DOE/EA – 1290

Environmental Assessment

DISPOSITION OF RUSSIAN FEDERATION TITLED NATURAL URANIUM

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LIST OF ACRONYMS

AEA	The Atomic Energy Act of 1954, as amended. 42 USC 2011 *et seq.*
ACGIH	American Conference of Governmental Industrial Hygienists
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
BEA	Bureau of Economic Analysis
CERL	Construction Engineering Research Laboratory
CIS	Commonwealth of Independent States
CFR	Code of Federal Regulations
DOE	The United States Department of Energy
DOS	The United States Department of State
DOT	The United States Department of Transportation
EA	environmental assessment
EC	European Community
EDE	effective dose equivalent
EIS	environmental impact statement
EPA	United States Environmental Protection Agency
ERPG	Emergency Response Planning Guideline
FR	Federal Register
GDP	gaseous diffusion plant
HEDD	High Energy Density Device
HEU	highly enriched uranium
HIGHWAY	computer code for determining highway transportation routes
IDLH	Immediately Dangerous to Life or Health
LCF	latent cancer fatality
LEU	low enriched uranium
MINATOM	the Russian Federation atomic energy agency
MTU	metric tons (metric tons) of uranium
MWe	megawatts (electrical)
NAAQS	National Ambient Air Quality Standards
NEPA	The National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PL	Public Law
ppm	parts per million: liters/million liters of air or mg/liter of water
psi	unit of pressure: pounds per square inch
rad	unit of absorbed dose of ionizing radiation in the historic unit system
RADTRAN	code for estimating radiation doses and risks from transporting RAM
RAM	radioactive material
rem	unit of dose equivalent in the historic unit system
RMIR	Radioactive Materials Incident Report
SI	Standard International system of radiation units.
Sv	sievert: unit of absorbed dose of ionizing radiation in the SI unit system

SWU	separative work unit
TENEX	Technabexport, the Russian executive agency for export
TI	Transport Index: dose rate (mrem/hr) one meter from a package surface
TLV	threshold limiting value
U-235	uranium isotope of atomic weight 235; also written U^{235} and U-235
U-238	uranium isotope of atomic weight 238; also written U^{238} and U-238
UF_6	uranium hexafluoride
U_3O_8	uranium oxide, also known as yellowcake
USC	United States Code
USEC	United States Enrichment Corporation

1.0 PURPOSE AND NEED FOR ACTION

The United States Department of Energy (DOE) has prepared this Environmental Assessment (EA) pursuant to the National Environmental Policy Act (NEPA, 10 CFR 1021) to examine the environmental impacts in the United States of transporting up to an average of 9,000 metric tons per year of natural uranium as uranium hexafluoride (UF_6) from the United States to the Russian Federation. This amount of uranium is equivalent to 13,300 metric tons of UF_6. The EA also examines the impacts of this action on the global commons. Transfer of natural UF_6[1] to the Russian Federation is part of a joint U.S./Russian program to dispose of highly enriched uranium (HEU) from dismantled Russian nuclear weapons.

1.1 History of the U.S.-Russian Agreements Regarding Russian Weapons HEU

1.1.1 Background

In February 1993, the United States and the Russian Federation signed the United States/Russian Government-to-Government HEU agreement for the disposition and purchase of 500 metric tons of highly enriched uranium (HEU) extracted from Russian nuclear weapons. Pursuant to this agreement (hereinafter referred to as the "1993 Agreement"), the U. S. Executive Agent, the U. S. Enrichment Corporation (USEC), and the Russian Executive Agent, Techsnabexport (TENEX) executed an implementing contract[2]. The DOE and U. S. Department of State (DOS) have signed agreements with the Russian Atomic Energy Agency (MINATOM) and with TENEX outlining implementing protocols.

Under the implementing contract, USEC will purchase a total of 15,260 metric tons[3] of low-enriched uranium (LEU), as 22,570 metric tons of uranium hexafluoride (UF_6), derived from blending 500 metric tons of HEU with LEU.[4] Blending is done in the Russian Federation. It should be noted that the cost of producing enriched uranium (HEU or LEU) includes the cost of the uranium, the cost of conversion from U_3O_8[5] to UF_6, and the cost of uranium enrichment (the "uranium enrichment component"). The uranium enrichment component is priced in separative work units (SWU). To date, the Russian Federation has converted 50.5 metric tons of HEU and delivered it to the United States. However, the Russian Federation has not received payment for the natural

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[1] The term "natural UF_6" is used throughout this document to refer to uranium hexafluoride in which the uranium is 0.711% U-235 – the percent of uranium found naturally that is U-235 (the rest of the uranium is almost entirely U-238). General references to the compound uranium hexafluoride are to "UF_6." "Uranium" is used in this document when only the element itself is meant. "Natural uranium" means uranium (not UF_6) that is 0.711% U-235.

[2] The USEC was a government corporation until it was privatized in July, 1998. It serves as U. S. Executive Agent under an agreement among USEC, DOE, and the Department of State.

[3] One metric ton is equal to one million grams or 1,000 kg.

[4] The Russian LEU is UF_6 in which the uranium is enriched to about 4.4% U-235. It is produced by blending HEU from dismantled nuclear weapons with LEU enriched to 1.5% U-235.

[5] The product of the purification of uranium ore is U_3O_8, also known as "yellowcake." U_3O_8 must be chemically converted to UF_6 for enrichment.

uranium component of this material. In a commercial transaction for enrichment work, the purchaser of LEU delivers natural UF_6 feed material and purchases enrichment services (SWU) from the gaseous diffusion plant (GDP) in return for the LEU. However, because of the different origin of this LEU, the United States is not furnishing natural UF_6 feed to the Russian Federation. Instead, the Russian Federation needs to be paid for this component or otherwise compensated for it.

The 1993 Agreement and the initial contract between USEC and TENEX provided for prompt payment for the enrichment component of the LEU delivered to the United States. The enrichment component accounts for about 2/3 of the total value of the LEU. With regard to the natural uranium component of the LEU delivered under the 1993 Agreement (about 1/3 of the total value of the delivered LEU), the initial contract provided for payment when this component was either sold or utilized for overfeeding the gaseous diffusion plants by USEC. However, sale of this component in the United States was complicated by restrictions on Russian natural (UF_6) included in the Suspension Agreement between the U.S. Department of Commerce and the Russian Federation (USEC, 1993; USDOE, 1996).

The USEC Privatization Act (PL 104-134), which became law on April 26, 1996, clarified the disposition of the natural uranium component. This Act directs USEC to either auction the material and return the proceeds to TENEX, or return the natural uranium component of deliveries made under the HEU agreement to TENEX and to facilitate its disposition of natural uranium.

In September 1996, USEC and TENEX contracted to implement provisions of the Act that free USEC of responsibility for the natural uranium component related to the shipments. In addition, with regard to the enrichment component, in November, 1996, USEC and TENEX reached agreement on quantities and prices for the five year period, 1997 through 2001, providing for the purchase, by USEC, of the enriched component of Russian LEU, as shown in Table 1-1. Under this agreement, the Russian Federation will deliver the LEU derived from 30 metric tons of weapons HEU in each of the years 1999, 2000, and 2001, and will receive payment each year for the enrichment component.

Table 1-1 Government-to Government Agreement Purchases (www.usec.com)

YEAR	HEU BLENDED TO LEU (metric tons)	LEU DELIVERED (metric tons)	DELIVERED OR PROJECTED
1995	6	186	Delivered
1996	12	371	Delivered
1997	18	480	Delivered
1998	24	450	Only 60% delivered
1999	30		Projected
2000	30		Projected
2001-2013	30 per year		Projected

1.1.2 Disposition of the Natural Uranium Component

In December 1996, USEC transferred the U_3O_8 equivalent of 6,500 metric tons of natural uranium as UF_6 (16.9 million pounds of U_3O_8)[6] to the DOE, in accordance with 42 USC 2297h-10(b)(1). This represents the natural uranium component of the LEU purchased from the Russian Federation in 1995 and 1996.

> *On or before December 31, 1996, the United States Executive Agent under the Russian HEU Agreement shall transfer to the Secretary without charge title to an amount of uranium hexafluoride equivalent to the natural uranium component of low-enriched uranium derived from at least 18 metric tons of highly enriched uranium purchased from the Russian Executive Agent under the Russian HEU Agreement.* (42 USC 2297h-10(b)(1))[7]

As this citation indicates, this transfer resolved the issue of the natural component of the 1995 and 1996 LEU deliveries. To resolve the issue for subsequent deliveries, the Russian Federation has tried to negotiate agreements with commercial entities, including a Cameco/Cogema/Nukem consortium, to sell the remaining natural uranium component of the LEU shipped to the United States from 1997 to the present. However, obstacles to that agreement have included the significant quantities of uranium involved, restrictions on sale of this uranium to the United States, and an unattractive market price. Delivery of natural uranium of Russian Federation origin to end users in the United States is limited in accordance with terms of the Act and the 1996 amendment to the Suspension Agreement.[8] These limits are shown in Table 1-2 and Table 1-3. However, conversion of U_3O_8 to UF_6 is not limited.

In an attempt to help resolve this situation, the Omnibus Appropriations Act of October 31, 1998 allows DOE to request an emergency appropriation to buy the natural uranium component of the Russian Federation's 1997 and 1998 LEU deliveries, once the Russian Federation government entered into long term agreements with commercial partners for the sale of the natural uranium component of the post-1998 Russian LEU deliveries.

At the September 22, 1998, summit meeting between the United States and the Russian Federation, Presidents Clinton and Yeltsin recognized the need to address additional payments to the Russian Federation as compensation for the value of the natural uranium contained in the LEU delivered to the United States. Therefore, the United States proposed a number of steps to encourage and facilitate a deal between the Russian Federation and the western companies. These steps could include deferring sales of

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[6] Calculation of U_3O_8 equivalent from a given quantity of uranium and of UF_6 is shown in Appendix A.

[7] 14.3 million pounds of U_3O_8 equivalent as natural UF_6 – 6.5 million kg of uranium -- is equivalent to about 18 metric tons of HEU,. The 18 metric tons cited in the relevant section of the Act is the sum of the 1995 and 1996 deliveries.

[8] The United States/Russian Federation Suspension Agreement provides that, after 2003, "Russian" natural uranium would either be sold outside the United States, used for overfeeding, or sold for domestic use at a maximum rate of three million pounds U_3O_8 equivalent per year

uranium by the DOE; arranging an advance payment to the Russian Federation to be repaid through future deliveries of enriched uranium; and assistance in returning a portion of the natural UF_6 to the Russian Federation

As a result of these Congressional and Presidential efforts, DOE and MINATOM, on March 24, 1999, concluded an agreement (the "1999 Agreement") that provides for the shipment to the Russian Federation of natural UF_6 not purchased under the Russian Federation's commercial agreements. In return, the Russian Federation concluded an agreement with the group of western companies that will allow the Russian Federation to realize fair value for the Russian material.

Table 1-2 Annual Maximum Deliveries of Russian Federation Origin Natural UF_6 to U. S. Domestic End Users Under the USEC Privatization Act[9]

YEAR	MILLION POUNDS U_3O_8	THOUSAND METRIC TONS UF_6	THOUSAND METRIC TONS U
1998	2	1.14	0.77
1999	4	2.28	1.54
2000	6	3.43	2.31
2001	8	4.56	3.08
2002	10	5.70	3.85
2003	12	6.86	4.62
2004	14	7.98	5.39
2005	16	5.12	6.16
2006	17	9.71	6.54
2007	18	10.28	6.92
2008	19	10.86	7.31
2009 and annually thereafter	20	11.40	7.70

Table 1-3 Annual Maximum Deliveries of Russian Origin Natural UF_6 to U. S. Domestic End Users Under the U.S./Russian Federation Suspension Agreement*

YEAR	MILLION POUNDS U_3O_8	THOUSAND METRIC TONS UF_6	THOUSAND METRIC TONS U
1996	1.93	1.10	0.74
1997	2.71	1.55	1.04
1998	3.60	2.05	1.39
1999	4.04	2.31	1.55
2000	4.23	2.42	1.63
2001	4.04	2.31	1.55
2002	4.89	2.79	1.88
2003	4.30	2.46	1.65

*Note: such sales must be matched with sales of equivalent quantities of domestically produced uranium

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[9] The use of the terms "uranium," "UF_6," and "U_3O_8 equivalent" is necessary because all are used in discussions of uranium commerce, but can be confusing. Relationships among them are shown in Appendix A. In order to minimize confusion, the amount of UF_6 equivalent to each amount of U_3O_8 is shown in Tables 1-2 and 1-3.

1.2 Relationship to Other DOE NEPA Documents

The proposed actions and the alternatives considered in this EA would be in addition to actions evaluated in three other NEPA analyses: the *Environmental Assessment for the Purchase of Russian Low Enriched Uranium Derived from Dismantlement of Nuclear Weapons in the Countries of the Former Soviet Union* (USEC/EA-94001; DOE/EA-0837, 1994), the *Disposition of Surplus Highly Enriched Uranium Final EIS* (DOE/EIS-0240, 1996), and the *Environmental Assessment for the DOE Sale of Surplus Natural and Low Enriched Uranium* (DOE/EA-1172), 1996. This section discusses three DOE NEPA analyses of actions that have an impact on the domestic uranium market. The current EA considers the environmental impacts of shipping natural UF_6 from the Portsmouth, OH and Paducah, KY gaseous diffusion plants to the Baltic Sea ports of the Russian Federation, as well as socioeconomic impacts.

1.2.1 *Environmental Assessment for the Purchase of Russian Low Enriched Uranium Derived from Dismantlement of Nuclear Weapons in the Countries of the Former Soviet Union* (USEC/EA-94001; DOE/EA-0837)

This EA considers the environmental impact of the purchase of an estimated 500 metric tons of HEU converted to LEU over a 20-year period beginning in fiscal year 1994 (FY94) and ending in fiscal year 2013 (FY13). In total, an estimated 15,250 metric tons of LEU or 22,570 metric tons of natural UF_6 would be transported to the United States from the Russian Federation. The LEU would be sold by the USEC for ultimate use as commercial nuclear reactor fuel. This EA is related to the current EA in that the purpose of the proposed action of the current EA is to pay for the natural uranium component of the delivered LEU. This EA led to a Finding of No Significant Impact (FONSI).

1.2.2 *Disposition of Surplus Highly Enriched Uranium Final EIS* (DOE/EIS-0240), 1996

This EIS considers the potential environmental impacts of alternatives for a program to reduce global nuclear proliferation risks by blending down surplus HEU to LEU to make it non-weapons-reusable. The weapons-usability of HEU can be eliminated by blending it with material that is low in U-235 and high in U-238. Much of the LEU resulting from blend-down will be suitable for fuel fabrication for commercial nuclear power plants. In its Record of Decision (61 FR 40619, 1996), DOE decided to implement the preferred alternative over a 15-year period, gradually blending up to 85% of the surplus HEU to a U-235 enrichment level of approximately 4% for eventual sale and commercial use, and blending the remaining surplus HEU down for disposal as low-level radioactive waste.

1.2.3 *Environmental Assessment for the DOE Sale of Surplus Natural and Low Enriched Uranium* (DOE/EA-1172), 1996

This EA considers alternatives available to DOE for selling approximately 35.7 million pounds of uranium, including surplus uranium in its inventory and transferred Russian uranium, for subsequent enrichment and fabrication into commercial nuclear power reactor fuel. This EA led to a Finding of No Significant Impact (FONSI).

1.3 Need for Action

As described above, options for disposition of the Russian Federation natural uranium are limited in the United States. Without the proposed action, important non-proliferation agreements between the Russian Federation and the United States regarding the 500 metric tons of HEU extracted from dismantled nuclear weapons could be in jeopardy. While the Russian Federation has brokered a deal with commercial entities, it also wants the ability to transfer natural UF_6 to the Russian Federation if this natural UF_6 is not purchased. Otherwise the Russian Federation is simply continuing to receive less than full payment for its delivered "product."

The United States and the Russian Federation are proposing to ship up to an average of 9,000 metric tons of natural uranium, containing 0.711% U-235, as UF_6 from the GDPs at Paducah, KY, and Portsmouth, OH, to the Russian Federation each year from 1999 through the 2013. The 9,000 metric tons is equivalent to the natural uranium component of the LEU delivered by the Russian Federation in each of these years. If this material were shipped to the Russian Federation by TENEX, it would have to be transported from the GDPs to a commercial United States port and then by sea to a Russian Federation port. The return of the Russian owned natural UF_6 must be approved by the U.S. Nuclear Regulatory Commission (NRC) under Atomic Energy Act (AEA) requirements for government distributions. Specifically, Section 111(a) of the AEA states:

> *The Nuclear Regulatory Commission is authorized to license the distribution of special nuclear material, source material, and byproduct material by the Department of Energy pursuant to section 54, 64, and 822 of this title, respectively, in accordance with the same procedures established by law for the export licensing of such material by any person.* (42 USC 2141(a))

DOE proposes to apply to the NRC for a license pursuant to the provisions of the AEA.

2.0 DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES:

USEC requires that purchasers of uranium enrichment services provide their own natural UF_6 to USEC in amounts sufficient to compensate for the natural uranium used to produce LEU at the enrichment levels requested by the customer. Because USEC is selling only the SWU contained in LEU obtained from the Russian Federation under the HEU agreement, USEC is not using the natural UF_6 (supplied by purchasers who receive the Russian-origin LEU) at the GDPs. Thus, USEC is effectively stockpiling natural UF_6 (0.711%U-235). In order to compensate the Russian Federation for the value of the natural uranium component of the Russian LEU delivered to USEC, USEC has, since 1997, transferred title to the Russian Federation of an amount of natural uranium equivalent to that in the Russian LEU delivered to USEC.

Even though the natural UF_6 is Russian owned, the Russian Federation is limited by the USEC Privatization Act in its ability to sell it in the United States (see Tables 1-2 and 1-3). Therefore, for the Russian Federation to receive fair value for its natural uranium, and to use all of the natural UF_6 under its control at the USEC GDPs, DOE is proposing that at least some of the Russian owned natural UF_6 be returned to the Russian Federation.

It is expected that each year after 1998, the Russians will deliver 30 metric tons of HEU blended to LEU to USEC. Contained in this LEU will be approximately 9,000 metric tons of natural uranium. Under the terms of the 1993 Agreement, with subsequent modifications of the implementing contract, USEC will continue to transfer to Russian Federation title an average of about 9,000 metric tons per year of natural uranium as UF_6 (contained in approximately 1,400 Model 48X cylinders) that has already been delivered to the GDPs.

2.1 Proposed Action

DOE submits a license application to the NRC that would allow up to an average of 9,000 metric tons of natural uranium as UF_6 that is Russian titled and stored at the GDPs to be shipped to the Russian Federation each year.

As part of the recently concluded 1999 Agreement between the Russian Federation and the United States, the Russian Federation could ship up to an average of 9,000 metric tons of natural uranium as UF_6 from the USEC sites to the Russian Federation each year until the year 2013. It is anticipated that for most of this period, significantly less than that amount would be shipped to the Russian Federation because of purchases by western uranium companies under a contract with the Russian Federation. In sum:

- The Russian Federation ships LEU to the GDP
- USEC customers order LEU, deliver natural UF_6 to the GDP, pay for the enrichment separative work units (SWU), and receive LEU.

- The natural UF_6 delivered by USEC's customers that receive Russian-origin LEU is re-titled to the Russian Federation and is either shipped to Russia or sold to western uranium companies.

Implementing the new government-to-government agreement would require that the NRC grant a license for the export of the material, consistent with other United States nonproliferation requirements. Accordingly, DOE is proposing to submit such a license application to the NRC.

As a necessary step in the licensing process, the NEPA requires that the United States Government assess the relevant environmental impacts associated with the storage, transportation, and export of this material. The environmental analysis is bounded by the cases of (a) returning all the natural uranium to the Russian Federation for the entire period, and (b) accumulating all the material at USEC for the entire period. Although neither extreme would be likely, this EA has analyzed the case of returning all of the natural UF_6 to the Russian Federation for the entire period – the first bounding case. Much of the material would be marketed on a regular basis, on terms contemplated in 1996 United States law (see Tables 1-2 and 1-3), and in a long term commercial agreement concluded by the Russian Federation and Western companies in parallel with the new government-to-government agreement.

Environmental impacts to be considered are those of storing this material at the GDPs and transporting this material from the GDPs to the Russian Federation. The ports of Hampton Roads, VA and Baltimore, MD are the United States ports of export considered as destinations for overland transport. Other reasonable East Coast and Gulf Coast ports are considered as alternatives. Although both truck and rail transportation are considered, commercial truck transportation is the mode used in the proposed action because most shipments of UF_6 in the United States have been made by truck. In assessing overland transportation impacts, both incident-free transportation and transportation accidents are considered, as are transfer to ships in port and marine transport. Finally, socioeconomic impacts are considered.

2.2. Alternatives

This section briefly describes alternatives to the proposed action which are analyzed in this Environmental Assessment.

2.2.1 No Action Alternative

Russian Federation titled natural UF_6 would remain in storage at USEC.

Although the Russian Federation could sell stored natural UF_6 for United States end use, within the limits prescribed in the Act and the United States/Russian Federation Suspension Agreement (see Tables 1-2 and 1-3), the remaining natural UF_6 would remain in storage at USEC. The Russian Federation could sell remaining quantities of natural

UF_6 for foreign end use via USEC's international customers or by shipping the uranium component to a foreign enricher. In sum:

- The Russian Federation ships LEU to the GDP
- USEC customers order LEU, deliver natural UF_6 to the GDP, pay for SWU, and receive LEU
- The natural UF_6 is retitled to the Russian Federation
- Any of the Russian Federation natural UF_6 that can not be sold within or outside of the United States remains in storage at the GDPs.

Under this alternative, the 1993 Agreement would be jeopardized and the Russian Federation would not realize the full value of the natural uranium component of the LEU.

2.2.2 Transportation of Natural UF_6 by Rail from the GDPs to Proposed United States Seaports

Under this alternative, the Russian Federation would ship up to an average of 9,000 metric tons of natural UF_6 by rail from the GDPs to the United States seaports of Hampton Roads, VA and Baltimore, MD. A rail car can carry up to four Model 48X cylinders or two Model 48Y cylinders. Queuing for shipment could require several rail cars to a shipment. Because of the expense and logistics involved in organizing rail shipments, it is likely that a rail shipment would involve many cylinders of natural uranium that have been queued for shipment to a port.

2.2.3 Overland Transportation of Natural UF_6 to Alternate United States East Coast and Gulf Coast Seaports

Under this alternative, the Russian Federation would ship up to an average of 9,000 metric tons of natural UF_6 overland by truck to one of the following ports: Philadelphia, PA, New York, NY, Houston, TX, Charleston, SC, Savannah, GA, Fernandina Beach (Jacksonville), FL, and Morehead City, NC. Under this alternative, overland rail transportation to these ports is also considered, except for Fernandina Beach and Morehead City, which have no rail access. Use of a Gulf Coast departure port is unlikely.

2.3 Alternatives Considered But Not Analyzed In Detail

In addition to the alternatives described in Section 2.2, there were a number of reasonable alternatives whose environmental impacts were not analyzed in detail, because they are subsumed by the environmental impacts of the analyzed alternatives. These are summarized in Section 2.3.1. Alternatives that are not considered to be reasonable are summarized in Section 2.3.2.

2.3.1 Variants of the Proposed Action

Many alternative strategies would enable the Russian Federation to receive value, in compensation or in kind, for the natural uranium component of LEU delivered to the GDPs. Options include:

(1) USEC or the United States Government paying the Russian Federation for the natural uranium component of LEU delivered to the GDPs;
(2) the United States Government increasing the limits on sales of Russian natural uranium in the United States and allowing customers to purchase additional quantities of Russian Federation titled natural uranium;
(3) USEC providing customer information to the Russian Federation and allowing the Russian Federation to deliver LEU directly to USEC customers, bypassing the GDPS, and having customers pay for the enrichment service and natural feed component; and
(4) providing a mechanism whereby USEC customers transfer title to the Russian Federation of natural UF_6 purchased outside the United States, and then deliver that natural UF_6 to the Russian Federation instead of to USEC at the GDPs.

Each of these options meets the intent of the proposed action; that is, the Russian Federation receives value either in natural UF_6 or dollars for the natural uranium component of the LEU delivered to USEC under the HEU Agreement. The environmental impacts of each option are also bounded by the proposed action. Each option involves less natural uranium transportation in the United States than the proposed action. However, the socioeconomic impacts of some of these options are not the same as those of the proposed action, and are analyzed in Section 4.10. None of these options is under consideration as an implementing strategy for the latest proposed government to government agreement. In the case of transferring title of natural UF_6 in a third country, not the United States or the Russian Federation, diplomatic agreements would have to be reached to make this option feasible. In the case of paying the Russian Federation for the natural uranium component of the LEU, United States legislation would have to be passed and appropriations made or significant changes made to USEC contracts.

2.3.2 Transportation of Natural UF_6 to West Coast Seaports

Ships transporting natural UF_6 from the United States to the Russian Federation would use normal shipping lanes through the Atlantic Ocean, the North Sea, the Baltic Sea, and Gulf of Finland to St. Petersburg. Since the most frequently scheduled, and also the shortest, voyages from the United States to St. Petersburg depart from the East Coast of the United States, it is unlikely that a ship carrying cargo from either GDP and destined for the Russian Federation would use a West Coast port.

If a West Coast port of departure were used, the shipping routes through the Gulf of Mexico or the Pacific Ocean would be significantly longer than those for East Coast ports. The truck travel distance from either the Portsmouth or the Paducah GDP to a West Coast or Gulf Coast port is much greater than the distances associated with East Coast ports. Although Vladivostok is closer to United States West Coast ports, it is not the port of choice for shipments from the United States. Overland transportation to the Russia interior is considerably better from St. Petersburg than from Vladivostok.

3.0 DESCRIPTION OF THE AFFECTED ENVIRONMENT

3.1 Current Operation of the Gaseous Diffusion Plants (GDPs)

This section discusses the operation of the gaseous diffusion plants at Portsmouth, OH, and Paducah, KY. The role of Russian LEU in the proposed action and alternatives, and the natural and anthropogenic environments of both gaseous diffusion plants are described. The cylinders used for storing and transporting UF_6 are also described. The uranium enrichment and gaseous diffusion processes are described in Appendix B.

3.1.1 Current Uranium Inventory

DOE has currently stockpiled 23.8 million pounds of U_3O_8 equivalent as natural UF_6. Of the 23.8 million pounds, 14.2 million pounds is United States origin and 9.6 million pounds is Russian Federation origin (the DOE's remaining balance from the natural uranium component from the 1995 and 1996 LEU deliveries under the 1993 Agreement). The 14.2 million pounds U_3O_8 equivalent are stored at the Paducah GDP. The 9.6 million pounds U_3O_8 equivalent of Russian Federation origin are stored at both the Paducah and Portsmouth GDPs (USDOE, 1999).

3.1.2 The Blending Process and the Role Of Russian HEU

Under the 1993 Agreement, LEU that the Russian Federation has produced by blending HEU with 1.5% enriched UF_6 is sold to USEC in quantities specified by the HEU Purchase Contract (see Tables 1-2 and 1-3). The 9,000 metric tons of natural uranium as UF_6 titled to the Russian Federation represents the natural uranium component of the LEU purchased by USEC.

3.1.3 The Portsmouth GDP

The Portsmouth GDP was constructed between 1952 and 1954 on a 4,000-acre site immediately east of the Scioto River, three miles south of Piketon, OH and 22 miles north of Portsmouth, OH. The plant has been in operation as a uranium enrichment facility since 1955. Shipments of Russian LEU under the 1993 Agreement would go only to the Portsmouth GDP, because final enriched product is currently transported only from the Portsmouth GDP to the fuel fabricators. Depending on customer requirements, Portsmouth GDP generally ships the UF_6 directly to the fabricator, but sometimes does some blending to the desired assay. However, natural UF_6 would be titled to the Russian Federation at both Portsmouth and Paducah.

Natural UF_6 is delivered to the Portsmouth GDP and stored in Model 48X and 48Y cylinders. Under the proposed action, natural UF_6 would be shipped from the GDPs in the same cylinders in which it has been delivered to the GDPs, so that no transfer of contents would be necessary. UF_6 cylinders have been handled safely at the plant since the beginning of its operation, demonstrating that the plant has both adequate experience and a good safety record in handling UF_6 at various enrichment levels. No new processes or equipment would be required to handle Russian Federation titled natural UF_6 cylinders.

The GDPs currently store UF_6 on site, in the open air, stacked in rows, two high, on special concrete storage pads. A variety of cylinders are used for storage, including Type 30B, Type 48X, and Type 48Y. The cylinder used depends on the enrichment and on minimizing the handling of UF_6 (USEC, 1998). Atmospheric corrosion on the cylinders is very slight, and an extensive test program started in the early 1970s indicates that the oldest cylinders are expected to have a remaining service life until at least 2020. At that time, the wall thickness of the oldest cylinders is expected to approach ¼ inch. The newest cylinders are expected to have a service life of more than 70 years.

Two cylinders at the Portsmouth plant were each found to have a small hole in the side, apparently caused by bumping against a lifting lug on an adjacent cylinder. In one case, the UF_6 formed a relatively insoluble plug, and no contents were lost. In the other case, less than 0.5% was found to have been released, with no measurable impact. These two cylinders were emptied. All cylinders are now inspected in accordance with ANSI N14.1 standards on a five year cycle to ensure that no leaks have developed. In addition, improved stacking procedures have been instituted to eliminate the possibility of cylinder damage in the future (USEC, 1998).

3.1.3.1 The Portsmouth Natural Environment

The plant site lies in Pike County, OH, where winters are moderately cold and summers, moderately warm and humid. Soils at the site are strongly acidic, and soil productivity varies from low on steep uplands to very high on terraces and flood plains; texturally, the soils are predominantly silt loams. The site sits among gently rolling hills, many of which have dry ridge tops, dry to moist slopes, and low-lying bottom lands. The vegetational community is dominated by deciduous tree cover consisting of white oak, red oak, and hickory. The animal species, their abundance, and their relative distributions are typical of those found in southern Ohio. Drainage from the entire area flows into various tributaries of the Scioto river, which in turn flow into the Ohio River at Portsmouth. The area around the site is generally sparsely populated, marginal farmland (USEC, 1993).

The natural environment of the Portsmouth GDP off-site environs is not likely to be affected by accidental releases of natural UF_6 at the plant, because of the chemical nature of an accidental release and the emergency response to it. When gaseous UF_6 is released to the atmosphere, it reacts rapidly with water in the air to form a dense white cloud of gaseous hydrofluoric acid (HF) and fine particles of uranyl fluoride (this reaction is described in Section 4.1.1.). External exposure can result in skin burns and inhalation of fumes for more than a few breaths may result in lung impairment. The chemical hazard greatly exceeds the radiation hazard (USEC, 1998).

There are potential hazards to workers in handling and monitoring UF_6 cylinders, and existing emergency procedures ensure that exposure to a release is limited. Small leaks in cylinders containing UF_6 tend to be self-sealing (USEC, 1998). Because the plant (including cylinder storage) occupies 17% of the 5.8-square-mile (3708 acre) site (www.usec.com), any accidental release of uranyl fluoride and HF aerosol into the air at the plant would be sufficiently diluted at the site boundary to be insignificant (Wark and Warner, 1981). Therefore, an accidental release would affect only the plant workers. Other hazards to workers include those associated with ordinary industrial processes: maintaining equipment that draws large quantities of power, moving heavy equipment, etc. The occupational hazards exist no matter what the enrichment of the UF_6, because they are essentially functions of the chemical and physical properties of UF_6 and of the equipment of the plant.

3.1.3.1.1 Threatened and Endangered Species

The State of Ohio Department of Natural Resources has identified two threatened mollusks that occur in the Scioto river near Piketon, OH; neither occurs on land owned by Portsmouth GDP (USEC, 1993).

3.1.3.2 Environmental Monitoring and Protection

Environmental monitoring systems at Portsmouth include emission monitoring networks for air and surface water discharges, waste sampling and characterization, and ambient sampling networks for air, surface water, groundwater, drinking water, vegetation (cattle forage), food crops, fish, soil, creek and river sediments, and direct (gamma) radiation levels. The Portsmouth GDP has an established radiological protection and surveillance program, which monitors radiation doses received by employees and seeks to keep exposures as low as reasonably achievable (an ALARA program). For example, in 1995 the maximum individual worker EDE was 636 millirem (0.636 rem) (USDOE, 1996). DOE regulation limits annual occupational exposure to 5,000 millirem (5 rem) effective dose equivalent, or EDE (10 CFR Part 835, 1997). The EDE is calculated from the whole body monitored dose by partitioning the dose among the organs of the body and taking into account the relative radiosensitivity of various parts of the body. Average annual individual background radiation exposure in the United States is 360 mrem (0.360 rem) (Upton, 1990). The Portsmouth GDP has an emergency response plan approved by the Nuclear Regulatory Commission (USDOE, 1996).

3.1.4 The Paducah GDP

The Paducah GDP was constructed between 1951 and 1954 on a 5.35 square mile (3,423-acre) site 10 miles west of Paducah, KY. The plant occupies 22% of the site (www.usec.com). Paducah GDP enriches UF_6 0.711% assay U-235 to 1.9% assay U-235. The 1.9% assay U-235 is then transported to the Portsmouth GDP, where it is enriched to the desired final product assay. The Paducah GDP currently stores about

1500 cylinders of natural UF_6. Storage and cylinder life are the same as those described in Section 3.1.3.

3.1.4.1 The Paducah Natural Environment

The Paducah GDP occupies 748 acres of the site. It is surrounded by predominantly open fields and forested land with intermittent agricultural activities. Rural residential clusters form seven small communities within seven miles of the plant. The immediate area of the site is underlain by 18 to 24 feet of fill (gray to brown silt with a trace of clay) excavated during plant construction. The primary aquifers include Lower Continental deposits, the Eocene sands, and the sands of the McNairy formation.

The plant is located south of the Ohio river, above the historic high water flood level of the river, in an area of low geographic relief. Surface drainage from the site is to two small tributaries of the Ohio river: Big Bayou Creek on the west and Little Bayou Creek on the east. The climate is temperate, with moderately cold winters and warm humid summers. The county (McCracken County) is an attainment area: ambient air concentrations of most criteria air pollutants comply with the National Ambient Air Quality Standards (NAAQS). The upland forests in the area are hardwoods: oak and hickory, with many tree species. The site contains no extensive areas of upland hardwood forest, but does include small woodlots. The riparian forest along Big and Little Bayou Creeks is dominated by river birch, black willow, and eastern cottonwood.

The natural environment of the Paducah GDP off-site environs is not likely to be affected by accidental releases of natural UF_6 at the plant. As described in Section 3.1.3.1, any accidental release would affect only the plant workers.

3.1.4.1.1 Threatened and Endangered Species

The bald eagle, arctic peregrine falcon, and the interior least tern are listed as threatened or endangered species in McCracken County, but none of these birds is known to nest on the site or other DOE land at Paducah. Several federally listed species of threatened mussel are known to exist in McCracken County waters, but have not been reported in Big or Little Bayou Creeks. No threatened or endangered plants are known to occur in McCracken County, although two species listed by the state of Kentucky as threatened, the sweet cone flower and the compass plant, are considered possible occurrences at the site but are not afforded any special protection by the state.

3.1.4.2 Environmental Monitoring and Protection

Environmental monitoring systems at Paducah include emission monitoring networks for air and surface water discharges, waste sampling and characterization, and ambient sampling networks for air, surface water, groundwater, drinking water, vegetation (cattle forage), food crops, fish, soil, and creek and river sediments. The Paducah GDP has an established radiological protection and surveillance program, which monitors radiation doses received by employees and seeks to keep exposures as low as reasonably achievable (an ALARA program). In 1995 the maximum individual worker EDE at Paducah was 285 millirem (0.285 rem) (USDOE, 1996).

3.1.5 Cylinders For Natural UF_6 Storage and Transportation

Shipments of natural UF_6 in the solid state would be made in Model 48X and Model 48Y cylinders that meet all U.S. and international radioactive material packaging requirements. Differences between the Model 48X and Model 48Y packagings are taken into account in the analyses of incident-free transportation, transportation accidents, and ship loading accidents (Sections 4.3 through 4.6 of this report). The Model 48X and Model 48Y cylinders meet DOT requirements for Type A packaging (sometimes called strong, tight packaging). The DOT and NRC regulations treat UF_6, when enriched to less than 1% U-235, as presenting a sufficiently minimal radiation hazard that an "unlimited" quantity of uranium can be shipped in Type A packaging (10 CFR71.53(b)). Nevertheless, in accordance with the most current IAEA safety standards. It is expected that overpacks will be used with Model 48X and Model 48Y cylinders carrying natural UF_6, if required. The analyses of environmental impacts in Section 4 assume for purposes of conservatism that all cylinders are transported without overpacks.

All cylinders used in the United States, including those fabricated outside of the United States, must comply with the American National Standards Institute (ANSI) UF_6 standard: ANSI N14.1-1995 Uranium Hexafluoride - Packaging for Transport. The International Standards Organization develops packaging standards in parallel, and in cooperation with, ANSI. The standards provide specifications for package design, fabrication, loading, shipping, and requirements for valves, valve protectors, inspection, cleaning, and maintenance. DOT regulations on authorized packaging of fissile materials in 49 CFR §173.417 require that handling procedures and packaging criteria be in accordance with USEC, 1995. A Model 48X cylinder is shown in the photograph in Figure 3.1 and a schematic drawing, in Figure 3.2. A Model 48Y cylinder is shown in the photograph of Figure 3.3 and a schematic drawing, in Figure 3.4 (USEC, 1995).

UF_6 is a relatively stable compound. The radioactivity of UF_6 varies with the U-235 enrichment. Naturally occurring uranium (enrichment of 0.711% U-235) has a specific activity of 1.5 disintegrations per minute per microgram (d/m-μg) (0.068 μCi/g or 0.025 Bq/μg). Therefore, each Model 48X cylinder containing 9,500 kilograms of natural UF_6 would have an activity of about 4.4 curies and a Model 48Y, about 5.2 curies. In comparison, a cask containing spent nuclear fuel from a pressurized water reactor contains approximately one million (1,000,000) curies.

The bulk of the activity in UF_6 comes from alpha-emitting radionuclides (uranium and some products of uranium decay). Alpha particles, resulting from the primary disintegration of uranium, present no external radiation problem, since they do not penetrate the skin. Other decay products of uranium, however, include isotopes that emit mildly penetrating beta rays and highly penetrating gamma rays. Beta radiation levels as high as 200 mrad/hr may be found on the inner surface of UF_6 cylinders after the UF_6 has been removed, because the uranium daughters (decay products) tend to remain on the inner cylinder surface when residual UF_6 left in a cylinder evaporates. The gamma radiation from an empty cylinder will be much higher than from a filled cylinder, and may range up to 200 mrad/hr. Much of the radiation producing these doses is absorbed by the UF_6 when the cylinder is full. Radiation exposures of employees working around UF_6 cylinders are easily controlled at very low levels through conventional distance-time limitations. Moreover, empty cylinders are thoroughly cleaned and decontaminated before being transported or put to other uses (USEC, 1998).

The amount of UF_6 that may be contained in an individual cylinder and the total number of cylinders that may be transported concurrently are determined by the nuclear properties of enriched UF_6. The Model 48X cylinder is certified to transport up to 9,539 kg of UF_6 up to a maximum enrichment of 4.5% ^{235}U, and the Model 48Y, up to 11, 924 kg of 4.5% ^{235}U. However, only natural UF_6 would be transported in the shipments covered by this EA. The fissile content of natural uranium is so small that developing a critical mass in these cylinders and under the proposed shipping conditions would be essentially impossible. In fact, the U.S. Department of Transportation (DOT) packaging regulations recognize that there can be no criticality hazard at less than 1% U-235.

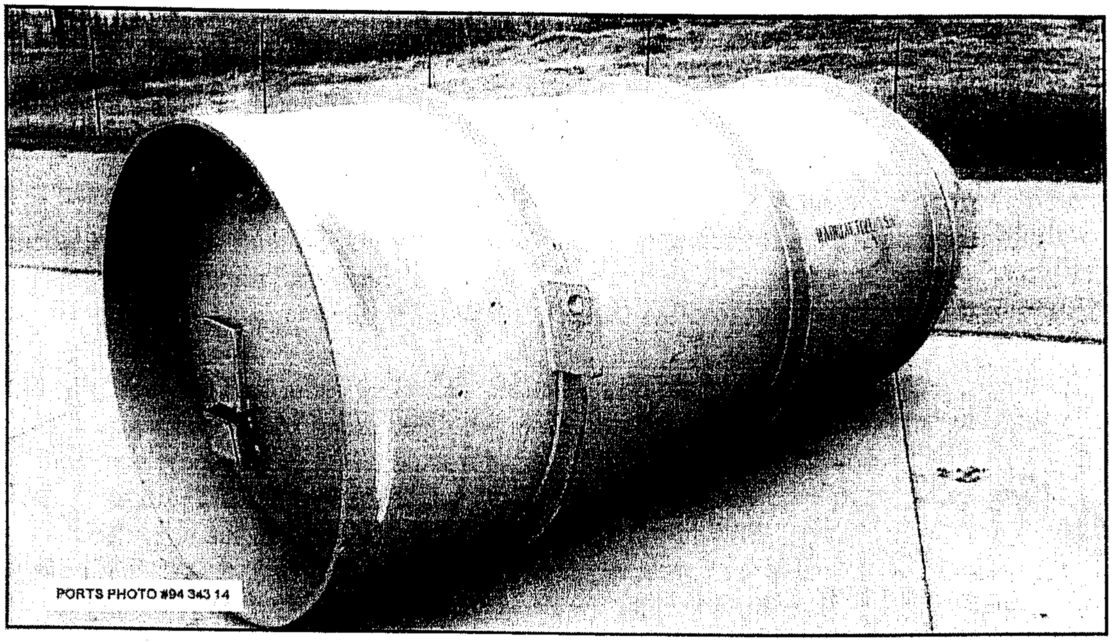

Figure 3.1. A Model 48X cylinder. Nominal specifications are: diameter: 48 inches; length: 119 inches; wall thickness: 5/8 inch; tare weight: 4,500 lb; maximum net weight: 21,030 lb. The Model 48X is made of ASTM A-516 steel and the maximum enrichment it can be used for is 4.5% U-235 (from USEC, 1995).

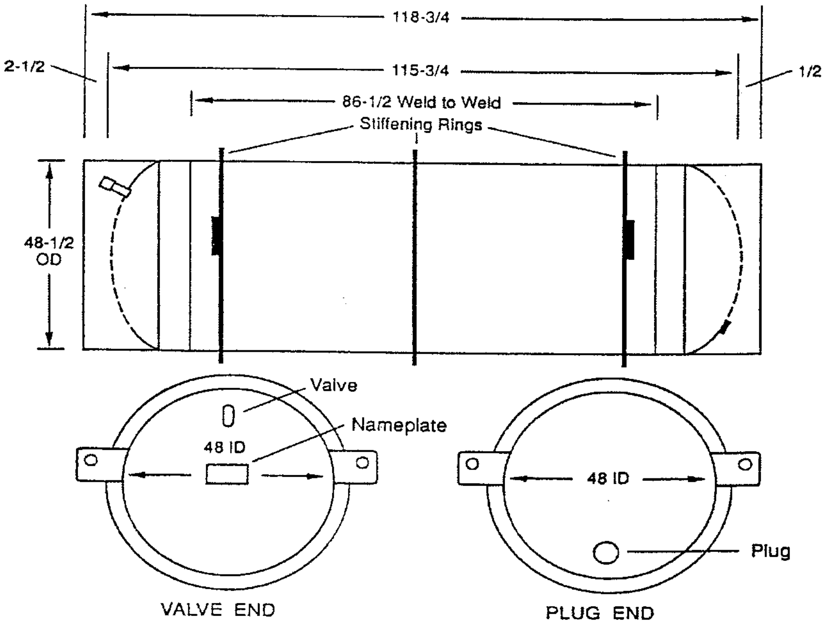

Figure 3.2 Schematic diagram of a Model 48X cylinder.

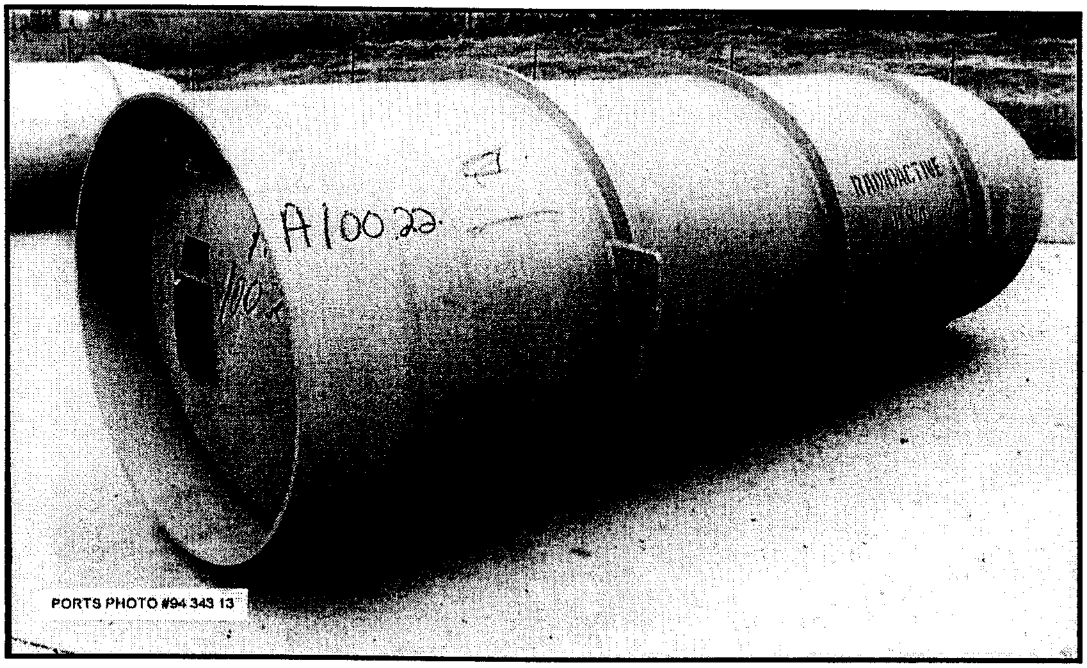

Figure 3.3 A Model 48Y cylinder. Nominal specifications are: diameter: 48 inches; length: 150 inches; wall thickness: 5/8 inch; tare weight: 5,200 lb; maximum net weight: 27,560 lb. The Model 48Y is made of ASTM A-516 steel and the maximum enrichment it can be used for is 4.5% U-235 (from USEC, 1995).

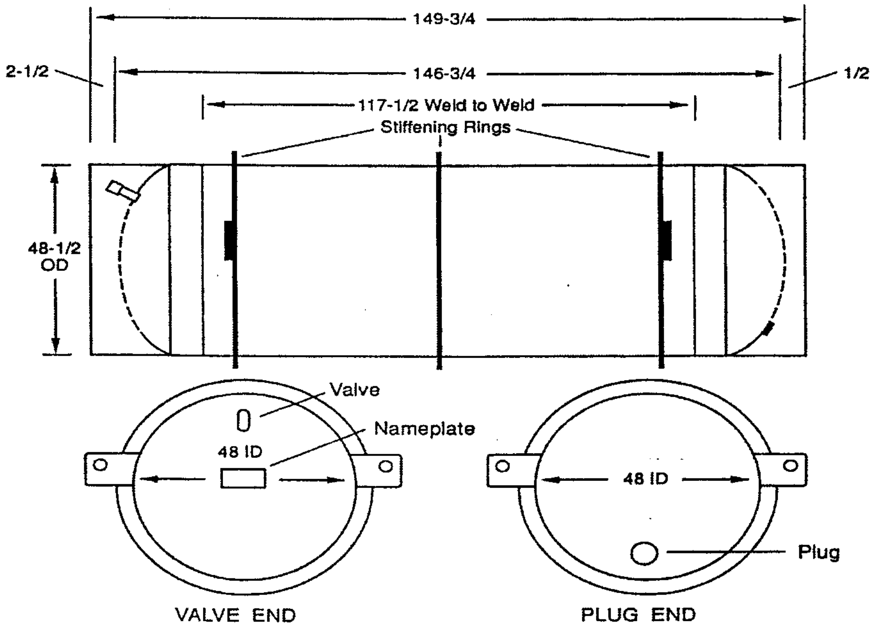

Figure 3.4 Schematic diagram of a Model 48Y cylinder.

3.2 Truck Transportation

This section describes the truck routes that could be used to transport natural UF_6 overland from the gaseous diffusion plants to several East Coast ports and one Gulf Coast port.

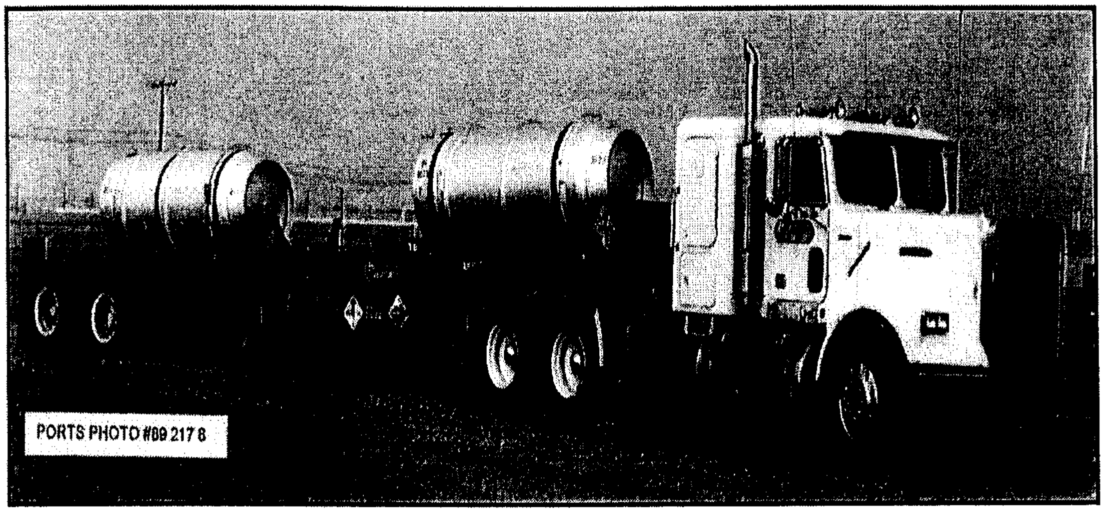

Figure 3.5. Shipment of natural UF_6 (USEC, 1995)

Historically, most shipments of UF_6 in the United States have been made by truck under commercial carrier contracts. Natural UF_6 would be transported from the GDPs to one of the proposed or alternate ports via local transportation routes to the nearest interstate or highway, and then by interstate highway to the port. Import or export shipments of LEU require that the shipper notify the NRC at least ten days prior to departure from the port. The shipper provides this notification for natural UF_6 shipments also.

In examining the affected environment of the transportation routes, only those environmental parameters needed for transportation risk and hazard analysis – distances, population densities, accident frequencies, and populations near the vehicle – need to be considered. No new roads or highways would be needed for the proposed action. Moreover, UF_6 transported by truck must be transported on interstate highways. The DOT routing regulations (49 CFR 177.825) require that interstate system highways be used for shipping highway route controlled quantities of hazardous materials.

Although the potentially affected environment includes the natural environment along the interstate routes, this environment is not discussed in this EA. The affected natural systems and ecosystems along the routes, including terrestrial and aquatic species, possibly threatened or endangered species, and air, land, and water resources, were most seriously impacted when the highway was constructed. When such interstate construction postdated NEPA, that environmental impact was assessed when the highway was planned. Interstate highways and interstate highway traffic have similar environmental impact regardless of the route selected. In addition, the natural UF_6 transported overland to the various ports would be at most 0.005% of the average commodities traffic on the selected routes (USDOT, 1996), and its incremental environmental impact would be negligible. Thus, no further description of the affected natural environment is needed.

Incident-free radiological risks of transporting natural UF_6 depend primarily on distance traveled and population density. The three overland routes in the proposed action (two from Portsmouth and one from Paducah) and an additional eight overland routes to alternate ports (seven from Portsmouth and one from Paducah) are analyzed. These are:

- Portsmouth to Hampton Roads,
- Portsmouth to Baltimore,
- Portsmouth to Philadelphia/South New Jersey,
- Portsmouth to New York/New Jersey,
- Portsmouth to Charleston,
- Portsmouth to Savannah,
- Portsmouth to Houston,
- Paducah to Hampton Roads,
- Paducah to Houston,
- Portsmouth to Fernandina Beach,
- Portsmouth to Morehead City.

The HIGHWAY code (Johnson, *et al*, 1993a) was used to determine the distance traveled in areas of urban, suburban, and rural population zones for the highway routes analyzed, as summarized in Table 3-1. HIGHWAY provides a flexible tool for predicting and describing highway routes for transporting radioactive materials in the United States. The HIGHWAY data base is essentially a computerized road atlas that currently describes over 240,000 miles of highways. Complete descriptions of all interstate systems and most U.S. highways are included in the data base. Many of the principal state highways and a number of local and county highways are also identified, as are locations of nuclear facilities, including the Portsmouth and Paducah GDPs. Routes are calculated by minimizing a combination of distance and driving time for a highway route between two points.

HIGHWAY identifies routes that maximize use of interstate system highways. This explains why the same major highways would be used repeatedly for shipments of radioactive materials, rather than alternate routes over non-interstate highways. Other features of the model include the ability to select routes that bypass a specific city, town, or highway segment. With the alternative routing feature, the HIGHWAY program offers a selection of different but nearly equal routes. The population density distribution is calculated for each highway segment in the route and is reported on a state-by-state basis. The population information used for this calculation is based on data from the United States Bureau of Census, which is routinely updated.

Table 3-1. Route Distances and Populations for Truck Transportation

ROUTE	DISTANCE (KM)	POPULATION DENSITY PER KM^2 *
Portsmouth GDP to Hampton Roads		
Urban	43	2180
Suburban	285	384
Rural	584	14.1
Portsmouth GDP to Baltimore		
Urban	24	2203
Suburban	237	308
Rural	533	13.4
Portsmouth GDP to Philadelphia		
Urban	50	2428
Suburban	310	339
Rural	591	13.6
Portsmouth GDP to New York		
Urban	94	2965
Suburban	284	602
Rural	700	19.1
Portsmouth GDP to Charleston, SC		
Urban	25	2075
Suburban	272	337
Rural	633	14.9
Portsmouth GDP to Savannah, GA		
Urban	18	2052
Suburban	277	312
Rural	726	14.5
Portsmouth GDP to Houston		
Urban	48	2194
Suburban	459	354
Rural	1438	13.2
Paducah GDP to Hampton Roads		
Urban	28	2165
Suburban	352	297
Rural	1004	15.5
Paducah GDP to Houston		
Urban	24	2167
Suburban	281	321
Rural	1144	11.0
Portsmouth to Fernandina Beach, FL		
Urban	27	2083
Suburban	291	301
Rural	925	13.9
Portsmouth to Morehead City, NC		
Urban	25	2095
Suburban	332	329
Rural	597	15.3

*This population density is within a half mile on either side of the route.

3.3 Rail Transportation

Route selection for rail shipments was made using the INTERLINE 5.0 code (Johnson, et al, 1993b). The same overland routes listed in Section 3.2 were analyzed for rail transportation, except for Fernandina Beach, FL and Morehead City, NC, neither of which has rail access to the port. Rail routes are presented in Table 3-2.

Table 3-2. Route Distances and Populations for Rail Transportation

ROUTE	DISTANCE (KM)	POPULATION DENSITY PER KM^2 *
Portsmouth GDP to Hampton Roads		
Urban	20.3	2250
Suburban	214	312
Rural	627	15.9
Portsmouth GDP to Baltimore		
Urban	50.9	2530
Suburban	253	365
Rural	582	15.3
Portsmouth GDP to Philadelphia		
Urban	75.1	2610
Suburban	294	386
Rural	682	14.0
Portsmouth GDP to New York		
Urban	117	2550
Suburban	623	354
Rural	698	18.7
Portsmouth GDP to Charleston, SC		
Urban	34.6	2530
Suburban	343	365
Rural	801	15.3
Portsmouth GDP to Savannah, GA		
Urban	38	2210
Suburban	379	341
Rural	895	14.4
Portsmouth GDP to Houston		
Urban	42.4	2310
Suburban	522	312
Rural	1690	12.8
Paducah GDP to Hampton Roads		
Urban	23.7	1970
Suburban	521	300
Rural	1170	15.6
Paducah GDP to Houston		
Urban	44.8	2370
Suburban	386	323
Rural	1220	11.7

*This population density is within a half mile on either side of the route.

3.4 Port Environments

Considering ocean and land transport distances, as well as port characteristics such as harbor depth, facilities, costs, usage, access to interstate highways and railheads, and other less critical variables, the ports of departure for the proposed action are Hampton Roads, VA and Baltimore, MD. Personnel at these ports have experience with uranium and UF_6 shipments, the ports are frequently ports of entry for vessels from Russia, and they are conveniently located with respect to both GDPs. Nevertheless, in order to compare the risks of using alternate ports, several other ports on the East Coast and one on the Gulf Coast of the United States are analyzed.

Ships transporting natural UF_6 from the United States to the Russian Federation would use normal shipping lanes through the Atlantic Ocean, the North Sea, the Baltic Sea, and Gulf of Finland. St. Petersburg is the most reasonable Gulf of Finland port, and is the port preferred by the Russian Federation for import of natural UF_6 St. Petersburg is open all year, and the transportation infrastructure from St. Petersburg to Ekaterinburg, Novouralsk , and Krasnoyarsk is better than from other Russian ports. The ocean transport distance from Hampton Roads to St. Petersburg is approximately 8,900 kilometers (4,800 nautical miles) (USEC, 1993).Use of a Black Sea port would require shipping through the Straits of Bosporus, and the Siberian ports are poorly equipped and difficult to access. Thus, no Black Sea or Siberian ports were considered.

Military ports were not included because the Russian Federation would be contracting with commercial carriers to transport the natural UF_6. These commercial vessels would use commercial ports either because they would not routinely stop at military ports or because military ports would not be open to commercial vessels. Substantial commercial port experience with handling UF_6 exists and the import and export of UF_6 is a common commercial transaction.

Alternate ports of departure were selected on the basis of geographic, physical, historic, and economic criteria. Since ports have historically been established in areas with inviting geographic, physical and population attributes, many of the ports selected could be characterized as high population density ports. Likewise, population centers have been established in areas with appealing geographic and physical features and excellent transportation access. Thus, the busiest, most experienced, and typically best equipped ports are surrounded by relatively large populations in areas with good transportation links. In order to include ports that do not have a high population density among the alternatives, Morehead City, NC and Fernandina Beach, FL were included for analysis, although their use as departure ports for natural UF_6 bound for the Russian Federation is highly unlikely. Neither Fernandina Beach nor Morehead City are accessible from the ocean without negotiating an inside passage, and neither port has much Russian-bound traffic. Use of either port would probably require either transshipment of natural UF_6 or arrangement of a special port of call. Either option could entail additional handling requirements, additional overland transportation, and additional fees, and would probably be rejected by the Russian Federation.

3.4.1 Hampton Roads, VA

One of the two proposed ports of departure is Hampton Roads, VA. The Hampton Roads port complex, also known as the Ports of Virginia, is located at the confluence of the James River and the Chesapeake Bay, 18 miles from the Atlantic Ocean. Approximately 750,000 metric tons of foreign trade cargo were moved through Hampton Roads in 1997. Hampton Roads is one of the largest natural deep-water harbors in the world and is the leading port in the U.S. in terms of total foreign waterborne commerce. There were approximately 7,000 arrivals and sailings at the port that year.

Hampton Roads has a full-time risk management staff and many years of experience in handling nuclear materials. These activities include U.S. Coast Guard inspections of ships and their cargo, queuing overland carriers to receive the shipping containers, providing on-site escorts and security, clearing the port weigh station for weighing prior to leaving port, and other safety and security activities. Uranium products have been imported and exported through the port for the past 25 years. Approximately 4400 metric tons of UF_6 transited through the Hampton Roads port complex between June, 1997 and December, 1998.

The port is operated by Virginia International Terminals, Inc., for the Virginia Port Authority, which is an agency of the State of Virginia. Three separate marine terminals make up this facility: the Norfolk International Terminal, the Portsmouth Marine Terminal, and the Newport News Marine Terminal; the terminal used depends on the type of ship and cargo and the shipping company. The port of Hampton Roads is an industrialized port area. The Hampton Roads area has a population of about 650,000.

3.4.2 Baltimore, MD

The other proposed port of departure is the Port of Baltimore, which has a large terminal for importing and exporting automobiles and expanding facilities for handling containerized cargo. The port has a full-time risk management staff, years of experience handling nuclear materials, and a local Coast Guard inspection staff. The port is situated on the Patapsco River near its outlet in the Chesapeake Bay. Approximately 25 million metric tons of foreign trade cargo moved through the Port of Baltimore in 1998. The population of the Baltimore urban area is 2.5 million. Approximately 14,000 metric tons of UF_6 and uranium oxides passed through the Port of Baltimore between June, 1997 and December, 1998. The Maryland Port Authority is notified of UF_6 shipments in advance, and then notifies the Port of Baltimore.

3.4.3 Philadelphia and South New Jersey

The Port of Philadelphia and South New Jersey handles a great deal of bulk cargo. The port has been increasing its crane inventory and capacity for handling containerized cargo. The marine terminals are 100 miles (160 km) up the Delaware River from its outlet in the Atlantic Ocean. The terminals are near heavily populated areas (4,664 persons/km^2). During 1996 approximately 5.5 million metric tons of foreign cargo imports moved through the port. Approximately 141 metric tons of UF_6 passed through the Port of Philadelphia and South Jersey between June, 1997 and December, 1998.

3.4.4 New York and New Jersey

The Port of New York and New Jersey handles the world's greatest volume of intermodal traffic, much of it ship-to-truck containers. During 1997 approximately 2.5 million foreign cargo containers moved through the port. Population densities of areas near various terminals of the port include Brooklyn, 12, 564 persons/km^2, Manhattan, 25,703 persons/km^2, and Elizabeth, NJ, 3,516 persons/km^2. Approximately 2450 metric tons of UF_6 and uranium oxides passed through the Port of New York and New Jersey between June, 1997 and December, 1998.

3.4.5 Houston, TX

Access to the Port of Houston marine terminals is through Galveston Bay of the Gulf of Mexico and then 47 miles up the Houston Ship Channel. The Port of Houston owns 42 general cargo wharves and two liquid cargo wharves, and ranked first in foreign import and export tonnage in the United States in 1997 with 145 million metric tons. The population density of Houston is 1,161 persons/km^2. An estimated 1180 metric tons of UF_6 and uranium oxides a passed through the Port of Houston between June, 1997 and December, 1998. Although the proposed action does not envision using a Gulf port such as Houston, circumstances may require the use of a Gulf port, and it is included in the analysis.

3.4.6 Charleston, SC

The population of Charleston is 541,000. Approximately 9 million metric tons of waterborne commerce passed through the port in 1997. Approximately 207 metric tons of uranium oxides passed through the Port of Charleston between June, 1997 and December, 1998.

3.4.7 Savannah, GA

The population of Savannah and the surrounding area is 270,000. Approximately 10 million metric tons of waterborne commerce passed through the port in 1996. Approximately 3900 metric tons of UF_6 and uranium oxides passed through the Port of Savannah between June, 1997 and December, 1998.

3.4.8 Fernandina Beach (Jacksonville), FL

Fernandina Beach (population 8,800) is a port area for Jacksonville, FL and is located on Amelia Island, a 13-mile-long island just off the Atlantic coast at Jacksonville. Fernandina Beach and other port areas of Jacksonville are accessed via a passage between Amelia Island and the mainland. In 1996, the port areas of Jacksonville handled about 6.7 million metric tons of foreign cargo, but no uranium or uranium compounds. Use of Fernandina Beach for the export of natural UF_6 would be problematic for several reasons: (1) Amelia Island is a wildlife preserve and includes a state park, (2) Fernandina Beach is a historic preservation area whose primary business is tourism, and (3) neither the port at Fernandina Beach nor the other Jacksonville port terminals have experience handling UF_6.

3.4.9 Morehead City, NC

Morehead City (population 25,000) is located on an intracoastal waterway on the Atlantic coast of North Carolina. Morehead City has not handled any uranium or uranium compounds. The port at Morehead City is small and rail and highway links are not as good as at larger ports.

3.5 The Marine Environment

Because the proposed action involves ocean transport, the environmental impacts of this proposed action on the global commons are considered.

Ships transporting the natural uranium from Hampton Roads, VA or Baltimore, MD (or even any of the other ports analyzed) to St. Petersburg, the Russian Federation, would use normal shipping lanes from the Atlantic Ocean through the North Sea, the Baltic Sea, and the Gulf of Finland. If a Gulf of Mexico port were used, the Gulf would also be transited. Figure 3.6 shows the proposed shipping lanes through which shipments of natural UF_6 would pass. The ocean transport distance from Hampton Roads to St. Petersburg is approximately 8,900 kilometers (4,800 nautical miles one way). The route from Baltimore has the same approximate length but involves the transit of the Chesapeake Bay from the mouth of the Patapsco River. The use of a West Coast port of departure was not considered a reasonable alternative, because overland distances from the GDPs to West Coast ports are much greater than to East Coast ports, and a Pacific Ocean route is longer than an Atlantic Ocean route. Therefore, the marine environments associated with West Coast ports of departure are not described.

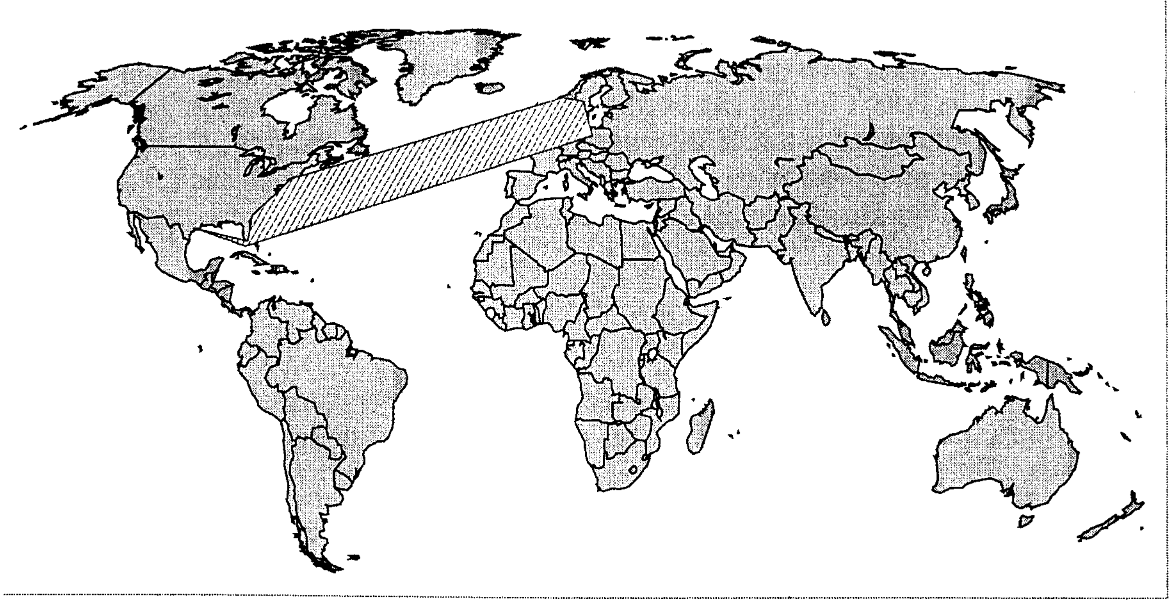

Figure 3.6 Marine Routes Between United States East Coast and Gulf Ports and the Russian Federation.

Sea water is a complex solution containing a majority of the naturally occurring elements. The average salinity of ocean water is about 35 parts per thousand. A significant feature of sea water is that while the total concentration of dissolved salt varies from place to place, the ratios of the more abundant components remain almost constant. This may be taken as evidence that over geologic time the oceans have become well mixed (Pickard, 1979).

Uranium is one of the elements naturally present in sea water. The ocean water concentration of uranium isotopes is as follows: U-234, 1.04-1.3 pCi/liter; U-235, 0.04 to 0.07 pCi/liter; and U-238, 0.9-1.13 pCi/liter (Cherry and Shannon, 1974).

In the marine environment the greater portion of the background radiation dose rate to phytoplankton, zooplankton, and pelagic fish arises from ingested radioactive material, alpha-emitting isotopes. Polonium-210 (Po-210), a daughter product of uranium, is the primary contributor, with potassium-40 (K-40) contributing most of the remainder (IAEA, 1976). Concentrations of the naturally occurring Po-210 have been measured in mid-water crustaceans and fish from depths to 1500m. High levels have been found in certain benthic organisms, indicating that these organisms were exposed to doses that were very large by human standards -- up to approximately 400 rem/yr (Cherry, 1982). The exposure of these organisms (marine invertebrates and fish) appears to make the oceans the highest known natural radiation domain in our biosphere. In general, aquatic organisms tend to be more resistant to adverse radiation effects than terrestrial mammals (NCRP,1991).

Radionuclides have been discharged deliberately into the oceans, as a result of human activity, since 1944. However, in 1981 it was estimated that the total anthropogenic input of radionuclides, essentially from waste disposal and nuclear weapons testing, approached only 0.7% of the natural radioactivity in the world's oceans (Needler, 1981). The total inventory of natural radioactivity in the world's ocean is estimated to be 500,000,000,000 (500 billion) curies (NAS, 1971). A ship transporting 100 cylinders of natural UF_6 would contain approximately 440 curies of activity.

The relationship between environmental concentrations of radionuclides and the concentration found in organisms is important in the study of food web effects. Bioamplification, the increase in concentration (over that in the water) in organisms progressively further up the food chain, is observed for some radionuclides in marine food webs. In the marine environment, uranium has not been found to bioamplify in fish and only slightly bioamplifies in crustaceans and mollusks (IAEA, 1985).

The deep sea bottom-dwellers, are diverse, with many taxonomic groups being represented there by more species than in most shallow water communities (Hessler and Sanders, 1967). However, the number of individual organisms in a given area decreases in the deep sea and this, together with a general tendency for the average size of the organisms also to decrease, results in a dramatic reduction in standing stock or biomass on the deep ocean floor. In round figures, the total wet weight of bottom-living organisms in and on each square meter of seabed decreases from 10 to 100 grams on the continental shelf, to 1 to 10 grams on the continental slope, and to only 0.1 to 1.0 gram on the abyssal plain (Rice, 1978).

The continental shelf extends from the shore with an average gradient of 1 in 500. The shelf has an average width of 65 km. Most of the world's fisheries are located on the continental shelf. The continental slope averages about 4000 meters vertically from the shelf to the deep-sea bottom (Pickard, 1979).

There are two major sources of deep water in the world's oceans: a northern component found in the Norwegian, Greenland, and Labrador Seas, and a southern component from the Weddell Sea. The water from the Greenland Sea flows through the Denmark Strait and flows south down the western Atlantic after being joined by deep water formed in the Labrador Sea (NEA, 1988).

Specific flow estimates for the North Atlantic are up to $5 \times 10^6 m^3/s$ for the total water volume crossing the whole Iceland-Scotland ridge (Steele et al., 1962). From the Greenland Sea the flow through the Denmark Strait has been estimated to be $5 \times 10^6 m^3/s$ (Swallow, 1960). Water from the Arctic that enters the Atlantic leaves mainly to the south toward midlatitudes (NEA, 1988).

An analysis of oceanic environments prepared by the Construction Engineering Research Laboratory (CERL), U.S. Army Corps of Engineers, provides valuable data on biotic resources, including whales, plankton, marlin, and four species of tuna, found in the

North Atlantic (CERL, 1990). The Right Whale, Eubalaena glacialis, was not considered by CERL, but is known to frequent North Atlantic waters. The National Oceanic and Atmospheric Administration (NOAA) recently proposed designation of critical habitat for the Right Whale (FR, 1993). The regions considered by NOAA include portions of Cape Cod Bay, Stellwagen Bank, and waters adjacent to Georgia and Florida. The latter designations include waters out to about 15 nautical miles from shore from the Altamaha River, Georgia, to Jacksonville, Florida (approximately between 30 and 31 degrees north latitude), which includes waters off Fernandina Beach; and out to about 5 nautical miles offshore at Sebastian Inlet, Florida (approximately between 28 and 30 degrees north latitude).

3.6 Socioeconomic Environment

3.6.1 Nuclear Fuel Cycle Markets and Industries

The front end of the nuclear fuel cycle consists of uranium mining and milling, conversion, enrichment, and fuel fabrication. Once fabricated into the form required for use as reactor fuel, the uranium is used to produce electric power. The status of the front end of the nuclear fuel cycle and nuclear power production is provided in this section, followed by a description of the market for these products and/or services.

3.6.2. Uranium Mining and Milling

Mining and milling produces the uranium oxide (U_3O_8) known as "yellowcake". The countries that were the major uranium mining and milling producers for domestic requirements in 1997 are listed in Table 3-3 (USDOE, 1998a). As shown in the table, the United States was the second largest uranium supplier of its own domestic requirements (19%), Canada was the largest (40%), followed by Australia (10%). All other nations supplied less than 10% of domestic requirements to the United States in 1997.

In 1997, domestic uranium mines were located in Texas, Wyoming, Nebraska, Utah, Colorado, Arizona, New Mexico, Louisiana, and Florida. Mining accounted for about 40% of domestic uranium production, and the remaining 60% was produced by *in situ* leaching or as a byproduct of phosphate production in Florida and Louisiana (USDOE, 1998a).

United States. uranium oxide production historically has been quite sensitive to developments in the current market (or spot) price. This relationship is shown in Figure 3.7, which compares estimated domestic production capability in millions of pounds of U_3O_8 equivalent as a function of the price in terms of dollars per pound.

Table 3-3 Major Producers and Suppliers of United States U_3O_8 Equivalent Requirements – By Country

Country	Percent of United States Requirements (1997)
Canada	40
United States	19
Australia	10
Russia	9
Uzbekistan	7
South Africa	6
Kazakhstan	5
Namibia	2
China	0.5

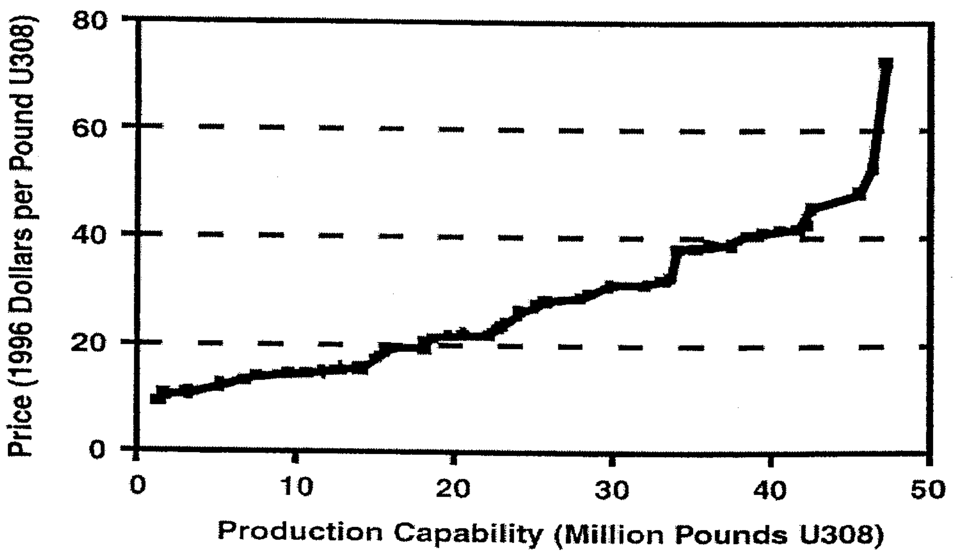

Figure 3.7 Domestic Production Capability Versus Price For Domestic Uranium Production. Includes operation, planned, and prospective production centers (USDOE, 1998b).

The DOE Energy Information Agency (EIA) has forecasted that the uranium oxide spot price will increase from the 1997 level of approximately $11.00/lb up to $16.00/lb (in 1996 dollars) by 2010, while annual domestic production will rise from approximately 6 million pounds. to 8.5 million pounds. of U_3O_8 equivalent (USDOE, 1997)

Employees in the uranium production industry are moderately to highly skilled. Uranium exploration, mining, and milling require personnel with varied backgrounds, including geologists, mining engineers, chemical engineers, equipment operators, maintenance workers, and administrative personnel to run these operations and market uranium. This employment is somewhat geographically concentrated, as uranium mines and processing facilities are located in the Rocky Mountain region, the southwest, and Louisiana and Florida.

3.6.3 The Uranium Service Market

The commercial nuclear fuel cycle evolved out of the United States government's uranium procurement program for nuclear weapons production. The AEC initiated a procurement program that provided incentives for uranium ore exploration and agreed to buy all the uranium ore delivered at a set price. The incentives were such that, by the 1960s, the AEC had largely satisfied its needs; and the procurement program was phased out. The uranium oxide requirements for the infant nuclear energy industry at that time were much smaller than the available production capability. This led to low prices and a substantial contraction in the industry.

After the rapid increase in oil prices in 1973-1974, the pace of new orders for nuclear power plants throughout the world accelerated. Consequently, there was a perception of future shortages of uranium oxide. Uranium oxide prices quadrupled over a three-year period (1975-1978) as a result. This prompted exploration for new supplies. Discovery of new low-cost ores and reductions in demand due to the economic impact of the second oil price shock and reactions to the accident at Three Mile Island resulted in an oversupply of uranium oxide in the late 1970s. As a result, the price of uranium oxide fell. By the early 1980s, the price of uranium oxide had declined to about the price level of the 1960s.

Other countries in the world market do not have such quotas on uranium oxide from the former Soviet Union republics. However, countries in the European Community (EC) have what may be considered an informal quota on uranium oxide and enrichment services from these countries. These quotas are administered by the Euratom Supply Agency which oversees nuclear fuel contracting in the EC. Euratom has pursued a policy to limit the reliance of the EC on nuclear fuel imports from any one particular country or region. To this end, and to protect nuclear fuel suppliers in the EC, Euratom has refused to approve contracts with former Soviet Union republics if they would result in too great a reliance on Commonwealth of Independent States (CIS) supplies or call for a price less than the prevailing market price.

The two-tier price structure of restricted[10] and non-restricted uranium and conversion, and enrichment services evolved as a result of implementing the Suspension Agreements. For example, a buyer of Russian-origin uranium under the United States/Russian Federation Suspension Agreement must purchase an equivalent quantity of United States domestically produced uranium. Because the latter is usually priced higher than the former, either the market or the United States buyer would only agree to a discounted price for the CIS-origin uranium, thereby creating a price differential.

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[10] "Restricted" uranium is of non-CIS origin. "Non-restricted" uranium is of CIS origin.

The price of uranium oxide continued to decline through the1980s and early 1990s due to the entry of the countries of the former Soviet Union into the market with their low-cost uranium oxide, and the discovery of large, low-cost uranium ore deposits in Canada, Australia, and Africa. By June, 1996 the price rose again, reaching $14.75 and $16.60/lb. as many utilities entered the market to fill uncommitted demand. However, by 1997 the price fell to $10.50/lb and $11.40/lb (Uranium Market Outlook, 1999). The spot market price of uranium oxide is projected to increase up to $16.00/lb. (in 1996 dollars) by 2010 (USDOE, 1997).

The low price of uranium oxide has caused many of the domestic mining and milling production facilities to shut down. Annual domestic production of uranium oxide fell from a high of 44 million pounds in 1980 to a low of 3.1 million pounds in 1993, and has gradually increased again to about 6 million pounds. (USDOE, 1997)

Major uranium oxide inventories are maintained by utilities, uranium producers, brokers and governments. In 1997 the commercially-owned domestic inventory was equivalent to 73.3 million pounds of uranium oxide (USDOE, 1997). Of this inventory, about 40 million pounds are required for the fuel pipeline, leaving about 33 million pounds available to cover U.S. production shortfalls. The commercial inventory is projected to decrease to approximately 40 million pounds by 2010 (USDOE, 1997).

The 1997 domestic uranium oxide requirement was about 42 million pounds, while domestic production was only 5.6 million pounds (USDOE, 1997). The balance of 36 million pounds was made up from imports and withdrawals for the inventory of both uranium oxide and LEU. Foreign suppliers have contracts for 60% of existing firm deliveries to domestic utilities for the period 1998 to 2008 (USDOE, 1998).

The United States went from being a net exporter of uranium in 1980 to importing approximately 80 percent of its domestic requirements. The domestic market for nuclear fuel is different from other geographic markets in several ways. The United States currently has restrictions on the importation of uranium oxide and enriched uranium from nations of the former Soviet Union. These restrictions are in the form of three different suspension agreements with three different types of quotas. The United States/Russian Federation Suspension Agreement (Table 1-3) defines maximum quantities of U_3O_8 that can be sold in the United States each year as long as such uranium is matched with an equivalent quantity of newly produced domestic uranium (a "matched sales" agreement). The second type of Suspension Agreement was executed between the United States and Uzbekistan. Under the Uzbek agreement, import quotas are tied to United States domestic uranium production levels. Lastly, the United States Suspension Agreement with Kazakhstan allowed import quotas based on a calculation of market price that is derived from a formula using spot market and long-term contract prices. In January, 1999, Kazakhstan terminated its Suspension Agreement with the United States.

The United States market is also different from other geographic markets because of the greater focus of United States utilities on spot versus term contracting, particularly in uranium oxide. The United States represents a disproportionately high percentage of the world's currently unfilled nuclear fuel needs because of United States utilities' preference for purchasing material under spot and short-term contracts. With some exceptions, United States utilities are also smaller, in size, both in absolute terms and relative to the national electricity supply as a whole. In comparison, the utilities Electricite de France (France), Tokyo Electric (Japan), Ontario Hydro (Canada), Nuclear Electric (UK), Synatom (Belgium), Taipower (Taiwan), and Korea Electric Power (Korea), represent the vast share of their countries' nuclear electricity generation.

United States utilities can accept U_3O_8 from virtually any origin for consumption, subject to quotas on the former Soviet Union material discussed earlier. Because the United States places fairly stringent restrictions on the end-use of its nuclear fuel exports, including the requirement of prior consent for subsequent reprocessing, some countries prefer to receive U_3O_8 which is of other than United States origin. Also, the United States cannot export nuclear material without an Agreement of Cooperation with the importing country (e.g., United States companies cannot currently send U_3O_8 to the Russian Federation for enrichment).

There is no direct United States government management of the uranium mining, uranium conversion, and fabrication industries, and little direct involvement in the utility industry. The United States utility industry is high regulated, although mostly by individual states. The nuclear power industry is highly regulated by the (NRC). This is in contrast to most other countries. There is some sort of government ownership of the uranium industries in Australia, Canada, France, Gabon, Namibia, Niger, and South Africa, as well as all of the republics of the former Soviet Union, Czechoslovakia, Bulgaria, Germany, and Hungary. There is government ownership or participation in the uranium conversion industries in Canada, France, UK, and Russia.

4.0 ENVIRONMENTAL IMPACTS

This section discusses potential environmental impacts of the proposed action and alternatives. The section includes a discussion of some properties and potential health effects of natural UF_6, a discussion of potential impacts of overland and marine transportation and handling of cylinders at the departure ports, and a discussion of socioeconomic impacts of the proposed action and alternatives.

4.1 Possible Health Effects of UF_6 Exposure

This section describes the properties of the compound UF_6 that are important to assessment of health and environmental risks.

4.1.1 Properties of UF_6

The chemical and physical properties of the material being transported are critical to understanding the potential for environmental impacts related to the proposed action and the alternatives. Under the proposed action, the natural uranium would be transported as UF_6 in its solid form in Model 48X or Model 48Y cylinders. Under ordinary ambient conditions (one atmosphere pressure, and ambient temperatures in the zero to 27°C range) solid UF_6 is chemically stable. Although UF_6 reacts with moist air, as described below, this is a surface reaction, and a solid block of UF_6 will react very slowly, particularly when contained with limited amounts of moist air. The compound will remain in solid form at atmospheric pressure and most ordinary ambient temperatures, but can sublime directly from the solid at temperatures below the triple point (148°F). Figure 4.1 shows the phase diagram of UF_6. At 75°F, the vapor pressure of UF_6 is about 0.4 atmospheres. Although this is a relatively high vapor pressure, it is not sufficient to cause health effects or breathing problems from exposed UF_6 in an adequately vented place where no one is very close to the material. In addition, this vapor pressure is not sufficient to cause deformation in a container.

Gaseous or liquid UF_6 poses potentially greater toxicological and radiological risk than solid UF_6. As a gas, UF_6 reacts exothermically with water vapor in the air to produce a visible white cloud of uranyl fluoride (UO_2F_2), and hydrogen fluoride (HF) gas. As a result of the existence of these reaction products, UF_6 in the gas phase is corrosive to lungs and other internal tissues. The liquid, which is also corrosive, can produce burns in contact with skin. Liquid UF_6 reacts rapidly with moist air, particularly since the liquid only exists at temperatures above the triple point. UF_6 can be kept in the liquid state only under pressure significantly above atmospheric pressure and at elevated temperatures. Consequently, a cylinder rupture, or rupture of a fill line during cylinder filling, would result in instantaneous release, vaporization, and reaction of the UF_6 to very fine particulate matter and gas. The reaction of UF_6 with water in the air, if the UF_6 is in the liquid state, as a finely divided solid, or in small chunks with relatively large surface area, is:

$$UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF + heat$$

The resulting cloud of gas and fine particles would be transported and dispersed by air currents and much of it is respirable.

Nationally accepted standards for occupational exposure to chemicals are given in Table 4-1 in terms of threshold limit values (TLVs). The TLV represents a time-weighted average air concentration to which workers can be exposed for a normal 8-hour day, 40-hour work week without adverse health effects (Sax and Lewis, 1987). An air concentration can be compared to the TLV to determine the relative impacts to humans from an exposure. If the concentration is at or below the TLV, there are no adverse health effects. In addition to the TLV, there is an Immediately Dangerous to Life or Health (IDLH) level that represents the maximum concentration from which individuals could escape within 30 minutes without experiencing any escape-impairing or irreversible health effects (NIOSH, 1990).

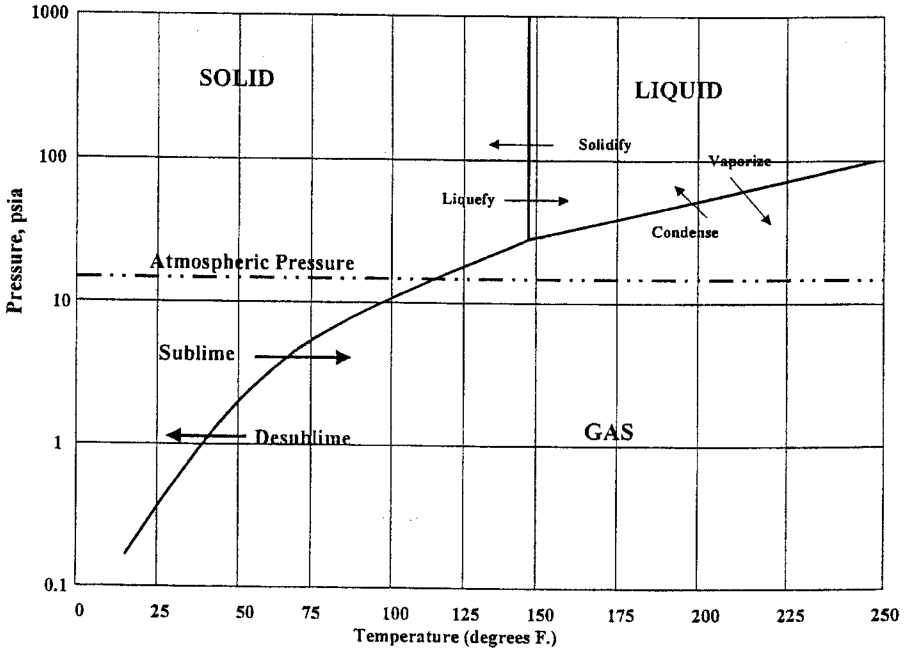

Figure 4.1. Phase Diagram of UF_6 (from USEC, 1998)

Table 4-1: Threshold Limit Values (TLVs) and Immediately Dangerous to Life or Health (IDLH) for HF and Uranium

MATERIAL	TLV (mg/m^3)	IDLH (mg/m^3)
HF	2.5	25
Uranium	0.2	30

Hydrogen fluoride (HF), which remains a gas at room temperature and pressure, is exceedingly corrosive and has an intolerable odor. It exhibits chemical toxicity when inhaled or ingested. In water, HF gas reacts to form hydrofluoric acid. External contact with HF in its liquid or vapor form at levels above 2.5 μg/liter (2.5 mg/m^3) causes severe irritation of eyes and eyelids and may result in prolonged or permanent visual defects or total destruction of the eyes. Skin contact with HF may result in severe burns (Merck Index 1983).

The health effects of internal contact (inhalation) of HF depend on the concentration and duration of the exposure. Figure 4.2 shows health effects that result from inhalation of HF based on the concentration and the time of exposure. Five health effect levels have been established for HF: (1) no effect, (2) smell/no health effects, (3) smell/possible irritation, (4) irritation/possible health effects, and (5) lethal.

The uranium isotopes occurring in nature are U-234 (in trace amounts), U-235, and U-238, the last being the most abundant by far (99.3%). All are alpha emitters with relatively long half-lives: the half-life of U-234 is 247,000 years, U-235, 710 million years, and U-238, 4.9 billion years. Because long half-life isotopes have relatively low specific radioactivity, the specific activity and radiological hazards posed by ingestion or inhalation of these uranium isotopes are minimal. The relative amounts of these isotopes in natural uranium and LEU are almost the same, so that the radiological hazard from inhalation or ingestion would be almost the same for LEU as for natural uranium. UO_2F_2 is soluble and would tend to be eliminated relatively rapidly from the body. As a result, these uranium compounds present minimum radiological hazards.

By contrast, the chemical effects of the uranium compounds UO_2F_2 and UF_6 can be considerable. The relative effects are illustrated in Table 4-2.

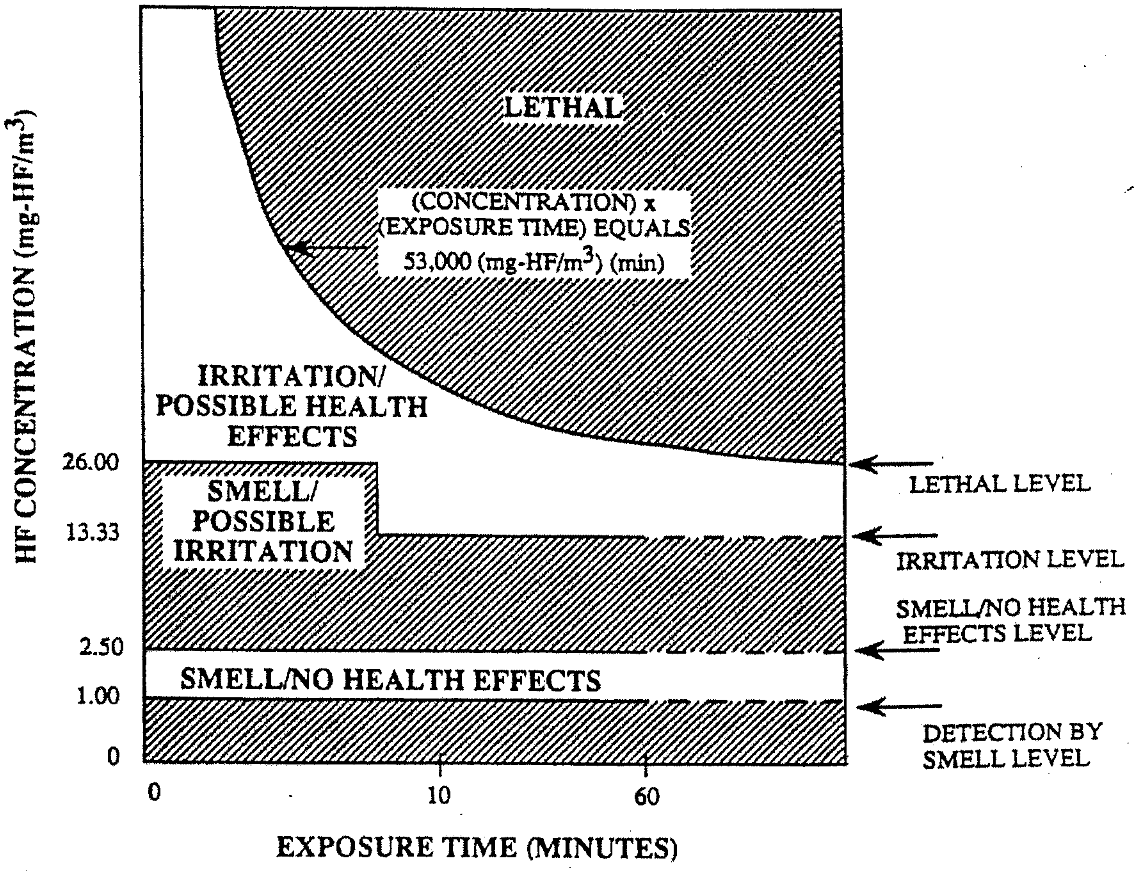

Figure 4.2 Toxicity of acute exposures to hydrogen fluoride (from IAEA, 1991)

Table 4-2: Comparison of Chemical Toxicity and Radiotoxicity of Soluble Uranium at 97.5 Weight % U-235 and 1.14 Weight % U-234 Enrichment (Martin Marietta, 1985)

Absorbed Dose of Soluble Uranium (mg-U per kg body weight)	Equivalent Radiation (μCi)	Acute Health Effects	
		Chemical Toxicity	**Radiotoxicity**
0.03	0.16	No effect	No effect
0.058	0.30	Renal injury	No effect
1.63	8.45	50% lethality	No effect
19.29	100	Lethal	Onset of radiological effects

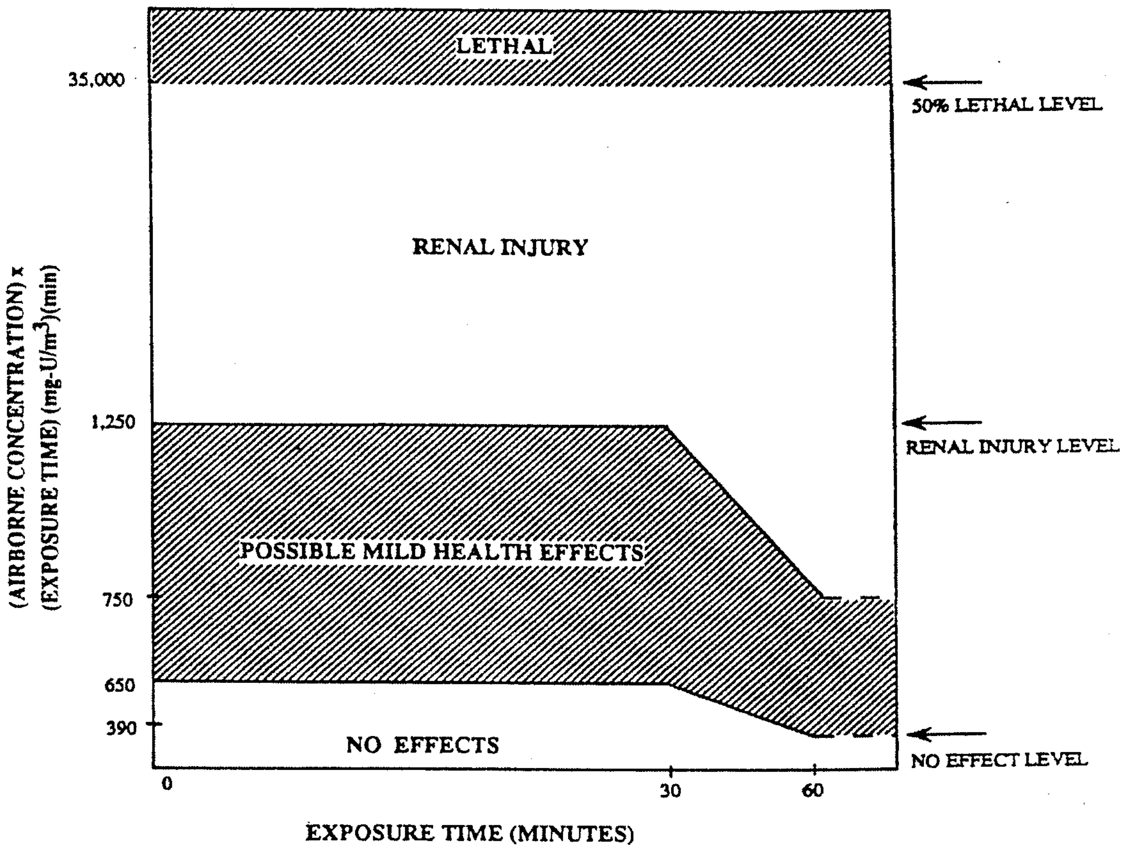

Figure 4.3 Toxicity of acute exposures to uranyl fluoride (IAEA, 1991)

As shown in Figure 4.3 four health effect levels have been established for inhalation of soluble uranium compounds: (1) no effect, (2) possible mild health effects, (3) renal injury, and (4) lethality in 50% of the exposed population (LD_{50}). Estimates of uranium toxicity for exposure times greater than 60 minutes should be based on extrapolation of the 60-minute toxicity estimates shown in Figure 4.3.

4.1.2 External Radiation Exposure

The human health effects that result from exposure to ionizing radiation depend on the absorbed dose. Dose to an individual is expressed in rem or millirem (mrem) or, in the SI system, sieverts (Sv) or millisieverts (mSv). Exposure to ionizing radiation from radioactive materials outside the body may produce some injury to cells, but does not result in deposition of radioactive material internally or concentration in any organ of the body. Incident-free transportation and other operations in which there is no release of radioactive material result in external exposure to ionizing radiation only. The doses from a single shipment are usually very low, much less than the average natural background radiation in the United States. Any external dose would be from gamma radiation only; alpha and beta radiation are readily absorbed and blocked by almost any substance.

Current theories about the effects of ionizing radiation hold that low doses (less than 100 mrem) probably have no adverse effect and probably produce no injury, but radiation protection regulations are based on the premise that low doses can result, on a statistical basis, in the formation of cancer (carcinogenesis). Cancer production is a "stochastic" health effect in that there is a probability associated with its occurrence (it may or may not occur) and that the occurrence in a population cannot be linked to any individual person in that population. The length of time between exposure to a carcinogenic substance and the appearance of a cancer is called the latency period, and is anywhere from 5 years to 40 years long. Thus possibly fatal cancers that might result from exposure to ionizing radiation are referred to as "latent cancer fatalities" or LCF.

The International Commission on Radiation Protection (ICRP) suggests a risk of a radiation induced cancer fatality of about 4 in 10,000 (0.0004 or 4×10^{-4}) fatal cancers per rem for workers[11]. A value of 5 in 10,000 (0.0005 or 5×10^{-4}) fatal cancers per rem is suggested by ICRP for the general population (ICRP, 1990). For example, if 10,000 people are exposed to one rem, five fatal cancers could result from the exposure among those 10,000 people in a lifetime of 70 years. In comparison, in the United States population there are about 950 cancer deaths in 70 years per 10,000 people resulting from causes other than radiation (Cohen, 1991). These risk estimates have been adopted by the NRC in its radiation protection standards (FR, 1991) and are the risk values used in this EA.

The effect of external radiation received by a population (not an individual) is keyed to a collective dose expressed in person-rem: the product of the number of people exposed and the average individual dose. A person-rem is the unit used to express the sum of all doses received by individuals in a population. The same cancer risk value used to assess health effects to an individual (0.0005 or 5×10^{-4}) is used to assess the risk to a large population. The application of the cancer risk value is more appropriate when used to assess the health effects for a large population than for a specific individual.

4.2 Potential Environmental Impacts at USEC Sites

Because the potential environmental impacts are essentially the same at both the Portsmouth and Paducah GDP, the two sites are discussed together in this section

4.2.1 Environmental Impacts of the Proposed Action

UF_6 is the most abundant hazardous material at both the Portsmouth and the Paducah GDP. The primary hazard is chemical rather than radiological (see Section 4.1.1). UF_6 can be handled safely in essentially the same manner as other corrosive or otherwise

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[11] Worker (occupational) standards and dose-to-risk ratios apply only to designated radiation workers. Workers who are not routinely exposed to ionizing radiation are protected by the same standards and dose-to-risk ratios as the general public.

hazardous materials in a controlled industrial setting. UF_6 is handled and managed in accordance with regulations and standards under the Occupational Safety and Health Act (OSHA). No new processes or activities are expected to result from the proposed action. Moreover, the only on-site activity associated with the proposed action is loading cylinders of UF_6 onto trucks for shipping. The level of routine worker exposure to chemicals is not expected to either decrease or increase as a result of the proposed action.

Occupational radiological exposure will not increase under the proposed action. Because no new processes or procedures will be carried out at the plants, and potential offsite radiological exposure from UF_6 is highly unlikely, radiological exposure of the public will neither increase nor decrease as a result of the proposed action. Neither GDP has any history of either lethal occupational exposure or significant injury from accidents involving either hazardous materials or ionizing radiation. The proposed action would essentially require the GDPs to handle UF_6 as is currently done, although fewer cylinders of UF_6 would remain in inventory. The sites are also required to meet the offsite radiological dose limit of 10 mrem per year (40 CFR Part 61). Exposure of the off-site general public could occur during transportation of the natural UF_6; this is discussed in Sections 4.3 and 4.4.

4.2.2 Environmental Impacts Of Alternatives on USEC sites

4.2.2.1 Rail Transportation

The environmental impact of rail transportation on the natural environment of either GDP site would be the same as truck transportation.

4.2.2.2 Alternate East Coast and Gulf Coast Departure Ports

The environmental impact of the use of an alternate departure port on the natural environment of either GDP site would be the same as the use of the preferred ports of Hampton Roads and Baltimore.

4.2.2.3 The No-Action Alternative

The no-action alternative would not involve any increased movement of UF_6 beyond the current situation. However, some impact on the natural environment at the site would be caused by increased storage if the Russian Federation were unable to sell natural UF_6 and it were to accumulate in storage. Additional concrete pads for storing cylinders would be needed, but additional monitoring could be accomplished by currently employed personnel. Because less than 25% of the federal land at each GDP site is now occupied by the facility, there would be no need for additional land purchase (USEC, 1999).

4.2.2.3 Other Alternatives

If no UF_6 were to be shipped to the Russian Federation, the only impact on the natural environment beyond that of the current operation would be due to increased storage. If the natural UF_6 inventory at both GDPs together were to be reduced, workers' responsibility for the safety of the inventory would be correspondingly decreased, and handling of UF_6 would be decreased also. However, since the GDPs have operated within accepted industrial safety and environmental limits since their inception, no increase or decrease in environmental impact on the natural environment would be expected. No increase would be expected because less UF_6 would be handled. If the Russian titled natural UF_6 would not be moving to or from the GDPs, there would be a decrease in the already low worker impacts and a reduction in the already low environmental impact of storage and transportation.

4.3 Potential Environmental Impacts of the Overland Transportation Component of the Proposed Action

This section includes the analysis of the environmental impacts of truck transportation of natural UF_6 from the gaseous diffusion plants to Hampton Roads, VA and Baltimore, MD. Under the proposed action cylinders of UF_6 would be loaded onto trucks at the gaseous diffusion plants and transported to the port being used. All truck transport would use existing roads, and no road construction would be required.

4.3.1 Potential Impacts on Threatened and Endangered Species.

4.3.1.1 Potential Incidental, Non-Cargo-Related Impacts

Through the states that would be involved in UF_6 transportation, there were about twenty-eight billion truck miles traveled in 1996 (USDOT, 1996) and 220 million tons of commodities moved by truck. The addition of these UF_6 shipments would result in less than 0.005% increase in truck traffic. Even if incidental impacts on any endangered species or critical habitats could be envisioned, the likelihood that the proposed shipments would have an incremental impact is vanishingly small.

4.3.1.2 Potential Cargo-Related Impacts

The estimated annual and 15-year doses and risks for incident-free transportation calculated for this EA are the bounding risks that could be expected, because 9000 metric tons of UF_6 are assumed to be shipped to the Russian Federation every year.

Radiation doses during normal, incident-free truck transport of UF_6 result from exposure to external radiation fields emanating from the uranium in the transportation cylinders. These fields are the source of the TI: the dose rate in mrem/hr at one meter from the cylinder surface. In this study, the TI for the filled 48X and 48Y cylinders was taken to be 0.2. This value is at the upper end of the TIs observed from these shipments, and is well within what is allowed by regulation. The NRC limits for transport of these cylinders require that the external radiation dose rates be less than 10 mrem/hr at 2 meters (6.6 ft) from the external surface of the cask. At distances greater than 2 meters, the external radiation dose decreases quickly and, at a distance of approximately 15 meters from the cylinder, the radiation dose is typically undetectable and indistinguishable from natural background radiation levels. At the dose rates or an actual UF_6 shipment, the non-detectable distance (using standard survey instrumentation) is approximately 10 feet. Aside from the presence of placards indicating that the cargo is radioactive, a truck shipment would be indistinguishable from any other commercial shipment. Radiological risk from transporting empty cylinders to the GDPs was not analyzed because these cylinders are thoroughly decontaminated before being shipped empty.

Because incident-free transportation does not involve the release of any radioactive material, flora and fauna along any route could only be exposed to low levels of radiation for short periods of time if the flora and fauna were located very close to the actual truck or train. According to generally accepted scientific studies “there is no convincing evidence from the scientific literature that chronic radiation doses below 1 milligray per day (0.1 rad per day) will harm animal or plant populations.” (IAEA, 1992)

The transportation radiological risk analysis was performed for this EA with the use of the computer code RADTRAN 4 (Neuhauser and Kanipe, 1992). A general description of RADTRAN is provided in Appendix C.

4.3.2 Impacts of Incident-Free (Routine) Transportation for the Proposed Action

Tables 4-3 through 4-6 show the radiation doses and cancer risks from incident-free transportation for the proposed action. The population dose (person-rem) shown in the tables is the total exposed population multiplied by the average dose. Latent cancer fatalities (LCF) are calculated by multiplying the estimated population dose by 0.0005 LCF/rem and the estimated crew dose by 0.0004 LCF/rem (ICRP, 1990)

Some conclusions about radiation doses from incident-free transportation that may be drawn from these tables are:

- The maximum radiation dose from these shipments to someone living within a half-mile of the route is insignificant.
- The maximum radiation dose from a year’s worth of shipments to someone living within a half-mile of the route is about 7×10^{-6} rem – about 0.002% of the average annual background dose in the United States, which is 0.36 rem/year (360 mrem/year).
- The average radiation dose[12] to the public from these shipments is insignificant.

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[12] The average dose to the public is calculated by dividing the population dose by the total population along the route. This population is the sum of the population living within ½ mile of the route, the people in vehicles sharing the route with the cargo (two occupants per vehicle) and the people at stops. Crew are not included.

- The average radiation dose from a year's worth of shipments (about 1400 cylinders) to a member of the public is at most about 3.66×10^{-6} rem
- This average dose is about 0.001% of the average annual background dose in the United States, and about 0.0037% of the maximum effective annual dose to the public recommended by the ICRP, which is 0.1 rem/year (100 mrem/year) (ICRP, 1990).
- The radiation dose to a member of a two-person truck crew, from a year's worth of shipments, is at most about 0.31 rem, about 6% of the ICRP recommended maximum occupational dose of 5 rem/year (ICRP, 1990)
- The risk to the public of fatal cancer from inhaling truck exhaust is about 25 times the risk of fatal cancer (LCF risk) from incident-free overland transportation.

Radiological doses and risks from incident-free truck transportation of one cylinder of natural UF_6 are shown in Tables 4-3 and 4-4. If two cylinders are shipped on a single truck as shown in Figure 3.5, the off-link, on-link, and stop doses and the total incident-free dose to the public are double the doses for a single cylinder, because the two cylinders are effectively two shipments. Population doses and risks for a year's incident-free overland shipments (about 1400 cylinders), shown in Table 4-5, would be the same whether one or two cylinders were shipped at a time. The crew dose, however, depends on the number of shipments rather than on the number of cylinders, and would be the same for two cylinders in a single shipment as for one. If two cylinders were shipped one time, the annual crew dose would be half as much as if only a single cylinder were shipped at a time.

Table 4-3. Population Doses from Incident-Free Truck Transportation of a Shipment of One Cylinder. Maximum Off-Link Dose is 4.91×10^{-9}rem.

ROUTE	POPULATION DOSE (person-rem)					DOSE (rem)
	CREW	OFF-LINK	ON-LINK	STOPS	TOTAL TO PUBLIC	AVERAGE PUBLIC
Portsmouth to Hampton Roads	2.80×10^{-4}	4.30×10^{-5}	1.95×10^{-4}	2.60×10^{-4}	4.98×10^{-4}	6.09×10^{-10}
Portsmouth to Baltimore	2.40×10^{-4}	3.02×10^{-5}	1.40×10^{-4}	2.25×10^{-4}	3.89×10^{-4}	6.24×10^{-10}
Paducah to Hampton Roads	4.39×10^{-4}	5.13×10^{-5}	3.67×10^{-4}	3.93×10^{-4}	8.11×10^{-4}	4.49×10^{-10}

Crew dose is dose to truck crew (usually two drivers), *off-link dose* is population dose to people within ½ mile on both sides of the road, the *on-link dose* is the population dose to occupants of vehicles sharing the route, and *stop dose* is dose to bystanders at places the truck is stopped (modeled as 50 people 20 meters from the cargo). *Total dose to the public* is the sum of the *off-link dose* + the *on-link dose* + the *stop dose.*

Table 4-5 shows the total incident-free dose to the public from the approximately 1400 cylinders intended to be shipped by truck each year, the public dose, and the total latent cancer fatality risk to the public. The dose to the public is the sum of the on-link, off-link, and stop doses and does not include the crew dose. The right-hand column in Table 4.5 shows the risk to the public of fatal cancer from truck exhaust.

Table 4-4. Latent Cancer Fatality Risk from Incident-Free Truck Transportation of a Shipment of One Cylinder.

ROUTE	LATENT CANCER FATALITIES					
	CREW (rad risk)	OFF-LINK (rad risk)	ON-LINK (rad risk)	STOPS (rad risk)	TOTAL TO PUBLIC (rad risk)	TO PUBLIC FROM TRUCK EXHAUST
Portsmouth to Hampton Roads	1.12×10^{-7}	2.15×10^{-8}	9.75×10^{-8}	1.30×10^{-7}	2.52×10^{-7}	9.22×10^{-6}
Portsmouth to Baltimore	9.60×10^{-8}	1.51×10^{-8}	7.00×10^{-8}	1.13×10^{-7}	1.98×10^{-7}	5.30×10^{-6}
Paducah to Hampton Roads	1.76×10^{-7}	2.57×10^{-8}	1.84×10^{-7}	1.97×10^{-7}	4.07×10^{-7}	6.15×10^{-6}

Crew LCF risk is to truck crew, *off-link LCF risk* is the risk to people within 1/2-mile on both sides of the road, *on-link LCF risk* is the risk to occupants of vehicles sharing the route, *stop LCF risk* is risk to public at places the truck is stopped. *Total LCF risk to the public* is the sum of *off-link* + *on-link* + *stop LCF risk.*

Table 4-5. Population Doses and Latent Cancer Fatality Risks From Incident-Free Truck Transportation of a Year's Overland Shipments (About 1400 Cylinders).

ROUTE	DOSE			LATENT CANCER FATALITIES		
	CREW (person-rem)	PUBLIC (person-rem)	AVERAGE PUBLIC (rem)	CREW (rad risk)	TOTAL PUBLIC (rad risk)	TO PUBLIC FROM TRUCK EXHAUS
Portsmouth to Hampton Roads	0.391	0.695	1.97×10^{-6}	1.56×10^{-4}	3.47×10^{-4}	0.00645
Portsmouth to Baltimore	0.335	0.551	2.42×10^{-6}	1.34×10^{-4}	2.76×10^{-4}	0.00371
Paducah to Hampton Roads	0.612	1.13	3.66×10^{-6}	2.44×10^{-4}	5.66×10^{-4}	0.00431

Average dose to a member of the public is the incident-free population dose divided by the total population along each route. Annual doses to the public and public risks would be the same whether one or two cylinders were shipped at a time; the crew dose would be half as large if all shipments were two-cylinders.

Table 4-6 shows total cumulative incident-free doses to the public (not including the crew) as well as average doses and total cancer risks for 15 years of truck shipments.

Table 4-6. Population Doses and Risks to The Public from Incident-Free Truck Transportation -- 15 Years of Shipments (About 1400 Cylinders Per Year).

ROUTE	DOSE		LATENT CANCER FATALITY RISK	
	TOTAL (person-rem)	AVERAGE (rem)	RADIATION	TRUCK EXHAUST
Portsmouth to Hampton Roads	10.4	2.96×10^{-5}	0.00521	0.0968
Portsmouth to Baltimore	8.27	3.63×10^{-5}	0.00413	0.0557
Paducah to Hampton Roads	17.0	5.49×10^{-5}	0.00849	0.0647

These doses and risks do not include the crew. The average dose to a member of the public is obtained by dividing the incident-free population dose by the total population along each route. 15-year doses to the public and public risks would be the same whether one or two cylinders were shipped at a time.

4.3.3 Impacts of Potential Truck Accidents for the Proposed Action

Any vehicle in a transportation accident stops when the accident occurs. Particulate material and gases released into the air as a result of an accident may be dispersed in the air like any other air pollutant. People may be exposed to this dispersed material by inhaling it or externally from deposited material (groundshine). This exposure results in a dose calculated in rem, from which the cancer risk in LCF may be calculated..

In the RADTRAN calculation, the dose calculation includes probability terms: the probability that the accident happens and the probability that the accident is of a certain severity. The calculated dose is thus different from the dose calculated for incident-free transportation (which does not include any probability terms) and is referred to as a dose risk. The term "dose risk" implies inclusion of probability factors. Dose risk is reported in rems. Accident dose risks are reported for the entire exposed population: no distinction is made between crew and public.

RADTRAN analysis of transportation accidents is described in Appendix C. Parameters relevant to accident analysis are presented in Tables 4-7 and 4-8, and results of this analysis for the proposed action are presented in Tables 4-9 and 4-10. Maximum individual dose was calculated using the associated code TICLD (see Appendix C) and is not tabulated (because there is only one value). A consequence analysis was also performed by setting all probabilities to one. The consequence analysis is not shown in the tables.

Risk of a truck accident involving a fatality (Saricks and Kvitek,1994) are developed from a state-by-state summary of the frequency of such accidents. These accident rates vary considerably from state to state.

Some conclusions about radiation dose risks from transportation accidents are:

- Population dose risks from a potential transportation accident are about ten times larger than the population doses from incident-free transportation.
- A fatal truck accident is up to about ten times more likely to happen than a fatal cancer.
- The consequences of the worst conceivable accident would be 12 LCF for a Model 48X cylinder and 15 LCF for a Model 48Y cylinder in a population of about 180,000 to 200,000[13]. However, the chemical hazard from HF, which would exceed the threshold effect level, to a downwind distance of about 5 km, would be much greater than the radiological hazard.

An analysis of the consequences of the worst conceivable accident – a Severity Category 6 accident – was performed. If it is assumed that the entire contents of a cylinder is released and aerosolized to particles less than ten microns in diameter (respirable

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[13] This is the population that resides within ½ mile of the route. Because an accident occurs at one spot on the road, occupants of other vehicles and people at stops are not included.

particles), and all of the respirable material is inhaled by the public (inhalation of all of this material, with no deposition on the ground, buildings, etc., is highly unlikely), The cancer risks would be 12 LCF for a Model 48X cylinder and 15 LCF for a Model 48Y cylinder. The radiological doses would be 24,300 person-rem if a Model 48X cylinder is involved, and 30,375 person-rem if a Model 48Y cylinder is involved. The potentially affected population would be about 180,000 to 200,000 (see Table 3-1). An additional consequence would be the reaction of the released aerosolized material to form a total of about 24,000 liters (24 m^3) of hydrogen fluoride (HF) gas from a Model 48X cylinder, and about 30,000 liters (30m^3) from a Model 48Y cylinder. HF gas would be present at a concentration well above the EPA one-hour evacuation guideline of 20 ppm[14] from the accident site to a downwind distance of 1.6 km[15] (Griego, et al, 1997) and above the threshold effect level, to a downwind distance of about 5 km (see Table 4-1).

The accident severity categories for this study, shown in Table 4-7, are for a Type A package (a Model 48X or Model 48Y cylinder without overpack). This analysis is conservative, because in accordance with IAEA, 1996, DOE intends to require the use of overpacks for these shipments after 2001. When an overpack is used, the total package (cylinder and overpack) can withstand considerably greater stresses, so that a Severity Category 2 accident would result in no release (like a Severity Category 1 accident) with a correspondingly lower risk from accidental releases.

The probability or likelihood of occurrence of an accident is estimated by multiplying the numbers in the right-hand column of Table 4-7 by the frequency of accidents along the route (from the state-by-state tabulation in Saricks and Kvitek, 1994). Thus, for example, the likelihood of a truck accident in Severity Category 6 occurring on a 26.5 km suburban part of the route through North Carolina would be:

$$(2 \times 10^{-6})*(2.22 \text{ truck accidents}/10^7 \text{ km})* (26.5 \text{ suburban km}) = 1.18 \times 10^{-11}$$

The RADTRAN accident analysis is exceedingly conservative, both in overestimating the frequency of accidents that affect the cargo, especially those that affect it severely, and in overestimating the amount of material released in an accident. A search of Radioactive Materials Incident Reports (RMIR) from 1972 until March of 1998 produced twelve accident reports involving UF_6 shipments in Type A containers, of which only one showed any evidence of cargo release. RMIR gives no further description of this accident, or the extent of any damage to the package or the vehicle.

Descriptions of Type A packages are provided in Section 3.1.5 and in the glossary. Model 48X and 48Y cylinders without overpacks are Type A containers, and are constructed to withstand the rigors of normal, incident-free overland transportation but not the stresses of transportation accidents. The amount of material released into the air in an accident depends on the physico-chemical nature of the material released as well as

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[14] The Emergency Response Planning Guideline 2 (ERPG2) is the concentration to which it is believed that almost all people can be exposed for one hour without irreversible or other serious health effects.(ACGIH, 1986)

[15] Dilution at various downwind distances was calculated using the code TICLD.

the severity of the accident. Release fractions for UF_6 used in the calculations are presented in Table 4-8. As the description of UF_6 indicates, on release, vapor, liquid, or finely divided solid UF_6 reacts rapidly with water in the air to produce a cloud of very fine particles of uranyl fluoride and hydrogen fluoride gas.

Table 4-7. Transportation Accident Severity Categories

SEVERITY CATEGORY	SEVERITY CATEGORY DESCRIPTION	FRACTION (%) OF ACCIDENTS IN CATEGORY		
		URBAN	SUBURB	RURAL
1	Conditions do not exceed those for Type A packages; no release of contents	0.604 (60.4%)	0.602 (60.2%)	0.603 (60.3%)
2	Severity of impact exceeds Type A conditions; reaction with moisture; release of gases and fine particles	0.395 (39.3%).	0.394 (39.4%)	0.395 (39.5%)
3	Impact damage enough to breach container and physically damage solid UF_6. Reaction with moist air, with release of fine particles and HF gas.	3.8×10^{-4} (0.038%)	0.004 (0.4%)	0.003 (0.3%)
4	Impact damage severe enough for package failure and exposure of large UF_6surfaces to air; more particulate and gas release than Severity 3.	3.8×10^{-7}	4×10^{-6}	3×10^{-6}
5	High crush or puncture forces on the package, some fire and UF_6 oxidation, and complete package failure.	2.5×10^{-7}	3×10^{-6}	5×10^{-6}
6	High crush or puncture forces on the package, severe fire with extensive UF_6 oxidation, and complete package failure.	1.3×10^{-7}	2×10^{-6}	7×10^{-6}

Accident dose risks and the related cancer risks for the overland truck transportation of UF_6 in a Model 48X cylinder are shown in Table 4-9 and results for a Model 48 Y cylinder are shown in Table 4-10 on an individual shipment basis. Two-cylinder shipments would have twice the accident dose risk, because these are Type A casks and the conditions causing accidents of a particular severity to one cylinder in the shipment may be assumed to be the same for the other cylinder. On a total shipping campaign basis, the risks from one- and two-cylinder shipments are the same.

Table 4-8. Fractions Of Material Released, Fraction of Released Material Aerosolized, and Respirable Fraction of Aerosol for Each Accident Severity Category

SEVERITY CATEGORY	RELEASED FRACTION	AEROSOL FRACTION	RESPIRABLE FRACTION
1	0	0	0
2	0.0025	1	1
3	0.05	1	1
4	0.75	1	1
5	1	1	1
6	1	1	1

Table 4-9. Population Dose Risks and LCF from Potential Truck Transportation Accidents Involving a Model 48X Cylinder

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LCF			FATAL TRUCK ACCIDENTS	
	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR	15-YEAR	1-YEAR	15-YEAR
Portsmouth to								
Hampton Roads	0.00706	9.85	148	3.53×10^{-6}	0.00492	0.0739	0.0340	0.511
Baltimore	0.0118	16.5	247	5.90×10^{-6}	0.00823	0.123	0.0035	0.052
Paducah to								
Hampton Roads	0.00753	10.5	158	3.77×10^{-6}	0.00525	0.0788	0.0177	0.265

Table 4-10. Population Dose Risks and LCF from Potential Truck Transportation Accidents Involving a Model 48Y Cylinder

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LCF			FATAL TRUCK ACCIDENTS	
	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR	15-YEAR	1-YEAR	15-YEAR
Portsmouth to								
Hampton Roads	0.00883	12.3	185	4.41×10^{-6}	0.00616	0.0923	0.0425	0.638
Baltimore	0.0148	20.6	309	7.38×10^{-6}	0.0103	0.154	0.0043	0.065
Paducah to								
Hampton Roads	0.00941	13.1	197	4.71×10^{-6}	0.00657	0.09085	0.0221	0.331

4.3.4 Consequences of Sabotage or Terrorist Attack

This section provides an evaluation of impacts that could potentially result from a malicious act on a shipment of natural uranium.

Since it is impossible to determine with certainty the probability of a deliberate act of sabotage or terrorist attack, this section presents an analysis of potential consequences of such an attack on a shipment of natural uranium, and does not attempt to estimate the risk of such an activity. Although judged very unlikely to actually occur, a malicious attack on a natural uranium shipping package is evaluated as if it might occur at a United States port or during transportation to the port from one of the GDPs, for purposed of illustrating the effects that might result from such an event.

The spectrum of attacks that can be postulated is broad, falling into three categories or scenarios: (1) exploding a bomb near a shipping cylinder (2) attacking a cylinder with a high energy density device (HEDD) such as an armor-piercing weapon (i.e., an anti-tank weapon), and (3) hijacking (stealing) a shipping cylinder. None of the scenarios considered would lead to a criticality accident.

4.3.4.1 Exploding a Bomb Near a Shipping Cylinder

This sabotage or terrorist attack scenario assumes that a large bomb, similar to that detonated in Oklahoma City in April 1995, is detonated in the immediate vicinity of a shipping cylinder. The primary threats to the package integrity would arise from: (1)

direct blast forces (shock wave) from the bomb, (2) impact forces from fragments (e.g., motor vehicle parts) generated by the bomb, and (3) other dynamic forces such as a roll-over of the cylinder transport vehicle in response to the blast forces.

The detonation of such an explosive device was assumed to lead to a total loss of packaging. Under such conditions, dispersal of large pieces of the natural uranium in solid UF_6 form would be expected. Dispersal of the uranium away from the detonation site would probably mitigate any burning of UF_6. If the assumption is made that the explosion would result in conditions such that 100% of the natural uranium were dispersed in aerosolized and respirable form, the consequences would be the same as those estimated for the accident Severity Category 6 scenarios as discussed in Section 4.3.3.

4.3.4.2 Attacking a Cask With a Shaped Charge or Armor-Piercing Weapon

If a cylinder containing natural uranium were attacked by an HEDD, the cylinder would be penetrated and the natural uranium in the cylinder could be dispersed.

The resulting consequences would be less severe than the accidents analyzed elsewhere in this EA. This is because (1) there would be no explosive material inside the cask so the cask would not explode. Therefore, no additional radioactivity, other than that released directly by the projectile, would be forced out of the cylinder, and (2) there wold be no fire to disperse the radioactivity that would be released when the cylinder was breached.

4.3.4.3 Hijacking a Shipping Cask

The discrete theft of a natural uranium transportation cylinder is considered to be very unlikely, due to unattractiveness of such natural uranium. In addition, the large size and weight of these cylinder (about 11.5 metric tons) would make hijacking difficult enough logistically to be an unattractive option for a terrorist.

Should such an attempt be made, the hijackers would not be able to alter the natural uranium configuration inside the cylinder to make it critical. If the hijackers were to dump a cylinder containing UF_6 into the water at a port, the UF_6 would react very quickly with the water and the resulting uranyl fluoride and HF would disperse rapidly. If the cylinder contents were simply dumped into the environment in a city the resulting consequences for the public from the bare uranium hexafluoride would be less severe than those already analyzed for other hypothetical scenarios in this document.

4.4 Impacts of Rail Transportation Alternative: Transportation of Natural UF_6 by Rail

Under this alternative, cylinders of UF_6 would be loaded onto rail cars at the gaseous diffusion plants and transported to Hampton Roads or Baltimore. All rail transport would use existing track, and no construction would be required.

4.4.1 Potential Impacts on Threatened and Endangered Species.

4.4.1.1 Potential Incidental, Non-Cargo-Related Impacts

About 31 billion rail freight car miles were traveled in 1996 in the United States (AAAR, 1997) and about 98 million tons of commodities moved by rail (USDOT, 1997). The addition of these UF_6 shipments would result in less than 0.002% increase in rail traffic. Even if incidental impacts on any endangered species or critical habitats could be envisioned, the likelihood that the proposed shipments would have an incremental impact is vanishingly small.

4.4.1.2 Potential Cargo-Related Impacts

Radiation doses during normal, incident-free rail transport of natural UF_6 result from exposure to external radiation fields emanating from the uranium in the transportation cylinders. External doses and dose rates for Model 48X and Model 48Y cylinders are discussed in Section 4.3.1.2.

Because incident-free transport does not involve the release of any radioactive material, flora and fauna along any route could only be exposed to low levels of radiation for short periods of time if the flora and fauna were located very close to the actual train. According to generally accepted scientific studies "there is no convincing evidence from the scientific literature that chronic radiation doses below 1 milligray per day (0.1 rad per day) will harm animal or plant populations." (IAEA, 1992)

4.4.2 Potential Environmental Impacts of Incident-Free Rail Transportation

Radiological doses and risks were modeled using RADTRAN, as described in preceding sections and in Appendix C. Doses and risks from incident-free overland rail transportation of one rail car shipment (four Model 48X cylinders) of natural UF_6 are shown in Tables 4-11 and 4-12. Risks were calculated by multiplying the population dose by 0.0005 LCF/rem (ICRP, 1990). If only two cylinders are shipped, as would be the case for the Model 48Y cylinders, the off-link, on-link, stop incident-free doses and the total incident-free dose to the public are half the doses for the four-cylinder rail car. Population doses and risks for a year's worth of incident-free overland shipments (about 1400 cylinders) are shown in Table 4-13; these would be the same whether four or two cylinders were shipped at a time.

Some conclusions about the rail transportation alternative are:

- Rail crew and yard workers are not considered radiation workers, so that the LCF/rem ratio is the same as for the public.
- Radiation doses and radiological cancer risks to the public from incident-free rail transportation are approximately the same as for the proposed action (truck transportation). Slight differences along the route are primarily the result of a different distribution of population (e.g., railroads go through cities, while trucks use interstate highway bypasses).
- The risk of a fatal cancer from inhaling rail diesel fuel exhaust, per shipment, is 30 to 100 times as high as the radiation risk from incident-free transportation.

Table 4-11. Population Doses From Incident-Free Rail Transportation of a Shipment of Four Cylinders.

ROUTE	POPULATION DOSE (person-rem)				
	CREW	OFF-LINK	ON-LINK	STOPS	TOTAL TO PUBLIC
Portsmouth to Hampton Roads	0.00115	1.74×10^{-4}	1.59×10^{-5}	1.00×10^{-4}	2.90×10^{-4}
Portsmouth to Baltimore	0.00117	2.38×10^{-4}	2.19×10^{-5}	1.22×10^{-4}	3.82×10^{-4}
Paducah to Hampton Roads	0.00165	3.95×10^{-4}	3.37×10^{-5}	1.32×10^{-4}	5.60×10^{-4}

The *crew dose* is the dose to the rail yard crew, the *off-link dose* is the population dose to people within a half-mile on both sides of the rail right-of-way, the *on-link dose* is the population dose to occupants of trains sharing the transportation link with the UF_6 rail car, and the *stop dose* is the dose to bystanders. The *total dose to the public* is the sum of the *off-link dose* + the *on-link dose* + the *stop dose.*

Table 4-12. Latent Cancer Fatality Risk from Incident-Free Rail Transportation of a Shipment of Four Cylinders.

ROUTE	LATENT CANCER FATALITIES					
	CREW (rad risk)	OFF-LINK (rad risk)	ON-LINK (rad risk)	STOPS (rad risk)	TOTAL TO PUBLIC (rad risk)	PUBLIC FROM DIESEL EXHAUST
Portsmouth to Hampton Roads	5.76×10^{-7}	8.72×10^{-8}	7.94×10^{-9}	5.00×10^{-8}	1.45×10^{-7}	5.28×10^{-6}
Portsmouth to Baltimore	5.84×10^{-7}	1.19×10^{-7}	1.09×10^{-8}	6.12×10^{-8}	1.91×10^{-7}	1.32×10^{-5}
Paducah to Hampton Roads	8.26×10^{-7}	1.97×10^{-7}	1.68×10^{-8}	6.60×10^{-8}	2.80×10^{-7}	6.16×10^{-6}

The *crew LCF risk* is the risk to the rail yard crew, the *off-link LCF risk* is the risk to people within a half-mile on both sides of the railroad right-of-way, the *on-link LCF risk* is the risk to occupants of vehicles sharing the route with the UF_6 truck, and the *stop LCF risk* is the risk to bystanders. The *total LCF risk to the public* is the sum of the *off-link LCF risk* + the *on-link LCF risk* + the *stop LCF risk.*

Tables 4-13 and 4-14 show the population doses and cancer risks for a year's shipments and 15 years' shipments, respectively, assuming that only one railcar in the train carries UF_6 cylinders, and assuming that all shipments are Model 48X cylinders (four to a shipment. Only two Model 48Y cylinders can be carried on a rail car, but a Model 48Y cylinder's capacity is 1.25 times the capacity of a Model 48X cylinder. Therefore, shipping UF_6 by rail would require 1.6 times as many shipments of Model 48Y cylinders as of Model 48 X cylinders.[16] This ratio is reflected in Tables 4-13 through 4-16.

Table 4-13. Population Doses and Latent Cancer Fatality Risks from Incident-Free Rail Transportation of a Year's Overland Shipments (About 1400 Cylinders).

ROUTE	DOSE			LATENT CANCER FATALITIES			
	CREW (person-rem)	TOTAL PUBLIC (person-rem)	AVERAGE PUBLIC (rem)	CREW (rad risk)	TOTAL PUBLIC (rad risk)	RAIL DIESEL EXHAUST	
						48X	48Y
Portsmouth to Hampton Roads	0.402	0.101	3.77×10^{-7}	2.01×10^{-4}	5.06×10^{-5}	0.00185	0.00300
Portsmouth to Baltimore	0.407	0.133	5.85×10^{-7}	2.04×10^{-4}	6.67×10^{-5}	0.00462	0.00739
Paducah to Hampton Roads	0.576	0.195	8.83×10^{-7}	2.88×10^{-4}	9.77×10^{-5}	0.0176	0.0282

The average dose to a member of the public is obtained by dividing the incident-free population dose by the total population along each route.

Table 4-14. Population Doses and Risks to the Public from Incident-Free Rail Transportation from 15 Years of Shipments (About 1400 Cylinders Per Year).

ROUTE	DOSE		LATENT CANCER FATALITIES		
	TOTAL (person-rem)	AVERAGE (rem)	TOTAL PUBLIC (rad risk	RAIL DIESEL EXHAUST	
				48X	48Y
Portsmouth to Hampton Roads	1.52	5.66×10^{-6}	7.59×10^{-4}	0.0278	0.045
Portsmouth to Baltimore	2.00	8.78×10^{-6}	0.0010	0.0693	0.111
Paducah to Hampton Roads	2.93	1.33×10^{-5}	0.00147	0.264	0.423

These doses and risks do not include the rail yard crew. The average dose to a member of the public is obtained by dividing the incident-free population dose by the total population along each route.

4.4.3 Environmental Impacts Of Potential Rail Accidents

- LCF risks from accidental releases are about the same order of magnitude as fatal train accidents.
- LCF risks from train accidents are the same order of magnitude as from truck accidents for the proposed departure ports (Hampton Roads and Baltimore). Train accidents occur less frequently, but the potentially exposed population is larger (see Tables 3-1 and 3-2).
- Risks from HF formed on release into the air would be the same per cylinder as for truck transportation.
- The risk of a fatal train accident for a year's shipments from Portsmouth is about 4 times the LCF risk for Model 48X and about 6.4 times, for Model 48Y cylinders. However, this assumes one flatcar of cylinders per train and uses the national average rail fatality rate (Saricks and Kvitek, 1994).

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[16] 2/1.25 = 1.6

- Radiation dose risks and cancer risks from rail transportation accidents involving Model 48Y cylinders are only 60% of the risks from accidents involving Model 48X cylinders, because the model assumed that all cylinders carried on a flatcar would suffer the accidents of the same severity. The Model 48Y holds 1.25 times as much UF_6 as the Model 48X, so the risk is not halved.
- Radiation dose risks and cancer risks from rail transportation accidents involving Model 48Y cylinders are about 20% of those from truck accidents, and accidents involving Model 48X cylinders are about 35% to 45% of those from truck accidents. This difference reflects the different accident rates of rail and truck transport.
- Maximum individual dose and maximum consequence are the same for rail and truck
- The risk of a fatal train accident is slightly larger than the latent cancer fatality risk from a rail accident for the Model 48Y cylinder, and about an order of magnitude smaller for the Model 48X cylinder.

Accident severity categories and release fractions are the same for rail as for truck accidents. However, the probability of occurrence of rail accidents is different. Development of the rail accident data is discussed in Appendix C. Accident dose risks and the related cancer risks were modeled using the same Gaussian dispersion model described in preceding sections and Appendix C. Dose risks and cancer risks for the overland rail transportation of UF_6 in a rail car carrying four Model 48X cylinders are shown in Table 4-15. Results for Model 48Y cylinders are shown in Table 4-16.

Table 4-15. Population Dose Risks, LCF, and Fatalities from Potential Transportation Accidents to a Rail Car Carrying Four Model 48X Cylinders

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LCF			FATAL TRAIN ACCIDENTS	
	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR
Portsmouth to								
Hampton Roads	0.00856	2.99	44.8	4.28×10^{-6}	0.00149	0.0224	5.6×10^{-7}	2.0×10^{-4}
Baltimore	0.0206	7.18	108	1.03×10^{-5}	0.00359	0.0539	5.8×10^{7}	2.0×10^{-4}
Paducah to								
Hampton Roads	0.0119	4.14	62.1	5.94×10^{-6}	0.00207	0.0311	1.1×10^{-6}	3.9×10^{-4}

Table 4-16. Population Dose Risks, LCF, and Fatalities from Potential Transportation Accidents to a Rail Car Carrying Two Model 48Y Cylinders

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LCF			FATAL TRAIN ACCIDENTS	
	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR
Portsmouth to								
Hampton Roads	0.00535	1.49	22.4	2.67×10^{-6}	7.46×10^{-4}	0.0112	8.96×10^{-6}	0.00031
Baltimore	0.0129	3.59	53.9	6.44×10^{-6}	0.00180	0.0269	9.21×10^{-6}	0.00032
Paducah to								
Hampton Roads	0.00742	2.07	31.1	3.71×10^{-6}	0.00104	0.0104	1.77×10^{-6}	0.00062

No separate analyses of the effects of sabotage was performed for rail transportation.

4.5 Environmental Impact of the Alternate Port Alternative: Transportation of Natural UF_6 to Several Alternate East and Gulf Coast Ports

The transportation risk analyses for transportation to these alternate ports was performed as described in Sections 4.2 and 4.3.

4.5.1 Impact of Incident-Free Transportation to Alternate Ports

4.5.1.1 Incident-free Truck Transportation

- Radiation doses and cancer risks to the public from incident-free truck transportation to alternate ports are slightly higher than from such transportation to the proposed departure ports, although there is not an order-of-magnitude difference.

The doses and risks are tabulated in Tables 4-17 through 4-20.

Table 4-17. Population Doses from Incident-Free Truck Transportation of a Shipment of One Cylinder.

ROUTE	POPULATION DOSE (person-rem)				
	CREW	OFF-LINK	ON-LINK	STOPS	TOTAL TO PUBLIC
Portsmouth to Philadelphia	2.93×10^{-4}	4.48×10^{-5}	2.00×10^{-4}	2.70×10^{-4}	5.15×10^{-4}
Portsmouth to New York	3.40×10^{-4}	2.98×10^{-5}	2.50×10^{-4}	3.06×10^{-4}	5.86×10^{-4}
Portsmouth to Charleston	3.00×10^{-4}	5.02×10^{-5}	3.18×10^{-4}	2.65×10^{-4}	6.33×10^{-4}
Portsmouth to Savannah	3.05×10^{-4}	3.43×10^{-5}	1.63×10^{-4}	2.90×10^{-4}	4.87×10^{-4}
Portsmouth to Houston	5.82×10^{-4}	5.06×10^{-5}	2.56×10^{-4}	5.52×10^{-4}	8.59×10^{-4}
Portsmouth to Fernandina Beach	3.61×10^{-4}	3.36×10^{-5}	1.70×10^{-4}	3.45×10^{-4}	5.49×10^{-4}
Portsmouth to Morehead City	3.49×10^{-4}	6.20×10^{-5}	4.30×10^{-4}	2.93×10^{-4}	7.85×10^{-4}
Paducah to Houston	4.28×10^{-4}	2.95×10^{-5}	1.42×10^{-4}	4.11×10^{-4}	5.83×10^{-4}

The *crew dose* is to the truck crew (two drivers), the *off-link dose* is the population dose to people within a half-mile on both sides of the road, the *on-link dose* is the population dose to occupants of vehicles sharing the route, and the *stop dose* is the dose to bystanders where the truck is stopped (modeled as 50 people 20 meters from the cargo). The *total dose to the public* is the sum of the *off-link* + *on-link* + the *stop dose.*

Table 4-18. Latent Cancer Fatality Risk from Incident-Free Truck Transportation of a Shipment of One Cylinder to Alternate Ports.

ROUTE	LATENT CANCER FATALITIES					
	CREW (rad risk)	OFF-LINK (rad risk)	ON-LINK (rad risk)	STOPS (rad risk)	TOTAL TO PUBLIC (rad risk)	TRUCK EXHAUST
Portsmouth to						
Philadelphia	1.18×10^{-7}	2.24×10^{-8}	1.00×10^{-7}	1.35×10^{-7}	2.57×10^{-7}	1.09×10^{-5}
New York	1.36×10^{-7}	1.49×10^{-8}	1.25×10^{-7}	1.53×10^{-7}	3.28×10^{-7}	1.95×10^{-5}
Charleston	1.20×10^{-7}	2.51×10^{-8}	1.59×10^{-7}	1.33×10^{-7}	3.17×10^{-7}	5.85×10^{-6}
Savannah	1.22×10^{-7}	1.72×10^{-8}	8.15×10^{-8}	1.45×10^{-7}	2.44×10^{-7}	4.21×10^{-6}
Houston	2.33×10^{-7}	2.53×10^{-8}	1.28×10^{-7}	2.76×10^{-7}	4.29×10^{-7}	9.64×10^{-6}
Fernandina Beach	1.45×10^{-7}	1.68×10^{-8}	8.50×10^{-8}	1.73×10^{-7}	2.74×10^{-7}	3.60×10^{-6}
Morehead City	1.40×10^{-7}	3.10×10^{-8}	2.15×10^{-7}	1.47×10^{-7}	3.93×10^{-7}	4.44×10^{-6}
Paducah to Houston	1.71×10^{-7}	1.48×10^{-8}	7.10×10^{-8}	2.06×10^{-7}	2.92×10^{-7}	4.72×10^{-6}

The *crew risk* is the risk to the truck crew (usually two drivers), the *off-link risk* is to people within a half-mile on both sides of the road, the *on-link risk* is to occupants of vehicles sharing the route with the UF_6 truck, and the *stop risk* is to bystanders at places the truck is stopped (modeled as 50 people 20 meters from the cargo). The *total risk to the public* is the sum of the *off-link risk* + the *on-link risk* + the *stop risk.*

Table 4-19. Population Doses and Latent Cancer Fatality Risks from Incident-Free Truck Transportation of a Year's Incident-Free Overland Shipments (About 1400 Cylinders) to Alternate Ports.

ROUTE	DOSE			LATENT CANCER FATALITIES		
	CREW (person-rem)	TOTAL PUBLIC (person-rem)	AVERAGE PUBLIC (rem)	CREW (rad risk)	TOTAL PUBLIC (rad risk)	TRUCK EXHAUST
Portsmouth to						
Philadelphia	0.409	0.718	1.76×10^{-6}	1.63×10^{-4}	3.59×10^{-4}	0.00763
New York	0.474	0.817	1.33×10^{-6}	1.90×10^{-4}	4.09×10^{-4}	0.0137
Charleston	0.418	0.883	3.87×10^{-6}	1.87×10^{-4}	4.42×10^{-4}	0.00410
Savannah	0.425	0.680	2.98×10^{-6}	1.70×10^{-4}	3.40×10^{-4}	0.00295
Houston	0.812	1.20	2.58×10^{-6}	3.25×10^{-4}	5.99×10^{-4}	0.00675
Fernandina Beach	0.504	0.765	4.88×10^{-6}	2.02×10^{-4}	3.83×10^{-4}	0.00252
Morehead City	0.487	1.10	6.39×10^{-6}	1.94×10^{-4}	5.48×10^{-4}	0.00311
Paducah to Houston	0.597	0.813	1.75×10^{-6}	2.39×10^{-4}	4.06×10^{-4}	0.00330

The average dose to a member of the public is obtained by dividing the incident-free population dose by the total population within ½ mile of each route. Annual doses to the public and public risks would be the same whether one or two cylinders were shipped at a time; the crew dose would only be half as large if all shipments were two-cylinder shipments.

Table 4-20. Population Doses and Risks to the Public from Incident-Free Truck Transportation from 15 Years of Shipments to Alternate Ports.

ROUTE	DOSE		LATENT CANCER FATALITIES	
	TOTAL (person-rem)	AVERAGE (rem)	RADIATION RISK	TRUCK EXHAUST
Portsmouth to Philadelphia	10.8	2.64×10^{-5}	0.00539	0.114
Portsmouth to New York	12.3	1.99×10^{-5}	0.00613	0.205
Portsmouth to Charleston	13.2	5.81×10^{-5}	0.00662	0.0614
Portsmouth to Savannah	10.2	4.47×10^{-5}	0.00510	0.0442
Portsmouth to Houston	18.0	3.87×10^{-5}	0.00896	0.101
Portsmouth to Fernandina Beach	11.5	7.31×10^{-5}	0.00574	0.0378
Portsmouth to Morehead City	16.4	9.59×10^{-5}	0.00821	0.0466
Paducah to Houston	12.2	2.63×10^{-5}	0.00609	0.0496

These doses and risks do not include the crew. The average dose to a member of the public is obtained by dividing the incident-free population dose by the total population within ½ mile of each route. 15-year doses to the public and public risks would be the same whether one or two cylinders were shipped at a time.

4.5.1.2 Incident-free Rail Transportation

- Doses and risks from incident-free rail transportation to alternate ports are about twice as large as for the proposed departure ports for shipments from Portsmouth.
- Doses and risks from incident-free rail transportation to alternate ports from Paducah are comparable to shipments to the proposed ports. Differences are functions of the sometimes circuitous rail routes.

Doses and risks are tabulated in Tables 4-21 through 4-24. If two cylinders are shipped per rail car, as would be the case for the Model 48Y cylinders, the off-link, on-link, stop incident-free doses and the total incident-free dose to the public are half the doses for the four-cylinder rail car. Population doses and risks for a year's worth of incident-free overland shipments (about 1400 cylinders) are shown in Table 4-24; these would be the same whether four or two cylinders were shipped at a time.

Table 4-21. Population Doses from Incident-Free Rail Transportation of Four Cylinders to Alternate Ports.

ROUTE	POPULATION DOSE (person-rem)				
	CREW	OFF-LINK	ON-LINK	STOPS	TOTAL TO PUBLIC
Portsmouth to					
Philadelphia	0.00126	2.94×10^{-4}	2.76×10^{-5}	1.36×10^{-4}	4.57×10^{-4}
New York	0.00149	5.56×10^{-4}	5.00×10^{-5}	1.70×10^{-4}	7.76×10^{-4}
Charleston	0.00134	3.00×10^{-4}	2.49×10^{-5}	1.28×10^{-4}	4.53×10^{-4}
Savannah	0.00142	3.26×10^{-4}	2.76×10^{-5}	1.31×10^{-4}	4.85×10^{-4}
Houston	0.00196	4.20×10^{-4}	3.84×10^{-5}	1.37×10^{-4}	5.96×10^{-4}
Paducah to Houston	0.00161	3.20×10^{-4}	3.01×10^{-5}	1.25×10^{-4}	4.75×10^{-4}

The *crew dose* is to the rail yard crew, the *off-link dose* is to people within 1/2-mile of the rail right-of-way, the *on-link dose* is to occupants of trains sharing the transportation link, and the *stop dose* is to bystanders.

Table 4-22. Latent Cancer Fatality Risk From Incident-Free Rail Transportation Of A Shipment Of Four Cylinders to Alternate Ports.

ROUTE	LATENT CANCER FATALITIES					
	CREW (rad risk)	OFF-LINK (rad risk)	ON-LINK (rad risk)	STOPS (rad risk)	TOTAL TO PUBLIC (rad risk)	DIESEL EXHAUST
Portsmouth to						
Philadelphia	6.32×10^{-7}	1.47×10^{-7}	1.38×10^{-8}	6.78×10^{-8}	2.28×10^{-7}	1.95×10^{-5}
New York	7.44×10^{-7}	2.78×10^{-7}	2.50×10^{-8}	8.48×10^{-8}	3.88×10^{-7}	3.04×10^{-5}
Charleston	6.68×10^{-7}	1.50×10^{-7}	1.25×10^{-8}	6.38×10^{-8}	2.26×10^{-7}	9.00×10^{-6}
Savannah	7.08×10^{-7}	1.63×10^{-7}	1.38×10^{-8}	6.56×10^{-8}	2.43×10^{-7}	9.88×10^{-6}
Houston	9.82×10^{-7}	2.10×10^{-7}	1.92×10^{-8}	6.86×10^{-8}	2.98×10^{-7}	1.10×10^{-5}
Paducah to Houston	8.26×10^{-7}	1.97×10^{-7}	1.68×10^{-8}	6.60×10^{-8}	2.80×10^{-7}	1.16×10^{-5}

The *crew LCF risk* is to the rail yard crew, the *off-link LCF risk* is to people within a half-mile on both sides of the right-of-way, the *on-link LCF risk* is to occupants of trains sharing the route, and the *stop LCF risk* is the risk to bystanders. The *total public LCF risk* is the sum of the *off-link* + *on-link* + *stop LCF risk*

Table 4-23. Population Doses and LCF Risks From Incident-Free Rail Transportation of a Year's Shipments (About 1400 Cylinders) to Alternate Ports.

ROUTE	DOSE			LATENT CANCER FATALITIES			
	CREW (person-rem)	TOTAL PUBLIC (person-rem)	AVERAGE PUBLIC (rem)	CREW (rad risk)	TOTAL PUBLIC (rad risk)	DIESEL EXHAUST	
						48X	48Y
Portsmouth to							
Philadelphia	0.441	0.159	4.99×10^{-7}	2.20×10^{-4}	7.97×10^{-5}	0.00683	0.0109
New York	0.519	0.270	5.08×10^{-7}	2.59×10^{-4}	1.35×10^{-4}	0.0106	0.0170
Charleston	0.466	0.158	7.55×10^{-7}	2.33×10^{-4}	7.89×10^{-5}	0.00315	0.00504
Savannah	0.494	0.169	7.48×10^{-7}	2.47×10^{-4}	8.46×10^{-5}	0.00346	0.00553
Houston	0.685	0.208	7.35×10^{-7}	3.42×10^{-4}	1.04×10^{-4}	0.00385	0.00616
Paducah to Houston	0.562	0.166	6.76×10^{-7}	2.81×10^{-4}	8.29×10^{-5}	0.00406	0.00650

The average dose to a member of the public is obtained by dividing the incident-free population dose by the total population along each route.

Table 4-24. Population Doses and Risks to the Public from Incident-Free Rail Transportation from 15 Years Of Shipments to Alternate Ports

ROUTE	DOSE		LATENT CANCER FATALITIES		
	TOTAL (person-rem)	AVERAGE (rem)	RAD RISK	DIESEL EXHAUST	
				48X	48Y
Portsmouth to					
Philadelphia	2.39	7.49×10^{-6}	0.00119	0.102	0.164
New York	4.06	7.63×10^{-6}	0.00203	0.160	0.255
Charleston	2.37	1.13×10^{-5}	0.00118	0.0473	0.0756
Savannah	2.54	1.12×10^{-5}	0.00127	0.0519	0.0830
Houston	3.12	1.10×10^{-5}	0.00156	0.0578	0.0924
Paducah to Houston	2.49	1.01×10^{-5}	0.00124	0.0609	0.0974

These doses and risks do not include the rail yard crew. The average dose to a member of the public is obtained by dividing the incident-free population dose by the total population along each route.

4.5.2 Impact of Potential Accidents in Transporting UF_6 to Alternate Ports

Accident dose risks were calculated as in Sections 4.3 and 4.4

4.5.2.1 Impact of Truck Accidents

- Radiological risks from truck accidents occurring during transportation to alternate ports are of the same order of magnitude as risks from truck accidents during transportation to the proposed departure ports. Differences are due to differences in potentially exposed populations.

Table 4-25. Population Dose Risks and LCF from Potential Truck Transportation Accidents to a Model 48X Cylinder Shipped to Alternate Ports. Fatal Truck Accidents Assume Two Cylinders Per Trip.

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LATENT CANCER FATALITIES			FATAL TRUCK ACCIDENTS	
	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR	15-YEAR	1-YEAR	15-YEAR
Portsmouth to								
Philadelphia	0.00921	12.8	193	4.61×10^{-6}	0.00642	0.0964	0.108	1.62
New York	0.0140	19.5	293	7.00×10^{-6}	0.00976	0.146	0.114	1.70
Charleston, SC	0.00574	8.01	120	2.87×10^{-6}	0.00400	0.0601	0.149	2.24
Savannah, GA	0.00519	7.24	109	2.60×10^{-6}	0.00362	0.0543	0.151	2.26
Houston	0.0112	15.6	234	5.60×10^{-6}	0.00781	0.117	0.154	2.30
Fernandina Bch	0.00554	7.73	116	2.77×10^{-6}	0.00386	0.0580	0.154	2.30
Morehead City	0.00718	10.0	150	3.59×10^{-6}	0.00501	0.0751	0.0548	0.82
Paducah to								
Houston	0.00501	6.99	105	2.51×10^{-6}	0.00349	0.0524	0.0403	0.60

Table 4-26. Doses and Risks From Potential Truck Accidents to a Model 48Y Cylinder Shipped to Alternate Ports.

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LATENT CANCER FATALITIES			FATAL TRUCK ACCIDENTS	
	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR	15-YEAR	1-YEAR	15-YEAR
Portsmouth to								
Philadelphia	0.00115	16.1	241	5.76 x 10^{-6}	0.00803	0.120	0.086	1.30
New York	0.00175	24.4	366	8.75 x 10^{-6}	0.0122	0.183	0.091	1.36
Charleston	0.000718	10.0	150	3.59 x 10^{-6}	0.00500	0.0751	0.119	1.79
Savannah	0.000649	9.05	136	3.24 x 10^{-6}	0.00452	0.0679	0.120	1.81
Houston	0.0140	19.5	293	7.00 x 10^{-6}	0.00976	0.146	0.123	1.84
Fernandina Beach	0.000692	9.66	145	3.46 x 10^{-6}	0.00483	0.0724	0.123	1.84
Morehead City	0.000897	12.5	188	4.49 x 10^{-6}	0.00626	0.0939	0.044	0.658
Paducah to								
Houston	0.000626	8.74	131	3.13 x 10^{-6}	0.00437	0.0655	0.032	0.483

4.5.2.2 Impacts of Rail Accidents

- Radiological risks from rail accidents occurring during transportation to alternate ports are of the same order of magnitude as risks from rail accidents during transportation to the proposed departure ports. Differences are due to differences in potentially exposed populations.
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Table 4-27. Doses and Risks From Potential Rail Accidents to Four Model 48X Cylinders Shipped to Alternate Ports.

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LCF			FATAL RAIL ACCIDENTS	
	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR
Portsmouth to								
Philadelphia	0.0076	2.65	39.8	3.80 x 10^{-6}	0.00133	0.0199	6.96 x 10^{-7}	2.38 x 10^{-4}
New York	0.0480	16.7	251	2.40 x 10^{-5}	0.00837	0.126	9.35 x 10^{-7}	3.26 x 10^{-4}
Charleston	0.0147	5.13	77.0	7.36 x 10^{-6}	0.00257	0.0385	7.66 x 10^{-7}	2.65 x 10^{-4}
Savannah	0.0159	5.54	83.1	7.94 x 10^{-6}	0.00277	0.0415	8.53 x 10^{-7}	3.00 x 10^{-4}
Houston	0.0192	6.64	99.6	9.52 x 10^{-6}	0.00332	0.0498	1.47 x 10^{-6}	1.47 x 10^{-4}
Paducah to								
Houston	0.0188	6.54	98.1	9.38 x 10^{-6}	0.00327	0.0491	1.07 x 10^{-6}	3.89 x 10^{-4}

Table 4-28. Doses and Risks From Potential Rail Accidents to Two Model 48Y Cylinders Shipped to Alternate Ports.

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LATENT CANCER FATALITIES			FATAL RAIL ACCIDENTS	
	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR	15-YEAR	SINGLE	1-YEAR
Portsmouth to								
Philadelphia	0.00475	1.32	19.9	2.37×10^{-6}	6.62×10^{-4}	0.00994	1.11×10^{-6}	3.90×10^{-4}
New York	0.0300	8.37	126	1.50×10^{-5}	0.00418	0.0628	1.50×10^{-6}	5.23×10^{-4}
Charleston	0.0092	2.57	38.5	4.60×10^{-6}	0.00128	0.0192	1.23×10^{-6}	4.29×10^{-4}
Savannah	0.0092	2.77	41.5	4.96×10^{-6}	0.00138	0.0208	1.36×10^{-6}	4.78×10^{-4}
Houston	0.0119	3.32	49.8	5.95×10^{-6}	0.00166	0.0249	2.34×10^{-6}	8.21×10^{-4}
Paducah to								
Houston	0.0117	3.27	49.1	5.86×10^{-6}	0.00164	0.0245	1.71×10^{-6}	6.01×10^{-4}

4.6 Potential Environmental Impacts of the No-Action Alternative

Under the no-action alternative, natural UF_6 would not be shipped from the GDPs to East Coast or Gulf ports as the disposition program is presently envisioned., so that the impacts of overland transportation described in the preceding sections would not occur. As shown in Tables 1-2 and 1-3, however, the Russian Federation may sell up to a certain amount of natural UF_6 to end users in the United States. In this case, the impacts of overland transportation would be estimated by the same methods used in this EA. However, since the impacts depend on transportation routes and population densities along those routes, analysis is not possible as long as routes and end users in the United States have not been identified. Per shipment and per mile traveled, the impacts would be the same, as those of the proposed action.

4.7 Potential Environmental Impacts of Other Alternatives

Under any alternative that would involve overland shipping of UF_6 in the United States, the impacts would be the same, per shipment and per mile traveled, as those of the proposed action.

4.8 Potential Impacts on Port Environments

This section discusses the potential impacts of the proposed action and alternatives on the port environments.

4.8.1 Potential Impacts of Routine Port Operation Under the Proposed Action

This section discusses the potential impacts on the proposed departure ports of Hampton Roads and Baltimore.

- Risks at ports are considered to be only to dock workers.

- Dock workers are not radiation workers. The exposure standard for dock workers is the same as for the public: 0.100 rem/year (100 mrem/year) (ICRP, 1990).
- A worker handling every shipment for a year, assuming 140 shipments (1400 cylinders) per year, would exceed receive a radiation dose of 0.156 rem (156 mrem), about 150% of the ICRP recommended dose but only 44% of the average annual United States background dose.

RADTRAN 4 (see Appendix C) was used to model the external dose to dock workers (handlers) during port operations. No risk to the general public from these operations was calculated because it was assumed that there are so few members of the general public residing within a half-mile of the port operations that the available population densities are not relevant. Because handlers are relatively close to the cylinder, the dose is inversely proportional to the distance from the source (1/r). The radiation source is the external radiation dose rate (in mrem/hr), the TI, measured at one meter from the cask surface. It is assumed that the cylinders are queued at the dock and that each shipment consists of 100 cylinders.

The cylinders are shipped racked in flatbed trailers or rail cars that are equipped with valve protection devices and are supplied by USEC (USEC, 1998). At the port, the entire flatbed trailer (holding one cylinder) or railcar rack (holding two or four cylinders) is lifted by a crane and loaded into the ship's hold. Cylinders of natural UF_6 are not considered a special or unusual cargo and do not require special handling. Loading a cylinder takes less than ten minutes, so having cylinders queued at the dock for long periods would happen only rarely. (USEC, 1999).

Although usually only two or three dock workers are needed to handle UF_6 cylinders at the port (USEC, 1999), radiological doses and risks to five handlers[17] from routine handling of a single sea shipment (100 cylinders), annual shipments, and 15 years' worth of shipments of natural UF_6 were calculated and are shown in Table 4-29. A single worker receives one fifth of tabulated population dose. LCF Risks were calculated from population doses by multiplying the population dose by 0.0005 LCF/rem (ICRP, 1990). Because routine doses depend only on TI, the routine handler dose is the same for all ports. TI is 0.2 for each cylinder. Since the workers handle each cylinder separately, they are exposed to TI = 0.2 one hundred times per shipments

Impacts of routine operations at the port are essentially independent of the particular port and completely independent of the mode of overland transportation to the port.

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[17] Previously published related EAs (USEC, 1993; USEC, 1994) analyzed five handlers, so the same number was used in this study. This number of handlers was chosen because it is reasonable to expect that between three and five handlers would be involved in dock or cargo.

Table 4-29 Handler Doses And Risks (to 5 Handlers) from Routine Handling of a Single Sea Shipment (100 Cylinders), Annual Shipments, and 15 Years of Shipments of Natural UF_6 In Port.

	DOSE (PERSON-REM)	RISK (LCF)
SINGLE SHIPMENT (100 CYLINDERS)	0.0561	2.81×10^{-5}
ANNUAL SHIPMENTS	0.783	3.91×10^{-4}
15-YEAR SHIPMENTS	11.7	5.87×10^{-3}

4.8.2 Potential Impacts Of Accidents At The Port

Potential impacts to any port environment are:

- Although ship collisions are more likely to occur in port than on the high seas, it would be unlikely that a significant release of UF_6 would occur during a ship collision.
- The consequences of a container drop would be the same as the consequences of the transportation accidents discussed in Section 4.3.3.
- The chemical hazard to human health from a cylinder breach would greatly exceed the radiological hazard. Appearance of a visible cloud (of uranyl fluoride and HF) would necessitate immediate evacuation of workers who are not equipped with adequate protective equipment (USEC, 1998, p. 30).
- A spill of UF_6 into the water at a port would have only minimal consequences.
- The probabilities of Severity 5 and Severity 6 accidents in port are about 100 times those probabilities during transportation, because a crane drop can considerably more severe than a transportation accident.

Container drops during handling could also impact the port's human environment. The ports considered in this EA handle large amounts of containerized cargo (Hampton Roads handles at least 750,000 containers a year) and, at most, one or two containers are dropped each year. The consequences of such a drop would be the same as the consequences of the transportation accidents discussed in the Section 4.3.3. Risks depend on the population density surrounding the port and are discussed in Section 4.8.1.2.1. The chemical hazard posed by a dropped breached cask greatly exceeds the radiological hazard. Properties of UF_6 and handling hazards are discussed in Section 4.1.1.

A leak or spill into the port's aquatic environment would not have significant consequences. Rather than dissolving, UF_6 reacts with water in an exothermic, non-explosive reaction that releases uranyl fluoride and HF.. The HF produced would dissolve very quickly in the sea water, dissociating into H^+ and F^- ions. The peak concentrations of H^+ and F^- ions from a total release of UF_6 from a container would be approximately 2 μg/l at a distance of 100 m. These concentrations are below toxic levels. The uranyl fluoride formed would settle on the sea-bed and slowly dissolve (USEC, 1994).

Because the impact on the marine environment would be minimal, there would be no significant impact on threatened or endangered species in the port areas. For accidents in a port, the immersion environment is rather benign because port waters average less than 200 meters in depth, and a Type 48X cylinder can survive immersion in 200 meters of water – an external pressure of about 280 psi (USEC, 1995), and present day recovery techniques allow for easy recovery at this depth (Kage, *et al*, 1980).

4.8.2.1 Potential Impacts of the Proposed Action

- The average annual individual accident dose risk is about 0.0013 rem: about 4% of average annual background and about 13% of the ICRP recommended maximum public exposure.
- An average individual dose risk can be calculated for a port because only the port population needs to be included in the calculation.
- Potential population dose and LCF risks are about 200 times as high for either proposed port as for a an accident while transporting UF_6 to the port.

Accidents at ports are treated in RADTRAN as involving a 15 km approach to the port, docking (stop) and unloading activities, at the port. Accident rate data for the particular port are used, so that (unlike routine operations) the risks will be different for different ports. The population density of the urban area of the port is used as the population density under the entire accident plume, which is modeled out to a downwind distance of 80 km. Severity category data for port accidents are from USEC, 1994 and are shown in Table 4-30. Tables 4-31 and 4-32 present population accident dose and LCF risks for a single (100 cylinder) shipment, annual shipments, and 15-year shipments for the Model 48X and Model 48Y cylinders, respectively, for the ports that are part of the proposed action. Radiological risks to dock workers are modeled as part of these risks. Hazardous chemical releases (discussed in the preceding section) would affect only the workers. Given the considerable traffic of hazardous cargo through these ports, UF_6 is not considered unusual (USEC, 1999).

Table 4-30 Fractions Released, Aerosolized, and Respirable for Port Accidents (from USEC, 1994)

SEVERITY CATEGORY	PROBABILITY	RELEASE FRACTION	AEROSOL FRACTION	RESPIRABLE FRACTION
1	0.603	0	0	0
2	0.395	0.00125	1	1
3	0.002	0.025	1	1
4	0.0004	0.375	1	1
5	0.0004	0.5	1	1
6	0.0004	1.0	1	1

Table 4-31. Population Dose Risks and LCF from Potential Accidents in Port to a Model 48X Cylinder.

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LCF		
	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS
Hampton Roads	1.61	22.5	337	8.05×10^{-4}	0.0112	0.168
Baltimore	1.95	27.2	408	9.75×10^{-4}	0.0170	0.204

Both the Model 48X and Model 48Y cylinders were assumed to be shipped in 100-cylinder shipments, at about 14 shipments per year. However, because the Model 48Y can contain 1.25 times as much as a Model 48X, it was assumed that only 80% as many shipment would be made over a 15-year period using entirely Model 48Y cylinders.

Table 4-32. Population Dose Risks And LCF From Potential Accidents In Port to A Model 48Y Cylinder.

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LCF		
	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS
Hampton Roads	2.01	28.1	337	0.00101	0.0140	0.169
Baltimore	2.44	34.0	408	0.00122	0.0170	0.204

4.8.2.2 Potential Accident Impacts of the Use of Alternate Ports

- Potential accident risks for alternate ports are very similar to those for the proposed ports.
- Potential accident risks depend on the population surrounding the port.

Although the release fraction data of Table 4-30 is the same for any port, accident rate data for the particular port are used, so that (unlike routine operations) the risks will be different for different ports. Data for the alternative ports considered are presented in Tables 4-33 and 4-34

Table 4-33. Population Dose Risks and LCF -- Potential Port Accidents: Model 48X

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LCF		
	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS
Philadelphia	2.14	29.9	448	0.00107	0.0149	0.224
New York	2.01	28.0	421	0.00101	0.0140	0.210
Charleston, SC	1.82	25.4	381	9.10×10^{-4}	0.0127	0.190
Savannah, GA	1.89	26.4	395	9.45×10^{-4}	0.0132	0.198
Fernandina Bch	1.58	22.0	331	7.90×10^{-4}	0.0110	0.165
Morehead City	1.76	24.6	368	8.80×10^{-4}	0.0123	0.184
Houston	1.59	22.2	333	7.95×10^{-4}	0.0111	0.166

Table 4-34. Population Dose Risks and LCF from Potential Accidents in Port to a Model 48Y Cylinder.

ROUTE	POPULATION DOSE RISK (PERSON-REM)			LCF		
	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS
Philadelphia	2.68	37.3	448	0.00134	0.0187	0.224
New York	2.51	35.0	421	0.00126	0.0175	0.210
Charleston, SC	2.28	31.7	381	0.00114	0.0159	0.190
Savannah, GA	2.36	33.0	395	0.00118	0.0165	0.198
Fernandina Bch	1.97	27.5	330	9.87×10^{-4}	0.0138	0.165
Morehead City	2.20	30.7	368	0.00110	0.0153	0.184
Houston	1.99	27.7	333	9.94×10^{-4}	0.0139	0.166

4.8.2.3 Environmental Impacts to Port Environments of the No- Action Alternative

Under the no-action alternative, natural uranium would not be shipped from the GDPs to a port, so that the impacts described in Sections 4.8.1.1 and 4.8.1.2 would not occur.

4.8.2.4 Environmental Impacts to Port Environments of Other Alternatives

Under any alternative that involved one of the ports cited, the impact on the port, per cylinder, would be the same.

4.9 Potential Environmental Impacts on the Marine Environment

This section discusses the impacts on the marine environment of routine operations and accidents during marine transport.

4.9.1 Impacts of the Proposed Action

4.9.1.1 Impacts of Routine Operations

- Routine operations at sea would impact only the ship's crew.
- Crew population doses and LCF are about 2% of the truck crew dose and about 10% of the port worker dose.
- Average individual crew dose is about 0.3% of average individual truck crew dose and about 6% of average individual port worker dose.

The dose and risk from routine operations are shown in Table 4-35. The slight differences in dose for different departure ports are the result of differences in travel times. Doses to the ship's crew were modeled in RADTRAN using a TI of 0.2, distance from the cask of 61 meters, and ten crew members. Exposure time is modeled as the length of the voyage. These are conservative assumptions. Only those cylinders not shielded by other cylinders would have any impact. These results would be the same for Model 48X and Model 48Y cylinders because the TI is the same.

Table 4-35. Ship's Crew Population Dose and Risk for Routine Marine Transport

DEPARTURE PORT	POPULATION DOSE (PERSON-REM)			LCF		
	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS
Hampton Roads	0.00670	0.0935	1.40	3.35×10^{-6}	4.67×10^{-5}	7.01×10^{-4}
Baltimore	0.00687	0.0985	1.44	3.44×10^{-6}	4.79×10^{-5}	7.19×10^{-4}

4.9.1.2 Impacts of Marine Transportation Accidents

- During ocean transport, the most severe accident would be a ship collision.
- It would be unlikely that a significant release of UF_6 would occur during a ship collision.
- If a release occurred, impact on the marine environment would be insignificant. Release of natural UF_6 into the marine environment would add to the sea only negligible quantities of substances already present in this environment

Accidents of all severities occur on the open seas with a frequency of 2.9 to 5.8 for every 10,000 trips. The lowest frequency is for the Atlantic Ocean and the highest for the Gulf of Mexico. About 10% of all marine accidents occur more than 60 miles from shore; about one-third occur within five miles of shore (Lloyd's, 1991). Port accident statistics do not distinguish between ships in transit and stationary vessels (vessels at anchor or dockside).

About 54% of all maritime accidents are collisions; the remaining are groundings and non-collision accidents The largest fraction of collisions on the open seas (about 25% of the total) occur in the Inland Sea of Japan. About 18% of the 758 ship collisions between 1979 and 1993 occurred in the North Sea (Fairplay, 1995). Collisions on the open seas tend to be more severe because of the higher ship speed.

Fires appear to be about equally likely to occur in the open seas as close to shore, and the parts of the world where the most ship fires occurred (about 25%) were the North Sea and the Gulf of Aqaba. About 2.5% of port accidents involve fires (Lloyd's, 1991). Almost half of the port collisions involve one ship at anchor. Thus a ship carrying radioactive cargo has an equal probability of being the struck ship or the striking ship. For purposes of conservatism in this analysis, port accidents are modeled as occurring at dockside where the greatest potential for public exposure exists. In reality, most port accidents do not occur at dockside (Warwick and Anderson, 1976).

The mechanical forces that can cause breach of a UF_6 container in the hold of a ship and mainly impact and crush forces. The frequencies of occurrence of accident environments in ship holds in port are given in Table 4-36 (from Warwick and Anderson, 1976, and Lloyd's, 1991).

Table 4-36. Frequency of Accident Environments Per Port Transit

IMPACT OR CRUSH	IMMERSION	FIRE
4.6/100,000 port transits	4.0/10,000 port transits	5.4 /100,000 port transits

As discussed in Section 3.0, the oceans contain significant quantities of uranium and its daughter products due to naturally occurring processes. As a result, marine organisms are exposed to relatively high levels of background radiation. Therefore, an accidental release and dispersal of uranium in the ocean would occur in an environment already containing large amounts of uranium and other radioactive materials. Since uranium has not been found to bioamplify in fish (and only slightly in other marine organisms) in the marine environment, an accidental release would only result in slight increases in the exposure of marine organisms which tend to be more radiation resistant than terrestrial mammals and which are already exposed to similar concentrations of uranium.

As a result of the large volume of water, the mixing mechanisms within it, the background concentrations of uranium, and the radiation resistance of aquatic organisms, the radiological impact of the very low probability accident releasing uranium into the ocean would be localized and of short duration.

In 1998, the DOE consulted with the National Marine Fisheries Service concerning the potential environmental impacts to threatened or endangered species and critical habitats, which could result from the shipments of spent nuclear fuel. Although the material proposed for shipment in this EA is natural UF_6, National Marine Fisheries Service conclusions regarding spent nuclear fuel apply, in general, to radioactive material transported by ship (Smith, 1998; Diaz-Soltero, 1998). The Service indicated that, under normal transport conditions, shipment of spent nuclear fuel by commercial vessel would be indistinguishable from any other commercial shipment, and that impacts to threatened or endangered species or critical habitat were unlikely. As a result, DOE has determined that, under routine operations there would be no impact on the marine environment as a result of the proposed action.

The hazardous chemical aspects of UF_6 releases on shipboard pose a considerably greater risk to the ship's crew than the concomitant radiological risk, just as to the port workers. Given the considerable international traffic of hazardous cargo, one may assume that crew who handle the UF_6 cylinders would be adequately trained in UF_6 handling and emergency procedures, and would have emergency equipment readily available (USEC, 1999). Any emergency procedures that protect the crew from chemical hazards would also protect against the radiological hazard. Because there is essentially no population downwind of any accident that happens on the open sea, RADTRAN analysis of airborne radioactive material is not appropriate.

4.9.2 Impacts of the Use of Alternate Ports

- The impact of the use of alternate ports would differ from the proposed action only in routine operations.
- Impacts of using alternate ports are not significantly different from impacts of using the proposed departure ports. The largest difference is for Houston, because of the considerably longer travel time.

Those radiation doses and risks are shown in Table 4-37.

Table 4-37. Ship's Crew Population Dose And Risk For Routine Marine Transport

DEPARTURE PORT	POPULATION DOSE (PERSON-REM)			LCF		
	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS	SINGLE SHIPMENT	ANNUAL SHIPMENTS	15-YEAR SHIPMENTS
Philadelphia	0.00669	0.0933	1.40	3.35×10^{-6}	4.67×10^{-5}	7.00×10^{-4}
New York	0.00646	0.0901	1.35	3.23×10^{-6}	4.51×10^{-5}	6.76×10^{-4}
Charleston, SC	0.00708	0.0988	1.48	3.54×10^{-6}	4.94×10^{-5}	7.41×10^{-4}
Savannah, GA	0.00682	0.0951	1.43	3.41×10^{-6}	4.76×10^{-5}	7.14×10^{-4}
Fernandina Bch	0.00743	0.102	1.42	3.67×10^{-6}	5.12×10^{-5}	7.68×10^{-4}
Morehead City	0.00679	0.0947	1.54	3.40×10^{-6}	4.74×10^{-5}	7.10×10^{-4}
Houston	0.00879	0.123	1.84	4.40×10^{-6}	6.13×10^{-5}E	9.20×10^{-4}

4.9.3 Impacts Of The No-Action Alternative

There would be no marine shipment of UF_6 beyond what is already occurring, so that the no-action alternative would have no environmental impact.

4.9.4 Impacts Of Other Alternatives to The Proposed Action

For alternatives for which there would be no marine shipment of UF_6 beyond what is already occurring, the alternative would have no environmental impact. In other cases, the impacts would be the same, per shipment, as those of the proposed action or for the use of an alternate port, since natural UF_6 could still be returned to the Russian Federation by the same overland and sea routes.

4.10 Socioeconomic Impact

The source of the Russian titled natural UF_6 would come from the annual stream of U_3O_8 equivalent[18] supplied to the USEC by its enrichment customers.

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[18] All of the uranium considered for this proposed action is in the form of UF_6. Natural uranium equivalent quantity expresses the quantity of uranium oxide U_3O_8 (e) (the form in which natural uranium is delivered from the mining industry) that would be required to produce a particular quantity of UF_6 (see Appendix A).

4.10.1 Impact of the Proposed Action

Under the proposed action the United States could send back to the Russian Federation up to 23.4 million pounds U_3O_8 equivalent (9000 metric tons of UF_6) annually through 2013. It is possible that potential sales agreements between the Russian Federation and western uranium customers may result in the sending back of significantly less than this amount each year. However, the Russian Federation, as title holder of this inventory, would have the opportunity to market the full 9000 metric tons of UF_6 annually to the world's uranium consumers, within the limits of the Act and the HEU Purchase Agreement, regardless of whether it is sent back to the Russian Federation or marketed while in the possession of the USEC. Thus, the potential impacts of the proposed action on the domestic uranium production industry would be indifferent to the physical location of the Russian titled UF_6. At issue is the Russian Federation's ultimate disposition of their uranium. It is not known specifically what the Russian Federation would do with the natural UF_6, but several options are possible. The Russian Federation could choose to market the entire inventory on the world market; it could stockpile the inventory; or it could use the inventory to offset its current and future domestic uranium needs (thus saving the Russian Federation uranium mining and conversion costs), or a combination of these factors. Under the agreement between DOE and MINATOM, the Russian Federation has agreed to stockpile 22 thousand metric tons of this material. The Russian Federation could only withdraw material from this stockpile for sale in accordance with the commercial contract and nonproliferation assurances provided to the United States government, or it may withdraw up to 4.6 million pounds. per year for blending down its HEU.

The United States domestic uranium industry would probably be most seriously impacted if the Russian Federation were to introduce the entire inventory back into the world market, so that will be the basis for assessing the socioeconomic impacts of the proposed action on United States domestic uranium production. The 1997 world production of U_3O_8 equivalent was approximately 164 million pounds, of which approximately 6 million pounds was produced by the United States (3 % of world production) (USDOE, 1997). The world requirement for U_3O_8 equivalent is estimated between (approximately) 140 million pounds to 170 million pounds through 2015 (USDOE, 1997). The 23.4 million pounds that would be sent back to the Russian Federation annually would be equivalent to approximately 15% (on the average) of the current and projected annual world requirement of U_3O_8 equivalent. If it is assumed that the Russian Federation reintroduces the entire 23.4 million pounds of Russian titled U_3O_8 equivalent then the actual annual world production of uranium could drop by this amount – 23.4 million pounds. This could continue until the stockpile of natural UF_6 available to fulfil the 1993 Agreement has been disposed of in this way.

If it is assumed that the impact of the drop in world uranium production in any year is distributed among all of the world's uranium producers of uranium, then the United States domestic production industry could absorb a share of the drop proportional to its share of the world market. Domestic production has been estimated to be 7.8 million pounds in 2000, 8.2 million pounds in 2005, and 11.0 million pounds. in 2010 (USDOE, 1998b). If 8.0 million pounds is taken as a representative domestic annual production level, then a 15% drop in domestic production would represent 1.2 million pounds.

The DOE has estimated that the domestic productivity rate for uranium mining is 11,235 pounds. U_3O_8 equivalent per worker (USDOE, 1996). At this production rate, annual United States uranium mining employment would be 712 workers for 8 million lb U_3O_8 equivalent. The loss of 1.2 million pounds. U_3O_8 equivalent could yield a loss of approximately 106 workers, or 15% of the uranium mining workforce during the years that the drop in world uranium production took place.

Secondary impacts to the workforce in the communities associated with the domestic uranium mining sites is assessed by deriving a job multiplier from Bureau of Economic Analysis (BEA) data (BEA, 1992). DOE has derived a job multiplier of 2.5 using the BEA's data and method (USDOE, 1996). The total labor force in the surrounding communities as been estimated at 42,415 (USDOE, 1996). Thus, the loss of 106 uranium employment slots could lead to a loss of 267 additional jobs from the local communities, or approximately 0.6% of the total local workforce.

4.10.2 Impact of the Overland Transportation of UF_6 by Rail

The use of rail for overland transportation instead of truck, would have no socioeconomic impact substantially different from the impact of the proposed action.

4.10.3 Impact of the Use of Alternate Ports

The use of alternate ports would have no socioeconomic impact substantially different from the impact of the proposed action.

4.10.4 Impact of the No-Action Alternative

Under the no-action alternative, the DOE would not send back to the Russian Federation any of the Russian titled natural UF_6, but the Russian Federation could sell to United States customers up to the limits shown in Table 1-3. The USEC would continue to stockpile the remainder.

Under the no-action alternative, unless the Russian Federation can sell natural UF_6 in the United States, it will continue to send LEU to the United States, as the Federation is now doing, but will receive no compensation for the natural UF_6. However, the Russian Federation is not satisfied with the current situation. As a result, if the no action alternative were selected, the possibility would exist for secondary and indirect impacts that could negatively impact the United States domestic industry, including the potential for major displacement of United States domestic uranium production capacity.

The United States and the Russian Federation have entered into several agreements regarding the blending down of HEU into LEU and the purchase and sale of both blended down LEU and natural UF_6 between the two countries (see Section 1.1). Under the no-action alternative the Russian Federation could be denied possession and disposition of some of its natural UF_6 that would be (and has been) stockpiled. If the Russian Federation were to withdraw from the agreements because they are not getting fair value for their uranium, then it is unknown what course of action the Russian Federation might adopt with regard to its own production and sale of natural and enriched uranium. The Russian Federation processes great quantities of uranium in various forms, including natural uranium ore deposits and stocks of LEU and HEU. If the Russian Federation were to withdraw from the agreements, then the potential exists for the Russian Federation to aggressively produce and market its own domestic uranium in the world market. Such a policy on the part of the Russian Federation could have significant, potentially ruinous, impacts on the domestic uranium production industry.

Under the proposed action, it is expected that the Russian Federation would adhere to the agreements. Under these agreements, the Russian Federation and the United States have entered into mutually beneficial arrangements regarding the blending down of Russian HEU and associated processing costs, the purchase of the blended down HEU by the United States, and the sale of Russian titled uranium in the domestic market. Under the proposed action, the United States would be in a position to exert influence over the Russian Federation's approach to marketing uranium inventories in the world market, but under the no action alternative, the United States would have little or no influence.

A perspective of the potential for negative impacts on the domestic uranium production industry can be gained from data on the domestic uranium industry. Figure 3.7 illustrates the relationship between world price for uranium and domestic production capability (USDOE 1998b). The precise impact that might befall the world market of uranium if an aggressive production and marketing policy by the Russian Federation is unknown. However, Figure 3.7 illustrates that the United States domestic industry could suffer greatly in the event of a significant drop in the world market price for uranium.

4.10.5 Impacts of Other Alternatives

The alternative strategies that would enable the Russian Federation to receive value for the natural uranium component of LEU delivered to the GDPs were not analyzed in detail, but may have a socio-economic impact. These alternatives are:

(1) USEC or the United States Government paying the Russian Federation for the natural uranium component of LEU delivered to the GDPs;
(2) the United States Government increasing the limits on sales of Russian natural uranium in the United States and allowing customers to purchase additional quantities of Russian Federation titled natural uranium;
(3) USEC providing customer information to the Russian Federation and allowing the Russian Federation to deliver LEU directly to USEC customers, bypassing the

GDPS, and having customers pay for the enrichment service and natural feed component; and

(4) providing a mechanism whereby USEC customers transfer title to the Russian Federation of natural UF_6 purchased outside the United States, and then deliver that natural UF_6 to the Russian Federation instead of to USEC at the GDPs.

Under Alternative (1), either USEC or the United States Government would be stockpiling 23.4 million pounds of U_3O_8 per year. As long as this was not sold, there would be no impact on the uranium market.

Under Alternative (2), the entire annual inventory of 23.4 million pounds of U_3O_8 equivalent could be sold by the Russian Federation directly to the USEC or to USEC customers. The impact on the domestic uranium production industry could potentially be greater than the impacts of the proposed action. The 23.4 million pounds of Russian titled U_3O_8 equivalent represents approximately 15% of the annual world requirement of 140 to 170 million pounds U_3O_8 equivalent. Thus, the sale of 23.4 million pounds U_3O_8 equivalent could displace domestically produced uranium in direct proportion to the domestic industry's share of the uranium market for USEC's American customers. Virtually all of domestically produced U_3O_8 equivalent is for American end users of uranium fuels (USDOE, 1996). Assuming that 42 million pounds (25% to 30% of the annual world requirement) is a representative domestic annual requirement level through 2015 (USDOE, 1997), and assuming that 8 million pounds is a representative annual domestic production level through 2015 (see Section 3.6), then about 27.5% of the domestic production, or 2.2 million pounds, would be replaced by Russian Federation uranium..

As stated in Section 3.6, the domestic productivity rate for uranium mining is 11,235 pounds U_3O_8 equivalent per worker, and the annual United States uranium mining employment would be 712 workers for 8 million pounds U_3O_8 equivalent. The loss of 2.2 million pounds U_3O_8 equivalent in domestic production would yield as loss of approximately 196 workers, or 27.5% of the uranium mining workforce. Also (Section 3.6), a job multiplier of 2.5 is used to assess secondary impacts to a total workforce of 42,415 in the communities that are associated with the mining sites. The loss of 196 uranium employment slots could lead to a loss of 490 additional jobs from the local communities, or approximately 1.2% of the total local workforce.

Under Alternative (3), the entire annual inventory of 23.4 million pounds of Russian titled U_3O_8 equivalent could be sold directly to USEC customers in the form of LEU. The USEC's customers' requirements for feed UF_6 would drop by 23.4 million pounds U_3O_8 equivalent annually, and their domestic orders for uranium would be displaced in proportion to the current level at which the United States domestic uranium industry supplies USEC's customers (8 of 42 million pounds U_3O_8, or 19%). Thus, the domestic production industry could realize a decrease of 19% production annually, resulting in the possible loss of 135 uranium mining jobs and 338 additional jobs from the total local workforce.

In addition to the impact on the domestic producers of uranium, the Russian Federation would be in direct competition with the USEC for, in effect, the sale of enrichment services. The DOE has estimated that under the 1993 Agreement, the Russian LEU received by the USEC will be equivalent to 30% of the USEC's pre-agreement SWU production during the later years of the agreements (USEC, 1994). Although the USEC has lowered its annual SWU production level to account for the LEU received under the 1993 Agreement, it has maintained market share of SWU sales by controlling the sale of the Russian LEU. Under Alternative (3), the USEC could now also lose control of the sale of enrichment services from its current market share. Additional erosion of the USEC's market share could weaken the USEC's position for enlarging or even maintaining its current market share in the future.

Under Alternative (4), the USEC's customers would be allowed to "reflag" quantities of their foreign-purchased natural UF_6 equivalent to the quantities of Russian titled uranium, with direct shipment of the retitled natural UF_6 from the foreign source to the Russian Federation, the impacts to the domestic uranium production industry would be essentially equivalent to the impacts of the proposed action.

The net effect of this alternative would be to send back to the Russian Federation up to 23.4 million pounds U_3O_8 equivalent annually. The difference between this alternative and the proposed action would be that this alternative would "send back" the uranium from foreign sources, as opposed to sending it back from the USEC's stockpile. Initially, the USEC's customers purchase levels of both domestically produced and foreign produced uranium would remain the same at current levels. However, as was discussed in Section 3.6 for the proposed action, the Russian Federation could decide to market the retitled 23.4 million pounds U_3O_8 equivalent in foreign sources back in the world market for uranium. The net potential impacts for this alternative would be the same as for the proposed action.

4.11 Environmental Justice Considerations

On February 11, 1994, Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, was published in the Federal Register (59 FR 7629). The Executive Order requires each federal agency to identify and address disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income communities.

At the GDP sites (Paducah and Portsmouth), there are no environmental impacts on the population surrounding the site from the proposed action and the alternatives in addition to the impacts of activities that have been ongoing for more than 30 years. Thus there are no particular environmental justice implications. For highway or rail transportation of hazardous materials, there is a distinction relative to issues connected with activities at fixed sites: the highways or railways are in place and cannot be relocated. Therefore, all alternatives (except the no-action alternative) are existing routes, and total avoidance of impacts on minorities or low-income populations located near the routes is generally impossible.

In the event that the total impacts of the proposed action are found to be not significant, then the environmental justice component does not require analysis (DOE, 1996). As stated in previous sections of this EA, the potential environmental impacts calculated for activities associated with the Proposed Action and the alternatives due to planned operations or accident conditions present little, if any, risk to the surrounding environment and population. Therefore, there would not be disproportionately high and adverse impacts on any minority or low-income populations.

4.12 Endangered Species

Potential impacts on endangered species are discussed in the relevant subsections of Sections 4.2, 4.3, and 4.4.

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No individuals outside of the Department of Energy, Sandia National Laboratories and Department of Energy contractors were consulted during preparation of this EA
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GLOSSARY OF TERMS

activity: The mean number of decays per unit time of a radioactive nuclide.

AEA: The Atomic Energy Act of 1954, as amended. 42 USC 10101 *et seq.*

ALARA: As Low As Reasonably Achievable: the program in a facility handling radioactive materials that controls occupational exposure and ensures that occupational exposure will be minimized.

alpha particle: A subatomic particle with an electric charge of +2 and atomic mass = 4; a nucleus of the element helium. Heavy radionuclides like the isotopes of uranium and plutonium emit alpha particles.

assay: The concentration by weight percent of a particular material.

background radiation: The average amount of radiation to which a member of the population is exposed from natural sources due to naturally occurring radionuclides in the soil, cosmic radiation originating in outer space, and naturally occurring radionuclides deposited in the human body, together with the average radiation exposure from ordinary widespread activities such as dental and diagnostic x-ray. This amounts to about 0.36 rem (360 mrem) per year in the U.S.

becquerel (Bq): A unit of radioactivity in the SI system equal to one disintegration per second.

beta particle: An electron. Many radionuclides emit beta particles.

book inventory - The quantity of nuclear material present at a given time as reflected by accounting records.

conveyance: Any vehicle, aircraft, vessel, freight container, or hold, compartment, or defined deck area of an inland waterway craft or seagoing vessel.

curie (Ci): A unit of radioactivity in the historic unit system equal to 3.7×10^{10} disintegrations per second.

depleted uranium: Uranium whose content of the isotope uranium-235 is less than 0.711%, which is the uranium-235 content of natural uranium.

EDE: The effective dose equivalent is a measure of physiological radiation dose that takes into account the distribution of inhaled and ingested radionuclides in various organs of the human body.

enriched uranium: Uranium whose content of the isotope uranium-235 is greater than 0.711%, which is the uranium-235 content of natural uranium.

feed stock: Natural uranium required for the enrichment process.

fissile material: Material containing a sufficient concentration of fissile radionuclides that nuclear criticality could be induced. Neither natural nor depleted uranium are fissile materials. Fissile materials are classified according to the controls needed to provide nuclear criticality safety during transportation.

fissile radionuclide: A radionuclide whose nucleus can be fissioned under neutron bombardment. Fissile radionuclides are plutonium-238, plutonium-239, plutonium-241, uranium-233, and uranium-235.

freight on board: A method of delivery of commercial goods whereby payment for the freight is made prior to shipment. As a result, the buyer is responsible for shipment costs.

gamma radiation: Very high energy radiation, like x-ray, that is emitted during radioactive decay.

GDP: Gaseous diffusion plant – a facility for the gaseous diffusion process.

gray (Gy): A unit of absorbed radiation dose in the SI system. One gray equals on joule of energy absorbed per kilogram of absorber.

gaseous diffusion process: A method of isotopic separation based on the fact that gas atoms or molecules with different masses will diffuse through a porous barrier (or membrane) at different rates.

half-life: Time required for a radioactive substance to decay by 50%

high energy density device (HEDD): an armor-piercing weapon

highly enriched uranium (HEU): Uranium whose content of the isotope uranium-235 is greater than 20%. Weapons HEU is enriched by about 90%.

HIGHWAY: a code for determining transportation routes (Johnson, *et al*, 1993).

IDLH: Level or concentration of a toxicant that is Immediately Dangerous to Life or Health, and represents the maximum concentration from which individuals could escape within 30 minutes without experiencing any escape-impairing or irreversible health effects

ionizing radiation: Radiation that can displace electrons from atoms or molecules, thereby producing ions. The particles and energy emitted from a radioactive nucleus, including alpha, beta, and gamma radiation, are all ionizing radiation.
low enriched uranium (LEU): Uranium whose content of the isotope uranium-235 is between 0.711% to less than 20%.

MINATOM: The Russian atomic energy agency.

mrem: A millirem; 0.001 rem.

MWe: megawatts (electrical): a measure of the electrical output capacity of an electric generating plant.

natural uranium: uranium that is 0.711% U-235

natural uranium hexafluoride (natural UF_6): uranium hexafluoride in which the uranium is 0.711% U-235

overfeed: In the gaseous diffusion cycle, the process by which additional uranium is fed into the enriching system in order to reduce the amount of separative work units required and reduce the amount of electricity consumed.

person-rem: Unit of population exposure obtained by summing individual dose-equivalent values for all people in the exposed population. Thus, the number of person-rems contributed by 1 person exposed to 1 rem is equal to that contributed by 100,000 people each exposed to 10 μrem.

physical inventory - The quantity of nuclear material that is determined to be on hand by physically ascertaining its presence using techniques that include sampling, weighing, and analysis.

PL: Public Law – Legislation enacted by the U. S. Congress is called a public law.

ppm: parts per million – a measure of concentration. For gases in air, ppm means liters of substance per million liters of air. For substances in water, ppm means milligrams per liter of water.

psi: pounds per square inch

rad: The unit of absorbed dose of ionizing radiation in the historic unit system equal to the absorption of 100 ergs of radiation energy per gram of absorbing material. One rad = 0.01 Gy.

radioactivity: The property of some nuclides of spontaneously emitting ionizing radiation, emitting x radiation after orbital electron capture, or undergoing spontaneous fission.

RADTRAN: a model and code for estimating radiation doses and risks from transporting radioactive material (Neuhauser and Kanipe, 1992)

rem ("Roentgen equivalent man"): Unit of dose equivalent in the historic unit system One rem is a measure of the biological damage done by absorption of one rad of x-ray or gamma radiation by biological tissue. The dose equivalent in "rem" is numerically equal to the absorbed doses in "rad" multiplied by a "quality factor," the distribution factor, and any other necessary modifying factor. One rem = 0.01 Sv.

RMIR: Radioactive Materials Incident Report: a database of radioactive materials transportation accidents extracted from Department of Transportation records.

sampling: Testing to confirm assay and purity of a material coming to the GDP. This involves heating a UF_6 cylinder to convert the solid to a liquid and withdrawing a small amount for testing.

separative work unit (SWU): A SWU is a measure of the separation achieved in a uranium enrichment plant after separating uranium of a given U-235 content into two components, one having a higher percentage of U-235 and one having a lower percentage of U-235.

SI unit system: The Standard International system of radiation units. The SI system units are the becquerel, the gray, and the sievert.

sievert (Sv): The International System of Units term for the unit of effective dose and equivalent dose; 1 Sv equals 100 rem.

tails assay: the concentration by weight percent of U-235 remaining in the depleted uranium stream produced during the enrichment process.

TENEX: Technabexport, the Russian executive agency for export

TI: Transport Index: the external dose rate in mrem/hr at one meter from the external surface of a container transporting radioactive material.

TICLD: Transportation Individual Center Line Dose – a code for calculating the maximum dose along the plume centerline in the event of a transportation accident.

TLV: The threshold limiting value, which represents a time-weighted average air concentration to which workers can be exposed for a normal 8-hour day, 40-hour work week without adverse health effects

Type A packaging: Packaging designed to retain the integrity of containment and shielding required under normal conditions of transport, as described in 10 CF Part 71.

Type B packaging: Packaging designed to retain the integrity of containment and shielding required when subjected to the normal conditions of transport and hypothetical accident test conditions, as described in 10 CF Part 71.

uranium hexafluoride (UF_6): A volatile compound of uranium and fluorine. UF_6 gas is the process fluid in the gaseous diffusion process.

uranium ore: Rock containing uranium mineralization (typically 1 to 4 pounds of U_3O_8 per ton or 0.05% to 0.20% U_3O_8) that can be mined economically.

yellowcake: Concentrate of uranium oxide with the chemical formula U_3O_8.

APPENDIX A

CONVERSION OF METRIC TONS OF UF_6 TO POUNDS OF U_3O_8

The conversion scheme described in this appendix is the scheme used in the 1993 Agreement. It represents a mass balance of uranium. In the steps below, numbers have been rounded to three significant figures.

The molecular weight of U_3O_8 is

$$3*238 + 8*16 = 842 \text{ grams/mole}$$

The fraction of U_3O_8 that is uranium is

$$3*238/842 = 0.848$$

The conversion of kilograms to pounds is 2.205 pounds/kg. One metric ton = one million grams or 1,000 kg. One kg of U in U_3O_8 is

$$(2.2 \text{ lb/kg})*(1/0.848) = 2.60$$

The molecular weight of UF_6 is

$$238 + 6*19 = 352 \text{ grams/mole}$$

The fraction of UF_6 that is uranium is

$$238/352 = 0..676$$

The conversion of kilograms to pounds is 2.205 pounds/kg. One metric ton = one million grams or 1,000 kg.

One kg of U in UF_6 is

$$(2.2 \text{ lb/kg})*(1\text{kg}/0.676) = 3.25 \text{ lb}$$

9,000 metric tons of U (9 million kg) is equal to

$$9{,}000/0.676 = 13{,}300 \text{ metric tons of } UF_6$$

and

$$9{,}000*2.60 = 23.4 \text{ million lb } U_3O_8$$

APPENDIX B

URANIUM ENRICHMENT AND GASEOUS DIFFUSION

B.1 The Uranium Enrichment Processes

Mined, or natural, uranium is 0.711% U-235[19]; most of the remaining fraction is the isotope U-238, though a small quantity of U-234 is also present. In order to serve as fuel in commercial nuclear power plants, the fraction of fissile uranium -- the isotope U-235 -- must be increased. This increase can be accomplished by any process that can separate the uranium isotopes according to their relative mass. On a large scale, two such processes have been developed: gaseous diffusion and separation by gas centrifuge. In the United States, gaseous diffusion is used at the Portsmouth GDP in Piketon, OH and at the Paducah GDP in Paducah, KY. Both of these plants are now operated by the U. S. Enrichment Corporation (USEC).

Power plants in the United States require a U-235 concentration, or assay, of between 3% and 5% to operate. Uranium with a concentration of fissile isotope between 0.7% and 20% is referred to as low-enriched uranium (LEU). The breeder reactor process and research reactors require a higher degree of enrichment, usually 20% or more U-235. Uranium in this or higher concentration of U-235 is referred to as high-enriched uranium (HEU). Nuclear weapons require enrichment of 90% or more fissile isotope. The LEU purchased under agreements between the United States and the Russian Federation is the product of weapons HEU which has been blended down to LEU concentrations.

Uranium is mined as uranium oxide, and the ore concentrate, called "yellowcake," is composed of U_3O_8, which is chemically converted to UF_6 for use in both enrichment and blend-down. Synthesis and properties of UF_6 are described in Katz, *et al* 1986. UF_6 is chemically stable through a wide range of temperatures and pressures, and because of its relatively high volatility at ambient temperatures and pressures, provides the feedstock for the gaseous diffusion process[20].

B.2 The Gaseous Diffusion Process

A gaseous diffusion plant operates on the principle that lighter weight molecules will diffuse more rapidly through a porous barrier than heavier molecules. Forcing gas molecules through successive stages of porous barriers (tubes that essentially have many extremely small holes) will thus concentrate lighter molecules. UF_6 is extremely volatile, with a vapor pressure about 15% of atmospheric pressure at room temperature. When heated to a minimum temperature of 134°F (52.2°C), solid UF_6 sublimes[21] readily into the

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[19] U-235 is fissile and is the fissile isotope of uranium most useful as nuclear power fuel.

[20] Chemical stability means that the substance does not decompose when strongly heated or compressed. High volatility means that the vapor pressure under ordinary ambient conditions is relatively high. High vapor pressure under ambient conditions indicates that a substance goes into the gas phase readily and is thus an excellent candidate for gaseous diffusion.

[21] Sublimation occurs when a substance goes directly from the solid state to a gas when it is heated, without going through a liquid phase. UF_6 sublimes at ordinary atmospheric pressure; liquid UF_6 can be formed only under higher pressures.

gas phase, making it an ideal compound for gaseous diffusion. The diffusion process that results in enrichment in U-235 requires gas-phase feed. The relative molecular weights of $U^{235}F_6$ and $U^{238}F_6$ are 349 gm/mole and 352 gm/mole, respectively. Gas-phase $U^{235}F_6$ will therefore diffuse faster through each stage of a porous barrier than gas-phase $U^{238}F_6$. Two streams are created: one enriched in U-235 and one depleted in U-235. The concentration of U-235 in the enriched stream increases with each barrier stage. The uranium in the depleted stream is also known as "tails." A plant constructed for producing 5% assay U-235 contain about 2,000 stages of porous barriers.

The commercial transaction for enrichment work takes place as follows. A GDP enrichment service customer, usually a utility, desires a certain quantity of LEU containing a particular assay or quantity of U-235. In order to obtain the desired quantity and assay of LEU, the utility customer delivers UF_6 feed material to the GDP (usually natural UF_6 containing 0.711 percent U-235) and purchases enrichment services from the GDP. The cost of the enrichment services to a customer is expressed in terms of dollars per separative work unit (SWU). A SWU is the conventional measure of the effort achieved in a uranium enrichment plant after separating uranium of a given U-235 content into the two streams. When customers buy services from GDP, they are buying separative work units (SWUs).

The relative amounts of feed material delivered to, and the enrichment services purchased from, the GDP by a customer are determined by the transaction tails assay (i.e., the tails assay at which that customer transacts with the GDP). If the GDP had only one customer, and the GDP did not have its own stockpile of natural uranium feed, then the GDP would use the feed delivered by the customers to operate at the tails assay specified by the customer to produce the LEU required by the customer. The GDP would collect revenues from the customer based on the amount of enrichment services required to produce the LEU and the price of the SWUs. In operating the Portsmouth and Paducah GDPs, the USEC utilizes the feed material delivered by all of its customers to produce the LEU required by the customers. In doing so, the operating tails assay of the GDPs is the average of the transaction tails assay specified by the customers.

Along with the LEU the customer has purchased, the tails (depleted uranium) may be taken by the customer or left at the GDP. Nearly all customers elect to leave the tails at the GDP. However, because the GDPs have their own stockpile of natural UF_6, the GDPs can supply additional uranium feed to the plants, which will cause the operating tails assay to increase and will reduce the enrichment required to produce the LEU product. This process is called "overfeeding."

APPENDIX C

RADTRAN

C.1 Incident-free Transportation

RADTRAN is a mathematical model of risks of transporting radioactive materials, which yields relatively conservative estimates (i.e., those that tend to overstate the impact) of integrated population dose in a way that can be supported by available data. The models in RADTRAN do not include features of the transportation environment that either do not affect the calculated risk values or reduce conservatism. This conservatism is discussed in Weiner, et al (1992).

RADTRAN models incident-free transportation as a separate module from transportation accidents. When radioactive materials are transported, an external gamma radiation dose, limited by regulation (10 CFR Part 71), is allowed. The radioactive cargo is modeled as a point source for distances to the receptor that are much longer than the cylinder dimension; a package correction factor is used to account for package dimensions, and the dose is inversely proportional to the square of the distance from the package center to the receptor ($1/r^2$). For receptors closer to the cylinder (e.g., truck crew, handlers, rail yard workers) the cargo is modeled with a different package shape factor, and the dose is inversely proportional to the distance from the source ($1/r$). Radiation dose to persons along the route is also inversely proportional to vehicle velocity, and directly proportional to distance traveled and to the number of shipments. The radiation source is the external radiation dose rate (in mrem/hr) measured at one meter from the cask surface, called the transport index, or TI. The modeled incident-free dose is independent of the isotopic content or radioactivity of the material being shipped, and depends only on the external, measured radiation dose rates.

Radiation doses for overland transportation are calculated separately for the truck or train crew (crew dose), the public along the transportation route within about ½ mile on either side of the road (off-link dose), occupants of vehicles that share the transportation corridor with the radioactive shipment (on-link dose), and people in the vicinity of the shipment when it is stopped (stop dose).

C.2 Transportation Accidents

The radioactive materials being shipped, and their activity, become important in calculating the effects of potential transportation accidents. RADTRAN models accidents as the risk from emission of fractions of the radioactive cargo into the air. This risk combines the probability of a breach of containment with the fraction of each isotope that would be released, aerosolized, and inhaled under a particular accident scenario.

C.2.1 RADTRAN Accident Module

This module calculates dose risk from inhaled radioactive material (including resuspended material, groundshine (whole-body radiation dose from aerosols deposited on the ground), and cloudshine. Ingestion dose is not calculated because it affects a different population. Dose to the receptor is then calculated by RADTRAN from dose conversion factors given in ICRP (1990).

In the model, the set of all possible accidents is divided into subsets, each with a particular probability of occurrence and varying degrees of damage to the cargo which results in aerosolized and respirable release fraction. Probabilities of accidents of a particular severity are based on a fault tree analysis of the accident response. The set of accidents always includes a subset for no release and no loss of shielding (by far the most probable case) and a subset for loss of shielding only (no actual release of material). A more detailed description of the accident severity category approach may be found in USEC, 1994.

Essentially, the probability of occurrence of an accident depends on truck accident statistics (accidents per vehicle-km) and indirectly on population density (e.g., a larger fraction of accidents in urban areas are minor). Releases and aerosol fractions depend on the physical and chemical nature of the transported material (e.g., volatility, particle size) and have been incorporated into the RADTRAN model (see Neuhauser and Kanipe, 1992). The universe of accidents is captured in the severity categories (the probabilities of the severity categories sum to one for rural, urban, and suburban routes, respectively).

C.2.2 Gaussian Dispersion and Meteorology

When material is released from a package in a transportation accident, it can disperse in the air. This dispersion of airborne gases and particulate matter is modeled using a Gaussian dispersion model. The shape of the resulting isopleths (curves of constant concentration) depends on meteorological stability and wind speed. In general, the isopleth is an elongated ellipse, with the release at one end, because the predominant movement of airborne material is downwind. The crosswind concentration decreases very rapidly (exponentially) with distance from the plume centerline. Outside of these ellipses there will be virtually no airborne concentration or deposition of radioactive material. RADTRAN calculations of populations exposed to possible accidental releases include these ellipses. RADTRAN 4 uses an extremely conservative population dose calculation, in that the population density for ½ mile on either side of the route is used as the exposed population for 80 miles downwind.

Dispersion of released pollutants depends on meteorology. Meteorological conditions and the stability (or instability) of the dispersing atmosphere are described by six "stability classes".

Class A: high vertical mixing of air layers, light winds, unstable, good dispersion

Class B and C: moderate to high winds, unstable air, good dispersion
Class D: light wind, neutral stability, poor dispersion
Class E: weak temperature inversion, high stability, very light wind, poor dispersion
Class F: strong temperature inversion, very high stability, very light wind, poor dispersion

RADTRAN allows selection of any desired combination of stability classes to represent the prevailing meteorological conditions for modeling the potential dispersion of radioactive materials released into the air after a severe accident. In this study, dispersion of released material was modeled out to about 50 miles from the site of the hypothetical accident using national average meteorological conditions (the fraction of a year that each stability class occurs, on the average, in the lower 48 United States). Releases are modeled as a puff that is depleted by deposition.

Any vehicle in a transportation accident stops when the accident occurs. Particulate material and gases released into the air as a result of an accident may be dispersed in the air like any other air pollutant. People may be exposed to this dispersed material by inhaling it or externally from deposited material (groundshine). This exposure results in a dose calculated in rem, from which the cancer risk in LCF may be calculated..

In the RADTRAN calculation, the dose calculation includes probability terms: the probability that the accident happens and the probability that the accident is of a certain severity. The calculated dose is thus different from the dose calculated for incident-free transportation (which does not include any probability terms) and is referred to as a dose risk. The term "dose risk" implies inclusion of probability factors. Dose risk is reported in rems. Accident dose risks are reported for the entire exposed population: no distinction is made between crew and public. No average individual dose risk can reasonably be reported for RADTRAN 4 transportation analyses.

C.2.3 Calculation of Maximum Individual Dose Using TICLD

Maximum individual dose to a receptor directly downwind from an accident may be calculated using the code TICLD (Transportation Individual Center Line Dose; Weiner, Neuhauser, and Kanipe, 1993). TICLD calculates the minimum ground-level dilution factors along the plume centerline for a ground-level release using a Gaussian dispersion model. Separate calculations are made for each meteorological stability class. TICLD also calculates dilution factors at downwind distances out to approximately 80 km.

C.2.4 Treatment of Rail Accident Data

The rail accident data (Saricks and Kvitek, 1994) are not differentiated with respect to population density but are tabulated for total and main line rail systems. It was assumed that main line usage for the current shipments would predominate in rural portions of the routes and the "total" category would typify suburban portions. In order to estimate the urban accident rate, the ratio of urban to suburban from the historical values (1.5×10^{-5} and 1.9×10^{-6}, respectively) was used to scale up the total rail system (suburban) value. The resulting accident rates derived from the averages over all states in Saricks and Kvitek are:

Rural: 2.7×10^{-8} per km
Suburban: 5.6×10^{-8} per km
Urban: 4.4×10^{-7} per km

These values give accident-risk estimates which are comparable to the truck transport values and are similarly conservative.