedule provided optimum timing for obtaining the performance data needed by DOE, and because it was the only reactor of compatible design that was not encumbered by vendor restrictions on use of its fuel or other components for defense-related research. All other U.S. PWRs of this design obtain their fuel from foreign vendors that impose contractual restrictions on use of their products for defense-related purposes. Use of any facility other than WBN would have required DOE to replace all of the reactor's fuel, resulting in possible delay of the tests as well as substantially increased cost. Therefore, DOE considered options other than use of WBN to be unreasonable for the proposed tests. A future, separate evaluation process would identify one or more facilities for the actual tritium production mission. Reactors owned by DOE (such as the Fast Flux Test Facility [FFTF] at Hanford or the Advanced Test Reactor at the INEEL) or reactors operated by universities were not considered reasonable alternatives because they do not meet the purpose of, and need for, the Proposed Action, which is to demonstrate the viability of producing tritium in a CLWR.

Other DOE laboratories could perform the post-irradiation activities if the technology were transferred to those laboratories, and if the laboratories possessed hot cells large enough to contain the full length of the TPBAR-LTAs. This alternative was not considered reasonable because Hanford has the technology for post-irradiation examination of the TPBARs. Further, Hanford has hot cells suited for this purpose and has conducted similar types of examinations in the past. Use of alternate facilities would introduce technical uncertainties and impact both the schedule and cost for the proposed tests; therefore, this alternative has not been evaluated in detail.

### **3.3 Analysis at Private Facility**

DOE has also considered the use of a private hot cell facility to conduct the analysis on the irradiated TPBARs. However, hot cells with the ability to handle the quantities of radioactive materials involved and to accommodate the full-length assemblies are generally not available outside the DOE complex. The exception would be a commercial nuclear fuel fabrication facility which is owned by a foreign corporation. However, the security measures required to perform the work in a foreign-owned facility would be difficult to implement. For these reasons, use of non-DOE facilities was not considered reasonable and is not evaluated further.

## **4.0 Affected Environment**

This section provides an overview of the environmental characteristics of the Hanford Site, WBN, and the ANL-W facilities, as well as site-specific characteristics of Hanford's 300 Area where most of the proposed post-irradiation examination activities would take place. Additional information about the Hanford Site can be found in the *Hanford Site National Environmental Policy Act (NEPA) Characterization* (Neitzel 1996), and the WBN environment is described in the *Final Environmental Statement related to the Operation of Watts Bar Nuclear Plant, Units 1 and 2* (NRC 1995).

### **4.1 Hanford Site Description**

The proposed analysis activities would take place in the 300 Area of the Hanford Site. (See Figure 4.1) The Hanford Site covers 1450 square kilometers (560 square miles) of south-central Washington State. It is a semi-arid region of rolling topography, with some trees along the Columbia River. Two topographical features dominate the landscape: Rattlesnake Mountain, a treeless 1074-meter (3525 feet) anticline located on the southwest boundary, and Gable Mountain, a small ridge 339 meters (1,112 feet) high, located on the northern portion of the Site.

The Hanford Site is located in the Pasco Basin, one of the structural and topographic basins of the Columbia Plateau. Thick basalt flows (greater than 3650 meters [12,000 feet] thick) underlie sedimentary material consisting of silts, sands, and gravel (Hanford Formation and Ringold Formation). The sedimentary deposits are moisture deficient and

have a high capacity to adsorb and retain cations (Neitzel 1996).

The Columbia River, the dominant river in the region, flows through the northern part of the Hanford Site and forms part of the Hanford Site's eastern boundary. An 84-kilometer (52-mile) stretch of the Columbia River between the 300 Area and Priest Rapids Dam (river mile 345 to 396) is known as the Hanford Reach. This section of the river has been evaluated by the National Park Service for possible inclusion in the National Wild and Scenic Rivers system, but no final action has been taken by Congress.

The Hanford Site is a shrub-steppe community of sagebrush and rabbitbrush, with an understory consisting primarily of cheatgrass and Sandberg's bluegrass. More than 300 species of insects, 39 species of mammals, 36 common species of birds, and 12 species of reptiles and amphibians have been identified on the Hanford Site.

Areas adjacent to the Hanford Site are primarily agricultural lands. The city of Richland, Washington (population 32,315), located in Benton County, adjoins the southernmost portion of the Hanford Site boundary and is the nearest population center.

The leading employers who affect the local economy are the DOE and its contractors; the Washington Public Power Supply System; and the agricultural sector, including food processing plants. Other major employers include a nuclear fuel fabrication plant, a meat packing plant, a pulp and paper mill, railroad, and small manufacturing firms.

Non-DOE facilities located at the Hanford Site include a commercial nuclear power plant operated by the Washington Public Power Supply System (WNP-2) and a commercial low-level radioactive waste disposal facility administered by the State of Washington and operated by U.S. Ecology, Inc. A privately owned specialty metal products fabrication enterprise is also located in a former DOE facility at the north end of the 300 Area.

Government facilities located on the Hanford Site include the following: waste management facilities (solid and liquid wastes), nuclear materials storage facilities, research laboratories, decontamination facilities, a research reactor (the FFTF, which is now on standby status), and deactivated facilities. Also, nine inactive production reactors and three inactive spent fuel reprocessing plants exist on the site.

During 1995, DOE facilities at the Hanford Site discharged approximately 6.7 Ci of tritium to the atmosphere, most of which originated in the 300 Area. Other atmospheric releases of radionuclides amounted to about 80 Ci of radon, 0.0007 Ci of transuranic isotopes, and 0.01 Ci of other fission and activation products. These estimated emissions did not result in air concentrations at the site perimeter that were statistically elevated compared with background concentrations at distant communities, with the exception of air concentrations for I-129. The Hanford Site complied with all federal, state, and local standards for radiological and nonradiological air quality in 1995 (Dirkes and Hanf 1996).

In addition to emissions from DOE facilities, the WNP-2 commercial nuclear power facility at Hanford discharges radionuclides to the atmosphere. In 1993, a year when the plant was operating at near capacity, these emissions amounted to 150 Ci of tritium, 140 Ci of noble gases, and 10 Ci of other fission and activation products (Tichler et al 1995).

Radioactive and hazardous wastes generated at the Hanford site in 1995 amounted to 1900 metric tons ( $4.2 \times 10^6$  lb) of radioactive waste, 130 metric tons of mixed radioactive and hazardous waste, and 800 metric tons ( $1.8 \times 10^6$  lb) of hazardous solids and liquids. Those radioactive and mixed wastes contained about 27,000 Ci of tritium, 44,000 Ci of activation products, and 34,000 Ci of other radionuclides (Dirkes and Hanf 1996). Low-level radioactive wastes are buried onsite in the 200 Areas, and mixed wastes are stored in permitted facilities in the 200-W Area. Nonradioactive hazardous wastes are shipped offsite for treatment and disposal at permitted facilities.

## **4.2 The 300 Area of the Hanford Site**

The 300 Area of the Hanford Site is north of the city of Richland and is contiguous to the Columbia River (see Figure 4.2). The 300 Area served as the research and development center and housed fuel fabrication facilities during the

operational phase of the Hanford Site's production reactors. The 325 Building is located about 1.9 kilometers (1.2 miles) north of Richland and 1.3 km (0.8 mile) from the far shore of the Columbia River.

The 300 Area of the Hanford Site is characterized by relatively cool, mild winters and warm summers with an average of about 15 to 18 centimeters (6 to 7 inches) of annual precipitation and occasional high winds of up to 129 kilometers (80 miles) per hour. No tornados have been reported on site; the area has low to moderate seismicity.

The terrestrial and aquatic ecology of the 300 Area closely resembles those ecological characteristics associated with being near the Columbia River. In this area, communities of wouldow-riparian vegetation are prominent. California quail, Chinese ring-necked pheasants, and mammals such as raccoons, beavers, and porcupines are likely to be found near the river. A Biological Review was completed for the 300 Area in May 1996 (see Appendix B).

### **4.3 Watts Bar Nuclear Plant**

The following has been excerpted from the Final Safety Analysis Report for WBN (TVA 1991).

WBN occupies approximately 710 ha (1770) acres in Southeastern Tennessee (see Figure 4.3). The facility is situated on the west shore of Chickamauga Lake and is approximately 80 km (50 miles) northeast of Chattanooga and 50 km (31 miles) northeast of the Sequoyah Nuclear Plant site.

The plant is located in the Valley and Ridge Province of the Appalachian Highlands. The province is made up of a series of folded and faulted mountains and valleys which are underlain by Paleozoic sedimentary formations totaling 12,000 m (40,000 ft) in thickness. The plant site is situated in a bend of the Tennessee River that has been covered by alluvial terrace deposits. Beneath these deposits lies the Middle Cambrian Conasauga Formation, an interbedded shale and limestone unit upon which the Category I structures are founded.

The controlling feature of the geologic structure at the site is the Kingston thrust fault, which developed 250 million years ago. The fault has been inactive for many millions of years, and recurrence of movement is not expected. The fault lies to the northwest of the site area and is not involved in the foundation for any of the major plant structures.

WBN was designed based on the largest historic earthquake to occur in the Southern Appalachian Tectonic Province - the 1897 Giles County, Virginia earthquake. This earthquake is estimated to have had a body wave magnitude of 5.8. The Safe Shutdown Earthquake for the plant has been established as having a maximum horizontal acceleration of 0.18 g and a simultaneous maximum vertical acceleration of 0.12 g.

Because of the contours of the land and strata there is little likelihood of abnormal releases of liquid wastes at the plant contaminating industrial or drinking water supplies derived from ground water sources.

No known meteorological measurements other than rainfall have been recorded in the immediate vicinity of the Watts Bar site. Therefore, the climatological appraisal of the site has been developed from meteorological data collected at stations within 80 km (50 mi). A permanent onsite meteorological facility has been in operation since May 1973 to meet NRC requirements. The FSAR indicates that there are no limiting meteorological factors present at the site.

The population density of the area surrounding the site is relatively low, and only two cities within 100 km (60 mi) of the plant (Chattanooga and Knoxville) have populations exceeding 100,000 people.

Radionuclide emissions to the atmosphere from WBN were estimated to consist of 13,000 Ci of noble gases and 0.34 Ci of iodine-131 per year with both units operating (NRC 1995). Because only one of the units is currently operational, the atmospheric emissions are estimated to be approximately half of those reported for both units, or 6500 Ci of noble gases and 0.17 Ci/yr of iodine-131. WBN has been operating for less than 1 year; therefore, results of annual effluent monitoring and ambient air quality monitoring are not yet available. However, the impacts of these emissions are expected to be well within NRC and EPA standards.

Liquid effluents discharged from WBN are regulated by the State of Tennessee under a permit issued in accordance with the federal Clean Water Act. These effluents are not expected to affect water quality in the Tennessee River or to

limit public uses of the waterway. Annual releases of radionuclides in liquid effluents were estimated to amount to 2600 Ci of tritium and 6.6 Ci of other radionuclides when both units are operating (NRC 1995). The estimated emissions for operation of one unit are therefore about 1300 Ci/yr of tritium and 3.3 Ci/yr of other radionuclides. These emissions are also expected to be well within federal and state standards for members of the public.

Low-level radioactive wastes generated at WBN for operation of both units are expected to amount to 150 m<sup>3</sup> (200 yd<sup>3</sup>) of ion exchange resins and filters, 40 m<sup>3</sup> (53 yd<sup>3</sup>) of other dry waste (after compaction), and 3 m<sup>3</sup> (4 yd<sup>3</sup>) of irradiated components per year (NRC 1995). Radioactive wastes generated at the plant are shipped to a commercial facility licensed by the NRC for disposal.

#### **4.4 Argonne National Laboratory-West**

Argonne National Laboratory-West (ANL-W), located at a desert site in Idaho on the INEEL, is part of the Argonne National Laboratory (ANL). ANL is a non-profit research Laboratory operated by the University of Chicago for the Department of Energy.

The ANL-W and INEEL are located in southeastern Idaho, about 44 km (27 mi) west of Idaho Falls (Figure 4.4). ANL-W is located in the southeast portion of the site, approximately 8.7 km from the site boundary. The northern and western borders of the INEEL site are roughly formed by the Bitterroot, Lemhi, and Lost River mountain ranges. The site encompasses 2312 km<sup>2</sup> (893 mi<sup>2</sup>) in Butte, Bingham, Jefferson, Bonneville, and Clark counties, Idaho. About 145 km (90 mi) of paved public highways run through the INEEL site, including U.S. highways 20 and 26, and state routes 22, 28, and 33. Other transportation routes include Interstate 15 and U.S. highways 93A and 191.

The INEEL is located in southeastern Idaho with Mud Lake to the east; Arco, Butte City, and Howe to the west; and Atomic City to the south. The larger communities of Idaho Falls, Rexburg, Blackfoot, Pocatello, and Chubbock are to the east and southeast of the INEEL site. The Fort Hall Indian Reservation is to the southeast of the INEEL. The Bitterroot, Lemhi, and Lost River mountain ranges border the INEEL site on the north and west. Most of the INEEL site consists of open undeveloped land, covered predominantly by large sagebrush and grasslands. Pasture and irrigated farmland border much of the INEEL site. The Craters of the Moon National Monument is about 24 km (15 mi) southwest of the INEEL site western boundary.

Examinations conducted in the Hot Fuels Examination Facility (HFEF) provide data that are essential for determining the performance of fuels and materials irradiated in the Experimental Breeder Reactor II (EBR-II), Transient Test Facility (TREAT), and other DOE reactor facilities. HFEF, which went into operation in 1975, consists of two shielded hot cells, the decontamination cell which contains an air atmosphere and the main cell which contains an argon gas atmosphere. Both cells are surrounded by high-density concrete walls, four feet thick, that protect workers from the high radiation levels present in the cells. Each of the twenty-one workstations in HFEF are equipped with shielded windows (also four feet thick) and master/slave manipulators. The main cell, with its inert argon gas atmosphere, is utilized for work involving exposure of materials such as sodium, plutonium, and other materials that would react chemically with air.

HFEF has several features that make it suited for examining irradiated fuels and materials experiments. The main cell is designed for containment of any plutonium contamination that may be released during the handling and examination of irradiated experiments. The cell is also designed for the vertical handling, cutup, and examination of experiments up to about 9 m (30 ft) in length. Much of the in-cell examination equipment for fuel elements is automated or semi-automated. All of the in-cell equipment is carefully designed to permit remote maintenance. No personnel entry has been required into the main cell.

Non-destructive in-cell examination capabilities include macro viewing and photography, weighing, precision dimensional surveys, gamma-ray spectroscopy, eddy-current testing, neutron radiography, and fission-gas sampling and assay. Destructive examination capabilities include in-cell equipment for cutting specimens from irradiated hardware or fuel and the preparation of samples for physical testing, chemical analysis, or microscopic examinations. Samples in the main cell are transferred by pneumatic "rabbit" to the ANL-W Analytical Laboratory or to a small

HFEF hot cell, where optical microscopy and scanning electron microscopy are available.

The capability to examine and characterize contact-handled transuranic waste destined for the Waste Isolation Pilot Plant in New Mexico was added to HFEF in 1990. A 250-kW research reactor is located in the basement of HFEF and provides a source of neutrons for neutron radiography. The Neutron Radiography Facility is equipped with two beam tubes and two separate radiography stations.

Specimens are lowered from the HFEF main cell to intersect one of the collimated neutron beams. The second neutron radiography station is outside of the main cell and permits neutron radiography of either unirradiated or irradiated specimens without introducing them into the contaminated main cell.

Other HFEF features include: a computer system for data acquisition and in-cell process control; a microdensitometer that supports neutron tomography (a process similar to medical CAT scanning); and facilities for decontaminating and repairing hot cell equipment and manipulators.

## **5.0 Environmental Impacts of the Proposed Action**

The potential environmental impacts associated with the Proposed Action and alternatives are discussed in this section. Activities associated with the Proposed Action are described in Section 2. Most of these activities would be conducted in conjunction with ongoing operations at each site and would result in minor changes, if any, to the existing impacts of those operations. The impacts of routine operations at the Westinghouse fuel fabrication facility, WBN, and the neutron radiography facility at ANL-W are addressed in this document in the context of cumulative impacts where appropriate.

Consequences associated directly with transporting, irradiating, and examining TPBARs at the identified facilities are discussed in this section. The types of potential impacts evaluated in detail include air quality, water quality, waste disposal, facility accidents, transportation, and health and safety. Impacts in other areas are considered to be minimal and are discussed only as necessary to demonstrate the absence of potential consequences.

### **5.1 Air Quality**

The potential consequences of the Proposed Action on radiological and non-radiological air quality at the respective locations where they would occur are discussed in the following sections.

#### **5.1.1 Atmospheric Emissions of Radionuclides**

Emissions of radionuclides to air from normal operations at DOE facilities are regulated under Subpart H of the National Emission Standards for Hazardous Air Pollutants (NESHAPs) for radionuclides (40 CFR Part 61). Emissions from commercial nuclear power reactors are regulated under 10 CFR Part 50, and doses to the public are limited to the standards in 10 CFR Part 20. Standards for DOE facilities provide that they may not emit radionuclides to air in quantities that would cause any member of the public to receive a dose greater than 10 mrem ( $1 \times 10^{-4}$  Sv) effective dose equivalent (EDE) in any year. Standards in 10 CFR Part 20 for NRC facilities provide that their operations may not result in a dose of greater than 100 mrem/yr ( $1 \times 10^{-3}$  Sv/yr) to any individual from all pathways. State and local standards for radionuclide emissions to the atmosphere are consistent with federal standards at the locations considered in this EA. All facilities used in the Proposed Action would comply with state and federal regulations.

##### *5.1.1.1 Assembly and Incorporation of the TPBAR-LTAs into the Integrated Assemblies*

Incorporation of TPBARs into TPBAR-LTAs at the Westinghouse fuel fabrication facility would not result in radionuclide releases because all materials are nonradioactive prior to irradiation in the reactor. Emissions would not be increased by incorporation of TPBAR-LTAs into the integrated assemblies.

##### *5.1.1.2 Irradiation of TPBAR-LTAs, Transportation, and NDE*

Tritium releases from the TPBAR-LTAs during irradiation at WBN are expected to be less than 214 Ci per year to the reactor's primary coolant system because the TPBARs are designed to retain tritium in a solid matrix (Erickson et al 1997). Because most of the tritium that enters the coolant would remain in liquid form, offsite consequences in terms of air quality are not expected. Tritium emissions during transport and NDE of the TPBARs at Hanford and ANL-W are likewise not anticipated because the TPBARs and hardware would be maintained at all times in a shielded environment or sealed within an NRC-licensed Type B transportation cask.

### 5.1.1.3 Post-Irradiation Examination of TPBARs

Most of the radionuclide releases that could occur would take place during destructive post-irradiation examination (PIE) of the TPBARs at the Hanford Site as they are cut or punctured to determine tritium production levels and to examine their internal structure (see section 2 for a description of the TPBARs). Three major activities associated with PIE have the potential to result in radionuclide releases:

- sectioning of TPBARs to examine their internal structure,
- puncturing and extraction of tritium from TPBARs to determine production and recovery levels, and
- permeability tests of the TPBAR cladding material using a commercial source containing 2000 Ci of tritium.

For this analysis, the range of potential impacts was estimated by assuming that tests are conducted on either the planned number of TPBARs, as noted in Table 5.1, or on all 32 TPBARs as a maximum. The tritium inventory of a single TPBAR was assumed to be 1.2 g (about 12,000 Ci), which represents an upper bound based on their design (Erickson et al 1997).

The consequences of the PIE activities with respect to air quality are summarized in Table 5.1; a detailed description of the assumptions for these estimates appears in Appendix C, Section C.2. The maximum total impact of the planned TPBAR post-irradiation examination activities would amount to less than 0.095 mrem/yr ( $9.5 \times 10^{-7}$  Sv/y) to a maximally exposed member of the public, if all of the activities were conducted within a 1-year period. This represents less than 1% of the 10 mrem/yr ( $1 \times 10^{-4}$  Sv/yr) standard for radionuclide emissions from DOE facilities (40 CFR Part 61, Subpart H). For the maximum case in which all 32 TPBARs are examined, the total would be 0.33 mrem ( $3.3 \times 10^{-6}$  Sv), which corresponds to 3.3% of the standard if all releases occurred within a single year. In reality, these activities would likely be conducted over a longer period, thereby reducing the annual dose to the maximally exposed member of the public.

The dosimetry models incorporated into software used for the analysis assume that tritium is released in the form of water vapor. If any of the estimated releases occur as elemental tritium gas, the dose would be lower than the estimates presented in this section, as discussed in Appendix C, Section C.1. Atmospheric emissions of radionuclides during interim storage or disposal of the TPBAR-LTA hardware and TPBARs are not anticipated.

**Table 5.1 Consequences of Routine Radionuclide Emissions from Post-Irradiation Examination of TPBARs at the Hanford Site 325 Building**

PIE Activities:	Estimated Tritium Emissions (Ci)	Dose to the Maximally Exposed Offsite Resident (mrem)	% of 10 mrem/y Regulatory Standard (40 CFR Part 61)	Collective Dose to Population within 80 km (person-rem)
Sectioning TPBARs				
• 1 TPBAR (see Appendix C)	48	$2.6 \times 10^{-3}$	-	$1.2 \times 10^{-2}$
• Planned (4 TPBARs)	190	$1.1 \times 10^{-2}$	0.11	$4.6 \times 10^{-2}$

• Maximum (32 TPBARs)	1500	$8.5 \times 10^{-2}$	0.85	$3.7 \times 10^{-1}$
Tritium Extraction				
• 1 TPBAR (see Appendix C)	130	$7.3 \times 10^{-3}$	-	$3.1 \times 10^{-2}$
• Planned (10 TPBARs)	1300	$7.3 \times 10^{-2}$	0.73	$3.1 \times 10^{-1}$
• Maximum (32 TPBARs)	4200	$2.3 \times 10^{-1}$	2.3	$1.0 \times 10^0$
Cladding Permeability Tests	200	$1.1 \times 10^{-2}$	0.11	$4.8 \times 10^{-2}$
Total				
• Planned	1700	$9.5 \times 10^{-2}$	0.95	$4.1 \times 10^{-1}$
• Maximum	6000	$3.3 \times 10^{-1}$	3.3	$1.4 \times 10^0$

### 5.1.2 Atmospheric Emissions of Regulated Nonradioactive Materials

Emissions of nonradioactive pollutants that are regulated under other provisions of the Clean Air Act are expected to be within regulatory limits, and they would consist largely of combustion products associated with generating primary or auxiliary power, producing process steam, or heating facilities. These emissions occur in conjunction with ongoing operations at each facility and would not increase because of the Proposed Action.

## 5.2 Water Quality

Of the activities considered in the Proposed Action, only irradiation of the TPBAR-LTAs at WBN has the potential to generate liquid effluents that are routinely released to groundwater or surface waters. None of the other activities, including production of the integrated assemblies, neutron radiography, and PIE, are expected to produce liquid effluents (other than the operating effluents typically generated at the facilities) that might affect water quality at the locations where these activities occur. Small quantities of liquid wastes that may be generated in association with these activities would be treated as appropriate and disposed of as described in section 5.3.

During irradiation of the TPBAR-LTAs at WBN, a small quantity of the tritium produced in the TPBARs may be released into the reactor's primary coolant system (up to a maximum of 6.7 Ci/y per TPBAR, or a total of 214 Ci/yr). Exchange of the primary coolant to maintain water chemistry could ultimately release tritiated water to the environment. However, the dose to the maximally exposed offsite individual from the plant's liquid effluents was estimated to be 0.70 mrem/yr ( $7.0 \times 10^{-6}$  Sv/yr) either with or without the tritium contribution from the TPBARs (Erickson et al 1997). That dose represents about 23% of the 3 mrem/yr ( $3 \times 10^{-5}$  Sv/yr) standard for demonstrating compliance with the requirements of 10 CFR Part 50, Appendix I, and irradiation of the TPBAR-LTAs would not alter the plant's compliance status with respect to the standard. The contribution of tritium from the Proposed Action to the plant's liquid effluents at the point of release to the river would not cause them to exceed the maximum concentration limits established in 10 CFR 20, Appendix C ( $1 \times 10^{-3}$   $\mu$ Ci/mL).

## 5.3 Waste

Wastes generated as a result of the Proposed Action would consist of relatively small quantities of low-level radioactive waste, mixed low-level radioactive and hazardous waste, and nonradioactive hazardous waste, in addition to the non-hazardous solid and liquid wastes typically associated with operation of the facilities. No transuranic or high-level radioactive wastes would be produced. Waste minimization practices would be used to reduce, to the extent possible, the quantities of radioactive and hazardous wastes generated at all facilities.

### 5.3.1 Assembly and Incorporation of TPBAR-LTAs into the Integrated Assemblies

Preparation of the integrated assemblies, including incorporation of TPBARs at the Westinghouse fuel fabrication facility, would not produce any radioactive or hazardous wastes in addition to those typically generated at the plant.

### 5.3.2 Irradiation of TPBAR-LTAs

Wastes associated with irradiation of the integrated assemblies at WBN would consist of low-level radioactive liquids and solids generated as the TPBAR-LTAs are removed from the spent fuel pool, decontaminated, and packaged for shipment to Hanford. The quantity of waste generated during this activity is expected to be less than 1% of the waste generated annually at WBN (i.e., less than  $0.4 \text{ m}^3$  or  $5 \text{ yd}^3$ ). These wastes would be treated as appropriate and disposed of at a licensed commercial facility with similar types of wastes from routine reactor operations. The fuel assemblies that initially contained the TPBAR-LTAs would be returned to the reactor core during refueling.

### 5.3.3 Post-Irradiation Examination of TPBARs

Construction at the 325 building to provide an access port into the hot cells could generate radioactive waste in the process of penetrating the hot cell wall. The volume of potentially contaminated materials removed from the wall and associated construction materials is not expected to exceed  $1 \text{ m}^3$  ( $1.3 \text{ yd}^3$ ) of low-level radioactive waste. Wastes produced during disassembly of the TPBAR-LTAs at Hanford and NDE of the TPBARs at Hanford and ANL-W would consist of laboratory materials and protective clothing used to prevent possible spread of contamination during receipt, handling, and examination. At each facility, the volume of these wastes is expected to be less than  $0.1 \text{ m}^3$  ( $0.13 \text{ yd}^3$ ) of low-level radioactive waste, which would be disposed of at onsite facilities.

The greatest quantities of low-level radioactive waste, about  $20 \text{ m}^3$  ( $26 \text{ yd}^3$ ), would be generated during destructive examination of the TPBARs at Hanford. These materials would consist of cuttings and small sections of the rod cladding and tubing, laboratory materials used to control spread of contamination, and either solid molecular sieve or bubbler liquids used to trap the tritium contained in gaseous effluents from the sectioning and extraction processes. Smaller quantities of mixed low-level waste, less than  $1 \text{ m}^3$  ( $1.3 \text{ yd}^3$ ), could be produced during liquid scintillation counting of tritium samples. An estimated  $5 \text{ m}^3$  ( $6.6 \text{ yd}^3$ ) of nonradioactive hazardous wastes would be produced during the laboratory activities as well. Ultimately, decontamination of the hot cells and disposal of unneeded equipment could generate up to  $200 \text{ m}^3$  ( $260 \text{ yd}^3$ ) of low-level radioactive waste. However, it is anticipated that the laboratory would retain this equipment for an indefinite period to use in future studies following completion of the Proposed Action.

Prior to disposal, the tritium inventory would remain either in the TPBARs that are not used for PIE tests, or within laboratory wastes consisting of molecular sieve or bubbler trap liquids that retain tritium which has been extracted from the test TPBARs. TPBARs that are not destructively examined would be placed in interim storage in sealed containers until DOE identifies another purpose for them or decides to dispose of them as low level radioactive waste. If the remaining TPBARs are to be disposed of, tritium would be extracted from them and they would be placed in appropriate packaging. The consequences of extracting the tritium would be bounded by the maximum PIE activities as described in section 5.1.1.3. The tritium-depleted TPBARs would contain less than 5% of their original tritium inventory in addition to neutron activation products in the structural components. Tritium extracted from the TPBARs that are not subject to PIE could either be disposed as low level radioactive waste, sold to a commercial enterprise, or collected on a tritium storage device for future DOE use.

If all of the TPBARs and hardware from the TPBAR-LTAs are disposed of at Hanford, they would consist of less than  $1 \text{ m}^3$  ( $1.3 \text{ yd}^3$ ) of solid low-level radioactive waste (exclusive of packaging) in addition to that generated during laboratory activities. All of the radionuclides remaining in the TPBARs and hardware would be bound in solid

components, where they would be relatively immobile following disposal. In addition, the TPBARs, hardware and other radioactive laboratory wastes would be appropriately packaged prior to disposal. All radioactive and hazardous wastes generated at Hanford would be disposed of either at the onsite radioactive waste burial grounds or in permitted commercial disposal facilities, in accordance with applicable state and federal regulations. Mixed low-level wastes would be stored onsite in permitted facilities. Because the activation products and tritium in these wastes are relatively short-lived relative to groundwater travel times between the 200 Areas and publicly accessible locations such as the Columbia River, these radionuclides are not expected to be detectable in either groundwater or the river over the long term.

## **5.4 Facility Accidents**

Consequences of potential accidents at facilities that would be involved in the Proposed Action are discussed in this section. These events have been evaluated, or would be evaluated prior to implementing any proposed activities, in sufficient detail to ensure that they would not affect the operational safety basis for those facilities. Operational restrictions and any needed modifications identified as a result of those evaluations would be implemented before work commences to ensure that the facilities remain within safety guidelines. Accidents during transport of the unirradiated or irradiated TPBARs are addressed in Section 5.5.

### **5.4.1 Assembly and Incorporation of TPBAR-LTAs into the Integrated Assemblies**

Because the unirradiated TPBAR-LTAs are non-radioactive and contain no hazardous materials, preparation of the TPBAR-LTAs and integrated assemblies at the Westinghouse fuel fabrication facility would not affect the frequency or consequences of potential accidents associated with that facility.

### **5.4.2 Irradiation of TPBAR-LTAs**

Accidents during irradiation of the TPBAR-LTAs at WBN were evaluated to determine whether substituting TPBARs for the standard burnable absorber rods in the reactor's fuel assemblies could affect the frequencies or consequences associated with off-normal events or accidents previously evaluated for the reactor (Erickson et. al 1997). The analysis determined that the presence of TPBAR-LTAs in the reactor core would not be likely to affect the course or severity of such events. This section contains a brief summary of that analysis.

An assumed event, in which the entire tritium inventory from one failed TPBAR might leak into the reactor coolant system over a 1-year period, could increase the offsite dose from the plant's projected liquid effluents from 0.700 to 0.713 mrem/yr ( $7.0 \times 10^{-6}$  to  $7.13 \times 10^{-6}$  Sv/yr). The incremental increase of 0.013 mrem/yr ( $1.3 \times 10^{-7}$  Sv/yr) to the maximally exposed offsite member of the public would represent less than 2% of the annual dose from the plant's typical liquid effluents, and would be well within the regulatory standards for routine reactor operation. Evaporation of coolant water released into the reactor's fuel handling area following a hypothetical event of this type could increase the tritium concentration in the facility air to about 5.8 % of the derived air concentration limit. Inhalation of tritium by an individual worker who spent 200 hours in the area during refueling operations would result in a cumulative dose of less than 50 mrem ( $5.0 \times 10^{-4}$  Sv). Although the likelihood of such an event was not estimated in detail, conditions severe enough to fail the TPBAR cladding are not anticipated during the LTA program.

Evaluation of more severe events indicated that the presence of TPBAR-LTAs in the reactor would also have a minimal impact on their consequences. Releases to the environment following a steam generator tube rupture or steam line break would amount to less than 9 Ci of tritium that could be in the primary coolant due to the presence of the TPBARs. The TPBAR-LTAs would not measurably increase the individual doses resulting from these events, or from other types of events such as a fuel handling accident.

A large break loss of coolant accident could involve conditions severe enough to release up to the entire end-of-cycle tritium inventory from all of the TPBARs to the reactor containment. The estimated offsite dose from this event would be 3.3 rem (0.033 Sv) to an individual at the exclusion area boundary for 2 hours or 2.0 rem (0.020 Sv) to an individual in the low population zone over 30 days, either with or without a contribution from the TPBAR-LTAs.

Therefore, the TPBAR-LTAs would not contribute to the overall risk associated with such an accident. Doses to plant personnel in the reactor control room over a period of 30 days following the event would amount to about 30 mrem ( $3.0 \times 10^{-4}$  Sv) from the TPBAR tritium, which is much lower than the contributions from other radionuclides that might be released from the reactor core. The TPBAR-LTAs are also not expected to affect the operation or effectiveness of plant safety systems, such as the emergency core cooling system or the combustible gas control system, during such an event.

### 5.4.3 Post-Irradiation Examination of TPBARs

The consequences of potential accidents during PIE of the TPBARs were evaluated for a spectrum of events having different severities and expected frequencies. A detailed safety analysis of the PIE activities would be performed before work commences; however, the scenarios evaluated for this assessment are representative of the types of events that are typically considered in safety assessments. Three accidents were evaluated for PIE activities, including: 1) breach of a single TPBAR during handling, 2) a localized fire involving the maximum quantity of tritium "at risk" during PIE, and 3) a seismic event and fire, which could involve all 32 TPBARs.

Accidents during PIE at Hanford are expected to bound those for similar types of events at ANL-W because the facilities are farther from the nearest offsite receptors than those at Hanford (greater than 8 km [5 mi] vs 0.58 km [0.36 mi]). In addition, the localized fire scenario would not apply to NDE activities because the TPBARs would remain intact and therefore would not be considered at risk for that type of accident. Accidents during interim storage and disposal of the TPBARs and hardware would be bounded by the accident consequences for PIE activities and transportation, as discussed in this section and in Section 5.5.

The assumptions for this assessment, as discussed in Appendix C, represent a bounding case for the purposes of preparing this EA and to demonstrate that the consequences of potential accidents are within established safety guidelines. The TPBARs were designed to retain tritium in the solid matrix of the components, even under the relatively severe conditions encountered during irradiation in the reactor. The quantity of free tritium is expected to be a small fraction of the total inventory. Therefore, both a mechanism to damage the TPBAR cladding and an extended period at high temperature would be required to release substantial quantities of tritium from the TPBARs. The probability of an accident that would produce these conditions is not known with accuracy. However, such an event (for example, the severe earthquake and fire) is assumed to be credible, although extremely unlikely, for the purposes of this analysis.

An accident involving damage to a single TPBAR with release of the free tritium would result in a dose of 3.5 mrem ( $3.5 \times 10^{-5}$  Sv) to an onsite worker, 0.40 mrem ( $4.0 \times 10^{-6}$  Sv) to an individual at the Hanford Site boundary, and 1.4 person-rem (0.014 person-Sv) to the population within 50 miles (80 km). That type of event is expected to occur with a frequency between 0.01 and 1.0 per year, or once in 1 to 100 years.

The dose from a localized fire that might release the maximum tritium inventory at risk during PIE (assumed to be 70,000 Ci) would be 2,500 mrem (0.025 Sv) to an onsite worker, 290 mrem ( $2.9 \times 10^{-3}$  Sv) for an individual at the site boundary, and 1,100 person-rem (11 person-Sv) to the population within 50 miles (80 km). The estimated frequency of a localized fire is less than 0.1 per year, or 1 event in 10 years.

The severe earthquake and fire scenario has an assumed frequency between  $10^{-4}$  and  $10^{-6}$  per year, or 1 event in 10,000 to 1 million years. If this combination of events occurred, the dose from a hypothetical release of the tritium inventory in all 32 TPBARs (about 385,000 Ci) would amount to 14,000 mrem (0.14 Sv) for the onsite worker 1,600 mrem (0.016 Sv) to an individual at the site boundary, and 5,800 person-rem (58 person-Sv) to the population within 50 miles (80 km).

## 5.5 Transportation

The consequences of transporting both unirradiated and irradiated TPBARs and TPBAR-LTAs are discussed in this section. Both incident-free transport and accidents during transport are addressed. Additional background information

and the basis for the results of the analysis presented in the following sections is contained in Appendix D.

### **5.5.1 Incident-Free Transportation Impacts**

This section addresses the incident-free transportation impacts associated with the shipments. The transportation impacts include external radiation exposures and the nonradiological impacts due to pollutants emitted by the transport vehicles.

For the analysis, all overland transportation was assumed to be by truck. It was also assumed that one shipment would be required to ship the unirradiated TPBARs to the Westinghouse fuel fabrication facility, and that one shipment of the integrated assemblies would be made from Westinghouse to WBN. Because the unirradiated TPBARs contain no radioactive material, they would not be regulated under the provisions of 49 CFR Parts 171-178. Unirradiated integrated assemblies would consist of low specific activity radioactive material, and they would be transported using a commercial carrier authorized to perform such shipments.

An NRC-licensed Type B shipping cask would be used to ship the irradiated TPBAR-LTAs from WBN to Hanford. For the purposes of this analysis, the transport was assumed to require two to four shipments, with either one or two TPBAR-LTAs per shipment. At Hanford, the TPBAR-LTAs would be disassembled and the 32 irradiated TPBARs would be transported in one shipment to a facility such as the HFEF at ANL-W. Following neutron radiography, the TPBARs would be returned to Hanford for additional PIE.

The hardware from the disassembled TPBAR-LTAs would eventually be placed in approved shipping containers and transported from the 325 Building to a Hanford Site solid waste facility for disposal. Following completion of the PIE, the spent TPBARs and other radioactive wastes would also be placed in approved shipping containers and transported from the 325 Building to a Hanford Site solid waste facility for disposal. It is assumed that a total of five shipments would be required to transport the TPBAR-LTA hardware, the TPBARs, and the laboratory wastes.

For this analysis, HIGHWAY 3.3 (Johnson et al. 1993) was used to develop transportation routing information including total distance traveled, en route population densities, and travel distances within three population zones (i.e., rural, suburban, and urban). It was assumed that all shipments of irradiated TPBAR-LTAs and TPBARs (except for those on the Hanford Site) would use "exclusive use" routes and all other shipments would use "commercial" routes. For exclusive use shipments, highway route controlled quantities are shipped on interstate highways or state-designated alternate routes (49 CFR 171-177). This was assumed for shipments of the irradiated TPBAR-LTAs due to the radionuclide inventories and sensitive nature of the shipments (i.e., tritium). Commercial routes are those used for truck shipments of ordinary freight, as designated by local ordinances or other restrictions based only on vehicle size or weight.

#### *5.5.1.1 Potential Radiological Impacts*

The radiological impacts associated with incident-free transport of the irradiated TPBAR-LTAs and TPBARs have been analyzed using RADTRAN 4 (Neuhauser and Kanipe 1992). The potential radiological impacts involve in-transit doses to the public or to Hanford Site workers from radiation emitted from the shipping cask and doses to the transport workers in the vicinity of the shipment during cask-handling activities (e.g., moving the cask on or off the truck trailer). In-transit doses have been estimated for the truck drivers and the general public, including persons at truck stops, persons living or working adjacent to the transport route, and nearby travelers (moving in the same and opposite directions).

No radiological impacts are associated with transporting the TPBARs to the Westinghouse fuel fabrication facility or with transporting the integrated assemblies from the Westinghouse fuel fabrication facility to WBN. No radiological impacts are expected to be associated with returning the empty shipping cask to WBN for reloading. Therefore, the routine radiological impacts have been estimated for shipments from WBN to Hanford, from Hanford to ANL-W, from ANL-W back to Hanford, and from the 325 Building to the Hanford Site solid waste facility.

Because of the lack of actual cask exposure rate measurement data, the exposure rate at the surface of the shipping

cask was assumed for the purposes of this analysis to be the maximum allowable in 10 CFR 71.51. The total estimated dose to the truck crew for all shipments (WBN to PNNL, PNNL to HFEF, HFEF to PNNL, PNNL to a Hanford Site solid waste facility) would be less than 0.90 person-rem (0.009 person-Sv). The total estimated collective dose to the public along the transportation route for those shipments would be less than 3.4 person-rem (0.034 person-Sv).

The estimated dose to the public for shipments from WBN to PNNL was compared with the estimated dose to the public from natural background radiation along the same transportation route. The comparative evaluation determined that the estimated dose to the public along the transportation route due to natural background radiation would be greater than 13 times the estimated dose to the public for all shipments from WBN to PNNL.

#### *5.5.1.2 Potential Nonradiological Impacts*

Impacts to the public from nonradiological causes were also evaluated. According to Rao et al. (1982), the types of air pollutants that are generated by transportation and which could affect the public would be sulfur oxides (SO<sub>x</sub>), particulates, nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), hydrocarbons (HC), and photochemical oxidants (O<sub>x</sub>). Rao et al. (1982) determined that most health effects are due to SO<sub>x</sub> and particulates.

For all shipments, approximately 210 km (132 mi) is within the urban population zone; therefore, according to the methodology described in Rao et al. (1982), the number of expected fatalities due to fugitive vehicle emissions is essentially zero (i.e., less than  $4.2 \times 10^{-5}$  fatalities for all shipments).

### **5.5.2 Transportation Accident Impacts**

This section addresses radiological and nonradiological impacts of accidents during transport. Potential nonradiological accident impacts consist of fatalities resulting from vehicular accidents involving the shipments.

Radiological impacts are calculated for the public as well as for a maximum onsite and offsite individual. The maximum individual doses have been calculated using GENII (Napier et al 1988). The collective impacts to the public are presented in this section as integrated population risks (i.e., accident frequencies multiplied by consequences of all shipments). Population risk calculations were performed using the RADTRAN 4 computer code (Neuhauser and Kanipe 1992).

#### *5.5.2.1 Radiological Impacts to the Public from Transportation Accidents*

Potential accident impacts can result from breaches in the shipping cask or damage to the cask shielding. However, the shipping casks are designed, tested, and certified to withstand specified conditions that would not be exceeded in most transportation accidents (i.e., for this analysis, the shipping casks for irradiated TPBAR-LTAs or their components were assumed to meet the Type B packaging requirements specified in 49 CFR Part 173 and 10 CFR Part 71). Therefore, only a small fraction of transportation accidents involve conditions that are severe enough to result in release of radioactive materials.

If radionuclides were released to the environment, they would be dispersed and diluted by weather action; and a small quantity would be deposited on the ground through plume depletion. Access to the area adjacent to the transportation accident would be controlled by emergency response personnel until the area could be remediated and the radiation monitoring personnel had declared the area safe.

The input data used to calculate the radiological dose to the public (i.e., population densities, travel times, and distances) were the same as the inputs used to calculate the incident-free dose to the population. The accident frequency data used in the analysis were based on a review of local or state-specific accident data (Saricks and Kvittek 1994). The Hanford Site accident rates (expressed as accidents/km) used in this analysis were taken from Bergsman et al. (1995) The accident rate used for truck shipments is  $8.86 \times 10^{-8}$  accidents/km ( $5.50 \times 10^{-8}$  accidents/mi). The radiological impacts to the public (including non-involved Hanford Site workers) associated with truck transportation accidents are estimated to be less than 0.65 person-rem (0.0065 person-Sv).

The maximum dose to an individual was calculated for a bounding accident that could occur during shipment of the TPBARs between Hanford and ANL-W. An accident during that portion of the shipments could potentially involve all 32 irradiated TPBARs; any other shipment would involve a smaller number. For accidents outside of DOE facility boundaries, an individual at 100 m from the release was evaluated. For accidents within DOE facility boundaries, the minimum distance to the Hanford Site boundary from the 325 Building (580 m or 0.36 mi) was evaluated as a bounding case (distances between ANL-W and the INEEL boundary are substantially greater). Assumptions related to this analysis are detailed in Appendices C and D. The estimated doses for such an event would be 3,100 mrem (0.031 Sv) to an individual at 100 m, and 160 mrem (0.0016 Sv) to the offsite receptor at 580 m (0.36 mi). As noted at the beginning of this section, the NRC-certified Type B casks are designed to prevent release of radioactive materials under conditions encountered in most transportation accidents. The frequency of an event severe enough to result in substantial tritium releases during the round trip between Hanford and ANL-W was estimated to be less than  $2 \times 10^{-5}$ . Because the TPBARs are designed to retain tritium even under severe conditions, accidents that would involve both extensive mechanical damage and a fire of sufficient duration and intensity to release greater quantities of tritium would be considered incredible (that is, they would have an estimated frequency lower than  $1 \times 10^{-7}$ , or 1 in 10 million).

#### *5.5.2.2 Nonradiological Impacts to the Public from Transportation Accidents*

Potential nonradiological accident impacts consist of fatalities resulting from vehicular accidents involving the shipments. The fatalities are due to vehicle crashes with solid objects, rollovers, or collisions. Impacts to the public, i.e. individuals on or immediately adjacent to roadways, have been estimated using unit risk factors (i.e., fatalities per kilometer). It is assumed that a vehicle accident that would result in a release from a shipping cask would also result in crew fatalities; therefore, nonradiological vehicular accident impacts are calculated for the public only. No impacts to the public are associated with the transport of the unirradiated and irradiated TPBARs, TPBAR-LTAs, and integrated assemblies (i.e., less than  $6.1 \times 10^{-4}$  acute fatalities).

## **Appendix A**

### **Description of the Tritium-Producing Burnable Absorber Rod for the CLWR Lead Test Assembly**

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## **Appendix B**

### **Biological Review of the Tritium Target Lead Test Assembly, 300 Area**

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## **Appendix C**

### **Consequences of Tritium Releases During Post-Irradiation Examination of Tritium-Producing Burnable Absorber Rods (TPBARs)**

Post Irradiation Examination (PIE) of the TPBARS would take place at Hanford, and neutron radiography would be conducted at a facility to be determined. For the purposes of this analysis, neutron radiography is assumed to occur at the ANL-W facility, near Idaho Falls, Idaho.

PIE of the TPBARs would take place at the PNNL Applied Chemistry Laboratory, designated the 325 building, which is located in the Hanford Site 300 Area. These activities may result in releases of tritium, as well as very small quantities of particulate activation products, to the environment. Routine releases could result from destructive examination of the TPBARs, extraction of tritium to determine production levels and retention efficiency, and permeability tests of the TPBAR cladding material. Accidental releases might result from damage to a TPBAR during handling, malfunctions of facility emission control equipment during PIE activities, or external events such as a fire or earthquake. The consequences of both routine emissions and potential accident scenarios have been evaluated for PIE activities, as described in the following sections.

### **C.1 Methods for Evaluation of Potential Consequences of PIE Activities**

Radiation dose estimates were calculated using the CAP88-PC software package (Parks 1992) for routine emissions, and the GENII software system (Napier et al 1988) for acute (short-term) releases. Both codes implement a straight-line Gaussian plume model for atmospheric dispersion, and the food chain models are similar to those of NRC (1977) for ingestion dose estimates. The GENII software incorporates a seasonal model for ingestion calculations following an acute release that accounts for the types and quantities of food products growing during each season, as well as the delay time between radionuclide deposition and harvest. The atmospheric dispersion and air concentrations for chronic releases are based on annual average atmospheric conditions, and acute releases assume conditions that would not be exceeded more than 5% of the time. The dosimetry models in both codes are consistent with recommendations of the International Commission on Radiological Protection (ICRP) in its publications 26 (ICRP 1979) and 30 (ICRP 1979-1988). Other assumptions are based on recommended parameters for the Hanford Site in Schreckhise et al (1993).

The dose resulting from release of tritium to the environment would depend on its chemical form. The inhalation dose from oxidized tritium (as HTO or T<sub>2</sub>O) is about 14,000 times higher than for tritium in elemental form (as HT or T<sub>2</sub>). Elemental tritium is also assumed to make no contribution to doses received via the food chain (ingestion) pathways (DOE 1988). The dosimetry models in both the CAP88-PC and GENII codes assume that tritium is released to the environment in the oxidized form, and therefore are conservative for releases that involve elemental tritium. For this analysis, tritium released in elemental form is assumed to oxidize slowly in the environment. Based on experimental results, Brown et al. (1990) estimate the long-term dose from elemental tritium releases to be about 1% of that for the oxidized form. Therefore, releases that occur as elemental tritium are multiplied by a factor of 0.01 to convert them to an equivalent release of tritium oxide for use with the environmental dosimetry software.

Health effects estimates are based on recommendations of the ICRP (1991) in its publication 60. The consequences in terms of latent cancer fatalities are estimated to be  $4 \times 10^{-4}$  per person-rem ( $4 \times 10^{-2}$  per person-Sv) for adult workers and  $5 \times 10^{-4}$  per person-rem ( $5 \times 10^{-2}$  per person-Sv) for the general population. The corresponding total incidence of detrimental health effects, including both fatal and nonfatal cancers and severe hereditary effects, is estimated to be  $5.6 \times 10^{-4}$  per person-rem ( $5.6 \times 10^{-2}$  per person-Sv) for workers and  $7.3 \times 10^{-4}$  per person-rem ( $7.3 \times 10^{-2}$  per person-Sv) for the general population. The higher rates for the general population account for the presence of more sensitive individuals, such as children, compared with the relatively homogeneous population of healthy adults in the work force. These estimates apply to radiation exposures at relatively low doses and dose rates (see ICRP 1991).

The ICRP estimates are based on radiation exposures to populations at higher doses and dose rates, and by different pathways, than those normally encountered in the environment. As a result, the health effects coefficients are presented in terms of collective dose to a relatively large population. Collective dose is defined as the sum of doses to all individuals in the population, who may exhibit a wide range of susceptibility to radiation-induced health effects. The health effects coefficients are therefore associated with substantial uncertainty when applied to dose estimates for individuals whose sensitivity may differ from the population average. However, the assumptions used to develop the health effects coefficients are sufficiently conservative that they would be "unlikely to underestimate the risks" (ICRP 1991).

## C.2 Consequences of Routine PIE Activities

Non-destructive evaluation (NDE) of the TPBARs and neutron radiography would not involve breaching the cladding under normal conditions. Therefore, the NDE would not be expected to result in air emissions other than those typically associated with operation of the facility.

The remaining PIE of the irradiated TPBARs and associated tests would consist of 3 major activities: 1) sectioning the rods to evaluate changes to their internal structure, 2) extraction of tritium from the rods to determine production rates and retention characteristics, and 3) permeability testing of the TPBAR cladding material using tritium obtained from a commercial source. The radionuclide releases from each of these activities are estimated as follows:

1. Sectioning of TPBARs - Each TPBAR has an active target length of approximately 142" and a bounding tritium inventory of 12,000 Ci. All tritium in the cut cross-section is presumed to be volatilized during the sectioning procedure. Assuming that the average distance between cuts is about 3.75", and the width of each cut is 0.015", the estimated tritium release from sectioning each TPBAR is calculated as follows:

$$\begin{aligned} \text{H-3 Release} &= (\text{total length of TPBAR} \div \text{distance between cuts}) \times (\text{cut width}) \times (\text{TPBAR H-3 inventory per unit length}) \\ &= (142" \div 3.75") \times (0.015") \times (12,000 \text{ Ci} / 142") \\ &= 48 \text{ Ci/TPBAR.} \end{aligned}$$

All of the tritium that would be volatilized during sectioning is assumed to be released via the building's heating, ventilation and air conditioning (HVAC) system. Small quantities of neutron activation products in the TPBAR cladding would also be converted to particulate form during this operation, but the facility emission controls would limit their releases to such small quantities that they would have no consequence when compared with the tritium releases.

2. Tritium Extraction and Analysis - An estimated upper bound for emissions from the tritium extraction and analysis process were approximately 0.1% of the total inventory via the mass spectrometer and 1% via the emission control system (either a bubbler or molecular sieve trap). The potential emissions from extracting tritium from one TPBAR are as estimated follows:

$$\begin{aligned} \text{H-3 Release} &= (\text{TPBAR tritium inventory}) \times (\text{release fraction}) \\ &= (12,000 \text{ Ci}) \times (0.01 + 0.001) \\ &= 130 \text{ Ci/TPBAR.} \end{aligned}$$

3. Cladding Permeability Tests - An upper bound estimate for tritium emissions from the cladding permeability tests is 10% of the total inventory volatilized from the commercial tritium source, which contains approximately 2000 Ci. The remaining tritium was assumed to be recovered and contained within the source following the test. The tritium emissions from this activity were therefore estimated as:

$$\begin{aligned} \text{H-3 Release} &= (\text{Source tritium inventory}) \times (\text{release fraction}) \\ &= (2000 \text{ Ci}) \times (0.10) \\ &= 200 \text{ Ci.} \end{aligned}$$

The consequences of routine tritium emissions were calculated using the CAP88-PC computer software and site-specific wind data from the Hanford Site 300 Area (Schreckhise et al 1993). The meteorological database represents the average of hourly data collected over the 9-year period from 1983 through 1991 at the 300 Area meteorological tower. Calculations were performed for a unit (1-Ci) release of tritium from the 325 building stack using normal ventilation parameters for stack EP-325-01-S. The effective stack height was set at 35 m, the exit velocity at 13 m/s, and the diameter at 2.44 m. Dose estimates are presented in Table C.1 for releases from all routine PIE activities. These results assume tritium is released in oxidized form, which provides a bounding estimate of the consequences. However, the tritium extraction process includes an oxidation step prior to trapping the gases in a bubbler or molecular sieve, so this assumption is not overly conservative for the specific processes considered in this assessment.

**Table C.1 Consequences of Routine Tritium Emissions from Post-Irradiation Examination of TPBARs at the Hanford Site 325 Building**

Consequences of Tritium Emissions from PIE Activities

PIE Activity and Estimated Tritium Release	Dose (mrem) to the Maximally Exposed Offsite Resident (2 km E)	Dose (person-rem) to the population within 50 mi (80 km)
1-Ci tritium release	$5.53 \times 10^{-5}$	$2.4 \times 10^{-4}$
PIE Activities		
Sectioning of 1 TPBAR (48 Ci)	$2.6 \times 10^{-3}$	$1.2 \times 10^{-2}$
Tritium Extraction from 1 TPBAR (130 Ci)	$7.3 \times 10^{-3}$	$3.1 \times 10^{-2}$
Cladding Permeability Tests (200 Ci)	$1.1 \times 10^{-2}$	$4.8 \times 10^{-2}$

**C.3 Consequences of Accidents During PIE Activities**

The consequences of potential accidents during PIE of the TPBARs were evaluated for a spectrum of events having different severities and expected frequencies. A detailed safety analysis of the PIE activities would be performed before work commences; however, the scenarios evaluated for this assessment are representative of the types of events that are typically considered in safety assessments. Three accidents were evaluated for PIE activities, including: 1) breach of a single TPBAR during handling, 2) a localized fire involving the maximum quantity of tritium "at risk" during PIE, and 3) a seismic event and fire, which could involve all 32 TPBARs. A bounding accident during transport of the TPBARs between facilities was also evaluated. Accidents during PIE at Hanford are expected to bound those for similar types of events during neutron radiography because the facilities at ANL-W are farther from the nearest offsite receptors than those at Hanford (greater than 8 km vs 0.58 km). In addition, the localized fire scenario would not apply to NDE activities because the TPBARs would remain intact and would therefore not be considered at risk for this type of accident.

**C.3.1 Rod Breach Scenario.**

The rod breach or similar scenario could release the gaseous (i.e., unbound) tritium content of a single TPBAR. This event is expected to occur with a frequency between  $1 \times 10^{-2}$  and 1.0 per year (or one event in 1 to 100 years). Following irradiation, most of the tritium in the TPBARs is expected to be bound to the getter and other internal components. Based on experimental results of Johnson et al (1976), less than 30% of the TPBAR tritium inventory was assumed to be in a gaseous state, which would consist almost entirely of elemental tritium. Less than 0.5% of the total TPBAR tritium inventory would be expected to exist as gaseous tritium oxide. (Johnson et al 1976) If 1% of the free elemental tritium is assumed to oxidize in the environment following release (see section C.1), the total equivalent release as tritium oxide from a damaged TPBAR is calculated to be:

$$\begin{aligned}
 \text{H-3 Release} &= (\text{TPBAR inventory}) \times [(\text{free oxide fraction}) + (\text{free elemental fraction}) \times (\text{fraction oxidized in environment})] \\
 &= (12,000 \text{ Ci}) \times [0.005 + (0.3 \times 0.01)] \\
 &= 96 \text{ Ci.}
 \end{aligned}$$

The scenario for this event assumes that the tritium release is not mitigated by emission control devices.

**C.3.2 Localized Fire.**

A localized fire during PIE is assumed to involve release of all tritium considered to be at risk at any time in the 325 Building laboratories. The quantity at risk is assumed to be the total inventory of TPBARs that are undergoing tests at any given time. TPBARs that are intact and remain in their sealed storage containers within the hot cells are not considered to be at risk for this event. The quantity of tritium assumed to be at risk for this event is 70,000 Ci, which represents the content of 6-8 TPBARs. Because the event includes an external mechanism for releasing tritium bound in the TPBAR components and oxidizing it, the entire at-risk inventory is assumed to be released as tritium oxide. The estimated frequency of a localized fire is less than 0.10, or 1 in 10 years.

### C.3.3 Seismic Event with Fire.

The bounding accident for PIE involves an external event such as a severe earthquake and fire that could damage all 32 of the TPBARs simultaneously. The anticipated frequency of accidents in this category is between  $1 \times 10^{-6}$  and  $1 \times 10^{-4}$  per year (or one event in 10,000 to 1 million years). The release scenario for this accident assumes that the building is breached, allowing the entire tritium inventory of all 32 TPBARs (385,000 Ci) to exit through an opening below the roof level with the HVAC system out of operation. Because this event includes a fire, the tritium was assumed to be oxidized prior to release from the building.

### C.3.4 Consequences of a Bounding Accident During Transportation

The consequences of a bounding accident during transport of the TPBARs between Hanford and ANL-W were also evaluated. A maximum credible accident during transportation is assumed to breach the shipping container and damage all 32 TPBARs, releasing the free tritium inventory. The quantity of tritium oxide released is therefore equivalent to 32 times that estimated for the single rod breach in section C.3.1, or about 3100 Ci. The assumptions associated with this accident are discussed in detail in Appendix D, section D.4.2.

## C.4 Summary of Accident Consequences

The dose to an individual located near the 325 Building was evaluated for each accident scenario described in Section C.3, and the results are presented in Table C.2. Atmospheric dispersion estimates and GENII results for a release of 1 Ci of tritium from the 325 Building are included in Table C-2. The dose calculations for releases from the facility use atmospheric dispersion estimates (E/Q values) for a ground-level release including a building wake dispersion model. The dose per Ci tritium released in the bounding transportation accident was estimated from the corresponding value for facility accidents, adjusting for the higher air concentration at each receptor location following an open-area ground level release as follows:

$$\begin{aligned} \text{Dose (mrem) per Ci Release} &= \text{mrem/Ci for facility accidents} \times (\text{E/Q for open-area} \\ \text{(Transportation accidents)} &\quad \text{ground level release} \div \text{E/Q for release from facility}) = 1.0 \times 10^0 \\ \text{100-m receptor:} &= 3.6 \times 10^{-2} \times (3.4 \times 10^{-2} \div 1.2 \times 10^{-3}) \\ \text{580-m receptor:} &= 4.2 \times 10^{-3} \times (1.7 \times 10^{-3} \div 1.4 \times 10^{-4}) \\ &= 5.1 \times 10^{-2} \end{aligned}$$

The dose for each accident scenario was then calculated by multiplying the dose per Ci tritium released by the estimated release for each type of event.

**Table C.2 Consequences of Acute Tritium Releases at or near the Hanford Site 325 Building**

Accident Releases - 325 Bldg.	Onsite Dose, mrem	Offsite Dose, mrem	Collective Dose to Offsite population, person-rem
H-3 Release (as tritium	100m ESE	580m ESE	

oxide)	E/Q = $1.2 \times 10^{-3}$ s/m <sup>3</sup>	E/Q = $1.4 \times 10^{-4}$ s/m <sup>3</sup>	
1 Ci	$3.6 \times 10^{-2}$	$4.2 \times 10^{-3}$	$1.5 \times 10^{-2}$
TPBAR Breach (96 Ci)	$3.5 \times 10^0$	$4.0 \times 10^{-1}$	$1.4 \times 10^0$
Localized Fire (70,000 Ci)	$2.5 \times 10^3$	$2.9 \times 10^2$	$1.1 \times 10^3$
Earthquake + Fire (385,000 Ci)	$1.4 \times 10^4$	$1.6 \times 10^3$	$5.8 \times 10^3$
Transportation Accidents Ground-level H-3 Release (as tritium oxide)	Onsite Dose, mrem 100 m ESE E/Q = $3.4 \times 10^{-2}$ s/m <sup>3</sup>	Offsite Dose, mrem 580 m ESE E/Q = $1.7 \times 10^{-3}$ s/m <sup>3</sup>	Not Applicable
1 Ci	$1.0 \times 10^0$	$5.1 \times 10^{-2}$	
3100 Ci	$3.1 \times 10^3$	$1.6 \times 10^2$	

## C.5 References

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## **APPENDIX D**

### **TRANSPORTATION IMPACT ANALYSIS**

This appendix evaluates the impacts of both incident-free (routine) transport of radioactive materials in which the shipments reach their destinations without incident and the impacts of accidents involving the shipments. The consequences of the maximum credible transportation accident are also calculated. The approaches and data used to calculate these impacts are presented, as well as the shipping scenarios and characteristics of the radioactive shipments that are important to determining the radiological impacts. Nonradiological impacts are also calculated.

Section D.1 provides a description of the shipping scenarios and the characteristics of the shipments analyzed in this Appendix. Descriptions of the approach and computer codes used in this analysis are presented in Section D.2. Section D.3 presents the results of the transportation impact calculations.

#### **D.1 SHIPPING SCENARIOS AND SHIPMENT CHARACTERISTICS**

This section presents the shipping scenarios and shipment characteristics for each of the shipments required for the transport of unirradiated and irradiated tritium-producing burnable absorber rods (TPBARs). The information presented includes container and shipment capacities, shipment inventories, numbers of shipments, and route information.

The radionuclide inventories used in the analyses are presented in Table D.1. The data in the table represent the maximum bounding inventories of each radionuclide. The bounding inventories were used in analyzing both incident-free and accident impacts.

This analysis was based on the following assumptions:

- All overland transportation would be by truck.
- The 32 TPBARs would be shipped in one package to the Westinghouse fuel fabrication facility located in Columbia, South Carolina. This shipment would consist of nonradioactive materials only.
- One shipment containing two packages (two integrated fuel assemblies per package) would be used to ship the assembled fuel to the Watts Bar Nuclear Power Plant (WBNP), located near Chattanooga, Tennessee. This shipment would utilize a commercial carrier approved for low specific activity material shipments.
- Two to four shipments, each containing one or two TPBAR-LTAs, would be used to ship the irradiated TPBARs from the WBNP to the Hanford Site near Richland, Washington. All shipments would utilize an NRC-licensed Type B cask on exclusive use routes, and the number of shipments would depend on the capacity of the specific cask used. For exclusive use shipments, highway route controlled quantities are shipped on interstate highways or state-designated alternative routes (49CFR171-177). This was assumed for the shipments of the irradiated TPBARs due to the radionuclide inventories and sensitive nature of the shipments (i.e., tritium).
- Following disassembly of the TPBAR-LTAs at Hanford, all 32 TPBARs would be transported in a single shipment to ANL-W, near Idaho Falls, ID, for nondestructive evaluation (NDE). These shipments would also utilize an NRC-licensed Type B cask on exclusive use routes. Upon completion of the NDE, all 32 TPBARs would be returned to Hanford for post-irradiation examination (PIE).
- When PIE activities are completed, all 32 TPBARs and associated laboratory waste are assumed to be disposed of at the Hanford Site low level waste burial grounds in the 200 Areas. After the TPBAR-LTAs are disassembled, the hardware other than the TPBARs (designated non-target bearing components, or NTBCs) were assumed to be packaged and transported to the burial grounds in 4 shipments using a DOE-approved shipping container. Spent TPBARs and associated laboratory wastes are assumed to be transported in one additional

shipment.

**Table D.1 Radionuclide Inventory**

Radionuclide	Quantity per TPBAR <sup>a</sup> (Ci)	Quantity per assembly (Ci)	Quantity per shipping cask <sup>b</sup> (Ci)	NTBC <sup>c</sup> : Quantity per solid waste package (Ci)	Targets <sup>d</sup> : Quantity per package (Ci)
H-3	1.13E+04	9.28E+04	1.81E+05	0	3.62E+05
Cr-51	5.64E+00	1.35E+02	2.71E+02	9.02E+01	1.80E+02
Mn-54	1.41E+01	3.38E+02	6.77E+02	2.26E+02	4.51E+02
Fe-55	9.21E+01	2.21E+03	4.42E+03	1.47E+03	2.95E+03
Fe-59	6.46E+01	1.55E+01	3.10E+01	1.03E+01	2.07E+01
Co-58	1.33E+01	3.19E+02	6.38E+02	2.13E+02	4.26E+02
Co-60	3.03E+01	7.27E+02	1.45E+03	4.85E+02	9.70E+02
Ni-63	3.51E+00	8.42E+01	1.68E+02	5.62E+01	1.12E+02
Zr-95	4.51E+00	1.08E+02	2.16E+02	7.22E+01	1.44E+02
Nb-95	8.89E+00	2.13E+02	4.27E+02	1.42E+02	2.84E+02
Mo-99	7.18E-18	1.07E-16	3.41E-16	1.14E-16	2.27E-16

a. Taken from TTQP-1-050, Conservative estimate for 180-day discharge  
b. Ci per shipping cask assuming 2 assemblies per cask  
c. NTBC - non-target-bearing components, Ci per waste package assuming 1 assembly per waste package  
d. Ci per package assuming 32 target rods per shipment to HFEF or solid waste

**D.1.1 Transportation Route Information**

The transportation routes assumed for this analysis are shown in Table D.2. The information shown in Table D.2 includes the number of shipments required, origin, and destination facilities.

The transportation route information used in this analysis is shown in Table D.3. The information shown in Table D.3 includes the shipping distances and population densities. These data are used to calculate transportation impacts and were developed using the HIGHWAY 3.3 (Johnson et al. 1993) computer code for truck shipments or were estimated using site maps. The population density data for shipments on the Hanford Site were developed using site maps and suburban population densities to represent occupied facilities and rural population densities for all other areas adjacent to the transport route.

**Table D.2. Transportation Routing Information**

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Material Transported	No. of Shipments	Origin	Destination
Unirradiated TPBAR assemblies	1 <sup>a</sup>	PNNL, Hanford, Washington	WBNP, Chattanooga, Tennessee
Irradiated TPBAR assemblies	2 - 4 <sup>b</sup>	WBNP, Chattanooga, Tennessee	PNNL, Hanford, Washington
Irradiated TPBARs	1 <sup>b</sup>	PNNL, Hanford, Washington	HFEF, Idaho Falls, Idaho
Irradiated TPBARs	1 <sup>b</sup>	HFEF, Idaho Falls, Idaho	PNNL, Hanford, Washington
Irradiated TPBARs	1 <sup>c</sup>	PNNL, Hanford, Washington	Solid Waste, Hanford, Washington
Non-target bearing components	4 <sup>c</sup>	PNNL, Hanford, Washington	Solid Waste, Hanford, Washington
Return shipment of empty cask	1 - 3 <sup>a</sup>	PNNL, Hanford, Washington	WBNP, Chattanooga, Tennessee
a. Commercial routes used for analysis b. HM-164 routes used for analysis c. Onsite roadways			

**Table D.3. Summary of Transportation Analysis Information**

Material Transported		No. of Shipments	Shipment distance (km one-way)	Population Density, people/km <sup>2</sup> <sup>a</sup>		
Origin	Destination			Rural	Suburban	Urban
<b>Unirradiated TPBAR assemblies<sup>b</sup></b>						
PNNL	Westinghouse, Columbia, S.C.	1	4282.3	7.0 (86.2)	333.3 (12.7)	2071.8 (1.1)
Westinghouse, Columbia, S.C.	WBNP	1	515.0	14.0 (71.2)	292.6 (27.9)	1917.5 (0.8)
<b>Irradiated TPBAR assemblies<sup>c</sup></b>						
WBNP	PNNL	2 - 4	4045.8	6.2 (87.5)	349.2 (11.3)	2174.7 (1.2)
<b>Irradiated TPBARs</b>						
PNNL <sup>c</sup>	HFEF	1	967.2	5.8 (91.6)	382.4 (7.9)	1984.0 (0.6)
HFEF <sup>c</sup>	PNNL	1	967.2	5.8 (91.6)	382.4 (7.9)	1984.0 (0.6)
PNNL <sup>d</sup>	Solid Waste	1	43.2	2.4 (97.1)	89.8 (2.9)	NA
<b>Non-target bearing components</b>						
PNNL <sup>d</sup>	Solid Waste	4	43.2	2.4 (97.1)	89.8 (2.9)	NA
<b>Empty shipping cask<sup>b</sup></b>						
PNNL	WBNP	1 - 3	4282.3	7.0 (88.3)	333.3 (10.6)	2071.8 (1.1)

- a. Values shown in parenthesis indicate percentage of total route in each population zone.
- b. Commercial routes used for analysis
- c. HM-164 routes used for analysis
- d. Hanford Site roadways

## **D.2 ROUTINE AND ACCIDENT IMPACT ANALYSIS METHODS AND MODELS**

This section describes the methods used to estimate consequences of normal and accidental exposure of individuals or populations to radioactive materials. The RADTRAN 4 computer codes (Neuhauser and Kanipe 1992) were used to calculate the transportation impacts, and the GENII software package (Napier et al. 1988) was used to estimate the consequences to the maximum individuals.

The output from computer codes, as total effective dose equivalent (TEDE or dose) to the affected receptors, was then used to express the consequences in terms of potential latent cancer fatalities (LCF). Recommendations of the International Commission on Radiological Protection (ICRP 1991) for low dose, low dose rate radiological exposures were used to convert dose as TEDE to LCF. The conversion factor applied to adult workers (i.e., Hanford Site workers) was  $4 \times 10^{-4}$  LCF/rem TEDE; and the conversion factor for the general population was  $5 \times 10^{-4}$  LCF/rem TEDE. The general population was assumed to have a higher rate of cancer induction for a given radiation dose than healthy adult workers because of the presence of more sensitive individuals (e.g., children) in the general population.

Nonradiological incident-free and accident impacts were also evaluated. Nonradiological incident-free impacts consist of fatalities from fugitive emissions or pollutants emitted from the vehicles. Nonradiological accident impacts are the fatalities resulting from potential vehicular accidents involving the shipments. Neither of these two categories of impacts is related to the radiological characteristics of the cargo. Hand calculations were performed using unit-risk factors (fatalities per km of travel) to derive estimates of the nonradiological impacts. The nonradiological impacts were calculated by multiplying the unit risk factors by the total shipping distances for all of the shipments in each shipping option. Nonradiological unit risk factors for incident-free transport were taken from Neuhauser and Kanipe (1992).

### **D.2.1 RADTRAN 4 Computer Code**

The RADTRAN 4 computer code (Neuhauser and Kanipe 1992) was used to perform the analyses of the radiological impacts of routine transport and the integrated population risks of accidents during transport of the irradiated TPBAR assemblies, TPBARs, and NTBCs. RADTRAN was developed by Sandia National Laboratories (SNL) to calculate the risks associated with the transportation of radioactive materials. The original code was written by SNL in 1977 in association with the preparation of NUREG-0170, *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977). The code has since been refined and expanded and is currently maintained by SNL under contract with DOE.

The RADTRAN 4 computer code is organized into the following seven models (Neuhauser and Kanipe 1992):

- material model
- transportation model
- population distribution model
- health effects model
- accident severity and package release model
- meteorological dispersion model
- economic model.

The code uses the first three models to calculate the potential population dose from normal, incident-free transportation and the first six models to calculate the risk to the population from user-defined accident scenarios. The economic model is not used in this study.

### **D.2.1.1 Material Model**

The material model defines the source as either a point source or as a line source. For exposure distances less than twice the package dimension, the source is conservatively assumed to be a line source. For all other cases, the source is modeled as a point source that emits radiation equally in all directions.

The material model also contains a library of 59 isotopes, each of which has 11 defining parameters used to calculate dose. The user can add isotopes not in the RADTRAN library by creating a data table in the input file consisting of eleven parameters.

### **D.2.1.2 Transportation Model**

The transportation model allows the user to input descriptions of the transportation route. A transportation route may be divided into links or segments of the journey, with information for each link on population density, mode of travel (e.g., trailer truck), accident rate, vehicle speed, road type, vehicle density, and length. Alternatively, the transportation route also can be described by aggregate route data for rural, urban, and suburban areas. For this analysis, the aggregate route method was used for each potential origin-destination combination.

### **D.2.1.3 Health Effects Model**

The health effects model in RADTRAN 4 is outdated and is replaced by hand calculations. The health effects are determined by multiplying the RADTRAN4 population dose (person-rem) by a conversion factor.

### **D.2.1.4 Accident Severity and Package Release Model**

Accident analysis in RADTRAN 4 is performed using the accident severity and package release model. The user can define up to 20 severity categories for three population densities (urban, suburban, and rural), each increasing in magnitude. Eight severity categories for SNF containers that are related to fire, puncture, crush, and immersion environments are defined in NUREG-0170 (NRC 1977). Various other studies have been performed for small packages (Clarke et al. 1976) and large packages (Dennis et al. 1978) that also can be used to generate severity categories. The accident scenarios are further defined by allowing the user to input release fractions and aerosol and respirable fractions for each severity category. These fractions are also a function of the physical-chemical properties of the materials being transported.

### **D.2.1.5 Meteorological Dispersion Model**

RADTRAN 4 allows the user to choose two different methods for modeling the atmospheric transport of radionuclides after a potential accident: Pasquill atmospheric-stability category data or averaged time-integrated concentrations. In this analysis, the dispersion of radionuclides after a potential accident is modeled by the use of time-integrated concentration values in downwind areas compiled from national averages by SNL.

### **D.2.1.6 Incident-Free Transport**

The models described above are used by RADTRAN 4 to determine dose from incident-free transportation or risk from potential accidents. The public and worker doses calculated by RADTRAN 4 for incident-free transportation are dependent on the type of material being transported and the transportation index (TI) of the package or packages. The TI is defined in 49 CFR 173.403(bb) as the highest package dose rate in millirem per hour at a distance of 1 m from the external surface of the package. Dose consequences are also dependent on the size of the package, which as indicated in the material model description, will determine whether the package is modeled as a point source or a line source for close-proximity exposures.

### **D.2.1.7 Analysis of Potential Accidents**

The accident analysis performed in RADTRAN 4 calculates population doses for each accident severity category using six exposure pathway models: inhalation, resuspension, groundshine, cloudshine, ingestion, and direct exposure. This

RADTRAN 4 analysis assumes that any contaminated area is either mitigated or public access is controlled so the dose via the ingestion pathway equals zero. The consequences calculated for each severity category are multiplied by the appropriate frequencies for accidents in each category and summed to give a total point estimate of risk for a radiological accident.

### **D.2.2 GENII Description**

GENII (Napier et al. 1988), which is also referred to as the Hanford Environmental Dosimetry Software System, was developed by the Pacific Northwest National Laboratory to analyze radiological releases to the environment. GENII is composed of seven linked computer programs and their associated data libraries, including user interface programs, internal and external dose factor generators, and the environmental dosimetry programs.

GENII is capable of:

- Calculating doses resulting from acute or chronic releases, including options for annual dose, committed dose, and accumulated dose
- Calculating doses from various exposure pathways evaluated, including those through direct exposure via water, soil, and air, as well as inhalation and ingestion pathways
- Acute and chronic elevated and ground level releases to air
- Acute and chronic releases to water
- Initial contamination of soil or surfaces
- Radionuclide decay.

The pathways considered in this analysis include inhalation, submersion, and external exposures due to ground contamination.

## **D.3 RESULTS OF INCIDENT-FREE TRANSPORTATION IMPACT ANALYSIS**

This section discusses the radiological and non-radiological impacts to the truck crew and the public during incident-free or routine transportation activities. The key input parameters for the RADTRAN 4 computer code that were used to perform the incident-free transportation impact calculations are provided in Table D.4. Separate subsections are provided below for the results of the radiological and nonradiological impact calculations.

### **D.3.1 Radiological Impacts of Incident-Free Transportation**

The radiological doses to the truck crew, onsite worker, and the public from transportation activities were calculated using RADTRAN 4 (see Section D.2). RADTRAN 4 uses a combination of meteorological, demographic, health physics, transportation, packaging, and material factors to analyze the radiological exposures from incident-free transport activities. The doses to the truck crew and the public were calculated on a per-shipment basis and for the entire campaign.

No radiological impacts are associated with transporting the unirradiated TPBARs to the Westinghouse fuel assembly facility or with transporting the assembled fuel to WBNP. It is also assumed that there are no radiological impacts associated with transporting the empty shipping cask from PNNL to WBNP for reloading. Therefore, the potential routine radiological impacts have been estimated for shipments from WBNP to PNNL, PNNL to HFEF, from HFEF to PNNL, and from PNNL to the Hanford Site solid waste facility.

The potential radiological impacts, based on the radionuclide inventories shown in Table D.1, have been calculated using the RADTRAN 4 computer code (Neuhauser and Kanipe 1994) and the assumptions provided in Tables D.3 and D.4. The potential radiological impacts involve in-transit doses to the public or, where appropriate, Hanford Site workers from radiation emitted from the shipping cask and doses to the transport workers in the vicinity of the shipment during cask-handling activities, e.g., loading or unloading the cask on or off the truck trailer. In-transit doses have been estimated for the truck drivers; the general public, including people at truck stops or those living or working

adjacent to the transport route; and nearby travelers (moving in the same and opposite directions). The results of the analysis are shown in Table D.5.

The total collective doses to the crew and members of the public for all shipments are 0.50 person-rem and 1.9 person-rem, respectively if 2 shipments are made between WBNP and PNNL; the corresponding estimates for 4 shipments would be 0.9 person-rem to the crew and 3.4 person-rem to the public (see Table D.5). To place these impacts in perspective, the estimated dose the public and Hanford Site workers might receive can be compared with the natural background dose they receive. The natural background dose was calculated for the exposed population along the route for one shipment from WBNP to PNNL. The exposed population was determined to be unshielded individuals within 30 m on both sides of the route. Thus, the total area involved is the product of the total shipping distance times 60 m. The number of persons in this area along the route was determined by multiplying the total affected area by the sum of the products of the travel fractions and population densities in rural, suburban and urban zones (see Table D.3), as shown below.

$$\begin{aligned}
 \text{Total shipping distance} &= 2514 \text{ km} \\
 \text{Exposure area, A} &= (2514 \text{ km})(0.06 \text{ km}) = 151 \text{ km}^2 \\
 &= A [(\text{travel fraction})(\text{population density})] \\
 \text{Total exposed population} &= 151 \text{ km}^2 [(0.875)(6.2)+(0.113)(349.2)+(0.012)(2174.7)] \\
 &= 10,700 \text{ persons}
 \end{aligned}$$

According to the National Council on Radiation Protection (NCRP 1987), the average annual natural background exposure in the United States is 300 mrem per year per person. The resulting average annual radiation dose to the exposed population (i.e., 10,700 persons) for the shipment from WBNP to PNNL is estimated to be 3,200 person-rem per year or 0.37 person-rem per hour. Based on the HIGHWAY 3.3 computer runs, the shipment from WBNP to PNNL will take approximately 2.25 days or 54 hours; therefore, the estimated dose from natural background radiation for a 54- hour period is 20 person-rem to the exposed population--greater than 13 times the estimated dose to the public or 1.5 person-rem per shipment (see Table D.5).

**Table D.4 Incident-Free and Accident Analyses Input Parameters<sup>a</sup>**

Parameter	Value
Fraction of travel time per population zone	See Table D.3 <sup>b</sup>
Radiation dose rate (mrem/hr) at 1m: Type B shipping cask solid waste container	1,000 <sup>c</sup> 200 <sup>d</sup>
Number of crewmen	2
Distance from source to crew, meters	10
Stop time per kilometer, hours per kilometer	0.011
Persons exposed while stopped	50
Average exposure distance while stopped, meters	20
Number of people per vehicle	2
Traffic count in rural zone, one-way vehicles per hour	470
Traffic count in suburban zone, one-way vehicles per hour	780

Traffic count in urban zone, one-way vehicles per hour	2,800
Total shipping distance, kilometers	See Table D.3 <sup>b</sup>
Population densities by population zone	See Table D.3 <sup>b</sup>
<ul style="list-style-type: none"> <li>a. RADTRAN 4 default values except where indicated</li> <li>b. Values are shipment dependent</li> <li>c. Regulatory maximum for a Type B package (10CFR71), RADTRAN 4 automatically adjusts for maximum allowable in crew compartment</li> <li>d. Hanford Site waste acceptance criteria</li> </ul>	

**Table D.5. Radiological Impacts of Routine or Incident-Free Transportation**

Material Transported		Radiological Impacts (person-rem)		Health Effects (LCFs)
Origin	Destination	Truck Crew	Public	Public
<b>Irradiated TPBAR assemblies</b>				
WBNP	PNNL			
	2 shipments	0.40	1.5	None (7.5E-04)
	4 shipments	0.80	3.0	None (1.5E-03)
<b>Irradiated TPBARs</b>				
PNNL	HFEF	0.046	0.18	None (9.0E-05)
HFEF	PNNL	0.046	0.18	None (9.0E-05)
PNNL	Solid Waste	0.0020	0.0024	None (9.6E-07)
<b>Non-target bearing components</b>				
PNNL	Solid Waste	0.0080	0.0094	None (3.8E-06)

### D.3.2 Non-Radiological Impacts of Incident-Free Transportation Activities

Impacts to the public from non-radiological causes were also evaluated. These impacts included fatalities resulting from fugitive emissions or pollutants emitted from the vehicles during normal transportation. Based on Rao et al. (1982), the types of pollutants that could impact the public are sulfur oxides (SO<sub>x</sub>), particulates, nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), hydrocarbons (HC), and photochemical oxidants (O<sub>x</sub>). Of these pollutants, Rao et al. (1982) determined that the majority of the health effects are due to SO<sub>x</sub> and the particulates. Rao et al. (1982) developed unit risk factors (fatalities per kilometer) for truck shipments traveling in urban population zones. The unit risk factor is 1.0E-07 fatalities/km for truck shipments.

The nonradiological incident-free impacts were calculated based on the travel distances shown in Table D.3. The results are shown in Table D.6. No nonradiological impacts are associated with this activity. That is, the total estimated number of fatalities is less than 4.2E-05.

**Table D.6. Nonradiological Impacts of Routine or Incident-Free Transportation**

Origin	Material Transported Destination	Nonradiological Impacts of fugitive emissions (fatalities)
<b>Unirradiated TPBAR assemblies</b>		
PNNL	WBNP	None (5.9E-06)
<b>Irradiated TPBAR assemblies</b>		
WBNP	PNNL 2 shipments	None (1.1E-05)
	4 shipments	None (2.2E-05)
<b>Irradiated TPBARs</b>		
PNNL	HFEF	None (5.3E-07)
HFEF	PNNL	None (5.3E-07)
PNNL	Solid Waste	NA <sup>a</sup>
<b>Non-target bearing components</b>		
PNNL	Solid Waste	NA <sup>a</sup>
<b>Empty shipping cask for reloading</b>		
PNNL	WBNP 1 shipment	None (4.2E-06)
	3 shipments	None (1.3E-05)

<sup>a</sup> Travel is restricted to Hanford Site roadways; therefore, unit risk factor is not applicable.

## D.4 ANALYSIS OF TRANSPORTATION ACCIDENTS

This section discusses the potential radiological and non-radiological impacts of transportation accidents for each part of the transportation route discussed in Section D.1. Radiological accident impacts to the collective population (public) were calculated using the RADTRAN 4 computer code (Neuhauser and Kanipe 1992). The radiological impacts to the maximum onsite and offsite individuals, were calculated using GENII (Napier 1988).

### D.4.1 Radiological Impacts to the Public from Transportation Accidents

This section describes the analyses performed to assess radiological impacts to the public and the maximum individuals from transportation accidents.

The transportation impacts are expressed as maximum individual doses or as integrated population risks. To determine the integrated population risks, the expected consequences of an accident were multiplied by the accident frequency, summed over all possible accidents, and then integrated over the entire shipping campaign. The potential impacts or consequences to the population from transportation accidents were expressed in terms of radiological dose and latent cancer fatalities.

Accident impacts can result from breaches in the shipping cask or damage to the cask shielding; however, the frequencies of occurrence of transportation accidents that would release significant quantities of radioactive material are relatively small. The shipping casks are designed to withstand specified transportation accident conditions (i.e., the shipping casks for all the materials shipped in this analysis were assumed to meet the Type B packaging requirements specified in 49 CFR 173 and 10 CFR 71); therefore, only a relatively small fraction of accidents involve conditions that are severe enough to result in a release of radioactive materials.

If the material were released to the environment, it would be dispersed and diluted by weather action, and a small amount would be deposited on the ground through plume depletion. Access to the area adjacent to the transportation accident would be controlled by emergency response personnel until the area could be remediated and the radiation monitoring personnel had declared the area safe.

The RADTRAN 4 computer code was used to calculate the radiological risk of transportation accidents involving radioactive material shipments. The RADTRAN 4 methodology was summarized previously. For further details, refer to the discussions presented by *RADTRAN III* (Madsen et al. 1986) and *RADTRAN 4: Volume 2 -- Technical Manual* (Neuhauser and Kanipe 1992).

The RADTRAN 4 computer code calculates potential accident transportation risk impacts using five major categories of input data : 1) accident frequency, 2) release quantities, 3) atmospheric dispersion parameters, 4) population distribution parameters, and 5) human uptake and dosimetry models. Accident frequency and release quantities are discussed below; the remaining parameters were discussed in Section D.2.1.

To calculate the frequency of a severe accident, an overall accident rate (accidents per truck-km) is multiplied by the conditional probability that an accident would involve mechanical and/or thermal conditions that are severe enough to result in container failure and subsequent release of radioactive material.

For this analysis, the six shipment-specific severity categories and conditional probabilities identified in DOE (1996) were used to model cask failure. The conditional probability for a given severity category is defined as the fraction of accidents that would fall into that severity category if an accident were to occur. Severity category 1 was defined as encompassing all accidents within the Type B package envelope that would not be severe enough to result in failure of the shipping cask (i.e., accidents with zero release). The higher categories (2-6) were defined to include more severe accidents that might lead to a release of radioactive material. The conditional probabilities of the various severity categories that were used in this analysis are shown in Table D.7.

**Table D.7. Severity Category Conditional Probabilities (DOE 1995)**

Mode/ Truck	Conditional Probability by Severity Category					
	1	2	3	4	5	6
Rural	0.462	0.302	0.176	0.0403	0.0183	6.84E-04
Suburban	0.436	0.285	0.221	0.0506	8.38E-03	7.31E-05
Urban	0.583	0.382	0.0278	6.36E-3	8.88E-04	1.22E-05

Release fractions are used to determine the quantity of radioactive material released to the environment as a result of an accident. The quantity of material released is a function of the severity of the accident (i.e., thermal and mechanical conditions produced in the accident), the response of the shipping container to these conditions, and the physical and chemical properties of the material being shipped. However, not all of the material released as a result of the accident is respirable and results in impacts to an individual. A fraction of the material released can be suspended in a plume

and inhaled by an individual. The release fractions used in this analysis are shown in Table D.8. The fraction of the material released and suspended in plume (Aerosol) that can be inhaled by an individual (Respirable) is shown in Table D.9.

**Table D.8. Release Fraction by Material and Severity Category**

TPBAR Assembly Component	Release Fraction by Severity Category					
	1	2	3	4	5	6
H-3 <sup>a</sup>	0	0.0099	0.033	0.39	0.33	0.63
NTBC <sup>a</sup>	0	3.0E-10	1.0E-09	1.0E-08	1.0E-08	1.0E-07

<sup>a</sup> Taken from DOE (1995), for aluminum and metallic spent nuclear fuel

**Table D.9. Aerosol and Respirable Fractions by Material and Severity Category**

TPBAR assembly component	Aerosol and respirable fractions by severity category <sup>a</sup>					
	1	2	3	4	5	6
H-3 <sup>b</sup>	A=0	A=1	A=1	A=1	A=1	A=1
	R=0	R=1	R=1	R=1	R=1	R=1
NTBC <sup>b</sup>	A=0	A=0.01	A=0.01	A=0.01	A=0.01	A=0.01
	R=0	R=0.05	R=0.05	R=0.05	R=0.05	R=0.05

a. A = fraction that is aerosol, R = fraction that is respirable

b. Taken from Neuhauser et al. (1992), H-3 characterized as a gas, and NTBC characterized as loose chunks.

The input data used to calculate the radiological dose to the public (i.e., population densities, travel times, and distances) were the same as the inputs used to calculate the incident-free dose to the population and are shown in Tables D.3 and D.4. The radiological inventory used in the accident analysis was shown in Table D.1. The accident frequency used in the analysis was based on a review of local or state-specific accident data (Saricks and Kvitek 1994). The Hanford Site accident data (or rates expressed as accidents/km) used in this analysis were taken from Bergsman et al. (1995) and are recommended for the Hanford Site. The accident rate used for truck shipments is 8.86E-08 accidents/km (5.50E-08 accidents/mi).

Table D.10 presents the expected consequences for each transportation mode by waste type and destination. As shown in Table D.10, there are no impacts to the public (i.e., LCFs are less than 3.3E-04).

**Table D.10. Radiological Impacts from Transportation Accidents**

Material Transported		Radiological Impacts (person-rem)	Health Effects (LCFs)
Origin	Destination	Public	Public

### Irradiated TPBAR assemblies

WBNP	PNNL	0.35	None (1.8E-04)
	2 shipments	0.59	None (3.0E-04)
	4 shipments		

### Irradiated TPBARs

PNNL	HFEF	0.030	None (1.5E-05)
HFEF	PNNL	0.030	None (1.5E-05)
PNNL	Solid Waste	0.00016	None (6.4E-08)

### Non-target bearing components

PNNL	Solid Waste	1.0E-11	None (4.0E-15)
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## D.4.2 Radiological Impacts to Maximum-Exposed Individuals

The consequences of a maximum credible accident to an individual were evaluated for shipments between the Hanford Site and ANL-W. Of the shipments evaluated, this leg would produce the greatest potential consequences because all 32 irradiated TPBARs could be involved. The receptor is assumed to be located at a distance of 100 m from the release if the accident occurs outside the boundaries of a DOE facility, or at the site boundary if the accident occurs onsite. Radiological doses were calculated for maximally exposed individuals near the PNNL 325 Building, either 100 m from the release point (the onsite individual), or at a distance of 580 m (the site boundary). For this bounding analysis, the maximum individuals were assumed to be located east-southeast of the release, which is the direction in which maximum consequences are obtained. These receptors were also presumed to bound the consequences of accidents that might take place within the INEEL site boundary or at offsite locations. The radionuclide inventory used in this analysis is shown in Table D.1. However, because tritium accounts for greater than 99% of the dose, only tritium releases are discussed in detail.

The bounding accident evaluated for transportation involves an impact severe enough to breach the shipping container and damage the TPBARs. Only free gaseous tritium within the TPBARs is assumed to be released in this event. Consistent with the evaluation for facility accidents (see Appendix C, Section C.3.1), the free tritium inventory in a single TPBAR amounts to an equivalent release of 96 Ci as tritium oxide. Therefore, if all 32 TPBARs were damaged, the maximum release of tritium oxide would amount to about 3100 Ci. The radiological impacts of this release to the maximum individuals were calculated using GENII (Napier et al. 1988), and the results are presented in Table D.11 (see also Appendix C, Table C.2).

The estimated frequency of this accident is less than  $2 \times 10^{-5}$  based on a round-trip transport distance of 1200 mi between ANL-W and Hanford (Table D.3), an accident rate of  $2.3 \times 10^{-7}$ /mi, and a conditional frequency of less than  $6 \times 10^{-2}$  for accidents of severity category 4 or greater (Table D.7). Accidents of lesser severity would release substantially less than the total free tritium inventory in the TPBARs (Table D.8), whereas accidents involving sufficiently high thermal and mechanical stress to release 100% of the tritium would be considered incredible (i.e., they have an expected frequency less than  $1 \times 10^{-7}$ ).

**Table D.11. Dose to Maximally Exposed Individuals**

Maximum Individual	Distance from Release	Total Effective Dose Equivalent (mrem)
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Public/Onsite	100 m	$3.1 \times 10^3$
Offsite	580 m	$1.6 \times 10^2$

### D.4.3 Non-Radiological Impacts due to Transportation Accidents

This section describes the analyses performed to assess non-radiological impacts to the public and Hanford Site workers. The non-radiological impacts associated with the transportation of the tritium lead test assemblies are assumed to be comparable to the impacts associated with general transportation activities in the United States. To calculate non-radiological impacts or fatalities, a unit risk factor (i.e. fatalities per km or fatalities per mi, developed for specific population zones or density) is multiplied by the total shipment distance (i.e., total distance per campaign). The fatalities are due to vehicular impacts with solid objects, rollovers, or collisions. Therefore, unit risk factors are required for crew members and the public, i.e., individuals on or immediately adjacent to roadways.

The unit risk factors applied to determine non-radiological impacts to the public (i.e., persons not on the Hanford Site) are taken from Saricks and Kvitek (1994). These factors are developed for specific population densities and are expressed as fatalities per km traveled. The unit risk factor used in this analysis for Hanford Site shipments, taken from Daling and Harris (1994), was  $5.3E-08$  fatalities/km for the public.

Results are obtained for each alternative by multiplying the unit risk factors by the appropriate total shipping distances for each alternative. It has been assumed that an accident that results in public or Hanford Site worker fatalities will also be fatal to the truck crew. The results of this analysis are shown in Table D.12 for all transportation modes, waste types, and destinations.

**Table D.12. Non-Radiological Impacts due to Transportation Accidents**

Material Transported	Origin	Destination	Non-radiological Impacts (fatalities)
<b>Unirradiated TPBAR assemblies</b>			
PNNL	WBNP		None ( $9.0E-05$ )
<b>Irradiated TPBAR assemblies</b>			
WBNP	PNNL		
	2 shipments		None ( $1.4E-04$ )
	4 shipments		None ( $2.8E-04$ )
<b>Irradiated TPBARs</b>			
PNNL	HFEF		None ( $1.6E-05$ )
HFEF	PNNL		None ( $1.6E-05$ )
PNNL	Solid Waste		None ( $1.9E-06$ )
<b>Non-target bearing components</b>			
PNNL	Solid Waste		None ( $9.2E-06$ )
<b>Empty shipping cask for reloading</b>			
PNNL	WBNP		
	1 shipment		None ( $6.4E-05$ )

## D.5 References

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