DRAFT

DOE/EA-1599

ENVIRONMENTAL ASSESSMENT

DISPOSITION OF RADIOACTIVELY CONTAMINATED NICKEL LOCATED AT THE EAST TENNESSEE TECHNOLOGY PARK, OAK RIDGE, TENNESSEE, AND THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, FOR CONTROLLED RADIOLOGICAL APPLICATIONS

U.S. Department of Energy
Oak Ridge Office
Oak Ridge, Tennessee

June 2008

JASON ASSOCIATES, INC. AND
DADE MOELLER & ASSOCIATES, INC.

contributed to the preparation of this document and should not
be considered eligible contractors for its review.

DOE/EA-1599
DRAFT

ENVIRONMENTAL ASSESSMENT

DISPOSITION OF RADIOACTIVELY CONTAMINATED NICKEL LOCATED AT THE EAST TENNESSEE TECHNOLOGY PARK, OAK RIDGE, TENNESSEE, AND THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, FOR CONTROLLED RADIOLOGICAL APPLICATIONS

Draft—June 2008

Prepared for
U.S. Department of Energy
Oak Ridge Office
Oak Ridge, Tennessee

SUMMARY

The U.S. Department of Energy (DOE or the Department) proposes the disposition (that is, sale, transfer, grant, or disposal) of approximately 15,300 tons (13,800 metric tons) of nickel metal scrap DOE has recovered from equipment it used in the uranium enrichment processes at the Paducah Gaseous Diffusion Plant (PGDP), in Paducah, Kentucky, and the East Tennessee Technology Park (ETTP) in Oak Ridge, Tennessee, where DOE currently stores the nickel. The purpose of this action would be to remove a nonessential DOE material from storage and to reduce the national need to expend additional resources through the mining and refinement of replacement nickel feedstock. In addition, DOE needs to perform this action to make space available for other uses where it stores the nickel at the ETTP and the PGDP. Further, this action would reduce annual storage and maintenance expenses and provide financial gain through the sale of the nickel

DISPOSITION

As used in this environmental assessment, disposition means DOE's sale, transfer, or grant of nickel to private industry for processing, use, and disposal under radiological controls.

DOE generated this nickel in areas under radiological controls; as a result, the nickel is volumetrically contaminated with radioactive materials. In 1995, DOE prepared an environmental assessment for the *Proposed Sale of Radioactively Contaminated Nickel Ingots Located at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*. That document considered only the PGDP portion of the DOE nickel inventory for sale to a private entity for decontamination, with resale of the decontaminated product on the international market. The Department issued a Finding of No Significant Impact on April 23, 1995. However, DOE did not implement that proposed action because the purchaser cancelled the sale as a result of a business decision. Since that time, the Secretary of Energy has issued two moratoria that prevent the release of all volumetrically contaminated metals into commerce – the January 12, 2000, Secretarial moratorium on the unrestricted release of DOE volumetrically-contaminated metals, and the July 13, 2000, Secretarial suspension on the unrestricted release for recycling of scrap metals from DOE radiological areas. These moratoria prohibit DOE from the release or recycling of the stored contaminated nickel in an unrestricted manner.

The proposed action described in this environmental assessment would allow private industry to use the contaminated nickel in a <u>controlled manner</u> to make high-quality products (for example, pure nickel components, stainless-steel components, or components made from other alloys). All aspects of the recycling and production would be controlled, and the final products would be controlled for <u>use in radiological applications only</u> [that is, for DOE-controlled, U. S. Nuclear Regulatory Commission (NRC)-licensed, or otherwise regulated use in radiological facilities].

This environmental assessment evaluates potential human health and environmental impacts in relation to the proposed action and the alternatives to the proposed action, which include disposal of the nickel as radioactive waste and a no-action alternative (continued storage). DOE prepared this assessment in accordance with Council on Environmental Quality regulations (40 CFR Parts 1500 to 1508) that implement the National Environmental Policy Act and DOE implementing regulations (10 CFR Part 1021).

The proposed action is the disposition of nickel for controlled radiological use. DOE intends to issue a Request for Proposal for the disposition of the nickel. On completion of the procurement process, DOE would select a successful bidder. This assessment evaluates impacts that relate the location of the industrial processes necessary for the proposed action at PGDP, ETTP, a generic industrial location, or a combination of these locations. Because DOE cannot identify a specific location for the generic metal processing facility at this time, this assessment summarizes essential environmental criteria that the facility would have to meet to ensure that the impacts of the proposed action would not be significant. DOE will use this summary of essential environmental criteria to make decisions on the disposition of the contaminated nickel. Based on the results of the procurement process, DOE will conduct a review to determine if the selected process and site are within the bounds of this environmental assessment or if further National Environmental Policy Act analysis is necessary.

ALTERNATIVES CONSIDERED IN THIS ENVIRONMENTAL ASSESSMENT

Proposed Action:	Disposition of the DOE nickel for controlled radiological use.
Disposal as Radioactive Waste:	Disposal of the DOE nickel as radioactive waste in a classified low-level radioactive waste landfill, or declassification of the nickel followed by disposal in an unclassified landfill.
No-Action Alternative:	Continued storage of the DOE nickel at ETTP and PGDP.

Because there is uncertainty about future industrial processes and processing locations, DOE could not conduct a full quantitative analysis for most of the resource and subject areas that this environmental assessment considers. As a result, the Department conducted a qualitative evaluation for all areas except human health and transportation, for which it conducted a quantitative analysis. For all areas, DOE used a bounding analysis approach. A bounding analysis relies on assumptions to produce results that will not underestimate the most likely impacts. For example, for low-level radioactive waste or mixed-waste disposal facilities, DOE analyzed the facility farthest from the point of waste generation for transportation impacts, regardless of whether that facility would actually receive and dispose of the waste. This bounding analysis approach provides DOE the flexibility to consider a range of available options for which there is an adequate description of the extent of potential environmental impacts.

The qualitative evaluation of most of the resource and subject areas indicated that there would be minimal adverse impacts from the proposed action or either of the two alternatives. DOE evaluated construction; operation; and decontamination, decommissioning, and demolition of the proposed industrial facilities. The prediction of minimal impacts is due in part to the small size of the facilities; the total quantity of nickel that is the subject of this environmental assessment represents less than 1 percent of the annual global refining of this metal.

For public health, DOE estimated radiation doses to the entire workforce, which resulted in a probability of latent cancer fatalities of less than 1 in 10,000. Risks to members of the public would be even smaller because all industrial processes and uses of the manufactured products would occur at DOE-controlled, NRC-licensed, or otherwise regulated facilities. These results would be due to the low concentrations of residual radioactive materials associated with the nickel scrap. DOE estimated that there would be fewer than four lost-time injuries and no industrial fatalities from any of the alternatives. No adverse transportation impacts are expected, which include highway capacity, vehicle emissions, traffic accidents, and radiation doses to truck drivers or the public along the transportation route.

DOE considered potential operational accidents and concluded that, because there would be no high-energy sources (for example, explosives) that could lead to accidents that involved the radioactive material at the nickel processing facilities, there would be little potential for offsite radiological consequences from accidents. Further, the impacts of sabotage events would have little potential for downwind distribution of significant quantities of radioactive material. The major impact of such events would be to disrupt normal facility operations, with little or no impact on general populations, the environment, or the national economy. The proposed facilities would be under DOE controls or NRC/Agreement State licenses, or under regulations that include provisions for security to reduce the potential for sabotage, among other events.

Finally, DOE reviewed the current and proposed industrial actions at PGDP and ETTP, and concluded that there would be minimal adverse cumulative impacts in the resource and subject areas for implementation of the proposed action or either alternative.

TABLE OF CONTENTS

Section Page

LIST OF TABLES

Table Page

LIST OF FIGURES

ACRONYMS

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
ETTP	East Tennessee Technology Park
IAEA	International Atomic Energy Agency
NRC	U.S. Nuclear Regulatory Commission
PGDP	Paducah Gaseous Diffusion Plant
PM_{10}	particulate matter with mean aerodynamic diameter of 10 micrometers (about 0.0004 inch) or less
$PM_{2.5}$	particulate matter with mean aerodynamic diameter of 2.5 micrometers (about 0.0001 inch) or less
RCRA	Resource Conservation and Recovery Act
TSCA	Toxic Substances Control Act
U.S.C.	United States Code

CHAPTER 1. INTRODUCTION

1.1 PURPOSE AND NEED FOR U.S. DEPARTMENT OF ENERGY ACTION

The U.S. Department of Energy (DOE or the Department) proposes the disposition (i.e., sale, transfer, grant, or disposal) of approximately 15,300 tons (13,850 metric tons) of nickel metal scrap recovered from equipment used in the uranium enrichment process. The purpose of this action is to remove a nonessential DOE material from storage and to reduce the national need to expend additional resources through the mining and refinement of replacement nickel feedstock. In addition, DOE needs to perform this action to make space available for other uses where it stores the nickel at the East Tennessee Technology Park (ETTP) in Oak Ridge, Tennessee, and the Paducah Gaseous Diffusion Plant (PGDP) site in Paducah, Kentucky. Further, this action would reduce annual storage and maintenance expenses and provide financial gain through the sale of the nickel.

DISPOSITION

As used in this environmental assessment, disposition means DOE's sale, transfer, or grant of nickel to private industry for processing, use, and disposal under radiological controls.

DOE generated the nickel that is the subject of this environmental assessment in areas under radiological controls; this nickel is volumetrically contaminated with radioactive materials. DOE has not released the nickel inventory for recycling in an unrestricted manner because of the January 12, 2000, Secretarial moratorium that prevents the release of all volumetrically-contaminated metals into commerce (DOE 2000a), and the subsequent July 13, 2000, Secretarial suspension on the unrestricted release for recycle of scrap metals from DOE radiological areas (DOE 2000b). These moratoria prohibit DOE from releasing or recycling the stored radioactively contaminated nickel in an unrestricted manner.

The Proposed Action described in this environmental assessment is consistent with the moratoria and would allow use of the stored contaminated nickel by private industry in a controlled manner to make high-quality products (for example, pure nickel components, stainless-steel components, or components made from other alloys). All aspects of the recycling and production would be controlled and the final products would be controlled for use in radiological applications only (that is, for DOE-controlled, U. S. Nuclear Regulatory Commission (NRC)[1]-licensed, or otherwise regulated[2] use in radiological facilities).

Controlled use means the nickel must be transported, processed, reused or recycled, and disposed in a manner that ensures:

- No release or recycling of the nickel and any nickel products in an unrestricted manner to general commerce;
- Transportation, storage, processing, fabrication, and use of the nickel would occur only under the appropriate regulatory authority (for example, the Atomic Energy Act (42 U.S.C. 2011 et seq.) or under the restrictions in radioactive materials licenses and effluent control permits that prohibit exposures to workers and the public and environmental effluents in excess of regulatory limits;

---

[1] As used in this environmental assessment, *NRC-licensed* means a facility that is licensed and regulated by the NRC or the appropriate Agreement State.

[2] As used in this environmental assessment, *otherwise regulated* acknowledges radiological control programs that foreign governments could impose if Steps 3 through 5 (see Section 2.1) occurred abroad.

- The use of all generated products only in controlled government or licensed commercial radiological applications, under radiological controls;
- The disposal of all low-level radioactive waste that would be generated in the processing of the nickel or fabrication of nickel-bearing products as radioactive waste or mixed waste (that is, waste that is both radioactive and contains hazardous materials) in radiologically controlled licensed or permitted disposal facilities; and
- No subsequent unrestricted release or recycle of the products into general commerce because of the potential for sustained radioactive properties of the products after use in radiological applications.

1.2 BACKGROUND

In 1995, DOE prepared *Environmental Assessment – Proposed Sale of Radioactively Contaminated Nickel Ingots Located at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1995). That document considered only the Paducah, Kentucky, portion of the DOE nickel inventory for sale to a private entity for decontamination, with resale of the decontaminated product on the international market. The Department issued a Finding of No Significant Impact on April 23, 1995. However, DOE did not implement that proposed action because the purchaser cancelled the sale as a result of a business decision. Since that time, the Secretary of Energy has issued two moratoria that prevent the release of all volumetrically-contaminated metals into commerce – the January 12, 2000, Secretarial moratorium on the unrestricted release of DOE volumetrically-contaminated metals (DOE 2000a), and the July 13, 2000, Secretarial suspension on the unrestricted release for recycling of scrap metals from DOE radiological areas (DOE 2000b). These moratoria prohibit DOE from releasing or recycling the stored radioactively contaminated nickel in an unrestricted manner.

The approximately 15,300 tons (13,880 metric tons) of nickel that DOE is considering in this environmental assessment consist of about 5,600 tons (5,080 metric tons) of classified shredded nickel scrap DOE currently stores at ETTP, and about 9,700 tons (8,800 metric tons) of classified nickel ingots at PGDP. All of the nickel is volumetrically contaminated with relatively low levels of uranium and technetium, and with trace quantities of neptunium and plutonium. A small subpopulation of the nickel at PGDP also contains asbestos that could not be abated.

In its current form, the shredded scrap nickel is “high-risk” property primarily because of its physical form and concerns over proliferation-sensitive property. This nickel requires further processing, i.e. melting, to render it unclassified and unfit for its original intended use (that is, so it is no longer high-risk property), provide for decontamination, and ready it for alloying, fabricating, or equipment manufacturing.

The nickel at the 3,556-acre (14.4-square kilometer) PGDP site has been processed and melted into the form of large ingots. The nickel ingots (Figure 1-1), are nominally 24 to 25 inches (61 to 64 centimeters) tall, 16 to 19 inches (41 to 48 centimeters) in diameter, and weigh from 2,000 to 2,200 pounds (900 to 1,000 kilograms). The ingots require further melting to render them unclassified. They are contaminated with radioactive materials, which means that additional decontamination will be necessary before alloying, fabricating, or equipment manufacturing.

The total quantity of nickel that is the subject of this environmental assessment represents less than 1 percent of the annual global refining of nickel. The proposed action would provide better stewardship

Figure 1-1. Nickel ingots in storage at PGDP.

through controlled radiological use of nickel as a valuable resource. This use would avoid environmental impacts from disposal of the nickel and subsequent mining and production of replacement virgin nickel. Processing of the nickel at either ETTP or PGDP could create employment opportunities in the communities. In addition, and consistent with applicable law, DOE could create additional proceeds that might offset local environmental cleanup costs or return some proceeds to local communities and stakeholders to promote economic development.

1.3 SCOPE OF THIS ENVIRONMENTAL ASSESSMENT

This environmental assessment evaluates potential human health and environmental impacts from the proposed action and alternatives, including a No-Action (continued storage) Alternative. DOE prepared this assessment in accordance with Council on Environmental Quality regulations (40 CFR Parts 1500 to 1508) that implement the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.) and DOE implementing regulations (10 CFR Part 1021). If DOE does not identify the estimated impacts in this assessment as significant, it could issue a Finding of No Significant Impact and proceed with the proposed action. If DOE identifies potentially significant impacts, it would have to prepare an environmental impact statement before it could proceed with the proposed action or implement another alternative.

DOE recognizes that certain aspects of the proposed action have a greater potential for creating adverse environmental impacts than others. The Council on Environmental Quality regulations recognize this (40 CFR 1502.1 and 1502.2) and recommend a "sliding-scale" approach so an agency can discuss those actions with greater potential effect in more detail in National Environmental Policy Act documents than those that have little potential for impact.

In this environmental assessment, DOE has assumed that the industrial activities for the proposed action would occur at ETTP, PGDP, a generic manufacturing facility, or a combination of these locations that would be regulated under NRC/Agreement State license or otherwise regulated. For these three locations and for the proposed action and alternatives, this assessment (1) describes the affected environment relevant to potential impacts; (2) analyzes potential environmental impacts; (3) identifies and characterizes cumulative impacts that could result; and (4) provides environmental information for use in prescribing restrictions and controls to protect, preserve, and enhance the human environment and natural ecosystem.

Because DOE cannot identify a specific location for the generic licensed or regulated processing facility at this time, this environmental assessment provides a summary of essential environmental criteria that such a facility would have to meet to ensure that the impacts of the proposed action would not be significant. DOE would use this summary to make decisions on the disposition of nickel. Based on the results of the procurement process, DOE will conduct a review to determine if the selected process and site are within the bounds of this environmental assessment or if further National Environmental Policy Act analysis is necessary.

Finally, because there is uncertainty about future industrial processes and processing locations, DOE used a bounding analysis to estimate potential impacts. A bounding analysis relies on assumptions to produce results that will not underestimate the most likely potential impacts; for example, if the Department identifies low-level radioactive waste or mixed waste disposal facilities, this environmental assessment analyzes the facility farthest from the point of waste generation for transportation impacts, regardless whether that facility would actually receive and dispose of the waste. This bounding analysis approach provides DOE with flexibility to consider a range of available options for which it has adequately described the extent of potential environmental impacts.

1.4 REFERENCES

DOE (U.S. Department of Energy), 1995, *Environmental Assessment – Proposed Sale of Radioactively Contaminated Nickel Ingots Located at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/EA-0994, Oak Ridge Operations Office, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), 2000a, "Secretarial Memorandum for Heads of All Departmental Elements on the Release of Materials for Re-use and Recycle," Bill Richardson, January 12, 2000, Washington, D.C.

DOE (U.S. Department of Energy), 2000b, "Secretarial Memorandum for Heads of All Departmental Elements on the Release of Surplus and Scrap Materials," Bill Richardson, July 13, 2000, Washington, D.C.

CHAPTER 2. DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

This environmental assessment considers three alternatives: the disposition of the DOE nickel for controlled radiological use, disposal of the DOE nickel as radioactive waste, and the no-action alternative (continued storage). A discussion of each follows.

ALTERNATIVES CONSIDERED IN THIS ENVIRONMENTAL ASSESSMENT

Proposed Action:	Disposition of the DOE nickel for controlled radiological use.
Disposal as Radioactive Waste:	Disposal of the DOE nickel as radioactive waste in a classified low-level radioactive waste landfill, or melting of the nickel followed by disposal in an unclassified landfill.
No-Action Alternative:	Continued storage of the DOE nickel at ETTP and PGDP.

2.1 PROPOSED ACTION – THE DISPOSITION OF NICKEL FOR CONTROLLED RADIOLOGICAL USE

The proposed action is the disposition of nickel for controlled radiological use. DOE intends to issue a Request for Proposal for the disposition of the nickel. On completion of the procurement process, DOE would select a successful bidder. The following five steps would be performed by the successful bidder: (1) Resizing and Declassification; (2) Decontamination (Purification and Alloying); (3) Alloying, Fabricating, and Equipment Manufacturing; (4) End Use of Manufactured Products in Controlled Radiological Applications; and (5) Disposal of Manufactured Products after the end use. DOE proposes the disposition of the stored nickel for controlled radiological applications only; that is, for DOE-controlled[3], NRC-licensed, or otherwise regulated use in radiological facilities. The term *regulated* includes all the identified steps for this option. Specifically, the Department will consider only facilities in the United States under DOE control or NRC/Agreement State license for Steps 1 and 2, while Steps 3 through 5 could occur inside or outside the United States, subject to regulatory and contractual limitations. DOE will not allow release of this material in an unrestricted manner for recycling into commerce. For the proposed action, DOE assumes that all transportation would be by truck to produce bounding estimates of transportation accidents and fatalities. Figure 2-1 summarizes the proposed action. A summary description of the five steps and associated activities follows.

Step 1: Resizing and Declassification

- Construct a regulated facility, or convert existing regulated facilities to resize and declassify the nickel for subsequent processing;

- Handle, package, and load the nickel at ETTP and PGDP;

- Transport the nickel to the regulated melting facility for declassification;

- Process the nickel by melting in the regulated melting facility to declassify and render it unfit for its original intended use and prepare the material for decontamination;

---

[3] For purposes of nickel processing (Steps 1 to 3), *DOE-controlled* means the imposition of (a) DOE radiation protection standards, limits, and requirements, such as 10 CFR Part 835, on nickel processing activities, and/or (b) use of restriction(s) on the processing of the nickel in accordance with authorized limits established under DOE Order 5400.5.

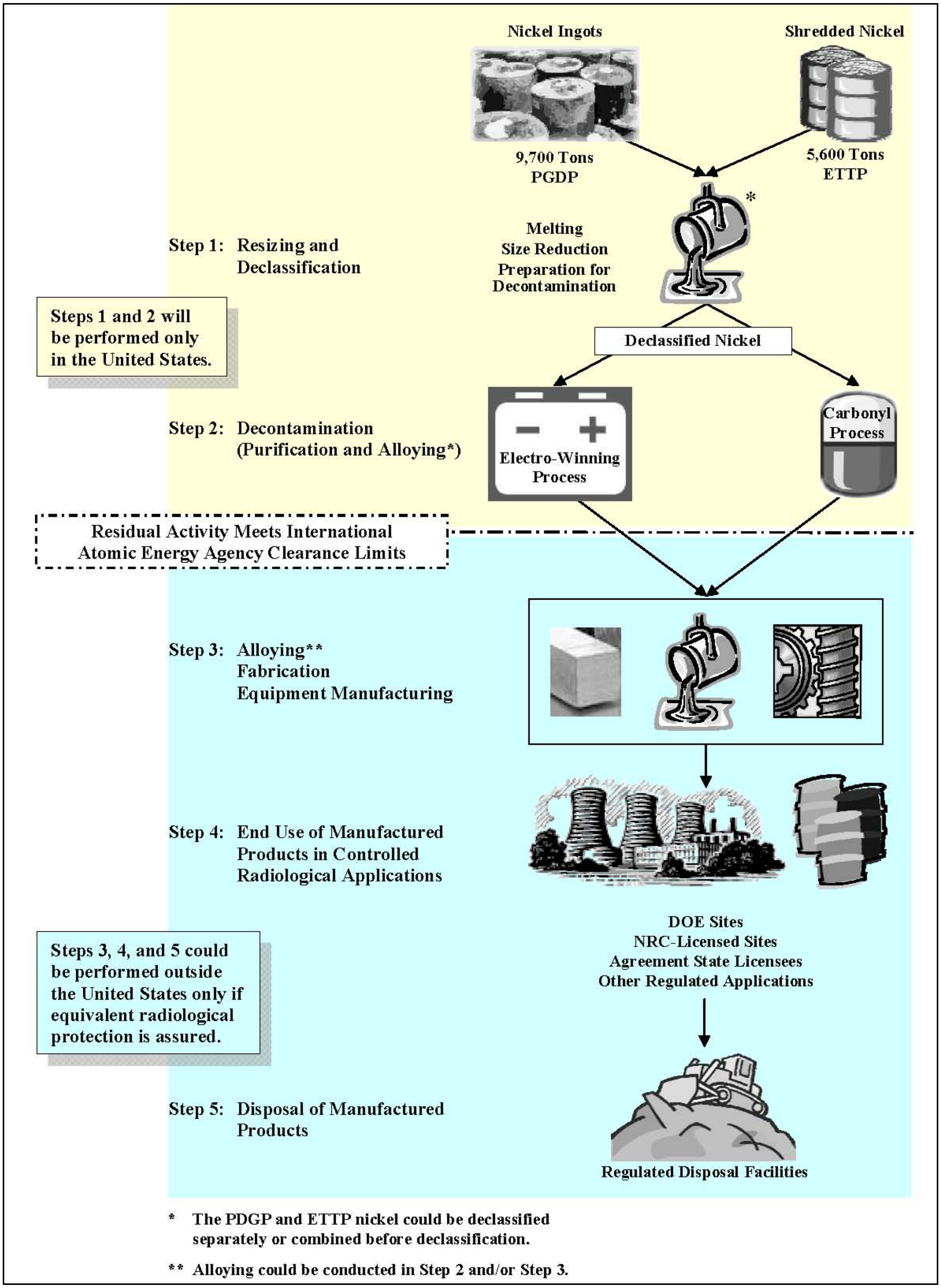


Figure 2-1. Disposition of nickel for controlled radiological use.

- Provide regulated control of process effluents, emissions, and radioactive and mixed wastes that the process could generate;

- Transport radioactive and mixed wastes to DOE-controlled or NRC-licensed disposal facilities;

- Handle, package, and load the declassified nickel for shipment to a regulated decontamination facility; and

- Decontaminate, decommission, and demolish the regulated melting facility consistent within applicable rules and regulations.

Step 2: Decontamination (Purification and Alloying)

- Construct a regulated purification facility, or convert an existing regulated facility for this purpose;

- Transport the nickel material to the regulated purification facility;

- Process the nickel material in the purification facility to produce a decontaminated material suitable for alloying (the alloying step could occur at the time of decontamination or in Step 3);

- Provide regulated control of process effluents, emissions, and radioactive and mixed wastes that the process generates;

- Transport radioactive and mixed wastes to DOE-controlled or NRC-licensed disposal facilities;

- Handle, package, and load nickel material with residual radioactivity that meets International Atomic Energy Agency (IAEA) clearance levels for shipment to a regulated alloying facility; and

- Decontaminate, decommission and demolish the facilities consistent with applicable rules and regulations.

Step 3: Alloying, Fabricating and Equipment Manufacturing

- Construct a regulated alloying, fabricating, and equipment manufacturing facility, or convert existing regulated facilities for nickel processing;

- Transport the nickel material that meets the clearance levels to a regulated alloying, fabricating, and equipment manufacturing facility or facilities;

- Alloy (as required), fabricate, and manufacture equipment in the regulated radiological facility; for example, when blended with iron and chromium, the nickel would produce well over 100,000 tons (90,700 metric tons) of high-quality stainless steel;

- Provide regulated control of process effluents, emissions, and radioactive and mixed wastes that the process generates;

- Transport radioactive and mixed wastes to DOE-controlled, NRC-licensed, or otherwise regulated disposal facilities;

- Transport the manufactured equipment to regulated radiological facilities; and

- Decontaminate, decommission, and demolish the alloying, fabricating, and equipment manufacturing facilities consistent with the applicable rules and regulations after completion of the processes.

Step 4: End Use of Manufactured Products in Controlled Radiological Applications

- End use of the manufactured products at DOE-controlled, NRC-licensed, or otherwise regulated radiological facilities. Examples include DOE nuclear facilities, and commercial nuclear power plants either in the United States or abroad.

Step 5: Disposal

- After the end of controlled radiological use, transport the equipment as waste to DOE-controlled, NRC-licensed, or otherwise regulated disposal facilities.

As stated above, the proposed action is the disposition of nickel for controlled radiological applications in DOE-controlled, NRC-licensed, or otherwise regulated radiological facilities. Specific activities have been identified that define the bounding analysis. The following paragraphs describe these activities.

As Figure 2-1 shows, the first step for the disposition of nickel would be to melt the nickel at a DOE-controlled, NRC-licensed, or otherwise regulated facility in the United States to declassify and render it unfit for its original intended use and to prepare it for decontamination before alloying, fabricating, and equipment manufacturing. DOE has assumed this facility would be at ETTP, PGDP, a generic site, or a combination of these in the United States. This environmental assessment considers construction activities associated with building the Step 1 melting facility; facility operations to declassify the DOE nickel; and decontamination, decommissioning, and demolition activities after its use. DOE or NRC/Agreement State license controls of the facility would limit process effluents and emissions and worker and public radiation doses, and would ensure disposal of all low-level radioactive and mixed waste in DOE-controlled or NRC-licensed disposal facilities.

In Step 1, the nickel in its present form would be fed into a smelter and heated to about 2,901 degrees Fahrenheit (°F) [1,594 degrees Celsius (°C)] to liquefy the contaminated metal. After slag removal and while still molten, the liquid nickel would be cast into shapes that meet the feed material requirements in Step 2, Decontamination. The melting and casting, if performed properly, would also render the nickel free from future classification and security concerns.

Facilities for Step 1 would include a melting furnace large enough to feed an ingot of the size and weight that Section 1.2 describes. Without such a furnace, equipment would be needed to resize the ingots into smaller pieces. A resizing operation would likely introduce a new constituent (from the cutting and grinding tools) to the nickel stream and produce an additional waste stream that would need to be addressed. In addition, after processing of the nickel material, the cutting tools would probably contain contaminated nickel residue.

Operation of the melting furnace in Step 1 would produce a waste stream that consisted of ceramic metal oxide slag from the melting, baghouse ash from the process air cleaning system, and expended furnace refractory (a mixture of magnesium oxide, calcium oxide, and silica), all of which would contain contaminated nickel residue. Furnace cooling water and electrical power would be other factors for consideration during the resizing and preparation process.

Step 2 would consist of the decontamination of the resized nickel at a regulated facility in the United States, sufficient to allow optional the alloying, fabricating, and equipment manufacturing in Step 3. DOE has assumed that this facility would be at ETTP, PGDP, a generic site, or a combination of these in the United States. This environmental assessment considers construction activities for the Step 2 decontamination facility; operations to decontaminate the DOE nickel; and subsequent activities to decontaminate, decommission and demolish the facility after its use. DOE or NRC/Agreement State license controls of the facility would limit process effluents and emissions and worker and public radiation doses, and would ensure the disposal of all radioactive and mixed waste in DOE-controlled or NRC-licensed disposal facilities. The Department has identified two alternative processes in Step 2 – the electro-winning process and the carbonyl process.

DECONTAMINATION PROCESSES

Electro-Winning:	A process to decontaminate and purify nickel by electrolytically dissolving nickel at an anode, processing the solution (the electrolyte) to remove contaminants, then collecting pure nickel on a cathode.
Carbonyl:	A process to decontaminate and purify nickel through chemical reaction with carbon monoxide gas, followed by heating and collection of pure nickel, carbon monoxide, and the collected impurities.

- <u>Electro-Winning Process</u>. In this process, prepared nickel plates would be submerged (as an anode) and dissolved electrolytically in a sulfate-based electrolyte. The nickel-containing electrolyte would be treated to remove undesirable contaminants (for example, technetium). Finally, an electrical current would be applied to propel the dissolved nickel through the electrolyte to a negatively charged cathode where the nickel would be plated onto the cathode.

  During operation, periodic adjustments would be required for the temperature, pH, composition of the electrolyte, and servicing of the contaminant extraction processes. The replacement of the feed anode and removal of the plated cathode would be ongoing production processes.

  Waste streams from the decontamination processes would include used filters (air and media), spent electrolyte, electrolytic sludge, air emissions from the electro-winning cell, and the removed contaminants in their respective process media. Production factors would include process chemicals for the electrolyte, contaminant removal processes, and air treatment systems. Process and cooling water and electric power would be consumed during the decontamination process.

  Physical facility size estimates for a 2,000-ton (1,810 metric ton)-per-year electro-winning facility are 400,000 square feet (37,200 square meters) based on the need for a 200,000-gallon (757,000-liter)-per-year processing capacity. For safety and operational considerations, this capacity would be divided among multiple process tanks. Electric process power requirements would be 2 to 3 megawatts. DOE does not currently have estimates of process and cooling water requirements.

- <u>Carbonyl Process</u>. The carbonyl process is also referred to as the Mond process after its inventor, Ludwig Mond. The appropriate nickel shapes from Step 1 for the carbonyl process (powder or pellets) would be introduced to a closed reaction vessel and subjected to a mixture of hydrogen gas and carbon monoxide at atmospheric pressure and a temperature of 122°F (50°C). The nickel would react with the carbon monoxide to create nickel tetracarbonyl. The nickel tetracarbonyl would be extracted and transferred to a second closed reaction vessel in which the carbonyl compound would be heated to about 446°F (230°C), which would cause the compound to decompose into pure nickel metal and carbon monoxide. The purified nickel product would be removed and the carbon monoxide would be recovered, cooled, and returned to the first vessel for reuse.

The chemical reaction in the carbonyl process can be summarized as follows:

$$\mathrm{Ni} + 4\mathrm{CO} \xrightarrow{50^\circ\mathrm{C}} \underset{\text{(impure)}}{\mathrm{Ni(CO)_4}} \xrightarrow{230^\circ\mathrm{C}} \underset{\text{(pure)}}{\mathrm{Ni}} + 4\mathrm{CO}.$$

The actual temperatures and pressures for this process could vary slightly from one processing facility to another, but the basic process as outlined would be common to all. During operation of the first reactor vessel, non-nickel impurities in the powder or pellets would not react with the carbon monoxide and would remain in the reactor vessel in the form of an ash. The ash would be a waste stream that contained technetium and other radioisotopes. A second waste stream would be filter media from between the two reactor vessels. The decontamination (purification) process would consume hydrogen and carbon monoxide gases, process cooling water, and electric power.

For purposes of this environmental assessment it has been estimated that the physical facilities for a 2,000-ton (1,814-metric-ton) per year nickel carbonyl processing facility would require about 10,000 square feet (929 square meters) on less than 1 acre (4,047 square meters) for industrial safety considerations.

As a condition of the sales contract, DOE would specify that the material from Step 2 meet IAEA clearance levels for unrestricted release of radioactive material. Specifically, the individual radionuclide concentrations after decontamination would have to be less than 2.7 picocuries per gram (0.1 becquerel per gram) of plutonium-239, 27 picocuries per gram (1 becquerel per gram) of uranium-238, and 27 picocuries per gram (1 becquerel per gram) of technetium-99, with compliance levels for mixtures that were derived from the use of the sum of fractions method.[4] The requirement to meet these stringent levels ensures maintenance of radiation doses and environmental impacts as low as reasonably achievable, even if subsequent controls failed.

The third step in Figure 2-1 is to conduct alloying (as required), fabricating, and equipment manufacturing in a DOE-controlled or NRC-licensed facility in the United States or in an otherwise regulated facility abroad. The location of the facility in the United States would be ETTP, PGDP, a generic site, or a combination of these locations. This environmental assessment considers construction activities for building the fabricating and equipment manufacturing facility (with the option of alloying); operation of the facility to process the DOE nickel; and decontamination, decommissioning and demolition activities after its use. This facility would produce material and equipment for use in DOE-controlled, NRC-licensed, or otherwise regulated radiological facilities. DOE-controlled, NRC-licensed, or other regulatory control of the facility would limit process effluents and emissions and worker and public radiation doses, and would ensure the disposal of all radioactive and mixed waste in DOE-controlled, NRC-licensed, or otherwise regulated facilities.

Step 4 is the end use of manufactured products in DOE-controlled or NRC-licensed applications in the United States or in otherwise regulated radiological applications abroad. DOE-controlled, NRC-licensed, or other regulatory controls of the facility would limit process effluents and emissions and worker and public radiation doses, and would ensure the disposal of all radioactive and mixed waste in DOE-controlled, NRC-licensed, or otherwise regulated facilities. The candidates to receive equipment that was manufactured from the nickel would be any DOE-controlled, NRC-licensed, or otherwise regulated radiological facilities. As discussed above, this facility would be either in the United States or abroad subject to regulatory and contractual limitations. DOE has assumed that facilities that would receive

---

[4] As defined by *Application of the Concepts of Exclusion, Exemption, And Clearance* (IAEA 2004). The sum of fractions method for mixtures requires that the sum across all radionuclides of the ratio of the activity concentration of each radionuclide to its clearance value is less than or equal to 1.

equipment in the United States would be at a generic site. A requirement that will be placed on the successful bidder is that the decontaminated nickel would only be allowed to be used once as a manufactured product. After the initial use, the material or equipment must proceed to final disposal in Step 5.

The final step in Figure 2-1 is the disposal of the end-use product. The industrial low-level radioactive and mixed waste Step 5 generated, which would include retired products and potentially other decontamination and decommissioning waste, could be shipped to a DOE-controlled or commercial NRC-licensed disposal facility if the products were used in the United States, or would be disposed of in otherwise regulated disposal facilities if the products were used abroad.

2.2 DISPOSAL AS RADIOACTIVE WASTE

Disposal of the nickel as low-level radioactive waste is an alternative to the proposed action. Under this alternative, DOE would (1) dispose of the scrap nickel at a DOE-controlled low-level waste disposal facility that could receive and dispose of classified, high-risk property as low-level radioactive waste, or (2) would melt the material to destroy classified attributes and dispose of it as low-level radioactive waste. Site activities at ETTP and PGDP would include packaging and loading of the nickel for low-level radioactive waste disposal, and potential melting operations before disposal as low-level radioactive waste.

The melting facility could also be at a generic site. This environmental assessment considers construction activities for building the melting facility; operation of the facility to melt the DOE nickel; and decontamination, decommissioning, and demolition activities after its use. To produce a bounding analysis of the transportation impacts, DOE assumed that all of the nickel would be shipped to a generic melting facility then to a low-level radioactive waste disposal facility at the furthest distance from the melting facility. These assumptions maximized the shipping distance to produce a bounding analysis.

2.3 NO-ACTION ALTERNATIVE – CONTINUED STORAGE

Under the no-action alternative, DOE would continue the current storage practices at ETTP and PGDP. Routine monitoring and occasional maintenance of the storage area at each site would continue.

2.4 ALTERNATIVES CONSIDERED BUT NOT ANALYZED

In developing this environmental assessment, DOE identified the following alternatives to the proposed action and excluded them from the analysis:

- Improved Long-Term Storage. In addition to the no-action alternative (continued storage), DOE considered improvement of the storage facilities and conditions at ETTP and PGDP. Because the largest impacts would probably be on the DOE operating budgets at the two sites and not to the environment or human health, this assessment does not include improved long-term storage.

- Unrestricted Release for Recycling into Commerce. The January 12, 2000, Secretarial moratorium prevents the release of all volumetrically-contaminated metals into commerce (DOE 2000). In addition, the current contamination levels are high enough to regard the scrap nickel as low-level radioactive waste. Therefore, unrestricted release into commerce is not a viable option and DOE did not include it in this assessment.

- Exclusive Internal Recycling. Internal recycle of the nickel for DOE-only uses would require the Department to own, regulate, and operate all the resizing , decontamination, alloying, fabrication, and equipment manufacture facilities and to use all end-use products in its programs. However, because DOE does not have these facilities, it could accomplish nickel disposition only through collaboration with private or other government entities in a regulated and controlled manner. Therefore, this assessment does not include exclusive internal recycling.

2.5 REFERENCES

DOE (U.S. Department of Energy), 2000, "Secretarial Memorandum for Heads of All Departmental Elements on the Release of Materials for Re-use and Recycle," Bill Richardson, January 12, 2000, Washington, D.C.

IAEA (International Atomic Energy Commission), 2004, *Application of the Concepts of Exclusion, Exemption and Clearance*, Safety Guide, Safety Standards Series No. RS-G-1.7, Vienna, Austria.

CHAPTER 3. AFFECTED ENVIRONMENT

This section provides background environmental information for evaluation of potential impacts of the proposed action and alternatives. Section 3.1 describes the affected environment for the PGDP site in Kentucky, Section 3.2 discusses the affected environment for the ETTP site on the Oak Ridge Reservation in Tennessee, and Section 3.3 discusses potentially affected elements of the environment at a generic industrial site. Each section provides information on the following resource and subject areas:

- Land use
- Geology and soils
- Air quality and climate
- Water resources
- Ecological resources
- Cultural resources
- Noise
- Socioeconomics
- Environmental justice
- Waste management
- Human health and safety
- Transportation

3.1 PADUCAH GASEOUS DIFFUSION PLANT

DOE owns PGDP, which is in rural McCracken County, Kentucky, approximately 10 miles (16 kilometers) west of the City of Paducah, 3.6 miles (6 kilometers) south of the Ohio River (Figure 3-1). The City of Paducah is the largest urban area in the six counties around the site. The six-county area is primarily rural; industrial uses account for less than 5 percent of land use.

Several small communities are within a 5-mile (8-kilometer) radius of the DOE property boundaries; these include Heath and Grahamville to the east and Kevil to the southwest. Metropolis, Illinois, is north of the PGDP site across the Ohio River. Bordering the DOE property to the northeast is the Shawnee Steam Plant, which is owned and operated by the Tennessee Valley Authority. The area around PGDP is predominantly rural, with residences and farms scattered throughout the region.

PGDP site obtains all of its water from the Ohio River through an intake at the steam plant near the Shawnee Power Plant north of the site. DOE treats the water on the site before use. Water use is approximately 15 million gallons (57 million liters) per day. The maximum site capacity is 30 million gallons (115 million liters) per day (DOE 1996a). Electric Energy supplies electric power to the site. The electrical need is about 1,600 megawatts, with a maximum capacity of 3,040 megawatts. The plant generates steam for onsite requirements; this uses 82 tons (74 metric tons) per day of coal, with a maximum capacity of 180 to 200 tons (160 to 180 metric tons) (DOE 1996a).

3.1.1 Land Use

The site consists of 3,556 acres (14.4 square kilometers) (BJC 2006a). The primary gaseous diffusion plant operations associated with the enrichment process are on 748 acres (3 square kilometers) inside the plant security fence. Of the remaining acreage that comprises the DOE-owned property (outside the main security fence), DOE licenses 1,986 acres (8 square kilometers) to the Kentucky Department of Fish and Wildlife Resources as part of the West Kentucky Wildlife Management Area. DOE maintains the remaining land, 822 acres (3.3 square kilometers) as a buffer zone around the secure area.

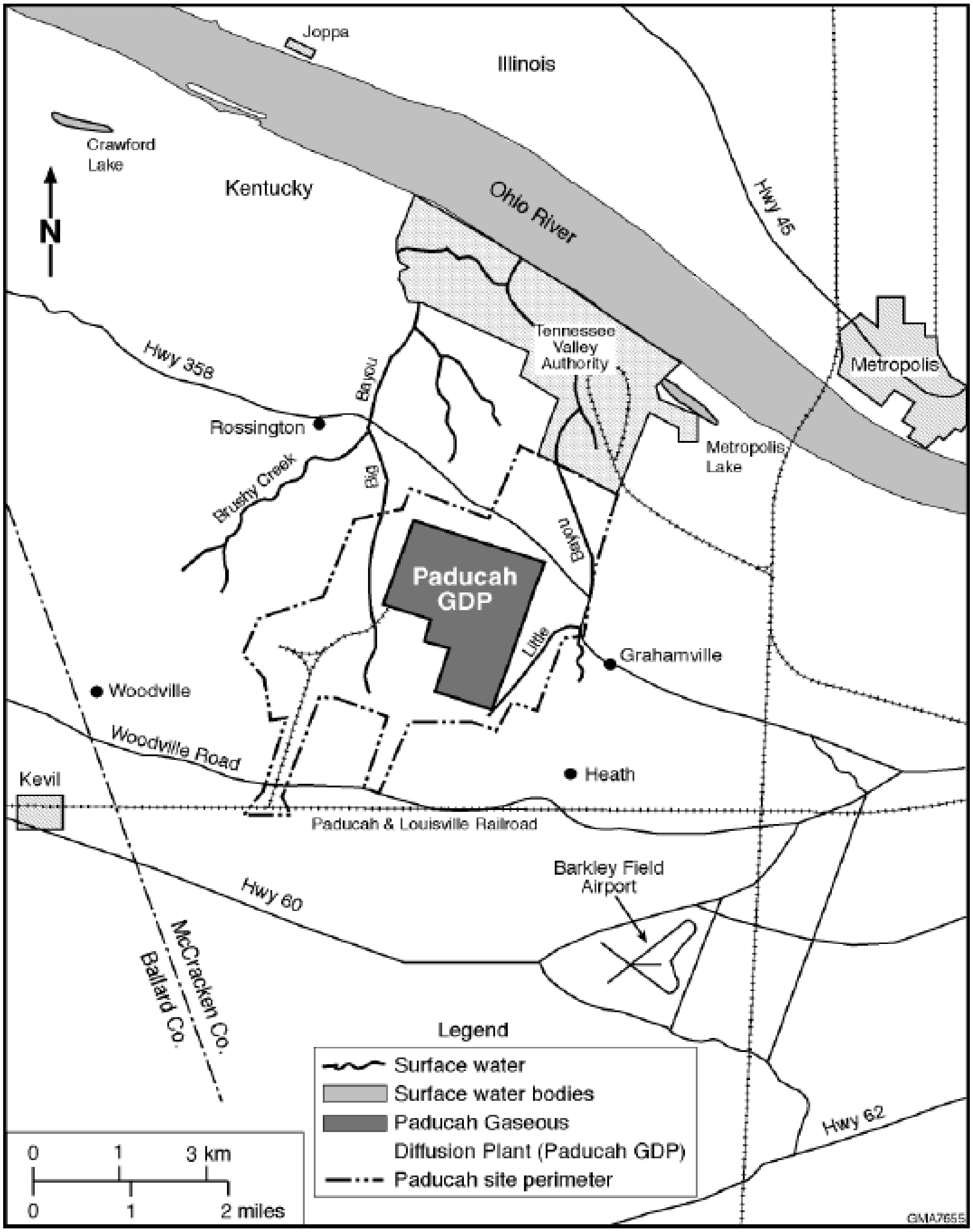


Figure 3-1. Regional map of the PGDP area.

Most PGDP facilities are inside the fenced security area. The heavily developed site includes about 115 buildings with a combined floor space of about 8.2 million square feet (760,000 square meters). The areas between buildings consist primarily of mowed grassy areas.

DOE maintains and uses the buffer zone that surrounds the security area for support services, which include the wastewater treatment plant and lagoons. In addition, the buffer zone contains an operating Resource Conservation and Recovery Act (RCRA) (42 U.S.C. 6901 et seq.) Subtitle D landfill. The area immediately around the PGDP site generally features a combination of pasture, row crops, and deciduous forest. Based on an analysis of LandSat satellite imagery from 1992, dominant land cover categories in

McCracken County include pasture/hay (27.8 percent), row crops (27.0 percent), and deciduous forest (17.8 percent) (USGS 2002). The most recent agricultural census recorded 531 farms in McCracken County in 2002, which occupied more than 85,459 acres (346 square kilometers) (USDA ca. 2003). Residential land use occurs throughout much of McCracken County, most in the eastern half in the communities of Concord, Hendron, Lone Oak, Massac, Paducah, Reidland, and Woodlawn-Oakdale. The site is in the western half of the county, where the land use consists primarily of pasture/hay and row crops.

3.1.2 Geology and Soils

3.1.2.1 Geology

The topography of the PGDP site is relatively flat. Western Kentucky has gently rolling terrain between 330 and 500 feet (101 and 152 meters) above mean sea level (DOE 1999a). Inside the PGDP security fence, the maximum variation in elevation is about 10 feet (3 meters) (ERC/EDGe 1989). The site is underlain by bedrock that consists of limestone and shale. Several zones of faulting, including the New Madrid Seismic Zone, occur near the site (ANL 1991).

The PGDP site is near the northern end of the Mississippi Embayment, which was a large sedimentary trough oriented nearly north to south that existed during Cretaceous and Tertiary time and received sediments from the central portion of the North American continent (Early et al. 1989).

The sedimentary sequence in the PGDP vicinity consists mainly of fine- to medium-grained clastic materials (sedimentary rocks formed from particles that were mechanically transported), and includes (from youngest to oldest) a basal gravel (Tuscaloosa Formation), the McNairy Formation (clay interlaminated with silt and fine-grained sand), the Porters Creek Clay (clay facies and variable thicknesses of sand and silt), and undifferentiated Eocene sands (fine sand with variable amounts of interbedded and interlensing silt and clay). The Eocene sands are thought to be thin and discontinuous beneath the northern portion of the site. At depth, the site is underlain by dense bedrock of Mississippian limestone and shale.

In the vicinity of the site, a unit designated as the Continental Deposits lies immediately beneath variable thicknesses of Pleistocene Loess, which is typically an unstratified, silty clay-clayey silt (EDGe 1987). The loess originated as windblown material that was generated by glacial activity to the north. The Continental Deposits lie directly on an ancient unconformity (erosional surface) that truncates several formations. The angular nature of the unconformity – coupled with the fact that the Eocene sands, Porters Creek Clay, and McNairy Formation lie unconformably on each other – creates a complex stratigraphy. The Continental Deposits resemble a large low-gradient alluvial fan deposited at the confluence of the ancestral Ohio and Tennessee Rivers.

Erosion and reworking of alluvial fan deposits modified the thickness and distribution of the Continental Deposits (DOE 1999a), which can be subdivided into two components or facies – a lower gravel or sandy gravel unit that varies in thickness from 0 to 106 feet (0 to 32 meters) and an upper clay-sand unit that has a comparable thickness (Early et al. 1989). Deposition of the gravel probably occurred in a high-energy braided stream environment that is closely associated with alluvial fans. Of particular interest is the presence of a prominent channel that passes in a northerly direction through the site and a second, less-prominent channel that occurs near the eastern site boundary. The upper clay-sand unit represents sediments that were deposited in a fluvial and lacustrine (lake) environment (DOE 1999a).

The PGDP site is in an area with a seismic risk rating of 3, the most severe rating on a scale of 1 to 3. Several minor seismic tremors have been recorded at the site since the early 1950s; the largest, in 1962, measured 5.5 on the Richter scale. There has, however, never been a release of contaminants or structural failure at the site as the result of seismic activity.

3.1.2.2 Soils

The soils near the PGDP site consist of silty loam and silty clay loam lying above the loess and alluvium surficial deposits. The U.S. Department of Agriculture has mapped six soil series in proximity to the site – the Calloway silt loam, Grenada silt loam, Loring silt loam, Falaya-Collins silt loam, Vicksburg silt loam, and Henry silt loam (USDA 1976). The Calloway-Henry association is the predominant soil association near the site. All but the Henry series are prime farmland based on general soil properties.

Prime farmland, as defined by the Department of Agriculture Natural Resources Conservation Service, is land that is best suited for food, feed, forage, fiber, and oilseed production. It does not include "urban built-up land or water" (7 CFR Parts 657 and 658). The Natural Resources Conservation Service determines prime farmland primarily based on soil types that exhibit desirable properties, which include soil quality, growing season, moisture supply, and other properties needed to produce sustained high yields of crops in an economical manner. The following soil series in the PGDP vicinity are representative of prime farmland: Calloway silt loam, Falaya-Collins silt loam, Grenada silt loam, Loring silt loam, and Vicksburg silt loam. These soil types are not likely to occur on the PGDP site. Construction and maintenance activities have disturbed the soils at the site since the early 1950s.

3.1.3 Air Quality and Climate

The Paducah area is in the Paducah-Cairo Interstate Air Quality Control Region. The Commonwealth of Kentucky ambient air quality standards for six criteria air pollutants – sulfur oxides as sulfur dioxide, particulate matter with mean aerodynamic diameter of 10 micrometers (about 0.0004 inch) or less (PM_{10}), carbon monoxide, ozone, nitrogen dioxide, and lead – are identical to the national ambient air quality standards. In addition, the Commonwealth has promulgated ambient standards for hydrogen sulfide, gaseous and total fluorides, and odors. The primary ambient air quality standards, which are for the protection of public health, and the secondary ambient air quality standards, which are for the protection and welfare of the environment, are specified in 40 CFR Part 50 and Title 401, Section 53:010, of the Kentucky Administrative Regulations.

Current air quality is good in the Paducah area. The area is designated as a Class II Prevention of Significant Deterioration area. New emission sources cannot "notably" degrade air quality, with significance defined in terms of maximum ambient air increments established for a Class II area (Title 401, Section 51:017, of the Kentucky Administrative Regulations). The nearest Class I prevention of Significant Deterioration Areas, which must meet more stringent ambient air quality requirements, are the Mingo National Wildlife Refuge in Missouri, approximately 90 miles (145 kilometers) west of the PGDP site, and Mammoth Cave National Park in Mammoth Cave, Kentucky, 135 miles (217 kilometers) east of the site (DOE 1999b).

The largest air pollution sources near the Paducah area include the United States Enrichment Corporation and the coal-fired Shawnee Power Plant, approximately 3 miles (5 kilometers) north-northeast of the PGDP site. The Joppa Power Plant and the Allied Signal Metropolis Works Uranium Hexafluoride Conversion Plant, across the Ohio River in Illinois, are approximately 6 miles (10 kilometers) northwest and 5 miles (8 kilometers) northeast of the PGDP site, respectively.

As a result of the transfer of the production part of PGDP to the United States Enrichment Corporation, DOE transferred major air emission sources to the corporation. Air emissions from the PGDP facilities are negligible, and DOE does not currently hold any air quality permits. The corporation is qualified as a major source and in 1998 applied for a Title V permit to the Kentucky Division of Air Quality. However, its emissions account for less than 1 percent of total area-wide emissions.

DOE evaluated wind data from Barkley Regional Airport about 5 miles (8 kilometers) to the southeast of the PGDP site. For 1990 through 1994, the average wind speed at the 33-foot (10-meter) level was about 8.6 miles per hour (3.8 meters per second), as Figure 3-2 shows. The dominant wind direction was from the south, with a secondary peak from the south-southwest. Directional wind speeds ranged from 6.9 miles per hour (3.1 meters per second) from the east to 10.5 miles per hour (4.7 meters per second) from the north-northwest, and the wind speed from the dominant wind direction was also high, at about 10.3 miles per hour (4.6 meters per second).

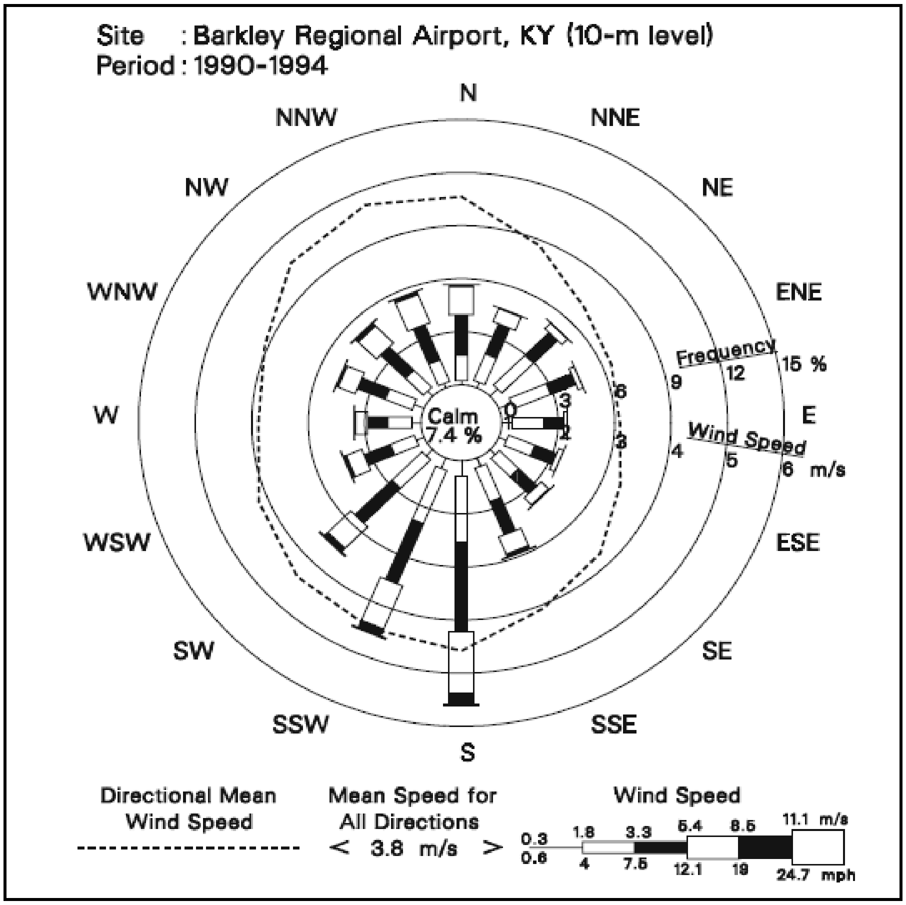


Figure 3-2. Wind rose for the Barkley Regional Airport at 33-foot (10-meter) level, 1990 to 1994 (NCDC undated).

Tornadoes are rare in the area around the PGDP site, and those that occur are less frequent and destructive than those in the Midwest. For 1950 through 1995, 402 reported tornadoes occurred in Kentucky, with an average of 9 per year (NOAA 2002). For the same period, six tornadoes occurred in McCracken County but most were relatively weak – at most F2 of the Fujita tornado scale.

3.1.4 Water Resources

3.1.4.1 Surface Hydrology

The PGDP site is in the western part of the Ohio River Basin. The confluence of the Ohio and Tennessee Rivers is approximately 10 miles (16 kilometers) upstream of the site. The confluence of the Ohio River and the Mississippi River is approximately 20 miles (32 kilometers) downstream of the site. Surface water from the site drains into tributaries of the Ohio River (Rogers and Ashburn 1988). Bayou Creek (formerly Big Bayou Creek) is on the western side of the site, and Little Bayou Creek is on the eastern side (Figure 3-1). These two streams join north of the site and discharge to the Ohio River at about River Kilometer 1,524, which is about 34 miles (55 kilometers) upstream from the confluence of the Ohio and Mississippi Rivers. The site is about 3.5 miles (5.6 kilometers) south of the Ohio River. The historical mean flow for this section of the river is about 200 million gallons (757 million liters) per minute (DOE 2001a). As mentioned above, all water the PGDP site uses is from the Ohio River through an intake at the steam plant near the Shawnee Power Plant (ANL 1991), which is adjacent to the Ohio River north of the facility. Current water use is approximately 15 million gallons per day (57 million liters per day).

The flows in Bayou Creek and Little Bayou Creek fluctuate greatly as a result of precipitation; however, during most of the year, most of the flow in both streams comes from plant effluents. Bayou Creek has a mean flow of about 67,300 gallons (254,758 liters) per minute, with a stage (depth) of about 2 feet (0.6 meter). The average annual low flow for this stream is about 22,400 gallons (84,793 liters) per minute (Pennington 2001). The mean flow rate for Little Bayou Creek is approximately 44,900 gallons (169,965 liters) per minute, with a depth of about 1 to 2 feet (0.3 to 0.6 meter). The average annual low flow for Little Bayou Creek is generally too low to be monitored or sampled. Annual precipitation near the site is about 49.3 inches (125 centimeters). The PGDP site is not in a 100-year floodplain [elevation of 333 feet (102 meters)], nor would it be affected by the historical high-water elevation of 342 feet (104 meters) (USACE 1994a). A small wetland of about 1 acre (4,000 square meters) is near the northwest corner of the site. As stated in the U.S. Army Corps of Engineers Wetlands Investigation Report (USACE 1994b), none of the potentially affected wetlands is of high ecological value in a regional context.

Most of the liquid effluents from the PGDP site consist of once-through noncontact cooling water, although activities such as metal finishing, uranium recovery, and facility cleaning produce a variety of liquid wastes (contaminated with uranium and uncontaminated) (Rogers and Ashburn 1988). In addition to these discharges, a large variety of conventional liquid wastes enter the surface-water system including treated domestic sewage, steam plant wastewater, and coal pile runoff.

All effluent discharges are regulated under Kentucky Pollutant Discharge Elimination System permits. At present, there are 15 outfalls – 10 for the United States Enrichment Corporation and 5 for DOE. Three of the DOE outfalls are to Bayou Creek and one is to an unnamed tributary of Little Bayou Creek. The average discharge of wastewater to Bayou Creek is approximately 4 million gallons (15 million liters) per day. The average discharge to the Ohio River through Bayou and Little Bayou Creeks is about 4.1 million gallons (16 million liters) per day. The average flow in the Ohio River is 1.7×10^{11} gallons (6.5×10^{11} liters) per day.

Results of surface-water monitoring in 2004 indicated that discharges of uranium and technetium-99 were small percentages of the corresponding derived concentration guidelines (BJC 2006a). The highest average concentration of uranium was 91 picocuries (3.4 becquerels) per liter, or 15 percent of the derived concentration guideline value for uranium of 600 picocuries (26 becquerels) per liter. The highest average concentration for technetium-99 was 32 picocuries (1.2 becquerels) per liter, or 0.032 percent of the derived concentration guideline value for technetium-99 of 100,000 picocuries (3,700 becquerel) per liter. Routine monitoring for nonradiological parameters in 2004 included testing for chronic and acute toxicity for *Ceriodaphnia dubia* (water fleas), total residual chlorine, copper, hardness, iron, nickel, polychlorinated biphenyls, phosphorous, suspended solids, uranium, and zinc (BJC 2006a).

3.1.4.2 Groundwater

Two near-surface aquifers are important at the PGDP site. The upper aquifer is a shallow, perched-water aquifer that consists of upper continental deposits of sand and of sand and clay mixtures that are discontinuous. Water yields from this aquifer are very low, and the hydraulic gradient (change in water elevation with distance) is difficult to detect. Water movement is generally vertical (DOE 2001b).

The lower aquifer, the primary aquifer, which is known as the Regional Gravel Aquifer, is a gravel aquifer that has an upper surface at a depth of about 39 feet (12 meters) and a thickness that ranges from about 20 to 59 feet (6 to 18 meters). This aquifer appears to be continuous beneath the site. The estimated hydraulic conductivity is 0.00004 to 0.4 inch (0.0001 to 1 centimeter) per second for the regional gravel aquifer and 0.000004 to 0.004 inch (0.00001 to 0.01 centimeter) per second for the upper Continental Deposits (sands). Water movement is 2 to 5 feet (0.6 to 1.5 meters) per year and toward the north-northeast (DOE 2001b).

About 200 monitoring wells, residential wells, and Tennessee Valley Authority wells on and off the PGDP site provide groundwater samples. Offsite sampling monitors three separate trichloroethene and technetium-99 plumes that were first detected in 1988 (LMES 1996). Data from the 2000 annual groundwater monitoring program (DOE 2001b) showed that three pollutants exceeded primary drinking water regulation levels in groundwater at the PGDP site; chromium was present in all wells, nitrogen as nitrate in one well, and trichloroethene in two wells. Beta activity in the form of technetium-99 occurred in seven wells. Data from the 2004 annual groundwater monitoring program indicated that trichloroethene and technetium-99 continued to be the primary offsite contaminants of concern (BJC 2006a). The PGDP provides municipal water to all residents whose wells are in the area of groundwater contamination from the site.

Recharge occurs as leakage from the Upper Continental Deposits, including the Upper Continental Recharge System. In general, flow in the Regional Gravel Aquifer is to the north, to discharge into the Ohio River or alluvial deposits along the river. The predominantly fine-grained deposits of the McNairy Formation act as a basal confining layer for the Regional Gravel Aquifer. Groundwater movement in the McNairy aquifer is north toward the Ohio River (DOE 2003a).

The Upper Continental Recharge System consists of heterogeneous silt and clay layers with interbedded or interlensed layers of sand and gravel. The distribution and depth of the sand and gravel layers determine the location of the water table in this recharge system. The discontinuous sandy horizons and interbedded finer-grained units result in perched groundwater throughout the Upper Continental Recharge System.

Groundwater flow through the loess and clay-silt facies of the Upper Continental Deposits is predominantly downward in the PGDP site area. Seasonally saturated perched zones occur in the surficial soils above fragipans and in isolated sand lenses of the Upper Continental Deposits. These sand lenses can produce only limited quantities of water during wet seasons. The limited extent of sands in the Upper Continental Deposits offers little enhancement of pathways for pollution migration. Use of perched aquifers for water supply is unknown in the PGDP site area but cannot be ruled out. Groundwater flow through the Upper Continental Deposits is predominantly downward rather than horizontally outward, and the sands are generally saturated only seasonally.

3.1.5 Ecological Resources

There are no state or national parks, forests, conservation areas, or scenic and wild rivers near the PGDP site. The following sections discuss vegetation, wildlife, and threatened or endangered species that might be on or near the site.

3.1.5.1 Terrestrial Habitat

The DOE reservation at Paducah is a highly disturbed area. Vegetation communities are indicative of old-field succession (that is, grassy fields, field scrub-shrub, and upland mixed hardwoods).

Open grassland areas (managed by the West Kentucky Wildlife Management Area) are periodically mowed or burned to maintain early successional vegetation, which is dominated by members of the composite family and grasses. Wildlife Management Area practices encourage reestablishment of once-common native grasses such as eastern gama grass (*Tripsacum dactyloids*) and Indian grass (*Sogastrum sp*.). Commonly cultivated for wildlife forage are corn, millet, milo, and soybean (CH2M HILL 1992). Field scrub-shrub communities consist of sun-tolerant woody species such as persimmon (*Diospyros virginiana*), maples (*Acer* spp.), black locust (*Robinia pseudoacacia*), sumac (*Rhus* spp.), scattered oaks (*Quercus* spp.), and mixed hardwood species (CH2M HILL 1992). The understory varies depending on the location of the woodlands. Wooded areas near maintained grasslands can have an understory that is dominated by grasses. Other communities can contain a thick understory of shrubs, including sumac, pokeweed (*Phytolacca americana*), honeysuckle (*Lonicera japonica*), blackberry (*Rubus sp*.), and grape (*Vitis sp*.).

Upland mixed hardwoods contain a variety of upland and transitional species. Dominant species include oaks, shagbark and shellbark hickory (*Carya ovata, C. laciniosa*), and sugarberry (*Celtis laevigata*) (CH2M HILL 1992). The understory varies from very open, with limited vegetation for more mature stands of trees, to dense undergrowth similar to those described for a scrub-shrub community.

3.1.5.2 Terrestrial Wildlife

Wildlife that commonly occurs at the PGDP site consists of species indigenous to open grassland, thickets, and forest habitats. Observations by ecologists during investigations at the site and information from West Kentucky Wildlife Management Area personnel provided a qualitative description of wildlife likely to inhabit the vicinity of the site. The primary game species in the area are deer (*Odocoileus virginianus*), turkey (*Meleagris gallopavo*), opossum (*Didelphis marsupialia*), eastern cottontail rabbit (*Sylvilagus floridanus*), raccoon (*Procyon lotor*), and squirrel (*Sciurus* spp. and *Tamiasciurus hudsonicus).* Both game and nongame species are attracted to the area because of the intense habitat management program that has been implemented in the Wildlife Management Area (CH2M HILL 1991).

Small mammal surveys in the West Kentucky Wildlife Management Area (KSNPC 1991) documented the presence of southern short-tailed shrew (*Blarina carolinensis*), prairie vole (*Microtus ochrogaster*), house mouse (*Mus musculus*), rice rat (*Oryzomys palustris*), and deer mouse (*Peromyscus* sp.*).* Larger mammals that are commonly present in the area include coyote (*Canis latrans*), eastern cottontail rabbit*,* opossum*,* groundhog (*Marmota monax*), white-tailed deer*,* raccoon*,* striped skunk (*Mephitis mephitis*), and gray squirrel (*Sciurus carolinensis).* Mist-netting activities in the PGDP site area have captured red bat (*Lasiurus borealis*), little brown bat (*Myotis lucifugus*), Indiana bat (*Myotis sodalis*), northern long-eared bat (*Myotis septentrionalis*), evening bat (*Nycticeus humeralis*), and eastern pipistrelle (*Pipistrellus subflavus).*

Late spring roadside surveys reported 45 species of birds in the PGDP site area (Battelle 1978); the most abundant were northern bobwhite (*Colinus virginianus*), northern cardinal (*Cardinalis cardinalis*), indigo bunting (*Passerina cyanea*), common grackle (*Quiscalus quiscula*), eastern towhee (*Pipilo erythrophthalmus*), and European starling (*Sturnus vulgaris)*. Other common species include mourning dove (*Zenaida macroura*), barn swallow (*Hirundo rustica*), blue jay (*Cyanocitta cristata*), common crow (*Corvus brachyrhynchos*), northern mockingbird (*Mimus polyglottos*), brown thrasher (*Toxostoma rufum*), common yellowthroat (*Geothlypis trichas*), eastern meadowlark (*Sturnella magna*), and red-winged blackbird (*Agelaius phoeniceus)*. The red-tailed hawk (*Buteo jamaicensis)* and American kestrel (*Falco sparverius)* were the most common raptors.

Several reptile and amphibian species are present near the PGDP site. Herpetofauna that have been documented by the Kentucky State Nature Preserves Commission include cricket frogs (*Acris crepitans*), Fowler's toad (*Bufo woodhousii fowleri*), common snapping turtle (*Chelydra serpentina*), green tree frog (*Hyla cineria*), chorus frog (*Psuedacris triseriata*), southern leopard frog (*Rana ultricularia*), eastern fence lizard (*Sceloporus undulatus*), and red-eared slider (*Trachemys scripta elegans)* (KSNPC 1991).

3.1.5.3 Threatened and Endangered Species

Mussels that include the orange-footed pimpleback (*Plethobasus cooperianus*), pink mucket pearly mussel (*Lampsilis arbrupta)*, ring pink (*Obovaria retusa*), fat pocketbook (*Potamilis capax*), as well as the Indiana bat are federally listed endangered species and might occur in or near McCracken County (USACE 1994c). Table 3-1 lists potential federally identified species of interest.

Table 3-1. Federally listed, proposed, and candidate species that potentially occur in the PGDP study area in 2004.[a]

Common name	Scientific name	Endangered Species Act[b] status
Indiana bat[c]	*Myotis sodalis*	Listed endangered
Interior least tern	*Sterna antillarum athalassos*	Listed endangered
Pink mucket	*Lampsilis abrupta*	Listed endangered
Ring pink	*Obovaria retusa*	Listed endangered
Orangefoot pimpleback	*Plethobasus cooperianus*	Listed endangered
Fat pocketbook	*Potamilus capax*	Listed endangered
Bald eagle	*Haliaeetus leucocephalus*	Listed threatened

a. USACE (1994d) discusses all the listed species. Note that the study area encompasses 11,719 acres (47.43 square kilometers) and extends to include the Ohio River, which is more than 3 miles (4.8 kilometers) north of the DOE reservation. There have been no reported sightings of these species on the DOE reservation, although potential summer habitat exists there for the Indiana bat. There is no designated critical habitat for any of these species anywhere in the study area.

b. 16 U.S.C. 1531 et seq.

c. Specimens of the Indiana bat were netted, identified, measured and released on West Kentucky Wildlife Management Area property in 1991 and 1992.

The Kentucky Department of Fish and Wildlife Resources conducted a mist net survey during the summer of 1999 on the West Kentucky Wildlife Management Area, which surrounds the PGDP site. Five Indiana bats were captured during the survey (KDFWR 2000). The four mussel species have not been identified in water resources near the site; however, they have been recorded between river miles 945 and 949 of the Ohio River, downstream from Metropolis, Illinois, and downstream of the confluence of Bayou Creek and the Ohio River (KSNPC 2000).

The compass plant, which is listed by the Commonwealth of Kentucky as threatened, and cream wild indigo, which is listed by the Commonwealth as a species of special concern, are prairie species that are known to occur in several locations on the PGDP site. State-listed species of special concern that occur on or near the site include Bell's vireo (*Vireo bellii*), great blue heron (*Ardea herodias*), and Northern crawfish frog (*Lithobates areolatus circulosa*). The lake chubsucker (*Erimyzon sucetta*), which is listed by the Commonwealth as threatened, is known from early, but not recent, surveys of Bayou Creek and Little Bayou Creek.

No Commonwealth or federally listed plant species are known or are likely to occur inside the PGDP site security fence. Habitat has been previously disturbed, is mowed on a regular basis, and is unlikely to support any of the listed species. Because of the availability of suitable habitat at the site, three Commonwealth-listed species might occur: (1) Bell's vireo (but this species has not been sighted near the site recently), (2) the great blue heron (which has been observed), and (3) the Carolina silverbell (*Halesia carolina*), due to the moist woodlands on the site. Thorough evaluations, however, have not identified the Carolina silverbell at the site.

3.1.6 Cultural Resources

The PGDP site has recently undergone a complete cultural resources survey, including the prehistoric and historic cultural resources on the PGDP site and in its immediate surroundings. In a previous study area of about 12,000 acres (49 square kilometers) in and around the site, the State Historic Preservation Officer recorded 35 sites of cultural significance and several more unrecorded sites (USACE 1994c,e). Most of these are prehistoric sites in the Ohio River floodplain. Six were identified to be on DOE property at the site but are not inside the site fence. None of the sites were included in, or nominated to, the *National Register of Historic Places*, but at least three prehistoric sites and one historic site were identified to be potentially eligible (USACE 1994c,e).

In 2004 DOE contracted to complete a cultural resource survey of the PGDP site (BJC 2006b). The survey identified a National Register-eligible historic district at the PGDP site. After the survey and historical research, the period of significance for the plant was recognized as extending from 1952 to 1973. The potentially eligible PGDP Historic District contains 119 buildings and structures, of which 10 would be considered as contributors to the character of the district. These properties are significant under National Register criterion A and criteria consideration G for their significance in Cold War history. The PGDP Historic District includes a large area that has remained in continuous industrial production since 1952.

Prehistoric archaeological sites at the PGDP site, which occur chiefly on floodplains, include remains from the Archaic (8000 to 1000 Before Common Era), Woodland (1000 Before Common Era to 1000 Common Era), and Mississippian (1000 to 1700 Common Era) periods. PGDP is in what were once traditional Chickasaw hunting grounds, and there are reports of Chickasaw in the Paducah area as late as 1827. In addition, the Peoria Tribe of Oklahoma has land claims in McCracken County. No religious or sacred sites, burial sites, or resources significant to American Indians have been identified at the PGDP site to date.

Historically, what is now the PGDP site was part of the Jackson Purchase – land the United States purchased from the Chickasaw in 1818. Uplands included dispersed 19th-century farmsteads, settlements, and three associated cemeteries. The Federal Government initially acquired the PGDP site in 1942 for construction of the Kentucky Ordnance Works; some of those structures remain. The U.S. Atomic Energy Commission (a DOE predecessor agency) acquired the Kentucky Ordnance Works for the construction of a gaseous diffusion plant in 1950 as part of the nation's Cold War nuclear armament program. Construction began in 1951 (USACE 1994c) and ended in 1954, with enriched uranium production beginning in 1955. The Plant's mission has continued unchanged, and the upgraded and refurbished original enrichment facilities remain in operation under lease to the United States Enrichment Corporation (DOE 2001a).

3.1.7 Noise

The Noise Control Act, as amended (42 U.S.C. 4901 et seq.), delegates authority to the states to regulate environmental noise and directs government agencies to comply with local community noise statutes and regulations. The Commonwealth of Kentucky and McCracken County, the location of the PGDP site, have no quantitative noise limit regulations.

The U.S. Environmental Protection Agency has recommended a maximum noise level of 55 A-weighted decibels to protect against outdoor activity interference and annoyance (EPA 1974). This is not a regulatory goal, but it is “intentionally conservative to protect the most sensitive portion of the American population” with “an additional margin of safety.” For protection against hearing loss in the general population from nonimpulsive noise, the Agency guideline recommends an Leq(24 h) of 70 A-weighted decibels or less.[5]

The noise-producing activities on the PGDP site are processing and construction activities and local traffic, similar to those at any other industrial site. During site operations, noise levels near the cooling towers are relatively high, but most noise sources are enclosed in the buildings. Another noise source is rail traffic in and out of the site. In particular, train whistle noise, at a typical noise level of 95 to 115 A-weighted decibels, is high at public grade crossings. At present, rail traffic noise is not a factor in the local noise environment because of infrequent traffic (one train per week).

The PGDP site is in a rural setting, and no residences or other sensitive receptor locations (for example, schools, hospitals) are in the immediate vicinity of noisy onsite operations. Ambient noise levels around the site are relatively low. Measurements at the nearest residence ranged from 44 to 47 A-weighted decibels when the site was in full operation (Pennington 2001; ANL 1991). Measurements at nearby residences reported that noise emissions from the plant were undetectable from background noise.

3.1.8 Socioeconomics

Socioeconomic data for the PGDP site focus on a region of influence around the site that consists of six counties: Ballard, Carlisle, Graves, Marshall, and McCracken Counties in Kentucky, and Massac County in Illinois. The region of influence is defined on the basis of the current residential locations of government workers who are directly connected to site activities and includes the area in which these workers spend much of their wages. More than 92 percent of Paducah workers currently reside in these counties (Sheppard 2002). The following sections contain data for each of the counties in the region of influence. However, the majority of PGDP workers live in McCracken County and in the City of Paducah, and DOE anticipates that most impacts from the PGDP site would occur in these locations. Therefore, these sections emphasize these two areas.

3.1.8.1 Population, Employment, and Personal Income

In 2000, 65,514 people (41 percent of the region of influence total) resided in McCracken County, with 26,307 of them in the City of Paducah (Bureau of the Census 2002a) (Table 3-2). During the 1990s, each of the counties in the region of influence experienced a small increase in population, with an average of 0.6 percent. The City of Paducah experienced a decline of 0.4 percent in its population during that period.

---

[5] Leq is the equivalent steady sound level that, if continuous during a specific period, would contain the same total energy as the actual time-varying sound. For example, Leq(24 h) is the 24-hour equivalent sound level.

Over the same period, the population grew at a rate of 0.9 percent in Kentucky and 0.8 percent in Illinois. In 2006, the population of the region of influence was 1688,458 people (FedStats 2007).

Table 3-2. Population in the PGDP region of influence, Kentucky, and Illinois in 1990, 2000, and 2006.

Location	1990	2000	Growth rate (%) 1990–2000[a]	2006[b]
City of Paducah	27,256	26,307	-0.4	25,661
McCracken County	62,879	65,514	0.4	64,950
Ballard County	7,902	8,286	0.5	8,245
Carlisle County	5,238	5,351	0.2	5,317
Graves County	33,550	37,028	1.0	37,872
Marshall County	27,205	30,125	1.1	31,278
Massac County	14,752	15,161	0.3	15,135
Region of influence total	178,779	187,773	0.6	186,458
Kentucky	3,685,296	4,041,769	0.9	4,206,074
Illinois	11,430,602	12,419,293	0.8	12,831,970

a. Average annual rate. Source: Bureau of the Census (2002a), except as noted.

b. Based on population estimates from Bureau of the Census (2007) and FedStats (2007).

In 2000, total employment in McCracken County was 37,406, and in 2005, total employment in McCracken County was estimated to be 34,263 (FedStats 2007). The trade and service industries dominate the county economy, with employment in these activities currently contributing almost 71 percent of all employment in the county (Table 3-3). Excluding mining, which grew from a very small base, employment growth in the highest growth sector (services) was 6.7 percent during the 1990s in comparison with 2.7 percent in the county for all sectors as a whole (Bureau of the Census 1992, 2002b).

Table 3-3. Employment in McCracken County by industry in 1990 and 2000.

Sector	People employed in 1990[a]	Percentage of county	People employed in 2000[b]	Percentage of county	Total growth rate (%), 1990–2000	Total full-time and part-time employment in 2005[c]
Agriculture	785[d]	2.7	489[e]	1.3	-4.62[f]	540
Mining	10	0.0	175	0.5	33.1	28
Construction	1,604	5.6	1,786	4.8	1.1	2,656
Manufacturing	3,965	13.8	4,210	11.2	0.6	3,376
Transportation and public utilities	2,316	8.0	3,400	9.1	3.9	2,737[g]
Trade	9,951	34.6	9,258	24.7	-0.7	9,807[h]
Finance, insurance, and real estate	1,042	3.6	914	2.4	-1.3	2,286[i]
Services	9,022	31.3	17,174	45.9	6.7	12,833[j]
Total	28,695		37,406		2.7	34,263

a. Bureau of the Census (1992).

b. Bureau of the Census (2002b).

c. BEA (2007).

d. These agricultural data are for 1992 and are from USDA (1994).

e. These agricultural data are for 1999 and are from USDA (1999).

f. Agricultural data are for 1992 and 1997.

g. Transportation and warehousing.

h. Retail and wholesale trade.

i. Finance, insurance, real estate and rental and leasing.

j. Services include professional and technical services, administrative and waste services, educational services, accommodation and food services, and other services.

As shown in Table 3-4, in 2000, total employment in the region of influence was 67,866, and projections indicated it would reach 69,300 by 2003. The trade and service industries dominated the regional economy, with employment in these activities currently contributing 60 percent of all employment (Table 3-4). Employment growth in the highest growth sector, services, was 6.4 percent during the 1990s in comparison with 0.7 percent in the region of influence for all sectors as a whole (Bureau of the Census 1992, 2002b). Employment at the PGDP site is about 1,800 (Sheppard 2002).

Table 3-4. Employment in the PGDP region of influence by industry in 1990 and 2000.

Sector	People employed in 1990[a]	Percentage of region of influence	People employed in 2000[b]	Percentage of region of influence	Total growth rate (%), 1990–2000
Agriculture	5,758[c]	9.1	4,652[d]	6.9	-2.1[e]
Mining	245	0.4	175	0.3	-3.3
Construction	3,730	5.9	3,651	5.4	-0.2
Manufacturing	14,748	23.3	11,866	17.5	-2.2
Transportation and public utilities	4,335	6.8	4,795	7.1	1.0
Trade	17,803	28.1	13,639	20.1	-2.6
Finance, insurance, and real estate	2,356	3.7	1,842	2.7	-2.4
Services	14,578	23.0	27,170	40.0	6.4
Total	63,410		67,866		0.7

a. Bureau of the Census (1992).
b. Bureau of the Census (2002b).
c. These agricultural data are for 1992 and are from USDA (1994).
d. These agricultural data are for 1999 and are from USDA (1999).
e. Agricultural data are for 1992 and 1997.

Unemployment in McCracken County steadily declined during the late 1990s from a peak rate of 6.2 percent in 1990 to the current rate of 5.4 percent (Table 3-5) (BLS 2002). Unemployment in the region of influence in December 2002 was 6.0 percent compared with 5.4 percent for the Commonwealth.

Table 3-5. Unemployment rates in McCracken County, the PGDP region of influence, and Kentucky.

Location and period	Rate (%)
McCracken County	
1992–2002 average	4.6
December 2006 (current rate)	5.4
Region of influence	
1992–2002 average	5.8
December 2006 (current rate)	6.0
Kentucky	
1992–2002 average	5.4
December 2006 (current rate)	5.4

Sources: BLS (2002), FedStats (2007).

In 2005, the average income was $32,200 in comparison with $24,771 for 2000, and in 2005 the total personal income was $2 billion in McCracken County (FedStats 2007) (Table 3-6). In the region of influence, total personal income grew at an annual rate of 2.1 percent over the period from 1990 through 2000, and was expected to reach $4.8 billion by 2003. Region of influence per capita income was expected to grow from $22,054 in 1990 to $29,000 in 2003, an average annual growth rate of 1.5 percent.

3.1.8.2 Housing

Housing stock in McCracken County grew at an annual rate of 1.0 percent from 1990 through 2000 (Table 3-7) (Bureau of the Census 2002a), with total housing units projected to reach 30,900 in 2003, which reflects the relatively slow growth in county population. By July of 2006, the total housing units numbered 31,757 (Bureau of the Census 2007). Growth in the City of Paducah was slight at 0.1 percent per year, with total housing units projected to reach 13,100 in 2003.

Table 3-6. Personal income in McCracken County and the PGDP region of influence.

Location and type of income	1990	2000	Growth rate (%), 1990–1997	2003[a]	2005[b]
McCracken County					
Total personal income (millions of 2002 $)	1,558	1,910	2.1	2,200	2,084
Personal per capita income (2002 $)	24,771	29,147	1.6	33,200	32,217
Total region of influence					
Total personal income (millions of 2002 $)	3,342	4,125	2.1	4,800	4,530
Personal per capita income (2002 $)	22,054	25,548	1.5	29,000	28,260

a. Argonne National Laboratory projections.

b. FedStats (2007).

Table 3-7. Housing in the City of Paducah, McCracken County, and the PGDP region of influence in 1990 and 2000.

Location and type of unit	Number of units 1990	2000
City of Paducah		
Owner-occupied	6,501	6,254
Rental	5,454	5,571
Total unoccupied	1,195	1,396
Total	13,150	13,221
McCracken County		
Owner-occupied	17,470	19,054
Rental	8,155	8,682
Total unoccupied	1,956	2,625
Total	27,581	30,361
Total region of influence		
Owner-occupied	45,815	50,412
Rental	15,181	16,441
Total unoccupied	5,935	7,856
Total	66,931	74,709

Source: Bureau of the Census (2002a).

Almost 2,800 new units were added to the existing housing stock in the County during the 1990s; fewer than 100 of those units were constructed in Paducah. Vacancy rates in 2000 stood at 10.6 percent in the city and 8.6 percent in the County as a whole for all types of housing. On the basis of annual population growth rates, 2,700 vacant housing units were expected in the County in 2003. About 850 of these were expected to be rental units available to incoming construction workers at the proposed facility.

In the region of influence as a whole, housing grew at a higher rate than in McCracken County or Paducah during the 1990s, with an overall growth rate of 1.1 percent per year. Total housing units were expected to reach 76,600 by 2003, with more than 7,800 housing units added in the 1990s. On the basis of vacancy rates in 2000, which stood at 10.5 percent, more than 2,000 rental units were expected to be available for incoming construction workers at the proposed facility.

3.1.8.3 Community Fiscal Conditions

Revenues and expenditures for local government jurisdictions, which include counties, cities, and school districts, constitute community fiscal conditions. Revenues come primarily from state and local sales taxes, and each jurisdiction uses them to support local community services. Tables 1 and 2 in Allison (2002) present information on revenues and expenditures by the local government jurisdictions in the region of influence.

3.1.8.4 Community Public Services

The McCracken County school system includes twelve schools and has three high schools (MCPSS 2007). The City of Paducah has five schools and one high school (PPS 2007). The police department in Paducah has over 70 officers with a 2007–2008 budget allocation of $8 million. The fire department maintains five fire stations and a staff of over 60 firefighters with a 2007–2008 budget allocation of $6 million (City of Paducah 2007). Construction and operation of the proposed facility would increase demand for community services in the counties, cities, and school districts likely to host relocating construction workers and operations employees. They would also add to demands on local medical facilities and physician services.

3.1.9 Environmental Justice

This environmental assessment uses data from the most recent decennial Census in 2000 to evaluate environmental justice implications of the proposed action and the no-action alternative in relation to minority populations. To identify census tracts with disproportionately high minority populations, this environmental assessment used the percentage of minorities in each state that contains a given tract as a reference point. Using the individual states to identify disproportionality acknowledges that minority distributions in the state can differ from those in the nation as a whole. In 2000, of the 173 census tracts within 50 miles (80 kilometers) of the proposed conversion facility at PGDP, 42 had minority populations in excess of state-specific thresholds – a total of 47,093 minority people. In McCracken County, 14.4 percent of the population in 2005 was minority (FedStats 2007).

To identify census tracts with disproportionately high low-income populations, this environmental assessment used the percentage of low-income people who lived in each state that contains a given tract as a reference point. In 1999, of the 204 census tracts within 50 miles (80 kilometers) of the proposed conversion facility at PGDP, 109 had low-income populations in excess of state-specific thresholds – a total of 118,029 low-income people. In McCracken County in 2004, 16.7 percent of the individuals for whom poverty status was known had low incomes (FedStats 2007).

3.1.10 Waste Management

The PGDP site generates wastewater, solid low-level radioactive waste, solid and liquid mixed low-level waste, nonradioactive hazardous waste, and nonradioactive nonhazardous solid waste. DOE manages wastes from site operations and environmental restoration. The site has an active program to minimize the generation of solid low-level radioactive waste, hazardous waste, and mixed low-level waste. Waste minimization efforts for radioactive waste include the prevention of packaging material from entering radiological areas and the replacement of wood pallets that are used in radiological areas. Hazardous waste and mixed low-level waste minimization actions include less use of chlorinated solvents, recycling of paint waste, and compaction of polychlorinated biphenyl wastes. Solid waste minimization actions include recycling of paper and cardboard and offsite recycling of fluorescent bulbs and used batteries.

3.1.10.1 Solid Nonhazardous, Nonradioactive Waste

DOE collects solid waste – which includes sanitary refuse, cafeteria waste, industrial waste, and construction and demolition waste – and disposes of it at the onsite landfill. The current permit (Kentucky Permit Number KY073-00045) allows a maximum of 1.56 million cubic yards (1.19 million cubic meters) to be disposed of in the solid waste landfill.

3.1.10.2 Process Wastewater

Wastewater at the PGDP site consists of nonradioactive sanitary and process-related wastewater streams, cooling water blowdown, and radioactive process-related liquid effluents. DOE processes wastewater at onsite treatment facilities and discharges it to Bayou Creek or Little Bayou Creek through eight permitted outfalls. The total capacity of the site wastewater control facilities is approximately 1.75 million gallons (6.6 million liters) per day.

3.1.10.3 Low-Level Radioactive Waste

DOE stores the low-level radioactive waste it generates at the PGDP site on the site pending shipment to a DOE or commercial facility for treatment, if necessary, and then for final disposition. Solid low-level radioactive waste DOE generates at the site includes refuse, sludge, and debris that are contaminated with radionuclides, primarily uranium and technetium.

3.1.10.4 Nonradioactive Hazardous and Polychlorinated Biphenyl Waste

The PGDP site generates hazardous waste, which includes spent solvents, heavy-metal-contaminated waste, and polychlorinated biphenyl-contaminated waste. The site has a RCRA permit that authorizes it to treat and store hazardous waste. DOE sends certain hazardous and polychlorinated biphenyl wastes to permitted offsite contractors for final treatment and disposal. The Department ships some liquid hazardous and mixed waste streams off the site for incineration in a Toxic Substances Control Act (TSCA; 15 U.S.C. 2601 et seq.) incinerator in Tennessee.

3.1.10.5 Mixed Low-Level Waste

Mixed low-level waste is low-level radioactive waste that contains RCRA hazardous components. PGDP onsite capacity for storing mixed low-level radioactive waste containers is 3,600 cubic yards (2,800 cubic meters). The site can treat up to 204 cubic feet (156 cubic meters) per year of aqueous mixed low-level waste (DOE 1996a).

3.1.11 Human Health

Current and past operations at PGDP have involved the routine use of radioactive materials and hazardous chemicals. Releases of such materials can combine with natural background radiation sources and augment exposures to humans on and off the site. Natural sources include cosmic radiation, radioactive materials in native rocks and soils, and manmade sources such as medical radiation and radiation from consumer products (for example, smoke detectors). These sources become the background exposure to which the effects of the manmade releases would be added. The *Paducah Annual Site Environmental Report for 2004* summarizes releases and environmental contamination levels of chemicals and radiation and resulting exposures for calendar year 2004 (BJC 2006a). In general, for PGDP, human exposure pathways include direct contact, inhalation, and ingestion of surface water, sediments, and deer meat. This section summarizes the human health environment in terms of human exposure to background radiation, and radiation and hazardous chemicals from historical and current operations at the PGDP.

3.1.11.1 Radiation Environment

Humans are exposed to ionizing radiation from many sources in the environment. One source is cosmic radiation, or charged particles, primarily protons, from extraterrestrial sources that are incident on the Earth’s atmosphere. Cosmic rays directly account for a portion of the naturally occurring radiation in the environment. In addition, cosmic rays indirectly contribute to radiation by creating radioactivity from interactions with atoms in the Earth's atmosphere and crust (Kathren 1984). Radioactivity is also present in soil, rocks, and living organisms from naturally occurring elements in the environment. Environmental radionuclides are of two general classes – primordial and cosmogenic. Primordial radionuclides are mostly isotopes of heavy elements and belong to three radioactive series headed by uranium-238 (the uranium series), uranium-235 (the actinium series), and thorium-232 (the thorium series) (NCRP 1987). Cosmogenic radionuclides, which have mostly intermediate or low atomic numbers, are produced by interactions of cosmic nucleons with atoms in the atmosphere or the ground (NCRP 1987).

The average annual cosmic ray dose equivalent in Kentucky is about 45 millirem (0.45 millisievert) per year. The average exposure from radionuclides in the soil in the United States is about 60 millirem (0.6 millisievert) per year (Kathren 1984). This value is typical of exposures in Kentucky. A major proportion of natural background radiation comes from naturally occurring radon in the air, which provides about 200 millirem (2 millisievert) per year from radioactivity in the soil and rocks (Kathren 1984). These natural radiation sources contribute to the annual dose that everyone receives.

Manmade sources contribute to the average amount of dose a member of the U.S. population receives. These sources include x-rays for medical purposes – about 40 millirem (0.4 millisievert) per year; nuclear medicine – about 14 millirem (0.14 millisievert) per year; and consumer products (for example, smoke detectors) – about 11 millirem (0.11 millisievert) per year. Radioactivity that remains in the environment from nuclear weapons testing is a minor contributor to the average radiation levels at levels less than 1 millirem (0.01 millisievert) per year. The current average dose to a person living in Kentucky from both natural radiation and manmade sources is about 370 millirem (3.7 millisievert) per year, which is typical of the total background radiation dose that people receive in Kentucky.

Operations at the PGDP site result in radiation exposure of onsite workers and offsite members of the public. Exposures of onsite workers generally result from the handling of radioactive materials in the onsite facilities and from inhalation of released radionuclides from onsite processes. The annual dose to onsite workers has historically been well within the maximum allowed values under the relevant occupational radiation dose limits. Offsite members of the public are exposed to radionuclides that are discharged from onsite facilities to the air and surface water and, in some cases, to radiation from radioactive materials that are handled in the onsite facilities. In 2004, the highest estimated dose a maximally exposed individual might have received from all combined PGDP radiation sources and pathways was 0.359 millirem (0.00359 millisievert) per year (BJC 2006a). This dose is less than 5 percent of the applicable federal radiation standard of 100 millirem per year.

Substances in soil that possibly associate with past and present cylinder management activities are uranium and fluoride compounds, which could have been released by breached cylinders or faulty valves. To evaluate ongoing activities at the PGDP site, DOE has conducted soil sampling to identify the accumulation of airborne pollutants that have deposited on the ground. Annual soil samples have been collected from 10 offsite locations – 4 at the site boundary, 4 at distances of 5 miles (8 kilometers) beyond the boundary, and 2 at more remote locations – to characterize background levels (LMES 1996; MMES 1994a). In 1994, uranium concentrations at the 10 sampling locations ranged from 2.0 to 5.8 micrograms per gram; plant boundary concentrations ranged from 2.3 to 4.9 micrograms per gram (LMES 1996).

Ongoing investigations under RCRA and the Comprehensive Environmental Response, Compensation, and Liability Act (42 U.S.C. 9601 et seq.) of PGDP operable units have identified soils in several areas as contaminated with radionuclides and chemicals, such as polychlorinated biphenyls and metals. An investigation indicated a limited number of samples with elevated concentrations of uranium, polycyclic aromatic hydrocarbons, and metals in comparison with human-health-based guidelines (DOE 2001b).

3.1.11.2 Chemical Environment

Health effects that are attributed to chemical exposures can be categorized as carcinogenic or noncarcinogenic. This discussion reports chemical carcinogenic risks as a lifetime probabilities of developing an excess cancer. The Environmental Protection Agency defines a target cancer risk range of 1×10^{-4} (1 in 10,000) to 1×10^{-6} (1 in 1 million), which defines when cleanup actions are to be considered under the Comprehensive Environmental Response, Compensation, and Liability Act. It reports noncarcinogenic hazards as hazard quotients, where unity (1) or greater represents a potential for adverse health effects. A hazard quotient less than unity indicates an unlikely potential for adverse health effects. The sum of more than one hazard quotient for multiple toxicants or multiple exposure pathways is called a hazard index. Pathways of concern for noncarcinogens are defined as those with a hazard index greater than 1.

RCRA governs the management of hazardous waste. PGDP received a RCRA permit to manage hazardous waste on August 19, 1991. The permit has been maintained and modified through the state permitting process. The current 10-year permit was effective October 31, 2004 and was last modified on November 9, 2007. PGDP monitors specific sources of contamination in specific environmental media including air, surface water and sediment, and groundwater. In 2004, PGDP reported three sources of airborne contaminants: the Northwest Plume Groundwater System, which is a program under the Comprehensive Environmental Response, Compensation, and Liability Act to remediate groundwater by air-stripping of trichloroethylene; the Scrap Metal Removal Projects; and the C-410 Decontamination and Decommissioning Fluorine Cell Blasting project (BJC 2006a). All of these operations have complied with the substantive requirements of the Clean Air Act (42 U.S.C. 7401 et seq.).

Discharges to surface water, via Kentucky Pollutant Discharge Elimination System-permitted outfalls, were in compliance with permit limits more than 99 percent of the time. Groundwater contamination is being addressed through Comprehensive Environmental Response, Compensation and Liability Act process, but there is currently no direct exposure pathway to humans from groundwater because there is no use of this groundwater for a drinking water source. Groundwater is not currently being used for any purpose other than routine sampling. Some species of fish in some bodies of water exceed consumption guidelines for polychlorinated biphenyls. These waterways are posted against fishing.

Monitoring and protection of groundwater resources at PGDP is required by federal and commonwealth regulations and DOE orders. When offsite groundwater contamination was discovered in 1988, Region 4 of the Environmental Protection Agency and DOE entered into an Administrative Consent Order. DOE provided an alternative water supply to affected residents and determined the nature and extent of the contamination through sampling. PGDP conducts two pump-and-treat systems to air-strip trichloroethylene contamination (BJC 2006a).

3.1.12 Transportation

PGDP is in an area with an established transportation network. Two interstate highways, several U.S. and state highways, several rail lines, and a regional airport serve the area.

Interstate Highway 24 passes through Paducah, Kentucky, approximately 16 kilometers (10 miles) east of the PGDP site. Four U.S. Highways (45, 60, 62, and 68) and many state highways traverse the area. Main access to the plant is on U.S. Highway 60. Because the site is in a secured area, traffic is minimal in the plant and surrounding area and generally is limited to trucks or service vehicles that move equipment and supplies in the facility. Rail access is available on the PGDP site.

DOE transports wastes in approved U.S. Department of Transportation, NRC, and DOE containers that meet the requirements of the waste receiver. Activities for the proposed action would adhere to these requirements. If DOE transported low-level radioactive waste by commercial truck, the waste would travel along interstate highways or other primary highways that are well suited to cargo-truck transport. If the Department transported waste by rail, it would use existing commercial rail routes and schedules.

3.2 EAST TENNESSEE TECHNOLOGY PARK

Much of the information in this section is from *Final Environmental Assessment for Lease of Land and Facilities within the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE 1997) and *Environmental Assessment Addendum for the Proposed Title Transfer of East Tennessee Technology Park Land and Facilities* (DOE 2003a).

ETTP is on the Oak Ridge Reservation, the DOE's multifacility complex in Oak Ridge, Tennessee. The Reservation consists of three major facilities – the Y-12 National Security Complex, Oak Ridge National Laboratory, and ETTP. As Figure 3-3 shows, the Reservation covers approximately 33,000 acres (134 square kilometers) in Anderson and Roane Counties in East Tennessee and is in the great valley of eastern Tennessee between the Cumberland Mountains, approximately 10 miles (16 kilometers) to the northwest, and Great Smoky Mountains approximately 32 miles (51 kilometers) to the southeast. Most of the reservation is within the city limits of Oak Ridge. Black Oak Ridge and Pine Ridge form the northern boundary; both of which feature residential areas. The balance of the Oak Ridge Reservation is bounded by the Clinch River. The area near the Reservation is mostly rural and residential and contains homes, farms, and pastures. Government-sponsored activities on the Reservation date back to the Manhattan Project and continue to the present. Both past and present activities involve hazardous chemicals and radioactive materials.

ETTP (Figure 3-4) was originally the Oak Ridge Gaseous Diffusion Plant. By 1985, demand for enriched uranium had declined, and DOE placed the gaseous diffusion cascades at the plant in standby mode. That same year, the Department canceled the gas centrifuge enrichment program. DOE announced the decision to shut down the diffusion cascades permanently in late 1987, and initiated actions necessary to implement that decision soon thereafter. Because of the termination of the original and primary missions, DOE renamed the plant site as the Oak Ridge K-25 Site in 1990 when the mission changed to clean-up, waste management and technology development. In 1997, the K-25 Site became ETTP.

DOE's long-term goal for ETTP is to convert the site into a privately owned and managed mixed-use business park. The site is undergoing environmental cleanup (remediation and decontamination and demolition), which DOE expects to complete by 2016. DOE has accelerated its clean-up schedule to achieve cleanup several years ahead of the original plan, which will reduce environmental and safety risks more quickly and reduce long-term maintenance costs.

The reuse of key site facilities through title transfer is part of the future plan for the site. The accelerated cleanup approach makes land and various types of buildings (for example, office and manufacturing) suitable for private industrial use and for title transfer to the Community Reuse Organization of East Tennessee or other entities such as the City of Oak Ridge. This will make the facilities available for sublease or sale, with the goal to stimulate private industry and recruit business to the area.

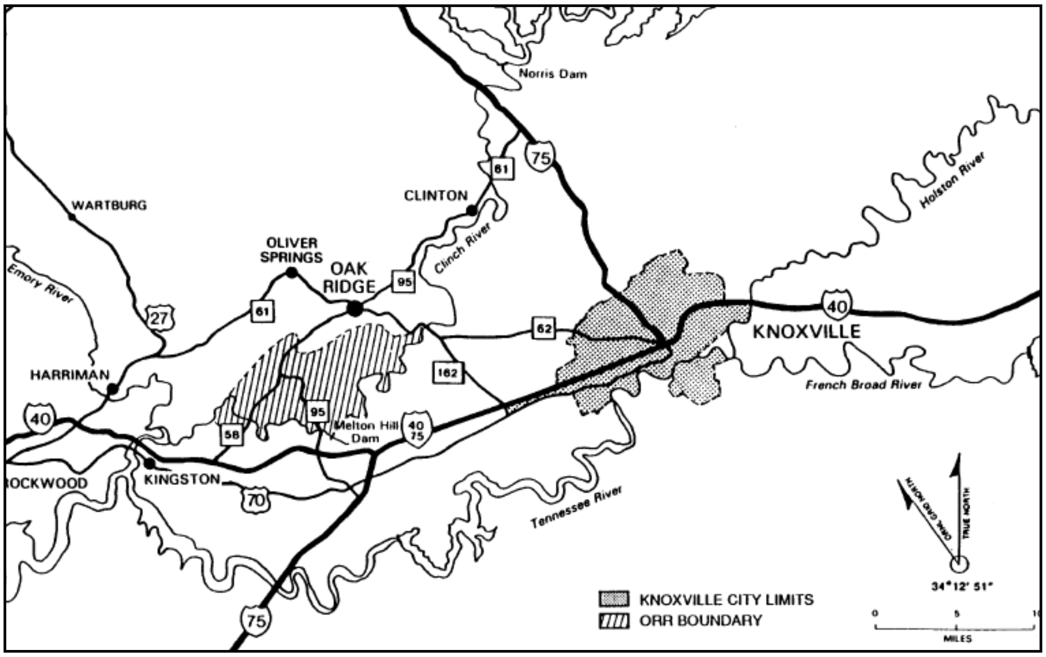


Figure 3-3. Oak Ridge Reservation region.

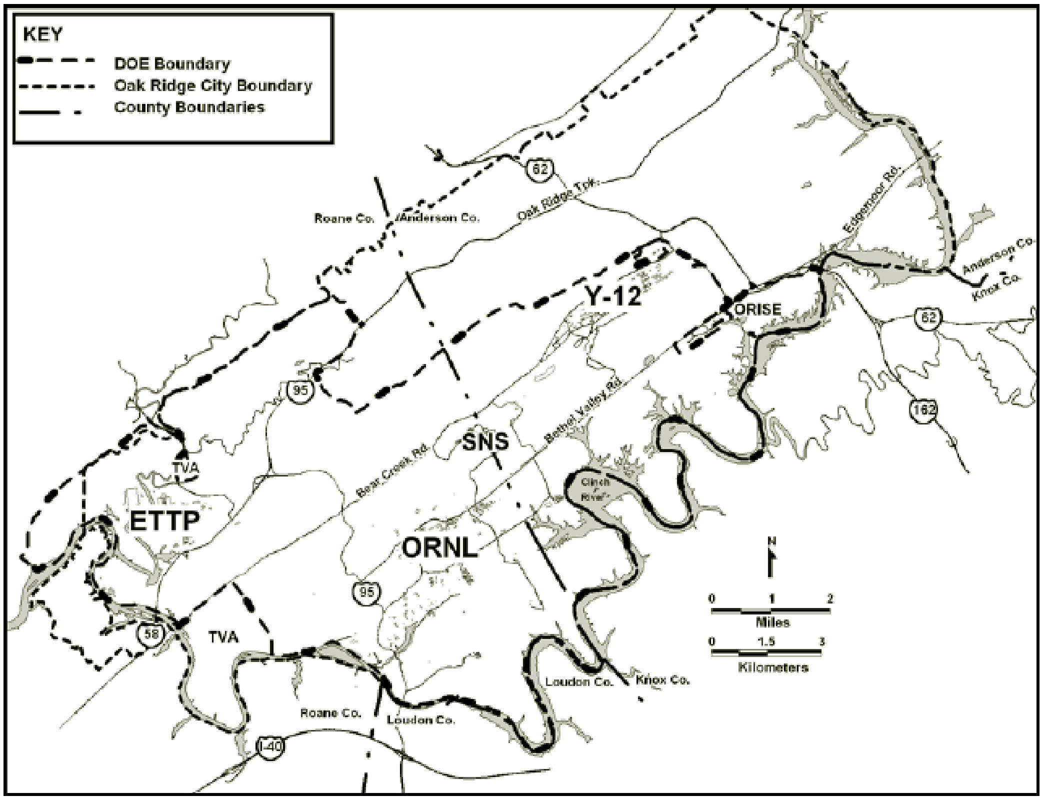


Figure 3-4. Oak Ridge Reservation showing ETTP location.

The ETTP mission is to reindustrialize and reuse site assets through transfer of excess or underutilized land and facilities and incorporation of commercial industrial organizations as partners in the ongoing environmental restoration, decontamination and decommissioning, and waste treatment and disposal. Since 2005, six buildings have been transferred from DOE ownership to the Community Reuse

Organization, and two have been transferred to the City of Oak Ridge. Transfer of two land parcels of approximately 25 acres has also occurred. Continued land and facility transfers are underway.

3.2.1 Land Use

The main plant area of ETTP (one of the proposed locations for Proposed action) consists of approximately 800 acres (3.24 square kilometers). The main plant area has historically had a heavy industrial use. All of the main plant area has been disturbed over time. Facilities (buildings and structures) occupy a large portion of the land within the main plant. These facilities and their adjacent support or service properties include offices, site support, waste handling and storage, roads, parking, and open space. Remediation and decontamination and demolition are ongoing. Significant progress has been made in this regard, many facilities have been demolished. As noted above, eight facilities and a parcel of land have also been transferred from DOE ownership. A number of facilities and systems are also leased by DOE to Community Reuse Organization of East Tennessee until such time as they are either transferred or demolished. The utility systems are also being transitioned to the City of Oak Ridge.

3.2.2 Geology and Soils

3.2.2.1 Geology

Discussions of the regional geology and structural and stratigraphic relationships on the Oak Ridge Reservation can be found in the *Status Report on the Geology of the Oak Ridge Reservation* (Hatcher et al. 1992). In summary, Oak Ridge is in the Valley and Ridge Physiographic Province of the Southern Appalachian Mountains. In Tennessee it consists of Cambrian- to Ordovician-age sedimentary rocks that occur as northeast-southwest-trending thrust sheets, which has created the pattern of parallel valleys and ridges characteristic of the region. Erosion-resistant sandstones, siltstones, dolomites, and cherty formations help form the higher ridges while less-resistant limestones and shales underlie the valleys. Karst processes that form sinkholes and cavern systems have created extensive underground drainage networks in the more soluble carbonate-rich rocks.

The Knox Group consists of carbonates that have been divided into five formations based primarily on the characteristics of chert and sandstone blocks in the residuum. For the most part, these rocks range from massive- to medium-bedded, fine- to coarse-grained dolomite with some interbedded limestones, primarily in the Kingsport Formation, and sandstone lenses, all of which contain chert. These formations weather chiefly by solutional attack with irregular thicknesses of soil developed above them.

The Chickamauga Supergroup includes the Stones River Group of formations, which includes the Pond Spring Formation, the Murfreesboro Limestone, the Ridley Limestone, and the Lebanon Limestone. These formations range from massive-bedded limestones to thin, irregular-bedded calcareous shales colored from dark gray to maroon, green, and yellowish-red with some beds that contain abundant fossils.

The mean strike and dip for these formations along strike in the vicinity of ETTP (Lemiszki 1995), is to the north, 49 degrees east by 35 degrees southeast. Lemiszki (1995) notes that faults are rare to nonexistent and fractures are generally consistent, with two primary bedding plane normal sets and as many as three additional local fracture sets in these same rocks in the vicinity of ETTP. The secondary fracture sets have orientations at 30 to 45 degrees east and west of the primary sets, which results in east-west and north-south fracture orientations. Karst development is common in the carbonate rocks of the Knox Group. Lithologic and bedding variations in the Chickamauga Supergroup result in less dramatic karst development in these rocks, but it still occurs.

In general, ETTP is underlain by bedrock that can be broadly characterized as carbonate (Chickamauga Supergroup and Knox Group) or clastic (Rome Formation).

The structural geology of ETTP area is complex and includes map-scale folds and faults, as well as smaller outcrop-scale folds, fractures, and faults. Bedrock structure is closely related to the development of the East Fork Ridge syncline (a fold in rocks in which the strata dip inward toward the axis of the fold) and Whiteoak Mountain Fault (Lemiszki 1995). The principal faults in this area include the Whiteoak Mountain Fault, a major regional thrust fault along the south side of ETTP. This fault closely parallels the Oak Ridge Turnpike south of ETTP at the base of Pine Ridge. A second principal fault, the K-25 Fault, begins near Highway 58 and trends north-northwest along the east side of ETTP.

As a result of poor exposure and lack of subsurface information, little is known about the specific stratigraphic and structural characteristics that comprise the Rome Formation at ETTP. The lower part of the Rome Formation generally consists of thin-bedded shale and siltstone with interbedded sandstones in variegated colors of maroon, green, and yellow-brown. A limestone unit is present in the lower Rome Formation in some areas of East Tennessee. The upper Rome consists of maroon sandstone, siltstone, and shale. *In situ* weathering of the Rome Formation yields saprolite (weathered bedrock that retains much of the relict bedrock structure) that consists of weathered shale or siltstone, which commonly becomes more competent with depth. The Rome bedrock on the hanging wall of the K-25 Fault is extremely contorted, with complex fracturing and folding. Exposures of Rome saprolite in the vicinity show many tight kink folds with widely variant orientations. Available exposures of the weathered Rome saprolite in the area west of ETTP reveal numerous tight, highly fractured folds with widely ranging bedding orientations. This degree of variability precludes predictions of bedrock flowpaths in the Rome Formation at ETTP.

Due to lack of exposures, the Cannon Limestone and Catheys Formation have been mapped as one unit at ETTP (Lemiszki 1995). The Cannon-Catheys Formation, which is poorly exposed at ETTP, generally consists of dark-gray, thick to massive beds of limestone with some thin to medium beds and shale seams and partings. Chert and siltstone fragments are common in soil that develops above the Catheys Formation (Lemiszki 1995). The carbonates of the Chickamauga commonly weather *in situ* and turn completely to clay and silty clay. The transition from weathered material to competent bedrock is generally distinct and occurs over a short interval.

Despite the presence of numerous faults in the ETTP area, the seismic activity, or likelihood of being subject to earthquakes, is no greater than that of the general East Tennessee area. The most recent significant movement of these faults likely occurred over 200 million years ago; these faults are considered inactive.

The Chickamauga formations are subject to the development of karst in the ETTP area. Karst features such as sinkholes, caves, sinking streams, subsurface cavities, and springs all occur in the ETTP area. Solutionally enlarged fractures, joints, and bedding planes are common in exposures of Chickamauga rocks near ETTP. Historical engineering boring logs from the area south of the Oak Ridge Turnpike indicate the presence of significant subsurface void space in bedrock that is interpreted as possibly being a carbonate unit within the lower Rome Formation.

Fill materials are widely distributed across ETTP and can be difficult to distinguish from native soils due to their largely local origin. With few exceptions, unconsolidated overburden materials that range in thickness from less than 1 foot (0.3 meter) to 70 feet (21 meters) overlie the bedrock at ETTP. The overburden was severely reworked throughout most of the main plant area as a part of initial site construction to the extent that it should all be considered disturbed.

3.2.2.2 Soils

Depth to bedrock is typically 50 feet (15 meters) or more over the Knox Group with bedrock generally shallower over the Chickamauga Supergroup rocks. The soils in the area consist primarily of Fullerton cherty silt loam and Clarksville cherty silt loam with smaller areas of Dewey silty clay loam, Talbott silty clay loam, Colbert silty clay loam, and Roane gravelly loam (USDA 1942). Soils of the Fullerton and Clarksville series occupy the majority of the site and occur on the steep, hilly, and rolling portions of the area, while soils of the other series primarily occupy the low areas near streams and East Fork Poplar Creek.

Soils of the Fullerton series are well-drained, strongly acid, moderately cherty, and moderately productive soils that originate from the weathering of moderately cherty dolomitic limestone. In uneroded areas, Fullerton cherty silt loam has a brownish-gray loose silt loam surface soil about 10 to 15 inches (25 to 38 centimeters) thick. This layer normally contains a moderate quantity of chert fragments. Underlying the surface soil is the yellowish-red or pale-red silty clay or silty clay loam subsoil, about 25 to 35 inches (64 to 89 centimeters) thick. This subsoil also contains a moderate quantity of chert fragments. Underlying the subsoil is the substratum, which consists of reddish-yellow silty clay splotched with yellow, red, brown, and gray. This material is generally tight, sticky, and plastic and contains a moderate quantity of chert fragments. The substratum continues to bedrock, which lies from 20 to 30 feet (6 to 9 meters) below the surface in most places (USDA 1942). The eroded phase of the Fullerton is similar with the exception that most or all of the surface soil is missing. Like the Fullerton soils, the Clarksville soils develop from the residuum of cherty dolomitic limestone. These soils have similar characteristics; however, the Clarksville soils contain more chert and have lighter-colored surface soils and yellow rather than yellowish-red subsoils.

3.2.3 Air Quality and Climate

The State of Tennessee has adopted the National Ambient Air Quality Standards set by the Environmental Protection Agency for six principal pollutants that are harmful to public health and the environment. These pollutants include PM_{10} and particulate matter with mean aerodynamic diameter of 2.5 micrometers (about 0.0001 inch) or less ($PM_{2.5}$) in diameter, sulfur dioxide, carbon monoxide, nitrogen dioxide, lead, and ozone. Based on the ambient (outdoor) levels of the criteria pollutants, the Agency evaluates individual Air Quality Control Regions to establish if they meet National Ambient Air Quality Standards. Areas that meet the standards are attainment areas; areas that exceed the standard(s) for a particular pollutant(s) are nonattainment areas for the pollutant(s).

Air quality around the Oak Ridge area is relatively good. However, Anderson County has been designated as a nonattainment area for the 8-hour ground level ozone standard, as part of the larger Knoxville nonattainment area. In addition, Anderson County and part of Roane County have been designated as nonattainment for the $PM_{2.5}$ standard. For all other criteria pollutants for which the Environmental Protection Agency has made attainment designations, existing air quality in the greater Knoxville and Oak Ridge areas is in attainment with the National Ambient Air Quality Standards.

As part of the Oak Ridge Reservation, ETTP is in a Class II Prevention of Significant Deterioration area. One set of allowable increments applies for Class II areas, and more stringent increments apply to Class I Prevention of Significant Deterioration areas, which include national parks that exceed 6,000 acres (24 square kilometers) and some national parks, monuments, wilderness areas, and other areas specified in 40 CFR 51.166. The nearest such area is the Great Smoky Mountains National Park, about 35 miles (56 kilometers) southeast of Oak Ridge. Prevention of Significant Deterioration standards exist for sulfur dioxide, nitrogen dioxide, and PM_{10}.

The Tennessee Department of Environment and Conservation issues air permits for nonradiological airborne emissions at ETTP. During 2005, ETTP operated five major air emission sources subject to Tennessee Title V Major Source Operating Permit program rules. No direct monitoring of airborne emissions is required for nonradionuclide air contaminants from permitted sources. Rather, key process and air pollution control device parameters are monitored to ensure compliance with all permitted emission limits. The TSCA incinerator is permitted as a major source of air emissions from ETTP. Extensive off-gas treatment controls emissions from the incinerator, which were considerably less than all permitted allowable emissions, including those of lead, beryllium, mercury, fluorine, chlorine, sulfur dioxide, and particulates in 2005 (UT-Battelle, BWXT Y-12, and BJC 2006a).

For radiological pollutants, emissions from ETTP are variable and emanate mostly from the TSCA incinerator. In 2005, emissions of uranium from ETTP operations were well within the allowable derived concentration guidelines in DOE Order 5400.5, and were similar to 2004 emissions (UT-Battelle, BWXT Y-12, and BJC 2006b).

Figure 3-5 shows an example wind rose from data DOE took at 33 feet (10 meters) above the ground level at Oak Ridge National Laboratory, which encompasses ETTP.

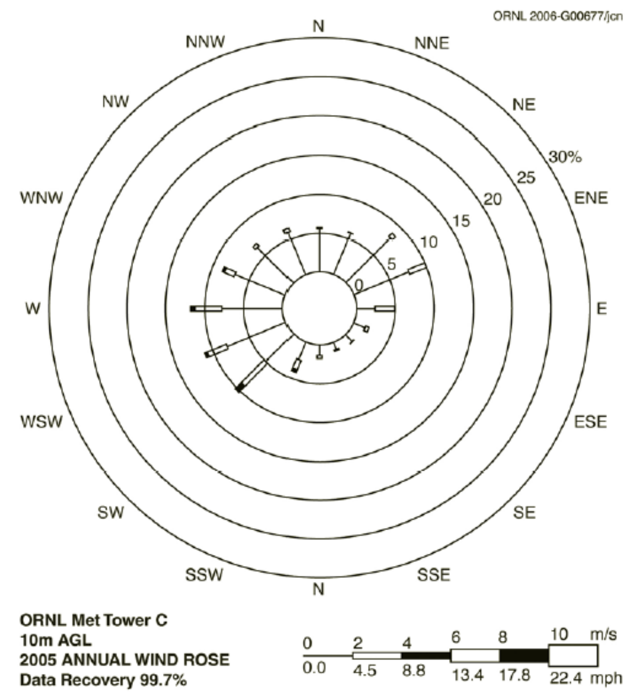


Fig. B.1. Wind rose for ORNL Meteorological Tower C for data taken at 10 m above ground level, 2005.

Figure 3-5. ETTP wind rose (UT-Battelle, BWXT Y-12, and BJC 2006a).

The climate of east Tennessee may be broadly classified as humid continental, although it is very near the region of temperate continental climate to the north. The Cumberland Mountains to the northwest and the Great Smoky Mountains to the southeast influence the patterns of temperature and precipitation over the region, with cooler temperatures and greater precipitation generally occurring at the higher elevations. The rugged terrain is not conducive to the buildup of large and violent tornadoes, and the distance from the coast combined with the presence of the Great Smoky Mountains keeps the region from being much affected by hurricanes.

3.2.4 Water Resources

3.2.4.1 Surface Hydrology

Surface water on the Oak Ridge Reservation includes all water naturally open to the atmosphere, such as rivers, lakes, reservoirs, ponds, streams, springs, or other collectors under direct influence if surface water. At ETTP, surface waters include Mitchell Branch, a minor tributary to Poplar Creek, Poplar Creek, a larger order stream that meanders through portions of the plant creating peninsulas, and the Clinch River. The Clinch River is the receiving body for all of the sites surface water. The Clinch River is impounded to form a portion of the Watts Bar Reservoir. The river enters East Fork Valley through a water gap in Pine Ridge and flows across the valley, perpendicular to geologic strike, before turning southwest to flow along the axis of the valley toward Watts Bar Dam. The Clinch River is about 500 feet (153 meters) wide, adjacent to ETTP, and the typical water depth ranges from 25 to 35 feet (7.6 to 11 meters) along the channel (DOE 1996b). Poplar Creek flows approximately 5.5 miles (8.8 kilometers) through ETTP from the upstream confluence with East Fork Poplar Creek to the confluence with the Clinch River (DOE 1996b).

The Clinch River and Poplar Creek elevations fluctuate up to 5 feet (1.5 meters) on daily, weekly, and seasonal cycles in response to the Tennessee Valley Authority reservoir operations at downstream Watts Bar and upstream Melton Hill dams. Discharge at Melton Hill has the most significant influence on river and creek stages near ETTP. In addition, as a result of power generation schedules at the two dams, there are periods in each day when flow in the Clinch River is reversed. Such reversals can be observed upstream in Poplar Creek to above the confluence with East Fork Poplar Creek (DOE 1996b). Under very rare conditions, Fort Loudon Dam operations on the Tennessee River can also affect the stage elevations of the Clinch River and Poplar Creek.

Other principal surface-water features include Mitchell Branch, the K-901-A pond, and an unnamed stream that discharges to the K-1007-P ponds before discharging to Poplar Creek. In addition, there are numerous seeps and springs throughout the ETTP area.

During 1991, The Tennessee Valley Authority performed a flood analysis that included the Clinch River and Poplar Creek (TVA 1991). Floodplains consist of mostly level land along rivers and streams that floodwaters could submerge. The Authority concluded that most of ETTP is above the probable maximum flood. In addition, TVA (1991) provided 25-year flood to probable maximum flood elevations and Norris and Melton Hill Dam failure scenarios for the Clinch River near the confluence of Poplar Creek. Flooding on the Tennessee River above Watts Bar Dam, which is designed to pass the probable maximum flood safely, controls such a flood; flooding on the Clinch River watershed controls all other floods. Areas within the 100- and 500-year floodplains are subject to development constraints. Figure 3-6 shows the extent of the 100- and 500-year floodplains in the ETTP area, as well as wetlands, which are discussed in Section 3.2.4.2.

3.2.4.2 Wetlands

A few small wetland areas have been identified on ETTP that are associated with Mitchell Branch, Poplar Creek, the K-770 Scrap Yard, and the K-1007 pond (Figure 3-6). These wetlands total about 8.6 acres (0.035 square kilometer) and are shown on Figure 3-6. The wetlands along Poplar Creek are the most natural and least disturbed of those on ETTP and are strongly influenced by fluctuations in Watts Bar lake. The Mitchell Branch wetlands occur in a narrow strip along the band and are all highly disturbed areas. The K-1007-P-1 pond-related wetland developed due to construction of the pond and compaction of soil.

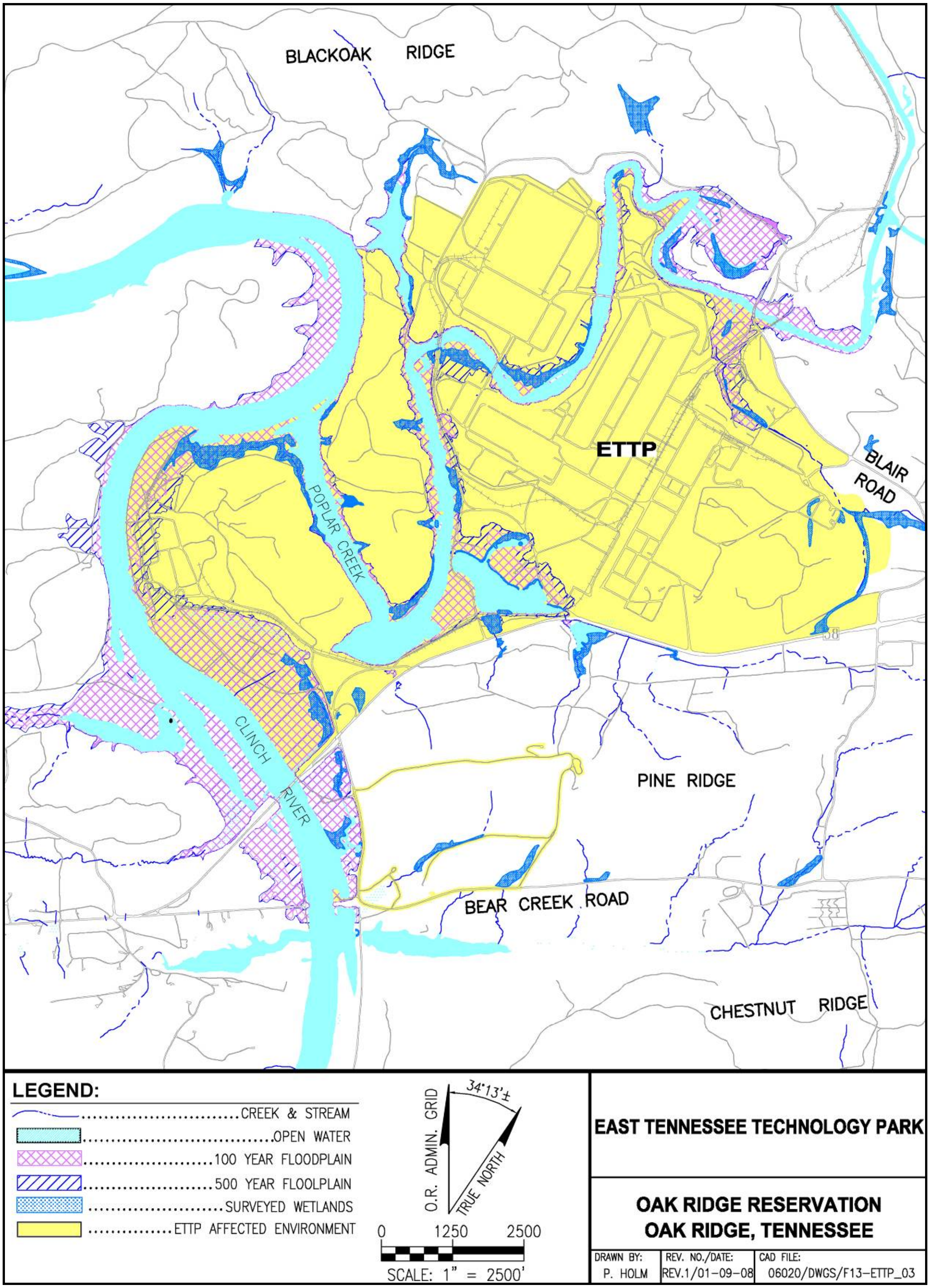


Figure 3-6. ETTP floodplains and wetlands map (UT-Battelle, BWXT Y-12, and BJC 2006a).

3.2.4.3 Groundwater

The principal aquifers in the Oak Ridge area include two general hydrologic units – the Knox Aquifer and the Oak Ridge Reservation Aquitards. The Knox Aquifer includes the Knox Group and the Maynardville Limestone of the Conasauga Group. Flow in the Knox Aquifer is primarily through solution cavities and enlarged fractures. The Reservation aquitards are associated with the remaining geologic units in the area. Hydraulic conductivity and potential yield in the Reservation aquitards are generally low and highly variable dependent on the density, width, and interconnectedness of local bedrock fractures and solution cavities. Shallow groundwater is likely to follow topography and discharge to the south into East Fork Poplar Creek. Groundwater flow in bedrock probably follows solution-enlarged features, such as bedding planes and fractures, with movement along geologic strike and dip of the bedrock formations. Groundwater is not used for agricultural, drinking, or industrial purposes in Oak Ridge. All water users in the area obtain water directly from the Oak Ridge municipal water system.

Groundwater in the ETTP area occurs in both the unconsolidated zone and bedrock, primarily as a single water table aquifer. With few exceptions, the water table occurs in the overburden above bedrock across the site, with saturated overburden thickness that ranges up to 70 feet (21 meters). In higher topographic areas, the water table occurs below the top of bedrock and can occur very near the surface (ORNL 1998). Groundwater flow in the unconsolidated zone generally follows mapped potentiometric gradients. However, because bedrock is exposed along the bottom of the Clinch River and Poplar Creek, the unconsolidated zone flow paths are short and terminate at the interface with the adjoining surface-water features. Water level data indicate that groundwater flows away from higher elevations toward the bounding surface-water features. Groundwater flow in bedrock is associated with secondary porosity features such as fractures, solutionally enlarged fractures, and possibly faults; typically, the bedrock flow paths tend to follow geologic strike (ORNL 1998; Morris 1998).

DOE developed the cleanup strategy described in *Accelerating Cleanup: Paths to Closure* (DOE 1999c) to accelerate the transition of areas of concern from characterization to remediation by making decisions at the watershed scale based on recommended land use. The watershed is a surface-drainage basin that includes an area of concern or multiple areas of concern to be investigated and remediated. This approach enables the systematic monitoring and evaluation of contaminant sources and migration through the use of integrated surface- and groundwater monitoring. Groundwater monitoring at ETTP focuses primarily on investigation and characterization of sites for remediation under the Comprehensive Environmental Response, Compensation, and Liability Act.

There is an active Groundwater Protection Program at ETTP, which is coordinated with the Water Resources Restoration Program, that provides a consistent approach to watershed monitoring across the Oak Ridge Reservation. This program is responsible for the performance of groundwater surveillance monitoring at ETTP, which includes exit pathway monitoring wells. Groundwater discharges into Poplar Creek, the Clinch River, and the three main surface-water bodies at ETTP (the K-901 Pond, K-1007 Pond, and Mitchell Branch). Many of the contaminants at ETTP migrate toward one of these surface-water bodies, which are monitored by the ETTP Environmental Monitoring Plan surface-water surveillance program. The 2005 Remediation Effectiveness Report (DOE 2006) includes summaries of groundwater monitoring actions necessary for individual cleanup actions at ETTP, along with recommendations to modify requirements that would further ensure protection of human health and the environment. All water users in the area and on the plant sites obtain water directly from the Oak Ridge municipal water system; groundwater is not used.

3.2.5 Ecological Resources

3.2.5.1 Terrestrial Habitat

The Oak Ridge Reservation consists of diverse habitats and supports a rich variety of flora, with vegetation characteristic of that are found in the intermountain regions of central and southern Appalachia. Vegetation around the buildings on the ETTP site is a mixture of mowed grasses with a few shrubs and trees. Small areas have mixed tree, shrub, and grass associations or mixed evergreen and deciduous vegetation. Many of the shrubs and trees have been planted as landscaping, although some native species are found in unmowed areas around ponds and along waterways. Areas of native grasses have recently been planted in selected areas of the main plant in an effort to minimize mowing and associated fuel use and emissions.

3.2.5.2 Terrestrial Wildlife

Wildlife species that are likely to occur in the main plant area include species typically found in urban settings and occasionally species that typically occur on the Oak Ridge Reservation in less developed areas.

Species that are typical of urban settings include mammals such as the gray squirrel (*Sciurns carplinersis)*, chipmunk (*Tamias striatus*), eastern cottontail rabbit (*Sylvilagus floridanus)*, striped skunk (*Mephitis mephitis)*, groundhog (*Marmota monax)*, and gray fox (*Urocyon cinereoargenteus*). Animals that might inhabit other portions include small mammals such as the white-footed mouse (*Peromyscus leucopus*), golden mouse (*Ochrotomys nuttalli*), and short-tail shrew (*Blarina brevicauda*), as well as the red fox (*Vulpes vulpes*), coyote (*Canis latrans)*, white-tailed deer (*Odocoileus virginianus)*, cotton rat (*Sigmodon hispidus*), and eastern harvest mouse (*Reithrodontomys humulis*).

Birds that commonly occur in the main plant area are similar to those found in urban areas of Oak Ridge and include the northern cardinal, robin (*Turdus migratorius*), eastern bluebird (*Sialia sialis*), tufted titmouse (*Baeolophus bicolor*), Carolina chickadee (*Poecile carolinensis*), song sparrow (*Melospiza melodia*), northern mockingbird (, common grackle, European starling, American crow, house finch (*Carpodacus mexicanus*), house sparrow (*Passer domesticus*), rock dove (*Columba livia*), rufous-sided towhee (*Pipilo erythrophthalmus*), Carolina wren (*Thryothorus ludovicianus*), eastern meadowlark, indigo bunting, mourning dove, northern flicker (*Colaptes auratus*), red-bellied woodpecker (*Melanerpes carolinus*), downy woodpecker (*Picoides pubescens*), and blue jay.

Other species of birds that might occur are the Kentucky warbler (*Oporornis formosus)*, ovenbird (*Seiurus aurocapillus*), brown thrasher (*Toxostoma rufum)*, wood thrush (*Hylocichla mustelina)*, turkey (*Meleagris gallopavo*), cardinal (*Cardinalis cardinalis*), mockingbird (*Mimus polyglottus)*, grackle (*Quiscalus quiscula*), starling (*Sturnus vulgans*), crow (*Corvus brachyrhyncas*), meadowlark (*Sturnella magna*), dove (*Zenaida macrura)*, bluejay (*Cyanocitta cristata)*and northern bobwhite (*Colinus virginianus)*. Birds of prey that might nest or hunt on or near the main plant are the red-tailed hawk (*Buteo jamaicensis)*, red-shouldered hawk (*Buteo lineatus)* broad-winged hawk (*Buteo platypterus*), great horned owl (*Bubo virginianus*), screech owl (*Otus asio*), barred owl (*Strix varia*), and Cooper's hawk (A*ccipiter cooperii*). The osprey (*Pandion haliaetus*) also occurs in the K-1007-P1 pond next to the main plant area (Mitchell et al. 1996). American bald eagles (*Halicetns leucocephalus)* have been spotted in the winter next to the K-1007 pond.

Reptiles and amphibians include the upland chorus frog (*Pseudacris triseriata*), tree frog (*Hyla versicolor*), spring peeper (*Hyla crucifer*), green frog (*Rana clamitans*), toad (*Bufo* spp.), various salamanders (*Eurycea* spp. and *Desmognathus* spp.), eastern box turtle (*Terrapene carolina*), northern copperhead (*Agkistrodon contortix*), black rat snake (*Elaphe obsolete*), and fence lizard.

3.2.5.3 Threatened and Endangered Species

Most of the ETTP area is an industrial setting that does not provide suitable habitat for sensitive species. The gray bat (*Myotis grisescens*), a federally listed endangered species, is known to forage over the Clinch River, but none have been captured during mist net surveys in the ETTP vicinity.

Two state-listed species that are deemed in need of management have occurred near ETTP. The southeastern shrew (*Sorex longirostris*) has been observed nearby on Black Oak Ridge, and the sharp-shinned hawk (*Accipiter striatus*) has been observed near the vicinity of the ETTP visitors' overlook.

3.2.6 Cultural Resources

Cultural resources include any prehistoric or historic district, site, building, structure, or object that is important to a culture, subculture, or community for scientific, traditional, religious, or any other reason. If these resources meet one of the National Register Criteria for Evaluation (36 CFR Part 60.4), they can be termed historic properties and, thereby, are potentially eligible for inclusion on the *National Register of Historic Places*.

During the summer and spring of 1994, ETTP properties were assessed for their architectural and historical significance, and two historic districts (the main plant and the power house) were established as eligible for inclusion on the National Register. The results of this cultural resources survey were published in March 1998 in *K-25 Site Cultural Resources Survey* (Morris 1998).

In July 2001, the *Cultural Resources Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee* (DOE 2001c) was issued to provide the mechanism by which DOE complies with cultural resources statutes, addresses cultural resources in the early planning process of its undertakings, and implements necessary protective measures for its cultural resources before initiating undertakings. This management plan is the basis of the DOE Oak Ridge Operations Office cultural resources management program in Oak Ridge, and is intended to strike a balance between DOE missions and its cultural resources planning and preservation responsibilities. The management plan was prepared pursuant to the *Programmatic Agreement Among the Department of Energy Oak Ridge Operations Office, the Tennessee State Historic Preservation Officer, and the Advisory Council on Historic Preservation Concerning Management of Historical and Cultural Properties at the Oak Ridge Reservation (PA)*, which the plan incorporates (DOE 2001c). The plan was also prepared in accordance with *Final Report, Environmental Guidelines for Development of Cultural Resource Management Plans* (DOE 1995), the *Secretary of the Interior's Standards and Guidelines for Preservation Planning* (Federal Register, Volume 48, page 44716), the *Section 110 Guidelines* (Federal Register Volume 52, page 4727), and the Advisory Council on Historic Preservation's 1991 report to Congress, *Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities* (ACHP 2002).

To fulfill responsibilities under Section 106 of the National Historic Preservation Act (16 U.S.C. 470 et seq.) and the Advisory Council's regulations, the following Memoranda of Agreement were prepared to comply with the Section 106 process for properties at ETTP:

- July 17, 2003, Memorandum of Agreement Among the U.S. Department of Energy, Oak Ridge Operations Office, the Tennessee State Historic Preservation Office, and the Advisory Council on Historic Preservation, Pursuant to 36 CFR Part 800.6(b)(2), Pursuant to 36 CFR Part 800.6(b)(2) (Hartman 2003)

- April 12, 2004, Memorandum of Agreement Between the U.S. Department of Energy, Oak Ridge Operations Office, and the Tennessee State Historic Preservation Office, Pursuant to 36 CFR 800.6(b)(1)(iv), Regarding the Demolition of 108 Buildings/Structures at the East Tennessee Technology Park (ETTP) (Formerly K-25 Site) on the Oak Ridge Reservation, Roane County, Tennessee (Hartman 2004)

- March 28, 2005, Memorandum of Agreement Among the U.S. Department of Energy, Oak Ridge Operations Office, the Tennessee State Historic Preservation Office, and the Advisory Council on Historic Preservation, Pursuant to 36 CFR Part 800.6(b)(2), Regarding Site Interpretation of the East Tennessee Technology Park (ETTP) (Formerly K-25 Site) on the Oak Ridge Reservation, Roane County, Tennessee (Hartman 2005)

These memoranda were developed, with participation of several consulting parties and the DOE Federal Preservation Officer, to identify the best and most cost-effective mitigation to permanently commemorate, interpret, and preserve the significance of the ETTP. On execution of the March 2005 memorandum, DOE was granted approval to proceed with demolition of Building K-25 (with the exception of the North End), Building K-27, and the remaining 108 buildings and structures at the ETTP (with the exception of K-1028-45, also known as Portal 4). DOE agreed to certain stipulations within the context of the memorandum, and is responsible for ensuring that the measures in the memorandum are carried out or the memorandum is revised accordingly.

3.2.7 Noise

Noise sources at ETTP can be categorized into two major groups – transportation and stationary. Transportation noise sources are moving vehicles that generally result in fluctuating noise levels above ambient levels for a short period. Stationary noise sources are those that do not move or that move relatively short distances. Stationary noise sources on and near ETTP include ventilation systems, air compressors, generators, power transformers, and construction equipment. During peak hours, traffic along State Route 58 is a major contributor to traffic noise in the area. Background noise at ETTP is mostly from local traffic and is comparable to noise levels in an urban residential area. Noise levels 200 feet (61 meters) from the main thoroughfares that serve ETTP have been estimated from traffic counts during rush hour to be between 58 and 66 A-weighted decibels. Noise levels at relatively isolated sites or farther from the highway might be lower than 55 A-weighted decibels. There are no sensitive receptor sites such as picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, or hotels near ETTP.

3.2.8 Socioeconomics

The region of influence for this analysis includes Anderson, Knox, Loudon, and Roane Counties. The region includes the Cities of Clinton, Oak Ridge, Knoxville, Lenoir City, Loudon, Harriman, and Kingston (Figure 3-3). These counties are geographically close to the Oak Ridge Reservation and account for more than 90 percent of DOE-related employment. This distribution has been relatively stable for the last decade (DOE 2002). This results in a relatively conservative estimate of impacts because Anderson County is also part of the Metropolitan Statistical Area for the City of Knoxville and draws commuters from at least 12 counties in eastern Tennessee (DOE 2002). Actual impacts could be distributed over a wider area, which would reduce the overall impact on the counties in this assessment.

3.2.8.1 Population, Employment, and Personal Income

Table 3-8 summarizes population, per capita income, and wage and salary employment from 2000 to 2004, the latest year for which data are available. Population increased over the 5-year period and employment for the region rose slightly at 0.65 percent, from 364,041 in 2000 to 376,318 in 2004. However, Knox County accounted for most of the growth, while population increased slightly in Anderson County and declined in Roane County during these years. Employment for the region declined from 74,997 in 1999 to 72,573 in 2004. Per capita income grew from $22,778 to $27,518 over the same period (BEA 2006).

Table 3-8. Demographic and economic characteristics in the ETTP region of influence.

County	2000	2001	2002	2003	2004	2005	Annual growth 2000–2005 (%)
Anderson							
Population	71,298	71,452	71,663	71,856	72,004	72,528	0.34
Per capita income ($)	25,033	25,985	26,798	27,566	28,055	29,007	2.99
Total employment	50,961	50,975	50,601	51,904	51,863	52,694	0.67
Knox							
Population	382,835	387,184	391,462	396,559	400,174	405,355	1.15
Per capita income ($)	28,552	29,179	29,583	30,059	31,417	32,815	2.82
Total employment	272,030	272,556	275,868	277,435	287,987	293,069	1.50
Loudon							
Population	39,232	39,962	40,762	41,568	42,226	43,411	2.05
Per capita income ($)	25,397	25,717	26,377	27,528	29,554	30,538	3.76
Total employment	15,749	15,834	16,075	17,253	18,047	18,721	3.52
Roane							
Population	51,956	51,974	52,211	52,439	52,719	52,753	0.30
Per capita income ($)	22,338	22,638	23,942	24,863	26,447	27,584	4.31
Total employment	23,798	20,953	20,975	21,023	20,857	21,420	-2.08
Regional Totals							
Population	545,321	550,572	556,098	562,422	567,123	574,037	1.03
Per capita income ($)	27,274	27,898	28,459	29,069	30,388	31,681	3.04
Total employment	362,538	360,318	363,519	367,633	378,754	385,904	1.26

Source: BEA (2006).

3.2.8.2 Housing

In Oak Ridge, there were 13,417 housing units in 2000, of which 12,062 (89.9 percent) were occupied and 1,355 (10.1 percent) were vacant. Of the occupied units, 68.4 percent were owner-occupied and 31.6 percent were renter-occupied (Bureau of the Census 2000). The total number of housing units represents a slow increase (0.6 per year) over the 12,694 housing units the 1990 Census reported. Citywide, the median asking price for Oak Ridge housing units in 2000 was $98,200 for owner-occupied units and $80,700 for vacant units (Bureau of the Census 2000). Among renter-occupied units, the median rent was $487 per month for occupied units and $389 per month for vacant units (Bureau of the Census 2000).

3.2.8.3 Community Fiscal Conditions

Table 3-9 lists City of Oak Ridge general fund revenues and expenditures for fiscal year 2005 and budgeted revenues and expenditures for 2006. The general fund supports the ongoing operations of local governments as well as community services such as police protection and parks and recreation. The largest revenue sources have traditionally been local taxes (which include taxes on property, real estate, hotel and motel receipts, and sales) and intergovernmental transfers from the federal or state government. Local property taxes account for nearly half (48.7 percent) of the current general fund revenues (City of Oak Ridge 2006). For fiscal year 2006, the property tax rate was $2.55 per $100 of assessed value. The assessment rate was 40 percent for industrial and commercial property and 25 percent for residential property (City of Oak Ridge 2005). The city receives a payment-in-lieu-of-tax for Oak Ridge Reservation acreage within the city limits. The payment is based on its value as farmland and assessed at the farmland rate of 25 percent (City of Oak Ridge 2005).

Table 3-9. City of Oak Ridge revenues and expenditures, fiscal years 2005 and 2007 ($).

Revenues and expenditures	2005 actual	2006 projected	2007 budget
Revenues			
Taxes	19,915,688	20,076,565	20,436,810
Licenses and permits	340,802	389,500	220,000
Intergovernmental revenues	10,574,555	11,482,459	11,731,263
Charges for services	388,577	336,500	346,000
Fines and forfeitures	238,503	265,000	289,000
Other revenues	527,689	553,000	558,500
Total revenues	31,984,814	33,103,024	33,581,573
Expenditures and other financing			
Expenditures	(14,737,841)	(15,412,843)	(16,326,766)
Other financing uses	(17,503,411)	(17,931,145)	(18,506,328)
Total	(32,241,252)	(33,343,988)	(35,761,135)

Source: City of Oak Ridge (2005, 2006).

Local sales taxes were the second largest source of revenue for the City of Oak Ridge and accounted for 23 percent of general fund revenues. In the Roane County portion of Oak Ridge, the sales tax rate is at the state maximum of 2.75 percent. The rate includes a 2.5-percent tax the county collects and shares with the City of Oak Ridge, and a 0.25-percent City of Oak Ridge rate (City of Oak Ridge 2005).

Roane County's budget for 2006 estimates $80,842,538 in expenditures and $77,687,382 in total revenues. Estimated property tax revenues were $20,587,201 or about 25 percent of total revenues. Expected sales taxes were $11,435,000 or 14 percent of revenues. As of 2005, the county property tax rate for the Roane County portion of Oak Ridge was $2.02 per $100 assessed value (TCT 2006). Roane County also receives payment-in-lieu-of-taxes on Oak Ridge Reservation property in the county (Huotari 2006).

3.2.8.4 Community Public Services

The Oak Ridge school system includes eight schools, which served a total of 4,306 students in 2007. The city budget for 2008 includes $13 million for school operations. Oak Ridge has one high school. In 2006 the city began a major renovation and upgrade to the high school buildings and infrastructure. It is expected to be complete in 2008.

The Police Department in Oak Ridge includes 64 uniformed officers and 12 nonuniform support personnel, with a 2008 budget allocation of $5.4 million. The Oak Ridge Fire Department maintains four fire stations with more than 69 uniformed personnel that are supplemented by fire specialists. The 2008 budget allocation for the Fire Department is $6.1 million. The city has mutual-aid agreements with DOE and most surrounding agencies.

3.2.9 Environmental Justice

For this assessment, a minority population consists of any census tract in which minority representation is greater than the national average of 30.7 percent. Minorities include individuals classified by the Bureau of the Census as Black or African-American, American Indian and Alaska Native, Asian, Native Hawaiian and Other Pacific Islander, and Hispanic or Latino, and those classified under "two or more races." This provides a conservative estimate consistent with Office of Management and Budget guidance (OMB 2000). Hispanics can be of any race and are excluded from the totals for individual races to avoid double counting. Figure 3-7 shows the census tracts in the ETTP area.

The distribution of minority and economically disadvantaged populations changed little between 1990 and 2000. Only one of the census tracts that immediately surround the Oak Ridge Reservation currently includes a minority population greater than the national average of 30.7 percent. As of the 2000 Census, minorities represented 40.1 percent of the population in Tract 201. As in 1990, African-American residents made up the largest group (29.6 percent). The proportion of minority residents in all other Oak Ridge census tracts was below the national average, which ranged from 17.4 percent in Tract 205 to 8.8 percent in Tract 206 (Bureau of the Census 2001).

According to the 2000 Census, 12.4 percent of the U.S. population and 13.5 percent of the Tennessee population had incomes below the poverty level in 1999 (Bureau of the Census 2001). In this assessment, a low-income population consists of any census tract in which the proportion of individuals below the poverty level exceeds the national average. In the region of influence, 13.1 percent of the population in Anderson County had incomes below the poverty level. The proportion in Knox County was 12.6 percent, in Loudon County it was 10.0 percent, and in Roane County it was 13.9 percent. In Oak Ridge, low-income populations were in census tracts 201 (15.8 percent below poverty level) and 205 (27.9 percent). Tract 201 roughly corresponds to the Scarboro community, and Tract 205 includes the area between Oak Ridge Turnpike and West Outer Drive that is bounded on the west by Louisiana Avenue and on the east by Highland Avenue and Robertsville Road. In other Oak Ridge census tracts, the percentages ranged from 12.1 percent in Tract 204 to 1.9 percent in Tract 301 (Bureau of the Census 2001).

3.2.10 Waste Management

ETTP generates wastewater, solid low-level radioactive waste, solid and liquid mixed low-level waste, nonradioactive hazardous waste, and nonradioactive nonhazardous solid waste. DOE manages wastes from site operations, environmental restoration, and decontamination and decommissioning activities. The site has an active program to minimize the generation of solid low-level radioactive waste, hazardous waste, and mixed low-level waste. This includes controlling entry into areas where these types of wastes are present, and preventing excessive materials from entering radiological areas including controlling tool usage within those areas. Other wastes such as oily rags, used oil absorbent materials, polychlorinated biphenyl-containing materials, and hazardous waste follow specific disposal requirements. When practicable, waste generation is minimized by using alternatives that prevent or reduce waste generation, reduce hazardous materials use, and increase resource conservation. Actions that support this minimization effort include the process for procurement of critical items; procurement of environmentally friendly products that do not constitute hazardous or toxic waste for disposal; procurement of low-sulfur diesel fuel that reduces greenhouse gases and particulates; recycling of items such as cardboard, paper, aluminum cans, plastic containers, universal waste, used oil, tires, scrap metal, and electronics for recovery; and adaptation for new use.

3.2.10.1 Solid Nonhazardous, Nonradioactive Waste

Solid wastes, such as sanitary refuse, industrial waste, construction and demolition waste, classified waste, and special wastes that include materials such as friable asbestos and manmade mineral fiber waste, are collected at ETTP and disposed of in Oak Ridge Reservation landfills. The landfills are permitted by the State of Tennessee which was granted Solid Waste Regulatory Authority by the Environmental Protection Agency. These facilities do not accept wastes that require management for hazardous or radioactive material content.

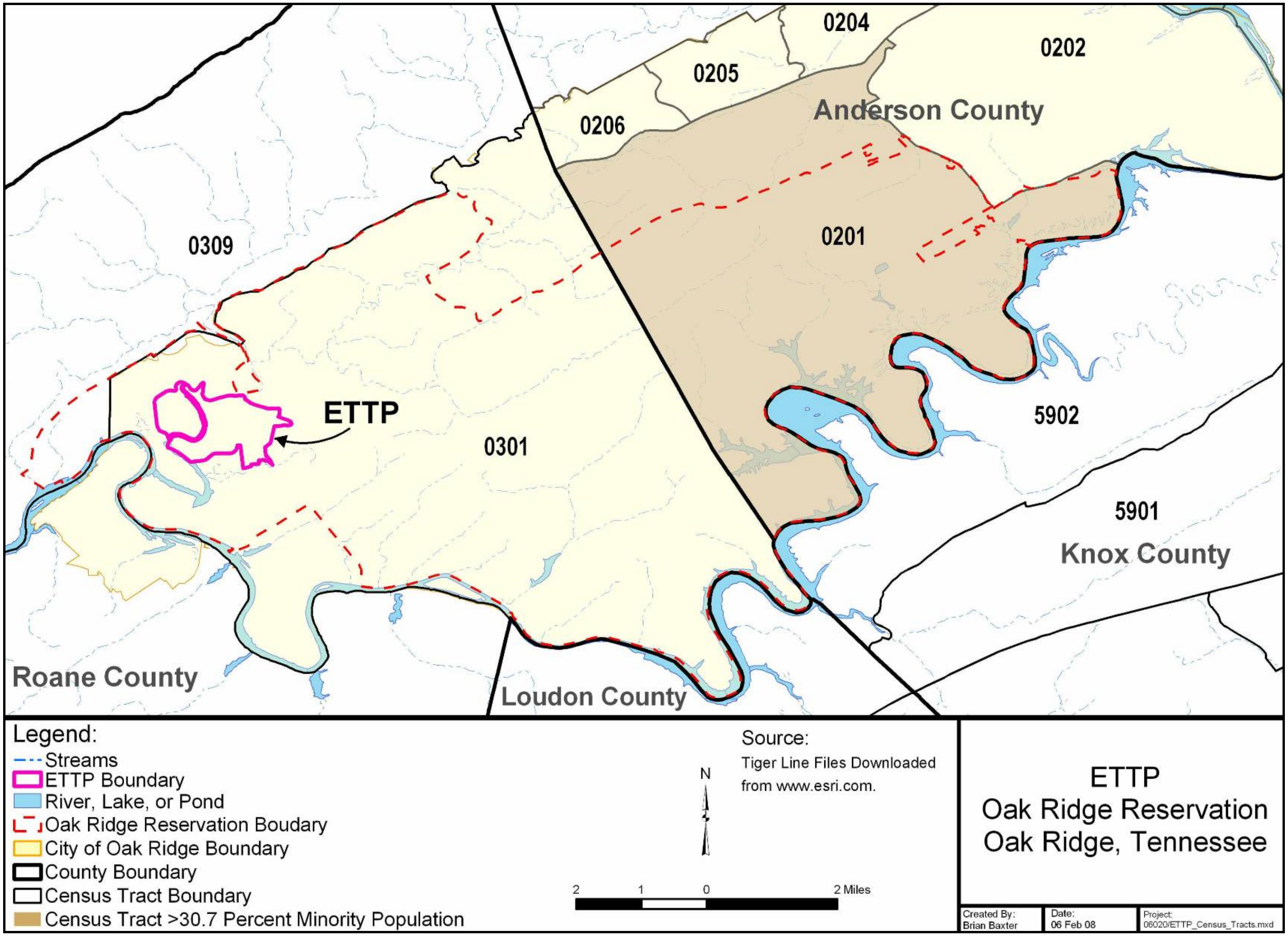


Figure 3-7. Census tracts in the ETTP area.

Other nonhazardous, nonradioactive waste not accepted at the DOE landfills, such as universal wastes, are recycled or disposed of at commercial facilities off the site.

Nonradioactive scrap metal is transferred to a local recycler and adapted for new use, empty aerosol cans are punctured and recycled as scrap metal, refrigerants are recovered and reused as appropriate, pressurized gas cylinders are returned to vendors for reuse, tires are returned to vendors for recycling or reuse, and utility poles are reused when possible. A concerted effort is made to conserve landfill space and reduce adverse impacts on the environment as part of the daily work routine.

3.2.10.2 Mixed and Low-Level Radioactive Waste

DOE stores ETTP-generated mixed and low-level radioactive waste on the site and at the Oak Ridge National Laboratory before shipment to a DOE or commercial facility for treatment, if necessary, and then for final disposition. These wastes are contaminated with radiological and hazardous constituents as a result of past weapons development or research operations, and have been accumulated for treatment and disposal pending development of appropriate technologies, availability of disposal sites, and availability of funding. Mixed waste could be contaminated with RCRA and/or TSCA hazardous constituents. Storage of hazardous waste is authorized under Tennessee Department of Environment and Conservation issued permit. TSCA-regulated, polychlorinated biphenyl-contaminated waste, and RCRA hazardous waste can be treated by incineration in the onsite TSCA Incinerator.

3.2.10.3 Process Wastewater

Wastewater at the ETTP site consists primarily of TSCA Incinerator blowdown (a process-related radioactive and hazardous liquid effluent). Wastewaters from remedial action areas and decontamination and decommissioning activities can also be treated on the site before release. DOE processes wastewater at onsite treatment facilities and discharges it to the Clinch River in accordance with National Pollutant Discharge Elimination System Permit TN0074225. The capacity of the principal site wastewater treatment facility (the Central Neutralization Facility) is approximately 35 million gallons (132 million liters) per year.

3.2.10.4 Nonradioactive Hazardous Waste

The ETTP site generates hazardous waste, which includes spent solvents, heavy-metal-contaminated waste, and polychlorinated biphenyl-contaminated waste. DOE sends certain hazardous wastes to permitted offsite contractors for final treatment and disposal.

All DOE hazardous waste management activities that are not conducted under the Comprehensive Environmental Response, Compensation, and Liability Act are conducted in accordance with RCRA permit requirements. DOE has three RCRA permits that cover the following hazardous waste activities: 19 permitted container storage/treatment units; 21 tank storage/treatment units; two portable units; and a RCRA/TSCA-permitted incinerator. The permits that regulate these units include closure plans that are designed to ensure clean closure with no postclosure care or monitoring.

One of the Community Reuse Organization of East Tennessee’s lessees operates 8 container storage units, 11 tank storage and treatment units, and 21 miscellaneous treatment units under a single RCRA hazardous waste permit. The tenant has a closure plan that is designed to ensure clean closure with no postclosure care or monitoring.

3.2.11 Human Health

Current and past activities at the Oak Ridge Reservation have resulted in releases of radionuclides and chemicals to the environment. Such releases combine with natural sources and can augment the exposure to humans both on and off the site. Natural background sources include cosmic radiation, radioactive materials in native rocks and soils, and manmade sources such as medical radiation and radiation from consumer products (for example, smoke detectors). Inorganic elements, such as arsenic and manganese, also occur in native soils on the Reservation, including ETTP. These naturally existing sources of radiological and chemical exposures become the background exposure to which the effects of the manmade releases would be added. The *Oak Ridge Reservation Annual Site Environmental Report for 2006* (UT-Battelle, BWXT Y-12, and BJC 2007) summarizes releases and environmental contamination levels of chemicals and radiation and resulting exposures for 2006. In general, human exposure pathways include direct contact, inhalation, and ingestion. This section summarizes the human health environment in terms of human exposure to background radiation, and radiation and hazardous chemicals from historical and current operations at the ETTP.

3.2.11.1 Radiation Environment

The average annual cosmic ray dose equivalent in Tennessee is about 45 millirem (0.45 millisievert) per year (Kathren 1984). The average exposure from radionuclides in the soil in the United States is about 60 millirem (0.6 millisievert) per year (Kathren 1984). External radiation exposure rates from background sources in Tennessee are equivalent to an average annual dose of 42 millirem (0.42 millisievert) with a range of 17 to 72 millirem (0.17 to 0.72 millisievert) per year (Myrick, Berren, and Haywood 1981). This average is less than the United States annual average of 60 millirem (0.6 millisievert) per year. A major proportion of natural background radiation is from naturally occurring radon in the air, which results in about 200 millirem (2 millisievert) per year from radioactivity in the soil and rocks (Kathren 1984). These natural radiation sources contribute to the dose that everyone receives annually.

Manmade sources contribute to the average amount of dose a member of the U.S. population receives. These sources include x-rays for medical purposes – about 40 millirem (0.4 millisievert) per year; nuclear medicine – about 14 millirem (0.14 millisievert) per year; and consumer products – about 11 millirem (0.11 millisievert) per year (for example, smoke detectors). Radioactivity that remains in the environment from nuclear weapons testing is a minor contributor to average radiation levels at levels less than 1 millirem (0.01 millisievert) per year. The current average dose to a person living in Tennessee from both natural radiation and manmade sources is about 350 millirem (3.5 millisievert) per year.

The calculated radiation dose to the maximally exposed offsite individual from airborne releases from the ETTP was about 0.04 millirem (0.0004 millisievert) during 2005, which is less than 1 percent of the natural external radiation background effective dose equivalent to an average Tennessee resident. The analysis assumed that the maximally exposed individual was 0.6 mile (1 kilometer) southwest of the TSCA Incinerator stack (K-1435). A hypothetical maximally exposed individual could have received a total effective dose equivalent of about 0.9 millirem (0.009 millisievert) from radionuclides that were emitted to the atmosphere from all of the sources on the Oak Ridge Reservation in 2006. This is well below the National Emission Standards for Hazardous Air Pollutants standard of 10 millirem (0.1 millisievert) and is about 0.3 percent of the 300 millirem (3 millisievert) that the average individual receives from natural sources of radiation. The calculated collective effective dose equivalent to the entire population within 50 miles (80 kilometers) of the Reservation (about 1,040,041 people) was about 11 person-rem (0.11 person-sievert), which is approximately 0.004 percent of the 312,012 person-rem (3,120 person-sievert) that this population received from natural sources of radiation (UT-Battelle, BWXT Y-12, and BJC 2007).

3.2.11.2 Chemical Environment

Section 3.1.11.2 describes the measures (hazard quotient and hazard index) for chemical hazards. The primary exposure pathways are ingestion of drinking water and fish. For ingestion of drinking water, hazard quotients were estimated upstream and downstream of ETTP discharge points. Hazard quotients were less than 1 for detected chemical analytes for which there are reference doses or maximum contaminant levels (that is, barium, manganese, and acetone). No hazard quotient values equal to or greater than 1 were calculated for consumption of sunfish with the exception of arsenic and Aroclor-1260. For consumption of catfish, hazard quotient values greater than 1 were calculated for arsenic, Aroclor-1254, and Aroclor-1260 at all three sample locations (UT-Battelle, BWXT Y-12, and BJC 2006a).

ETTP operates within the National Emission Standards for Hazardous Air Pollutants and their permit limits on emissions to the air from the TSCA Incinerator and other permitted sources. Discharges to surface water via the National Pollutant Discharge Elimination System-permitted outfalls were in compliance with permit limits more than 99 percent of the time. Groundwater contamination is being addressed through the Comprehensive Environmental Response, Compensation, and Liability Act process, but there is currently no direct exposure pathway to humans from groundwater because groundwater is not currently being used for any purpose. Some species of fish in some water bodies exceed consumption guidelines for polychlorinated biphenyls. These waterways are posted against fishing, and they are currently fenced or guarded to prevent recreational uses.

Monitoring and protection of groundwater resources at ETTP is required by federal and state regulations and DOE Orders. However, because there is no use of this groundwater as a drinking water source, there is no exposure.

3.2.12 Transportation

Two Interstate Highways (I-40 and I-75), and U.S. Highways 11 and 70 are the major transportation routes near the ETTP. Interstate Highway 40 is almost directly west of the ETTP site.

Motorists use four roadway segments near ETTP:

- State Route 95 (Oak Ridge Turnpike) from the State Route 95/58 interchange to Wisconsin Avenue,
- State Route 95 (White Wing Road) from the State Route 95/58 interchange to Bear Creek Road,
- State Route 327 (Blair Road) from Poplar Creek Road to State Route 58, and
- State Route 58 from Gallaher Road to the State Route 95/58 interchange.

Annual average daily traffic for roadways near the study site ranges from 3,280 to 12,050 vehicles a day, which is light in comparison with other roadways in Oak Ridge (which range from 17,040 to 30,360 vehicles a day). The majority of the ETTP commuting traffic (88 percent) comes from the east on State Route 58, and the remaining 12 percent comes from the west. Of the east side traffic, 62 percent comes from the Oak Ridge Turnpike, 8 percent comes from Blair Road, and 18 percent comes from State Route 95 (White Wing Road) (DOE 1997).

Operational characteristics such as delay, congestion, and conflicting movements are often described in terms of levels of service. A level-of-service definition generally describes these conditions in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, convenience, and safety.

Six levels of service, A through F, represent a continuum of operating conditions, where level A is the most desirable (Table 3-10). Many state and city traffic agencies currently consider level of service D acceptable.

Table 3-10. Level of service criteria for roadway segments.

Level	Criteria
A	Traffic flows freely with low volumes and high speeds.
B	Traffic flow is stable, but operating speeds and maneuverability are somewhat restricted because of increased volume.
C	Traffic flow is still stable, but most drivers are restricted in their freedom to select their own speed, change lanes, or pass.
D	Traffic flow approaches instability; tolerable operating speeds are maintained but may drop because of fluctuations in volume and temporary restrictions to flow. Maneuverability is limited.
E	Volumes are at or near the capacity of the roadway. Flow is unstable, speeds are low, and momentary stoppages may occur.
F	Volumes exceed roadway capacity, speeds are very low, and stoppages occur for long or short periods.

The Transportation Research Board used the Highway Capacity Manual (TRB 1994) to analyze roadway segments and found the segments ranged from level of service A to D (Table 3-11). However, construction has been completed to four-lane State Route 58 from Interstate Highway 40 to the ETTP. The state has plans to make the Oak Ridge Turnpike four lanes from the State Route 95/58 interchange to Westover Road in Oak Ridge (TDOT 1999). Once this work is complete the level of service for these roadways should improve.

Table 3-11. Existing levels of service and traffic during the peak traffic hour.

Roadway segment	Peak traffic volume (vehicles per hour)	Level of service
Blair Road	395	C
SR 95 from SR 95/58 interchange to Wisconsin Avenue	955	D
SR 95 from SR 95/58 interchange to Bear Creek Road	970	D
SR 58 from Gallaher Bridge to SR 95/58 interchange	1,210	A

SR = State Route.

3.3 GENERIC INDUSTRIAL SITE

This analysis assumed that any industrial nickel processing facility not at PGDP or ETTP would be at a generic manufacturing facility regulated under an NRC/Agreement State license or otherwise regulated (if located abroad). Because it is not possible at this time to define the location (or locations) of such a facility, the best DOE can do is to describe the essential environmental criteria in specific resource areas that it would have to meet to ensure that the site of the Proposed action was suitable. While the purpose of these criteria is to serve as a checklist to support the procurement process, DOE recognizes that when one or more specific sites are selected, additional information may be needed in specific resource areas to determine the overall suitability of the site.

Land Use. The regional land use should be well-defined, and should include an area suitable for industrial use. The land for development should be zoned to allow location of the facility in or close to existing industrial areas, ideally with existing road and rail access, utility easements, and the ability to install security fences and barriers as required. The location should enable installation of environmental monitoring equipment in compliance with the NRC/Agreement State license or other regulation.

Geology and Soils. The site should have a well-characterized, stable geology with low potential for earthquakes. The soils should be well-drained and have a proven ability to minimize the effects of soil erosion by wind and water, or mechanisms and good practices must be followed to achieve this outcome.

Air Quality. The site should be in an area with relatively good air quality and should allow provisions for dust mitigation during construction. There should be no significant limitations to industrial development based on air quality; for example, limitations that would jeopardize the ability to obtain facility permits to prevent adverse impacts to air quality.

Water Resources. Surface- and groundwater resources should be well characterized so that construction and operation of the industrial facility do not affect them. The site should enable control of storm-water runoff and installation of programs and equipment to prevent spills and sewer line leaks, and control or elimination of liquid effluents. The site should have no limitations that would prohibit facilities from obtaining Pollutant Discharge Elimination System permits in the host state to comply with relevant environmental regulations.

Ecological Resources. Ecological resources, which include threatened and endangered species and the locations of wetlands or other sensitive ecosystems, should be well defined to ensure the preservation of habitats during construction and operation of the facility.

Cultural Resources. Cultural resources near and on the site should be characterized so that potential impacts can be anticipated and avoided.

Noise. Background sources of noise near the site should be well defined; this would include sensitive noise sources such as wildlife areas or housing developments.

Socioeconomics. Socioeconomic conditions should be clearly defined so DOE can evaluate regional impacts.

Environmental Justice. Potential environmental justice concerns, including the locations and nature of affected minority and low-income populations, should be identified.

Waste Management. Waste management requirements for all construction, operation, and decommissioning activities should be well defined and consistent with regional and state requirements and conditions.

3.4 REFERENCES

ACHP (Advisory Council on Historic Preservation), 2002, "Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities (1991), Excerpt." Available at http://www.achp.gov/balancingsum.html.

Allison, T., 2002, "DUF6 County, City, and School District Financial Data," intraoffice memorandum to H. Avci, Argonne National Laboratory, Argonne, Illinois.

ANL (Argonne National Laboratory), 1991, *Environmental Site Description for a Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) Production Plant at the Paducah Gaseous Diffusion Plant Site*, ANL/EAIS/TM-59, Argonne, Illinois.

Battelle, 1978, *Final Report on Environmental Studies at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, to Union Carbide Corporation, Battelle Laboratories, Columbus, Ohio.

BEA (Bureau of Economic Analysis), 2006, “Regional Accounts Data, Table CA30 (May 2003),” available at http://www.bea.gov/regional/reis/drill.cfm.

BEA (Bureau of Economic Analysis), 2007, “U.S. Economic Data.” Available at http://bea.gov, accessed March 2008.

BJC (Bechtel Jacobs Company), 2006a, *Paducah Site Annual Site Environmental Report for 2004*, DOE/OR/07-2233, Volumes I through III, Paducah, Kentucky.

BJC (Bechtel Jacobs Company), 2006b, *Cultural Resources Survey for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, BJC/PAD-688/R1, Paducah, Kentucky.

BLS (Bureau of Labor Statistics), 2002, *Local Area Unemployment Statistics,* U.S. Department of Commerce, Washington, D.C. Available at ftp://ftp.bls.gov/pub/time.series/la/.

Bureau of the Census, 1992, *County Business Patterns, 1990,* Washington, D.C. Available at http://www.census.gov/ftp/pub/epcd/cbp/view/cbpview.html.

Bureau of the Census, 2000, “Bureau of the Census, Summary File 3 (SF 3). Available at http://factfinder.census.gov/, accessed October 7–22, 2002.

Bureau of the Census 2001, “U. S. Census Bureau, State and County Quick Facts.” Available at http://quickfacts.census.gov/qfd/.

Bureau of the Census, 2002a, *U.S. Census American FactFinder.* Available at http://factfinder.census.gov.

Bureau of the Census, 2002b, *County Business Patterns, 2000,* Washington, D.C. Available at http://www.census.gov/ftp/pub/epcd/cbp/view/cbpview.html.

Bureau of the Census, 2002c, *State and County Quickfacts, State of Kentucky and McCracken County, Kentucky,* Washington, D.C. Available at http://quickfacts.census.gov/qfd/states/21/21145.html.

Bureau of the Census, 2007, U.S. Census American FactFinder. Available at http://quickfacts.census.gov, accessed March 2008.

CH2M HILL, 1991, *Results of the Public Health and Ecological Assessment, Phase II at the Paducah Gaseous Diffusion Plant (Draft)*, KY/SUB/13B-97777C, P-03/1991/1.

CH2M HILL, 1992, *Results of the Site Investigation, Phase II at the Paducah Gaseous Diffusion Plant*, KY/SIB/13B-97777C, P-03/1991/1.

City of Oak Ridge, 2005, “City of Oak Ridge, Tennessee, Fiscal Year 2006 Annual Budget.”

City of Oak Ridge, 2006, “City of Oak Ridge, Tennessee, Fiscal Year 2007 Proposed Budget.”

DOE (U.S. Department of Energy), 1995, *Final Report, Environmental Guidelines for Development of Cultural Resource Management Plans*, DOE/EH-0501, Office of Environmental Policy and Assistance, Washington, D.C., August.

DOE (U.S. Department of Energy), 1996a, *Technical Report on Affected Environment for the DOE Sites Considered in the DOE Waste Management Programmatic Environmental Impact Statement*

(WM PEIS), Vols. I and II, META/Berger-SR-01, prepared by META/Berger, Gaithersburg, Maryland.

DOE (U.S. Department of Energy), 1996b, *Remedial Investigation/Feasibility Study of the Clinch River/Poplar Creek Operable Unit*, *Oak Ridge, Tennessee,* DOE/OR/01-1393/V1&D3.

DOE (U.S. Department of Energy), 1997, *Final Environmental Assessment for Lease of Land and Facilities within the East Tennessee Technology Park, Oak Ridge, Tennessee*, DOE/EA-1175, November.

DOE (U.S. Department of Energy), 1999a, *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Vol. 1, Sections 1-8, DOE/OR/07-1777/V1&V2.

DOE (U.S. Department of Energy), 1999b, *Final Environmental Assessment: Proposed Demonstration of the Vortec Vitrification System for Treatment of Mixed Wastes at the Paducah Gaseous Diffusion Plant,* DOE/EA-1230.

DOE (U.S. Department of Energy), 1999c, *Accelerating Clean-Up: Paths to Closure*, Oak Ridge Office, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), 2001a, *Annual Site Environmental Report for Calendar Year 2000*, BJC/PAD-237, prepared by CDM Federal Services, Kevil, Kentucky, for Bechtel Jacobs Company LLC and U.S. Department of Energy, Paducah, Kentucky.

DOE (U.S. Department of Energy), 2001b, *Baseline Human Health Risk Assessment and Screening Ecological Risk Assessment for the Proposed Site of the UF6 Conversion Facility, Including the Eastern Portion of SWMU 194, McGraw Construction Facilities (South Side), at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1928&D1, prepared by Science Applications International Corporation for U.S. Department of Energy, Office of Environmental Management.

DOE (U.S. Department of Energy), 2001c, *Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee*, DOE/ORO 2085, Oak Ridge Operations Office, Washington, D.C., July.

DOE (U.S. Department of Energy), 2002, *Remediation Effectiveness Report for the U. S. Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee,* DOE/OR/01-2011&D0.

DOE (U.S. Department of Energy), 2003a, *Environmental Assessment Addendum for the Proposed Title Transfer of East Tennessee Technology Park Land and Facilities*, DOE/EA-1175-A, Oak Ridge Operations Office, Oak Ridge, Tennessee, July.

DOE (U.S. Department of Energy), 2003b, *Draft Environmental Impact Statement for Construction and Operation of a Depleted Uranium Hexafluoride Conversion Facility at the Paducah, Kentucky, Site*, DOE/EIS-0359, Appendix F, "Assessment Methodologies," Oak Ridge Operations, Office of Environmental Management.

DOE (U.S. Department of Energy), 2006, *2005 Remediation Effectiveness Report for the U.S. Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee*, DOE/OR/01-2211&D1, Oak Ridge, Tennessee.

Early, T. O., et al., 1989, *Groundwater Monitoring Plan for the Paducah Gaseous Diffusion Plant*, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

EDGe, 1987, *Groundwater Monitoring Plan for U.S. Department of Energy Paducah Gaseous Diffusion Plant (DOE/PGDP) Reservation,* EDGe Project No. 1001, prepared by the Design Geosciences Group, Nashville, Tennessee.

EPA (U.S. Environmental Protection Agency), 1974, *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety,* EPA- 550/9-74-004, Washington, D.C.

ERC/EDGe, 1989, *The Geologic Setting of the DOE Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Knoxville, Tennessee.

FedStats, 2007, “Statistical Data for Kentucky.” Available at http://www.fedstats.gov/qf/states/21000.html, accessed March 2008.

Hartman, G. S., 2003, “National Historic Preservation Act, Section 106 Compliance Final Memorandum of Agreement for the Decontamination and Decommissioning of Buildings K-25 and K-27 Located at the East Tennessee Technology Park,” letter to Multiple Addressees, Oak Ridge Office, Oak Ridge, Tennessee, July 18.

Hartman, G. S., 2004, “National Historic Preservation Act, Section 106 Compliance - Final Memorandum of Agreement for Demolition of 108 Buildings/Structures at the East Tennessee Technology Park,” letter to Multiple Addressees, Oak Ridge Office, Oak Ridge, Tennessee, May 4.

Hartman, G. S., 2005, “National Historic Preservation Act, Section 106 Compliance, Final Memorandum of Agreement Regarding Site Interpretation of the East Tennessee Technology Park,” letter to Multiple Addressees, Oak Ridge Office, Oak Ridge, Tennessee, July 18.

Hatcher, R. D., P. J. Lemiszki, R. B. Dreier, R. H. Ketelle, R. R. Lee, D. A. Leitzke, W. M. McMaster, J. L. Foreman, and S. Y. Lee, 1992, *Status Report on the Geology of the Oak Ridge Reservation*, ORNL/TM-12074, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Huotari, J., 2006, “Anderson officials request change in DOE payments,” *The Oak Ridger,* March 14. Available at http://oakridger.com/stories/031406/new_20060314019.shtml.

Kathren, R. L., 1984, *Radioactivity in the Environment: Sources, Distribution, and Surveillance*, Harwood Academic Publishers, New York, New York.

KDFWR (Kentucky Department of Fish and Wildlife Resources), 2000, *Mist Net Surveys for the Indiana Bat at West Kentucky Wildlife Management Area,* Paducah, Kentucky.

KSNPC (Kentucky State Nature Preserves Commission), 1991, *Biological Inventory of the Jackson Purchase Region of Kentucky*, Frankfort, Kentucky.

KSNPC (Kentucky State Nature Preserves Commission), 2000, Response to Data Services Request from SAIC, Request number 01-078, November 14.

Lemiszki, P. J., 1995, *Mesoscopic Structural Analysis of Bedrock Exposures at the Oak Ridge K-25 Site, Oak Ridge, Tennessee,* K/ER-259, Lockheed Martin Energy Systems, Oak Ridge, Tennessee.

LMES (Lockheed Martin Energy Systems, Inc.), 1996, *Paducah Site Annual Environmental Report for 1994,* ES/ESH-60 (KY/EM-79), prepared by Environmental, Safety, and Health Compliance and Environmental Management staffs, Oak Ridge, Tennessee, and Environmental Management Division, Paducah Site, Paducah, Kentucky, for U.S. Department of Energy.

LMES (Lockheed Martin Energy Systems, Inc.), 1997, *Paducah Site Annual Environmental Report for 1996,* KY/EM-206, prepared by Environmental Management Division, Kevil, Kentucky, for U.S. Department of Energy.

MCPSS (McCracken County Public Schools System), 2007, "Description of McCracken County Public Schools." Available at http://www.paducah.k12.ky.us/, accessed March 2008.

Mitchell, J. M., E. R. Vail, J. W. Webb, J. W. Evans, A. L. King, and P. A. Hamlett, 1996, *Survey of Protected Terrestrial Vertebrates on the Oak Ridge Reservation*, Final Report, ES/ER/TM-188/R1, Environmental Restoration Program, Oak Ridge, Tennessee.

MMES (Martin Marietta Energy Systems, Inc.), 1994a, *Paducah Gaseous Diffusion Plant, Annual Site Environmental Report for 1993,* ES/ESH-53 (KY/ERWM-18), prepared by Martin Marietta Energy Systems, Oak Ridge Tennessee, and Paducah, Kentucky, for U.S. Department of Energy, and by Martin Marietta Utility Services for United States Enrichment Corporation.

MMES (Martin Marietta Energy Systems, Inc.), 1994b, *Paducah Gaseous Diffusion Plant, Annual Site Data for 1993,* ES/ESH-55 (KY/ERWM-20), prepared by Martin Marietta Energy Systems, Oak Ridge, Tennessee, and Paducah, Kentucky, for U.S. Department of Energy, and by Martin Marietta Utility Services for United States Enrichment Corporation.

Morris, M. W., 1998, *K-25 Site Cultural Resources Survey Archaeological Reconnaissance*, Jacobs Environmental Management Team, Oak Ridge, Tennessee, March.

Myrick, T. E., Berren, B. A., and Haywood, F. F., 1981, *State Background Radiation Levels: Results of Measurements Taken During 1975−1979*, ORNL/TM-7343, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

NCDC (National Climatic Data Center), undated, *Hourly United States Weather Observations, 1990–1995,* Asheville, North Carolina.

NCRP (National Council on Radiation Protection), 1987, *Ionizing Radiation Exposure of the Population of the United States*, Report 93, Washington, D.C.

NOAA (National Oceanographic and Atmospheric Administration), 2002, *Historical Tornado Data Archive*, Storm Prediction Center. Available at http://www.spc.noaa.gov/archive/tornadoes/index.html. Accessed June 2002.

OMB (Office of Management and Budget), 2000, "Guidance on Aggregation and Allocation of Data on Race for Use in Civil Rights Monitoring and Enforcement," March 9. Available at http://www.whitehouse.gov/omb/bulletins/b00-02.html.

ORNL (Oak Ridge National Laboratory), 1998, *Oak Ridge Reservation Annual Site Environmental Report for 1997*, ES/ESH-78, Oak Ridge, Tennessee, October.

Pennington, G. G., 2001, “Data Submittal for Preparation of the Site-Specific Environmental Impact Statement (EIS) for the Portsmouth and Paducah Conversion Facility Sites,” personal communication to L. D. Boggs (U.S. Department of Energy), Bechtel Jacobs Company LLC.

PPS (Paducah Public Schools), 2007, “Description of Paducah Public Schools.” Available at http://old.paducah.kyschools.us/, accessed March 2008.

Rogers, J. G., and D. L. Ashburn, 1988, *Environmental Surveillance of the U.S. Department of Energy Paducah Reservation and Surrounding Environs during 1987*, ES/ESH-4/V3, prepared by Martin Marietta Energy Systems Oak Ridge, Tennessee, for U.S. Department of Energy.

Sheppard, J.D., 2002, electronic data transmittal from Sheppard (U.S. Department of Energy, Portsmouth, Ohio) to H. Hartmann (Argonne National Laboratory, Argonne, Illinois.).

TCT (Tennessee Comptroller of the Treasury), 2006, *2005 Tennessee Property Tax Rates*. Available at http://170.142.183.29/Panew/.

TDOT (Tennessee Department of Transportation), 1999, Personal communication from TDOT Public Information Office to Julia Gartseff, SAIC, November 4.

TRB (Transportation Research Board), 1994, *Highway Capacity Manual*, Special Report 209, National Research Council, third edition.

TVA (Tennessee Valley Authority), 1991, *Flood Analyses for Department of Energy Y-12, ORNL and K-25 Plants Flood Analyses in Support of Flood Emergency Planning*, ES/CNPE-95/1, prepared for the U. S. Department of Energy, Oak Ridge, Tennessee, December.

U.S. Department of Commerce, 2002, *Regional Accounts Data, Local Area Personal Income,* Washington, D.C. Available at http://www.bea.doc.gov/bea/regional/reis.

USACE (U.S. Army Corps of Engineers), 1994a, *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky, Volume V: Floodplain Investigation, Part A: Results of Field Survey*, Nashville, Tennessee.

USACE (U.S. Army Corps of Engineers), 1994b, *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky; Volume II, Wetlands, Investigation,* Final Report, Volume 2, prepared by Waterways Experiment Station, Corps of Engineers Environmental Laboratory, Vicksburg, Mississippi, and Engineer District Nashville, Nashville, Tennessee, for U.S. Department of Energy, Oak Ridge Operations, Paducah Site Office, Paducah, Kentucky.

USACE (U.S. Army Corps of Engineers), 1994c, *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky; Volume IV, Cultural Resources Investigation; Part A, Results of Field Investigation,* Final Report, Volume 4A, prepared by Waterways Experiment Station, Corps of Engineers Environmental Laboratory, Vicksburg, Mississippi, and Engineer District Nashville, Nashville, Tennessee, for U.S. Department of Energy, Oak Ridge Operations, Paducah Site Office, Paducah, Kentucky.

USACE (U.S. Army Corps of Engineers), 1994d, *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky*, Volume III, Nashville District, Nashville, Tennessee, May.

USACE (U.S. Army Corps of Engineers), 1994e, *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky; Volume IV, Cultural Resources Investigation; Part B, Sensitivity Analysis,* Final Report, Volume 4B, prepared by Waterways Experiment Station, Corps of Engineers Environmental Laboratory, Vicksburg, Mississippi, and Engineer District Nashville, Nashville, Tennessee, for U.S. Department of Energy, Oak Ridge Operations, Paducah Site Office, Paducah, Kentucky.

USDA (U. S. Department of Agriculture), 1942, *Soil Survey, Roane County, Tennessee*, Bureau of Plant Industry, Tennessee Agriculture Experiment Station.

USDA (U.S. Department of Agriculture), 1976, *U.S. Department of Agriculture Soil Survey for McCracken County, Kentucky*.

USDA (U.S. Department of Agriculture), 1994, *Census of Agriculture — County Data, 1992,* National Agricultural Statistics Service, Washington, D.C. Available at http://www.nass.usda.gov/census/census92/agrimenu.htm.

USDA (U.S. Department of Agriculture), 1999, *Census of Agriculture, Volume 1: Geographic Area Series,* Washington, D.C.

USDA (U.S. Department of Agriculture), ca. 2003, "2002 Census of Agriculture County Profile, McCracken, Kentucky." Available at www.nass.usda.gov/Statistics_by_State/Kentucky/Publications/Cp/cp72.pdf. Accessed October 30, 2007.

USGS (U.S. Geological Survey), 2002, National Land Cover Data. Available at http://edc2.usgs.gov/scripts/mapserv.exe?map=d%3A%5CInetpub%5Cwwwroot%5Clccp%5Cnlcd%5Cnlcd.map&zoomsize=2.

UT-Battelle, BWXT Y-12, and BJC (Bechtel Jacobs Company), 2006a, *Oak Ridge Reservation Annual Site Environmental Report for 2005*, DOE/ORO/2218, Oak Ridge, Tennessee, September.

UT-Battelle, BWXT Y-12, and BJC (Bechtel Jacobs Company), 2006b, *Environmental Monitoring on the Oak Ridge Reservation: 2005 Results*, DOE/ORO-2220, Oak Ridge, Tennessee, September.

UT-Battelle, BWXT Y-12, and BJC (Bechtel Jacobs Company), 2007, *Oak Ridge Reservation Annual Site Environmental Report for 2006*, DOE/ORO-2233, Oak Ridge, Tennessee, September.

CHAPTER 4. ENVIRONMENTAL CONSEQUENCES

This chapter evaluates the environmental consequences of the proposed action and of the two alternatives that this environmental assessment considers (disposal as radioactive waste and the no-action alternative). Because there is uncertainty about future industrial processes and processing locations, DOE cannot conduct a full quantitative analysis for most of the resource and subject areas this assessment considers. Therefore, DOE has conducted a qualitative evaluation for most areas; the exceptions are human health and transportation. For these two areas, the Department used a bounding analysis approach to quantify and estimate potential impacts. A bounding analysis relies on assumptions to produce results that will not underestimate the most likely potential impacts. For example, for low-level radioactive waste or mixed-waste disposal facilities, the assessment analyzed the facility farthest from the point of waste generation for transportation impacts, regardless of whether that facility would actually receive and dispose of the waste. This approach provides DOE the flexibility to consider a range of available options for which there is an adequate description of the extent of potential environmental impacts.

4.1 PROPOSED ACTION– DISPOSITION OF NICKEL FOR CONTROLLED RADIOLOGICAL USE

The nickel process steps in Figure 2-1 for the disposition of nickel for controlled radiological use under the proposed action could occur at PGDP in Paducah, Kentucky, ETTP in Oak Ridge, Tennessee, or a generic manufacturing facility. In addition, Steps 3 to 5 could occur abroad. This section discusses the estimated environmental consequences for the disposition steps at those three locations. For the analysis, DOE assumed Steps 1, 2, and 3 would occur at PGDP, ETTP, or a generic site in the United States, and that Steps 4 and 5 would occur at a generic manufacturing facility in the United States. Separate sections discuss the potential transportation and human health impacts across all disposition steps, regardless of location. For the disposition steps that could occur outside the United States (that is, Steps 3 through 5), DOE did not estimate environmental consequences in foreign countries because they are “willing acceptors” and any activities under the proposed action would be subject to the regulatory requirements of the host country. As Section 2.1 describes, DOE would have the ability to include contract requirements to ensure that any activities under the in another country would be subject to regulatory controls. Although DOE recognizes that a ship that transported the nickel could sink, the potential environmental consequences would be very low because the nickel or alloyed material would not readily disperse in the ocean and because it would contain very low levels of residual radioactive material. Once through Steps 1 and 2, the nickel would comply with IAEA clearance levels, which define contamination levels that have minimal radiation consequences on human health and the environment, and which many Agency member nations have accepted. This is a conservative approach to help ensure that human and environmental impacts would be minimal if there was an inadvertent release of the nickel after decontamination.

4.1.1 Paducah Gaseous Diffusion Plant, Paducah, Kentucky

As Figure 2-1 shows, Proposed Action Steps 1 to 3 [Resizing and Declassification; Decontamination (purification with the option of alloying); and Alloying, Fabrication, and Equipment Manufacture] could occur at PGDP. The following paragraphs describe the qualitative impacts to the identified resource and subject areas, Sections 4.1.4 and 4.1.5 discuss potential impacts to human health and transportation, respectively.

Land Use. Step 1 of the proposed action involves melting the nickel ingots and scrap for resizing and declassification converting it to forms suitable for Step 2, which is decontamination (purification and optional alloying). Step 3 involves optional alloying, followed by fabricating and equipment manufacturing. These facilities would each need roughly 10 to 20 acres (0.04 to 0.08 square kilometer) and could be at any location on the 3,556-acre (14.4-square-kilometer) site. Locating these facilities at PGDP should have minimal impacts on land use because the facilities could be in areas that were previously disturbed for industrial uses. The PGDP site has existing roads and utility easements, security fences and barriers, and environmental monitoring; therefore, construction and operations activities for the proposed action should have minimal impacts on overall land use.

Geology and Soils. Although site clearing, grading, contouring, and facility construction could alter the topography of the development area, such activities should not affect geologic formations. Seismic risks in the vicinity of PGDP are of some concern, and structure design would have to conform to appropriate seismic standards. Construction would disturb soils and could cause the removal of some topsoil. However, requirements would be included in the sales contract to replace topsoil after completion of the buildings and access roads and to landscape unpaved areas to mitigate erosion. Therefore, construction and operation of the facilities for the proposed action at PGDP should have minimal impacts on geology and soils.

Air Quality. The current air quality is good in the PGDP region, with attainment area designations [that is, in compliance with the National Ambient Air Quality Standards for 8-hour ozone, carbon monoxide, sulfur dioxide, nitrous oxide, and lead (DOE 2007a)]. However, construction and operation of the facilities necessary for the proposed action could minimally affect air quality. During construction, emissions from vehicle and equipment exhaust and fugitive dust from vehicle traffic and disturbance of soils would be unlikely to affect local air quality adversely. These emissions would include carbon monoxide, nitrogen dioxide, sulfur dioxide, particulates, and hydrocarbons. Particulate emissions would consist primarily of airborne soil. Adverse impacts would be unlikely because the emissions from site preparation and construction would be sporadic, temporary, and localized (with the exception of those from personal vehicles of construction workers and vehicles transporting construction materials and equipment to the site). In addition, natural dispersion by local winds would decrease concentrations of pollutants in the ambient air as the distance from the construction site increased. Increments of pollutants from worker vehicles and construction vehicles and equipment would be unlikely to cause exceedances of primary or secondary National Ambient Air Quality Standards.

Specific details about atmospheric pollutants that facility operations could emit are not yet available. However, a requirement of the sales contract would be to ensure that the facility design and effluent control systems would ensure compliance with the National Ambient Air Quality Standards, including those for radioactive effluents. If required, the successful bidder would obtain the appropriate permits before construction and operation. Conventional treatment technologies, such as baghouse dust collectors or particulate filters, could be a required part of facility design. Potential emissions would be unlikely to result in a violation of air quality standards, and DOE anticipates minimal adverse impacts to air quality for the proposed action.

Water Resources. The greatest potential impacts to surface water on and near the construction site for the facilities at PGDP would be from soil erosion, runoff, and sedimentation; from a fuel, hazardous material, or waste spill; or from a sewer line leak. If the impacts could not be avoided, DOE would require the successful bidder to obtain aquatic resource alteration permits from the State of Kentucky before any construction activities. Changes in surface topography during construction could lead to alteration of local surface-water hydrology. These impacts could be avoided or mitigated depending on soil contouring measures during construction, the establishment of stream buffer areas, and the use of best management practices (that is, silt fences, straw bales, and temporary sediment detention basins). Storm-water runoff permits could be required from the state for the new facilities. The Kentucky Pollutant Discharge Elimination System permit would regulate all effluent discharges. The use of safety procedures and spill prevention plans would address impacts from accidental spills. Therefore, DOE does not anticipate adverse surface-water impacts. In addition, it is not anticipated that groundwater would be extracted to support operations. Impacts to groundwater quality could occur from fuel or waste spills or sewer line leaks, with subsequent migration of contamination to the water table. However, the facilities would use safety procedures, spill plans, and spill response plans in accordance with state and federal requirements to prevent or minimize the severity of potential impacts from accidents. Therefore, DOE anticipates no adverse impacts to water resources.

Ecological Resources. Although industrial activities have disturbed candidate construction areas at PGDP, DOE would consider locations across the entire site. Therefore, there is a potential that construction of these facilities would result in the removal of existing vegetation during grading. However, because of the limited area necessary for these facilities, approximately 10 to 20 acres (0.04 to 0.08 square kilometer) for each facility, this would not result in a significant loss of habitat in the short term. DOE does not expect to affect surface waters because it would require the use of soil-contouring measures during construction, establishment of stream buffer areas, and use of best management practices (that is, silt fences, straw bales, and temporary sediment detention basins). Therefore, the Department anticipates minimal impacts to terrestrial or aquatic habitats or other ecological resources. However, given the size of the PGDP site, it might be necessary to review the potential for construction and operation of the facilities to cause adverse effects on local ecological habitats. If sensitive areas were identified, they would be avoided to minimize potential impacts.

Cultural Resources. In 2004, a cultural resources survey of the PGDP inventoried all buildings and structures that were built into the early 1990s in accordance with Kentucky survey standards. As a result, the proposed PGDP Historic District includes a large area that has remained in continuous industrial production since 1952 (BJC 2006). Construction of the proposed facilities would probably occur on previously disturbed land in industrial areas of the site, which would minimize impacts to cultural resources. However, given the size of the site, and with the knowledge gained from the survey, once an exact location is selected, it might be necessary to perform an additional cultural resource survey to confirm that impacts on cultural resources would be minimal.

Noise. PGDP is in a rural setting, and there are no residences or other sensitive receptor locations (for example, schools, or hospitals) in the immediate vicinity. Consistent with current conditions, DOE anticipates no major noise impacts during either construction or operation of the proposed facilities because it should be possible to locate them on the site in a manner that minimized noise impacts. In addition, DOE does not anticipate adverse noise impacts from traffic due to the relatively small workforce necessary for construction and operation of the facilities and the lack of local sensitive receptors. DOE expects that the design of the facilities would contain noise within the building structures. Therefore, the Department does not expect adverse noise impacts during operation of the facilities.

Socioeconomics. Potential socioeconomic impacts for development of the facilities would depend on several factors, which include the employment recruiting strategy, the nature of the facilities and their operation, and the timing of the construction and operation activities. Socioeconomic impacts are important not only in themselves, but also for the secondary environmental distributional effects they could have. For example, economic growth can sometimes attract enough new people to an area that it places pressure on housing, schools, water supply, and other infrastructure. However, because of the relatively small size of the proposed facilities and the relatively small workforce, and although DOE conservatively assumed that all the nickel would be processed in about 8 years, with an annual throughput of 2,000 tons (1,810 metric tons) per year, the Department still expects that secondary impacts would be minimal.

Environmental Justice. In terms of environmental justice, this analysis suggests that there would be no high or adverse human health or environmental impacts; however, the actual impacts could depend on the siting and design of the proposed facilities. Bureau of the Census information for areas near PGDP indicates that 42 of 173 census tracts had a higher proportion of minorities in the population than the national average. In terms of income, 109 of 204 census tracts in the region had low-income populations in excess of state-specific thresholds. However, because of the mixture of minority and low-income population tracts around the site, the potential impacts of adverse events would be likely to have at least as much effect on all population groups. Therefore, DOE does not expect adverse health and environmental impacts that could occur under the proposed action to have a disproportionate effect on low-income and minority populations.

Waste Management. Operation of the proposed facilities at PGDP would be in full compliance with applicable rules and regulations from the Commonwealth of Kentucky and the U.S. Environmental Protection Agency. All waste from construction, operation, or decontamination and decommissioning of facilities would be disposed of at an appropriate DOE or regulated commercial waste disposal facility. Therefore, DOE anticipates that impacts from management of wastes from the proposed action would be minimal in comparison with the amount of waste from other local DOE activities.

4.1.2 East Tennessee Technology Park, Oak Ridge, Tennessee

As Chapter 2 describes, the successful bidder could choose to perform Steps 1 to 3 [Resizing; Decontamination (purification with the option of alloying); and Alloying, Fabrication, and Equipment Manufacture] at ETTP in Oak Ridge, Tennessee. The following paragraphs describe the qualitative impacts on the identified resource and subject areas, with the exception of human health and transportation (Sections 4.1.4 and 4.1.5, respectively).

Land Use. Under the proposed action, Step 1 involves melting of the nickel ingots and scrap into forms suitable for Step 2, which is decontamination (purification and optional alloying). Step 3 involves optional alloying followed by fabricating and equipment manufacturing. These facilities would each require roughly 10 to 20 acres (0.02 to 0.032 square kilometer). Locating these facilities at previously disturbed industrial locations on the roughly 800 acres (3.24 square kilometers) at ETTP would have minimal impacts. Further, the industrial locations at ETTP have existing roads and utility easements, security fences and barriers, and environmental monitoring. Therefore, construction and operations would have minimal impacts on overall land use.

Geology and Soils. Although site clearing, grading, contouring, and facility construction could alter the topography of the construction area, the activities would not affect geologic formations. Seismic hazards are relatively low in the Oak Ridge area, and structure design and construction would conform to appropriate seismic standards. Construction would disturb soils and could involve removal of some topsoil. However, if these facilities were constructed at ETTP, there would be a requirement in the sales contract to replace topsoil after the buildings and access roads were complete and would landscape unpaved areas to mitigate erosion. Therefore, construction and operation of the facilities necessary for the proposed action at ETTP would have no adverse impacts on geology or soils.

Air Quality. The current air quality in the ETTP region is good, with attainment area designations; that is, they are in compliance with the National Ambient Air Quality Standards for 8-hour ozone, carbon monoxide, sulfur dioxide, nitrous oxide and lead levels (DOE 2007b). Construction and operation could affect air quality for Step 1 through 3 facilities. During construction, emissions from vehicle and equipment exhaust and fugitive dust from vehicle traffic and disturbance of soils would not be likely to affect local air quality adversely. These emissions would include carbon monoxide, nitrogen dioxide, sulfur dioxide, particulates, and hydrocarbons. Particulate emissions would consist primarily of airborne soil. Emissions from site preparation and construction would be sporadic, temporary, and localized (except for emissions associated with the worker commuting and transport of construction materials and equipment to the site). Natural dispersion by local winds would decrease the concentrations of pollutants in the ambient air with increasing distance from the construction site. Increments of pollutants from worker vehicles and construction vehicles and equipment would not be likely to cause exceedances of primary or secondary National Ambient Air Quality Standards. Specific details about atmospheric pollutants that operations could emit are not yet available. However, under requirements specified in the sales contract, the facility design and effluent control systems would ensure that the National Ambient Air Quality Standards, including those for radioactive effluents, would be met. Further, new facilities at ETTP would be required to be evaluated for their potential to produce air emissions and to meet all applicable federal and state regulations in relation to air quality and permitting requirements. The successful bidder would be required to obtain the appropriate permits before construction and operation. Conventional treatment technologies, such as baghouse dust collectors or particulate filters, could be a required part of facility design. Given the requirement to construct a facility at ETTP, potential emissions would not be likely to result in an exceedance of air quality standards, and no adverse impacts to air quality would be likely.

Water Resources. The greatest potential impact to surface water on and near the construction site for the facilities necessary for the proposed action at ETTP would be from soil erosion, runoff, and sedimentation; from a fuel, hazardous material, or waste spill; or from a sewer line leak. If impacts could not be avoided, it would be necessary to obtain aquatic resource alteration permits from the State of Tennessee before construction began. Changes in surface topography during construction could lead to alteration of local hydrology. These impacts could be avoided or mitigated with soil contouring measures during construction, the establishment of stream buffer areas and the use of best management practices (that is, silt fences, straw bales, and temporary sediment detention basins). DOE expects the new facilities would require storm-water runoff permits from the state. Wastewater discharges would be to existing treatment facilities in Oak Ridge. The use of safety procedures and spill prevention and response plans would also address impacts from accidental spills. Therefore, DOE does not expect surface-water impacts. Groundwater is not permitted to be extracted and used at ETTP. Therefore, groundwater will not be used during operations. Impacts to groundwater quality could occur from fuel or waste spills and sewer line leaks, and the contaminants could then migrate to the water table. However, safety procedures and spill prevention and response plans would be required for facilities for Steps 1 through 3 in accordance with state and federal requirements to prevent or minimize the severity of potential impacts from accidents. Therefore, the Department does not expect adverse impacts to groundwater or surface-water resources.

Ecological Resources. Although activities at ETTP have disturbed many areas at the site, development of the construction site for the proposed action Steps 1 through 3 facilities could result in the removal of existing vegetation during grading. However, because of the limited area necessary for these facilities – about 10 to 20 acres (0.04 to 0.08 square kilometer) for each facility – this would not result in a significant loss of a habitat in the short term. The use of soil contouring measures during construction, establishment of stream buffer areas, and use of best management practices (that is, silt fences, straw bales, and temporary sediment detention basins) would minimize potential impacts to terrestrial or aquatic habitats or other ecological resources. However, once an exact location is selected for the facilities at ETTP, it could be necessary to review the potential for construction and operation of the facilities to affect local ecological habitats adversely. If sensitive areas were identified, there would be an attempt to avoid those areas to minimize potential impacts.

Cultural Resources. Because the facilities for Steps 1 through 3 would be on previously disturbed land in industrial areas of the ETTP, impacts to cultural resources would not be likely. However, once an exact location was selected, it could be necessary to perform a cultural resources survey to confirm that the impacts on cultural resources would be minimal.

Noise. DOE does not expect major noise impacts during construction or operations of the proposed action facilities at ETTP. Consistent with current conditions, no major noise impacts are likely because it should be possible to locate them at the ETTP in a manner to minimize noise impacts. In addition, adverse noise impacts from traffic would not occur because of the relatively small workforce necessary for construction and operations. In addition, and consistent with best management practices and requirements, the facilities would be designed to contain noise within the buildings. Therefore, DOE does not expect adverse noise impacts during operations.

Socioeconomics. Potential socioeconomic impacts for development of the proposed action Steps 1 through 3 facilities at the ETTP would depend on several factors, including the employment recruiting strategy, the nature of the facilities and their operation, and the timing of construction and operations activities. Socioeconomic impacts are not only important in themselves, but also for the secondary environmental distributional effects they can have. For example, economic growth can sometimes attract enough new people to an area that it places pressure on housing, schools, water supply, and other infrastructure. However, because of the relatively small size of these facilities, their relatively small workforce, and the fact that they would process all of the DOE nickel in about 8 years, with an annual throughput of 2,000 tons (1,810 metric tons) per year, secondary impacts would be minimal.

Environmental Justice. In terms of environmental justice, this analysis suggests that there would be no high or adverse human health or environmental impacts, but the actual impacts could depend on the siting and design of the proposed facilities. Bureau of the Census information for the area near ETTP indicates that there are few census tracts with a higher proportion of minorities in the population than the national average, and that many census tracts have low proportions of minorities. Because of the mixture of these population tracts around ETTP, the potential impacts of adverse events would be likely to have at least as much effect on all population groups. The same would be true of low- and higher income populations around ETTP. Therefore, any adverse health and environmental impacts that could occur would not be likely to have a disproportionate effect on low-income and minority populations.

Waste Management. The successful bidder would build and operate the proposed action facilities at ETTP in full compliance with applicable rules and regulations from the State of Tennessee and the Environmental Protection Agency. All waste from construction, operations, or decontamination and decommissioning of facilities would be disposed of at an appropriate DOE or commercial waste disposal facility. Therefore, impacts from management of wastes would be minimal in comparison with other local DOE activities.

4.1.3 Generic Industrial Site

In addition to evaluating the location of nickel processing facilities at PGDP and ETTP, this environmental assessment also considers a generic manufacturing facility. The facility would be regulated under an NRC/Agreement State license, DOE control, or, if located abroad, by the appropriate authority. Because it is not possible at this time to define the location (or locations) of these facilities, this section describes construction and operations impacts in a general qualitative manner. However, the following discussion provides a summary of essential environmental criteria that facility construction and operations would have to meet to ensure that the impacts of the proposed action at a facility would not be significant.

Land Use. A generic facility should have minimal land use impacts. This can be accomplished by locating facilities in existing industrial areas with road or rail access, utility easements, security fences and barriers, and the ability to impose environmental monitoring under an NRC/Agreement State license or, for implementation of Steps 3 to 5 of the proposed action, other regulatory requirements.

Geology and Soils. Construction and operations should have minimal impacts in terms of geology and soils. The site should be in an area that presents minimal seismic risks, or construction should include appropriate methods to minimize facility risks. Facility construction should occur in a manner to minimize disturbance of soils. Topsoil replacement and landscaping of unpaved areas after construction would minimize erosion.

Air Quality. A generic facility should maintain local air quality during both construction and operations. Measures to achieve minimal air quality impacts would include dust mitigation during construction and effluent control systems for operations to ensure there would be no exceedances of primary or secondary National Ambient Air Quality Standards. If necessary, a generic facility would be required to obtain appropriate permits to prevent adverse impacts to air quality.

Water Resources. Construction and operation of a generic facility must minimize impacts on surface- and groundwater resources. Facilities would include storm-water runoff controls, programs and equipment to prevent and respond to spills and sewer line leaks, and controls to reduce or eliminate liquid effluents. These facilities would need to obtain Pollutant Discharge Elimination System permits and comply with all relevant environmental regulations.

Ecological Resources. Impacts on ecological resources should be minimal. However, because of the limited area necessary for these facilities – about 10 to 20 acres (0.04 to 0.08 square kilometer) for each facility – this would not result in a significant loss of a habitat in the short term. Impacts to surface waters and aquatic ecosystems would be minimized through the use of soil contouring measures during construction, the establishment of stream buffer areas, and the use of best management practices (that is, silt fences, straw bales, and temporary sediment detention basins). The new facilities would obtain necessary storm-water runoff permits. Once an exact location (or locations) was selected for the nickel disposition facilities, it could be necessary to review the potential for construction and operation of the facilities for impacts to specific local habitats. If there were sensitive areas, siting and construction activities should avoid them to minimize potential impacts.

Cultural Resources. Once an exact location was selected, it may be necessary to perform a cultural resources survey to confirm that impacts on cultural resources would be minimal.

Noise. Although significant noise impacts as a result of the type of planned operations would be unlikely, facility designs should ensure that operational noise is contained within the buildings. In addition, due to the relatively small workforce necessary for construction and operations of the proposed action facilities, noise impacts from traffic would be minimal.

Socioeconomics. Potential socioeconomic impacts would be minimized if the facilities were on existing industrial or previously disturbed sites and if they maintained all effluents within regulatory limits.

Environmental Justice. Care should be taken in evaluating candidate sites and facilities to determine the locations of potentially affected minority and low-income populations to ensure minimal impacts.

Waste Management. Waste management requirements for all construction, operation, and decommissioning activities should be well defined and consistent with regional and state requirements and conditions.

4.1.4 Human Health

This section discusses estimates of the potential human health impacts from the proposed action in terms of radiation doses and risks, industrial injuries and fatalities, and hazardous chemical exposures. For radiation exposures, the analysis used the RESRAD-RECYCLE (Cheng et al. 2000) computer program, part of the RESRAD (Yu et al. 2001) family of computer programs, to assess the radiation doses from the nickel disposition processing steps. Argonne National Laboratory designed RESRAD-RECYCLE to provide a comprehensive assessment of radiation doses and risks from recycling and reusing radioactively contaminated metals and equipment. The program uses information from several previous assessments of metal recycling activities (IAEA 1992; Nieves et al. 1995; O'Donnell et al. 1978; SCA 1997). Short-term (total effective dose equivalent from 1 year of exposure), and long-term (lifetime) doses to the users of manufactured products, serve as the basis for estimates of risk. Input to RESRAD-RECYCLE includes the radionuclide concentrations associated with the DOE nickel, the total quantity of the nickel, and the processing steps that were identified and discussed in Chapter 2. Lost-time injuries and fatalities were estimated using injury and fatality rated from the Bureau of Labor Statistics and the estimated labor hours for each processing step. Finally, a qualitative analysis for hazardous chemical exposure is developed and discussed.

4.1.4.1 Radionuclide Concentrations

To estimate potential human health impacts from exposure to radioactively contaminated nickel, it was necessary to determine the radionuclides present and their concentrations for each of Steps 1 to 5 of the proposed action (Figure 2-1). Table 4-1 lists the estimated initial radionuclide concentrations for the nickel at PGDP and ETTP. The total activity is dominated by technetium-99, which makes up over 99 percent of the total radioactivity. Radionuclide concentrations for each processing step were estimated using the RESRAD-RECYCLE computer program. Appendix A contains details of the analysis.

Table 4-1. Summary of average radioactive properties for PGDP nickel ingots and ETTP shredded nickel.

	PGDP nickel ingots		**ETTP shredded nickel**	
Radionuclide	**Activity (pCi/g[a])**	**Relative contribution**	**Activity (pCi/g[a])**	**Relative contribution**
Technetium-99	2.59×10^{4} (b)	1.00	3.99×10^{3}	1.00
Cesium-137	4.21×10^{-3} (b)	1.63×10^{-7}	1.31×10^{-3}	3.28×10^{-7}
Thorium-230	6.66×10^{-4}	2.57×10^{-8}	2.07×10^{-4}	5.19×10^{-8}
Uranium-234	9.87×10^{-1}	3.81×10^{-5}	3.68×10^{-1}	9.22×10^{-5}
Uranium-235	4.55×10^{-2}	1.76×10^{-6}	2.49×10^{-2}	6.24×10^{-6}
Uranium-238	1.05	4.05×10^{-5}	2.55×10^{-1}	6.39×10^{-5}
Neptunium-237	5.36×10^{-1}	2.07×10^{-5}	5.06×10^{-4}	1.27×10^{-7}
Plutonium-238	1.84×10^{-2}	7.10×10^{-7}	1.88×10^{-5}	4.71×10^{-9}
Plutonium-239	4.11×10^{-2}	1.59×10^{-6}	3.13×10^{-5}	7.84×10^{-9}
Americium-241	1.84×10^{-2}	7.10×10^{-7}	1.31×10^{-5}	3.28×10^{-9}
Total	**2.59×10^{4}**	**1.00**	**3.99×10^{3}**	**1.00**

a. pCi/g = picocuries per gram; divide by 27 to convert to becquerels per gram.
b. Where 2.59×10^{4} equals 25,900 and 4.21×10^{-3} equals 0.00421.

Although it is highly likely that the nickel would be used to make alloys, for bounding purposes, the analysis assumed all manufacturing steps and product end use would use pure nickel rather than alloyed products. The process of alloying would typically reduce the radionuclide concentrations to about 10 percent of their concentrations in the nickel after decontamination. Therefore, the assumption of pure nickel products does not underestimate radiation doses.

The purified product would have to meet IAEA clearance levels (IAEA 2004). The analysis determined whether the values would be met by using the ratios of the radionuclide concentrations in the purified product to their respective clearance levels and summed those values over all radionuclides in the mixture (i.e., the sum of fractions rule). To be compliant with the clearance levels, the sum of these ratios must be less than or equal to unity (1). To ensure a bounding analysis for human health impacts from the controlled radiological use of nickel products, DOE used the maximum allowable radionuclide concentrations under the clearance levels (Table A-8) as the basis of the human health analysis (that is, the concentrations that would result when the sum of fractions equals unity). Table 4-2 lists the relative radionuclide contributions at the clearance levels.

Table 4-2. Relative radionuclide contributions at IAEA clearance levels.[a]

Radionuclide	Clearance level (Bq/g)	Clearance level (pCi/g)	Relative PGDP contribution at clearance level (pCi/g)	Relative ETTP contribution at clearance level (pCi/g)
Technetium-99	1	27	2.70×10^{1}	2.70×10^{1}
Cesium-137	0.1	2.7	5.60×10^{-8} (b)	1.13×10^{-7}
Thorium-230	1	27	1.77×10^{-9}	3.58×10^{-9}
Uranium-234	1	27	2.63×10^{-6}	6.36×10^{-6}
Uranium-235	1	27	1.21×10^{-7}	4.30×10^{-7}
Uranium-238	1	27	2.79×10^{-6}	4.40×10^{-6}
Neptunium-237	1	27	1.43×10^{-6}	8.74×10^{-9}
Plutonium-238	0.1	2.7	4.89×10^{-8}	3.25×10^{-10}
Plutonium-239	0.1	2.7	1.09×10^{-7}	5.41×10^{-10}
Americium-241	0.1	2.7	4.89×10^{-8}	2.26×10^{-10}
Total			$\mathbf{2.70 \times 10^{1}}$	$\mathbf{2.70 \times 10^{1}}$

a. Bq/g = becquerels per gram; pCi/g = picocuries per gram.

b. Where 5.60×10^{-8} equals 0.000000056.

4.1.4.2 Radiation Exposure Scenarios

To evaluate the potential for human health impacts from the proposed action, the analysis used two types of radiation exposure scenarios: (1) industrial workers under radiological controls, and (2) doses to members of the public from airborne effluents from the metal processing facilities. As Appendix A discusses, the analysis selected existing exposure scenarios in RESRAD-RECYCLE that are representative of the steps of the proposed action (Figure 2-1). Numerous scenarios were evaluated for each process step to identify the maximum exposed individual.

- Although RESRAD-RECYCLE allows modifications of exposure parameters for development of user-defined scenarios, the DOE analysis for the proposed action used default values in the software for most parameters and exposure scenarios to create an easily reproducible and understandable analysis. Appendix A contains tables of the detailed RESRAD-RECYCLE results for each facility and site.

For evaluation of potential radiation exposures from the DOE nickel, the analysis used industrial radiation worker scenarios to estimate dose and risk to workers who would process the nickel under radiological controls for Steps 1 through 4. For the resizing, declassification and decontamination steps, DOE assumed all generated waste (including baghouse dust, slag, and slimes) would be disposed as radioactive waste. For the fifth step, use of finished products, the analysis used controlled end-use scenarios for the dose and risk to individuals who would be exposed to residual radioactivity in the products. For this evaluation, DOE defined three example controlled product scenarios: shielding blocks, radioactive waste containers, and a large component for use in a commercial nuclear reactor. These scenarios represent a broad set of potential products that could be fabricated from the nickel.

To bound the estimates of annual doses and risks to workers and risks the public from airborne effluents, DOE assumed 15,300 tons (13,880 metric tons) of nickel would be processed in 1 year, even though the estimated throughput for the electro-winning and carbonyl processes would be only 2,000 tons (1,814 metric tons) of nickel per year. The total exposure to individual industrial workers would be limited by the hours they worked in a year, which relates to the total mass of metal to be processed.

4.1.4.3 Radiation Exposure Regulations

For radiation work under DOE control (e.g., Steps 4 and 5), 10 CFR Part 835 contains regulations that provide regulatory limits for occupational radiation exposures. For work in NRC-licensed facilities, 10 CFR Part 20 contains the regulations that provide the regulatory limits for occupational doses. In general, for occupational doses, these regulations contain the same annual dose limits, which limit the doses to workers to the lesser of:

- The total effective dose equivalent being equal to 5 rem (0.05 sievert); or
- The annual limits to the lens of the eye, to the skin of the whole body, and to the skin of the extremities which are:
  - A lens dose equivalent of 15 rem (0.15 sievert),
  - A shallow-dose equivalent of 50 rem (0.5 sievert) to the skin of the whole body, and
  - A shallow-dose equivalent of 50 rem (0.5 sievert) to the skin of any extremity.

Table 4-3 summarizes the estimated labor hours for proposed action Steps 1 to 3 that the analysis used to estimate worker radiation doses.

Table 4-3. Estimated numbers of workers and work hours for Proposed Action Steps 1 through 3.

Step	Number of workers	Number of hours	Number of worker years
Step 1: Declassification	31	66,010	33
Step 2: Decontamination	31	66,010	33
Step 3: Fabrication	35	42,250	21.1
Totals	**97**	**174,270**	**87.1**

For members of the public, DOE Order 5400.5, *Radiation Protection of the Public and Environment*, provides the basic radiation dose limits. For NRC-licensed facilities, 10 CFR Part 20 provides similar dose limits. The public radiation dose limit is a total effective dose equivalent limit of 100 millirem (1.0 millisievert) per year from all sources. This limit includes both internal and external doses through all pathways, including food, as each specific exposure scenario requires.

Under the provisions of the Clean Air Act, 40 CFR Part 61 limits the radiation dose to members of the public downwind of a DOE-controlled radiological facility at the location of the maximum annual air concentration as a consequence of routine DOE operations to be 10 millirem (0.1 millisievert) per year.

To express radiation doses in terms of health effects, the analysis used the Environmental Protection Agency-recommended conversion factor of 0.00006 latent cancer fatality per rem (0.0000006 per sievert) to individuals, or per person-rem (person-sievert) to populations of workers and the public, to calculate, respectively, the probability of contracting a latent fatal cancer for an individual and the estimated number of latent cancer fatalities in the exposed populations of workers and the public (Eckerman et al. 1999).

The estimated individual worker doses and risks from RESRAD-RECYCLE are the same for all sites for the proposed action Steps 1 through 3. This is because the analysis assumed the same number of workers, work categories, radionuclide concentrations, total mass of nickel, and exposure durations and conditions. The analysis assumed each step would occur in different years, so there would be no additive doses for individual workers from working at more than one facility in a year. This means that all of the bounding individual worker doses are independent of the site or location of the specific facilities. Table 4-4 identifies the maximally exposed individuals for each step in the process and their calculated doses after exposure to the nickel. The maximally exposed individual represents the bounding individual and the limiting radiation exposure scenario across all work categories for each step of the proposed action. Because of uncertainties in relation to recovery and disposal of the end-use products, the analysis assumed the doses during product use would bound those of recovery and disposal.

LATENT CANCER FATALITIES FROM IONIZING RADIATION

A latent cancer fatality is a death from a cancer that results from, and occurs an appreciable time after, exposure to ionizing radiation. Death from radiation-induced cancers can occur any time after the exposure. However, latent cancers generally occur from 1 year to many years after exposure.

The U.S. Environmental Protection Agency has suggested the use of a conversion factor of 0.00006 latent cancer fatalities per person-rem (0.006 per person-sievert). This means that for every 10,000 person-rem (100 person-sievert) of collective dose, about 6 people would develop a radiation-induced cancer during their lifetimes (Eckerman et al. 1999). These fatalities would be in addition to those that would occur in the same population if the 10,000 person-rem dose did not occur.

Applying the same conversion to the individual dose, the result is the individual increased lifetime probability of developing a latent fatal cancer. For example, if an individual received a dose of 0.033 rem (0.00033 sievert), that individual's probability of a latent fatal cancer from that dose over a lifetime would be 0.00005 (that is, 0.033 rem times 6 divided by 10,000, or 0.00033 sievert times 6 divided by 100). This risk corresponds to 1 chance in 50,000 of a latent cancer fatality during that individual's lifetime. To place the significance of the additional risk into context, the average individual has approximately 1 chance in 4 of dying from cancer (a risk of 0.25).

Because estimates of latent cancer fatalities are statistical, the results often indicate less than 1 latent cancer fatality for cases that involve low doses or small populations. For instance, if a population collectively received a dose of 500 person-rem (5 person-sievert), the number of potential latent cancer fatalities would be 0.3. If the estimated number of latent cancer fatalities is less than 0.5, none would be likely.

Table 4-4. Bounding individual worker radiation doses.[a]

Nickel disposition step	MEI workers (millirem/year)	MEI workers limiting scenario
Step 1: Declassification	1.5	Slag worker
Step 2: Decontamination	3.6	Slag worker
Step 3: Fabrication	1.4×10^{-5} (b)	Warehouse worker
Step 4: End use	2.1×10^{-5}	Shielding blocks
Step 5: Disposal	2.1×10^{-5}	Shielding blocks

a. MEI = maximally exposed individual; to convert millirem to millisievert, multiply by 0.01.

b. Where 1.4×10^{-5} equals 0.000014.

As Table 4-4 shows, all of the individual worker radiation doses would be a small fraction of the 5-rem (0.05-sievert) annual dose limit for workers. Further, the doses for Steps 1 and 2 would be higher than the doses for Steps 3 to 5, which would occur after decontamination of the nickel to meet the IAEA clearance levels.

Table 4-5 summarizes the bounding individual worker lifetime probabilities of latent cancer fatalities. Consistent with the small radiation doses, the estimated probability of latent cancer fatalities would be small. These latent cancer fatalities were estimated using the radiation dose-to-risk factors in Federal Guidance Report No. 13 (Eckerman et al. 1999). Because estimates of latent cancer fatalities are statistical, the results often indicate less than 1 latent cancer fatality for cases that involve low doses or small populations. If the estimated number of latent cancer fatalities is less than 0.5, none would be likely. The bounding estimated worker probabilities of latent cancer shown in Table 4-5 for all of the steps of the proposed action are far less than 0.5. There are no regulatory limits on collective worker dose or risk. Therefore, given the small individual worker doses and risks, and given the small number of workers involved, collective worker doses and risks were not evaluated.

Table 4-5. Bounding estimated worker probabilities of latent cancer fatalities for the Proposed Action.

Nickel disposition step	Individual worker lifetime risk
Step 1: Declassification	8.6×10^{-7}[a]
Step 2: Decontamination	2.1×10^{-6}
Step 3: Fabrication	8.0×10^{-12}
Step 4: End-use shield blocks	1.2×10^{-11}
Step 5: Disposal	1.2×10^{-11}

a. LCFs = latent cancer fatalities and where 8.6×10^{-7} equals 0.00000086.

For the public, DOE conducted a sensitivity study of potential radiation doses to the maximally exposed individuals for airborne releases using the RESRAD-OFFSITE (Yu et al. 2007) computer program with atmospheric effluents that were estimated using RESRAD-RECYCLE. The results indicated annual doses of less than 1 millirem (0.01 millisievert). These values are an insignificant percentage of the normal background radiation dose, are a small fraction of the dose limit of 40 CFR Part 61, are consistent with current DOE operations, and equate to an individual probability of an latent cancer fatality of less than 0.000001 (1 chance in 1 million). Therefore, the proposed action would not result in quantitative doses or risks to members of the public.

Because there would be no high-energy sources (e.g., explosives) that could lead to radiological accidents during nickel disposition, there would be little potential for offsite radiological consequences from accidents. Further, as demonstrated by the small worker and downwind public doses, the radioactive concentration of radionuclides would be quite low. The analysis of public health impacts concluded that the potential impacts from transportation of radioactive materials, including low-level radioactive waste, would exceed those from any onsite accidents. Therefore, this analysis did not consider specific accidents during nickel disposition activities that could involve exposure of offsite members of the public to radiation.

Last, decontamination and decommissioning of these facilities would occur under either DOE controls or NRC/Agreement State licenses. These actions would be covered under the appropriate National Environmental Policy Act documentation (that is, use in regulated or licensed facilities, decontamination and decommissioning of those facilities, and license termination actions). However, given the low concentrations of residual radionuclides that would be present, significant radiological impacts to either the facility workers or the downwind public would be unlikely. As a worst case, the radiological impacts in Table 4-5 would bound the impacts during facility decontamination.

4.1.4.4 Estimated Industrial Lost-Time Injuries and Fatalities

To estimate the number of potential nonfatal and fatal occupational injuries that could result from implementation of Steps 1 to 3 of the proposed action, the analysis used data on lost-time injury and fatality rates from the Bureau of Labor Statistics (BLS 2006). There was no analysis for Step 4 (use of the manufactured products) and Step 5 (disposal) because those activities would be part of regulated or licensed activities and, if appropriate, covered under existing National Environmental Policy Act documentation. The industrial injury and fatality data were for the year 2005 for Tennessee, Kentucky, and the average United States (to serve as the basis for the generic site). The data are specific to metal product manufacturing and construction. Table 4-6 summarizes the data (Table 4-3 provides numbers of workers and labor hours for these calculations).

Table 4-6. Worker lost-time injury and fatality rates for metal product manufacturing and construction.[a]

Location	Metal product manufacturing		Construction	
	Injury rate	**Fatality rate**	**Injury rate**	**Fatality rate**
Tennessee	2.0/100 workers	6.0/100,000 workers	1.5/100,000 workers	17/100,000 workers
Kentucky	2.5/100 workers	4.0/100,000 workers	1.9/100,000 workers	18/100,000 workers
Average U.S.	1.9/100 workers	2.4/100,000 workers	2.4/100,000 workers	11/100,000 workers

a. Source: BLS (2006).

Table 4-7 lists the estimated occupational lost-time injuries and fatalities. The total number of facility operations lost-time injuries over Steps 1 to 3 would be about 2 for each of the sites. The estimated number of fatalities for operation of these facilities would be far less than 1. Even if these estimates were doubled, they would still indicate relatively small numbers of lost-time injuries and fatalities in comparison with other routine industrial operations.

Table 4-7. Estimated facility operations lost-time injuries and fatalities for the Proposed Action.

Disposition step	PGDP		ETTP		Generic site	
	Injuries	**Fatalities**	**Injuries**	**Fatalities**	**Injuries**	**Fatalities**
Step 1: Declassification	0.83	0.0013	0.66	0.0020	0.63	0.0008
Step 2: Decontamination	0.83	0.0013	0.66	0.0020	0.63	0.0008
Step 3: Fabrication	0.53	0.0008	0.42	0.0013	0.40	0.0005
Totals	**2.18**	**0.0035**	**1.74**	**0.0052**	**1.66**	**0.0021**

In addition to occupational injuries and fatalities during facility operations, the analysis estimated injuries and fatalities during construction and demolition. Construction of either the electro-winning or carbonyl facilities would bound the overall construction estimates because of the specialty equipment necessary for these processes. Industrial experience indicated that construction of either the electro-winning or carbonyl facility would probably to require a frame-and-metal skin building on a concrete slab at grade. However, the acquisition of process equipment for both types of decontamination facilities would probably be the schedule drivers. This would include electrical step-down and control equipment for the electro-winning process (converting 1- to 3-megawatt alternating current to low-voltage, high-amperage direct current) and boiler pressure vessels for the carbonyl process. Both of these types of equipment are long-lead industrial equipment, typically available within 1 year after order. As a result, the construction time for both types of facilities would be about 18 months to include the lead time to order the equipment. Assuming an average full-time workforce of 30 construction workers over the entire 18-month period, the total estimated labor to construct these facilities would be 45 worker years. Table 4-8 lists the total lost-time injury and fatality estimates for construction of the facilities for proposed action Steps 1 to 3. The total number of facility construction lost-time injuries over the Steps 1 to 3 would be about 2 to 3 at each of the sites. The estimated number of construction fatalities for these facilities would be far less than 1 for each. Even if these estimates were doubled, they would still indicate relatively small numbers of lost-time injuries and fatalities in comparison with other routine industrial operations.

Table 4-8. Estimated construction worker lost-time injuries and fatalities for the Proposed Action.

Disposition step	ETTP		PGDP		Generic site	
	Injuries	**Fatalities**	**Injuries**	**Fatalities**	**Injuries**	**Fatalities**
Step 1: Declassification	0.86	0.0081	0.68	0.0077	1.08	0.0050
Step 2: Decontamination	0.86	0.0081	0.68	0.0077	1.08	0.0050
Step 3: Fabrication	0.86	0.0081	0.68	0.0077	1.08	0.0050
Totals	**2.58**	**0.024**	**2.04**	**0.023**	**3.24**	**0.015**

Decontamination and demolition of these facilities would occur under either DOE controls or NRC/Agreement State license. These actions would be covered under the appropriate National Environmental Policy Act documentation. If demolition occurred (after decontamination), as a worst case, the lost-time injuries and fatalities among demolition workers would be less than the estimated impacts for facility construction (Table 4-8) because the time to demolish facilities would be less than the time to construct them.

4.1.4.5 Occupational Exposures to Hazardous Chemicals

DOE conducted a qualitative analysis for hazardous chemical exposure. Because of the potential range of processing methods, and because of potential uncertainty about the technologies for the various process steps, it is impossible to identify the specific chemical hazards workers might encounter in a quantitative manner. Because proposed action activities would occur at DOE-controlled or NRC-licensed (or otherwise regulated) facilities, they would occur in a manner that would comply with all pertinent environmental safety and health agency regulations. Among the required procedures would be the development of a health and safety plan commensurate with the chemical and other hazardous materials present during operation of the facilities. These plans would identify potential chemical hazards for the resizing, decontamination, and fabrication steps. The identified chemical hazards would relate to the nickel feedstock (including nickel toxicity and potential contamination with asbestos or other hazardous materials), process hazards (including metal vapors, the use of various chemicals, potential exposures to heavy metals, and hydrogen generation), and waste management concerns (including mixed low-level radioactive and hazardous chemical waste). Employee health and safety programs at the facilities would comply with all appropriate requirements of the Occupational Safety and Health Administration or other appropriate authority. Facility operators would minimize occupational hazards through strict compliance with applicable requirements, and the appropriate authorities would conduct inspections to verify compliance. Last, the potential chemical hazards would not be unique to the proposed action; they would be consistent with similar hazards in the metal purification and manufacturing industries. Therefore, consistent with current industrial experience, the facility design and operation would occur in a manner that would protect workers and the environment from chemical risks.

4.1.5 Transportation

Under the proposed action, the analysis focused on the radiological and nonradiological human health impacts from the shipment of 15,300 tons of nickel to various facilities that would include resizing, decontamination and purification, fabrication, end-use, and disposal facilities. In addition, the analysis evaluated the transportation impacts from disposal of the nickel at a DOE- or NRC-licensed low-level radioactive waste disposal site. The transportation analysis considered the quantity and radioactive properties of the nickel, possible shipping configurations (i.e., size of trucks and packaging), and routing to determine both incident-free and accidental impacts. As a result of the shipment of materials to processing and low-level radioactive waste disposal facilities under the proposed action, there would be both nonradiological and radiological impacts on workers (i.e., truck drivers) and the public along the transportation route. Maximally exposed individuals and populations have been identified for both of these groups. For nonradiological impacts, there would be an increase in traffic on national roads and highways and on roads that access the sites from nearby highways. Potential transportation impacts could include traffic congestion on local highways, increased air pollution from vehicle emissions, increased potential for traffic accidents, potential radiation doses to individuals who shared the transportation corridor with radioactive material shipments, and radiation doses from transportation accidents that involved radioactive materials.

The following sections discuss potential nonradiological and radiological transportation impacts in relation to shipment of materials as part of the proposed action. Appendix B describes the analytical methods for estimation of nonradiological impacts and radiological impacts.

4.1.5.1 Nonradiological Transportation Impacts

Potential nonradiological transportation impacts include impacts to highway capacity (that is, level of service), increased fatalities from vehicle emissions, and increased risk of injuries and fatalities from traffic accidents.

4.1.5.1.1 Impacts to Highway Capacity

For PGDP or ETTP, the analysis assumed that loaded trucks that left the site would return empty for reloading, and that the proposed action would be complete within 1 year. The increased truck traffic on the local roads and highways would be about 280 trucks per year and 486 trucks per year for PGDP and ETTP, respectively (Appendix B, Table B-1). Under the assumption that the increased truck traffic would occur during 250 working days per year, the increase in daily truck traffic on the roads and highways near PGDP and ETTP would be less than 2 trucks per day. This increase in the daily truck traffic at these facilities would have a small adverse impact on the current level of service for the roads and highways in either region.

4.1.5.1.2 Vehicle Emissions

The analysis focused on the incremental risks from inhalation of nonradiological particulate emissions from transportation under the proposed action. These emissions would primarily be in the form of tire and brake particulates, diesel-fuel exhaust, and fugitive dust (resuspended particulates from the roadway). Strong epidemiological evidence exists that suggests that increases in ambient air concentrations of PM_{10} leads to increases in fatalities (EPA 1993). At present, it is assumed that no threshold exists and that the dose response functions for most health effects in relation to PM_{10} exposure, including premature mortality, are linear over the investigated concentration ranges (EPA 1996). Fatalities can result from respiratory or cardiovascular diseases. These fatalities are expressed as nonradiological latent cancer fatalities.

The analysis was based on a method (DOE 2002a) in which the risk of fatal exposure to particulate emissions (potential for latent cancer fatalities) is a function of total emissions from transportation (DOE 2002b). Table 4-9 lists the unit risk factors. The local population of about 14 million people who would live along the shipping routes (Appendix B, Table B-3) is also an input to the analysis.

Table 4-9. Vehicle emission unit risk factors.

Vehicle class	Weight (tons)[a]	Tire/brake particulates (g/km)[b]	Fugitive dust (g/km)	Diesel exhaust (g/km)	Total emissions (g/km)	Unit risk factor (fatalities/km/ person/km^2)[c]
Class VIIIB trucks[d]	40	0.030	0.26	0.141	0.43	1.5×10^{-11}

Source: DOE (2002b).

a. Assumed 40 tons (36 metric tons) per shipment.

b. g/km = grams per kilometer; to convert to ounces per mile, multiply by 0.05677.

c. km^2 = square kilometer; to convert to square miles, multiply by 0.3861.

d. Class VIIIB trucks include heavy-duty trucks with a gross vehicle weight of 60,001 pounds (27,216 kilograms) or more.

Under the proposed action, the increase in total number of vehicle miles would be about 5.5 million miles (8.9 million kilometers) (Appendix B, Table B-3) over that for the no-action alternative. Under the conservative assumption that these additional miles would occur within a 1-year period, inhalation exposure to vehicle emissions could result in an additional 0.064 nonradiological latent cancer fatality; a probability of 1 in 15 (Appendix B, Table B-12). This very small risk would represent a fraction of the more than 120,000 estimated fatalities per year from all causes (CDC 2002) that would otherwise be likely to occur in the affected population of 14 million people along the shipping routes (Appendix B, Table B-3).

4.1.5.1.3 Traffic Accidents

The analysis estimated the round-trip miles for two-way truck shipments under the proposed action at about 5.5 million miles (about 8.9 million kilometers) (Appendix B, Table B-3) under the assumption that all trucks would return from the processing and disposal facilities empty for reuse.

Based on the predicted total two-way truck mileage, and using the national accident injury and fatality rates for trucks of 3.85×10^{-7} per truck mile (2.39×10^{-7} per truck kilometer) and 2.285×10^{-8} per truck mile (1.42×10^{-8} per truck kilometer), respectively, the potential for injuries and fatalities in local traffic accidents could increase by 2.11 and 0.125, respectively (Appendix B, Table B-13). For traffic fatalities, because the predicted risk is less than 1, it is likely that no truck-related fatalities would occur under the proposed action. This risk represents a very small fraction of the more than 120,000 estimated fatalities per year from all causes (CDC 2002) that would otherwise be likely to occur in the affected population along the shipping routes. About 2 injuries could occur in traffic accidents.

4.1.5.2 Radiological Impacts from Routine Transportation and Transportation Accidents

This section summarizes the results of an analysis of the potential for increases in the number of radiological latent cancer fatalities after potential radiation exposures due to transportation under the proposed action. The analysis considers the population of transportation workers (that is, truck crews) and members of the general public who would work, live along, or share the proposed transportation routes. Appendix B describes the method for estimation of these effects in more detail.

The shipment of radioactive materials under the proposed action would result in an estimated increase in latent cancer fatalities of 1.12×10^{-8} and 3.91×10^{-8} in the general public and the transportation workers (truck crews), respectively (Appendix B, Table B-19). The increase in the risk of a latent cancer fatality to the maximally exposed member of the public would be 2.94×10^{-14} (Appendix B, Table B-19). Because of the uncertainties in dose response to low dose rates, the impact estimates provide a general indication of possible health impacts (the potential number of induced cancers), but readers should not interpret these estimates as exact numbers of induced cancers or as an indication of who could contract a cancer. If the estimated number of latent cancer fatalities is less than 0.5, none would be likely. The bounding estimated worker probabilities of latent cancer due to transportation for the proposed action are far less than 0.5.

Section B.4 of Appendix B describes the methods for estimation of radiological impacts from transportation accidents. The increase in the number of latent cancer fatalities from the maximum reasonably foreseeable accident would range from 3.08×10^{-6} to 9.25×10^{-6} latent cancer fatality for accidents that could occur in rural and suburban areas, respectively (Appendix B, Table B-20). The increase in the risk of a latent cancer fatality to the maximally exposed individual from exposure to radioactive materials from an accident would be 1.84×10^{-7} (Appendix B, Table B-20). These increases in potential latent cancer fatalities would be small in that they would be small fractions of the 3.2 million cancer deaths from all sources likely to occur in the affected populations. These increases in latent cancer fatalities from the incident-free transportation of radioactive materials would be small in that they would be very small fractions of the likely number of cancer fatalities from all sources in a population similar to the size of the population along the proposed truck transportation routes (that is, about 14 million).

4.1.6 Intentional Destructive Acts

Since the terrorist attacks of September 11, 2001, the Federal Government has initiated nationwide measures to reduce the threat of sabotage. These measures include security enhancements to prevent terrorists from gaining control of commercial aircraft including more stringent screening of airline passengers and baggage by the Transportation Security Administration, increased presence of Federal Air Marshals on many flights, improved flight crew training, and implementing measures to better secure aircraft cockpits.

In light of the need for heightened security, DOE evaluated the proposed action for impacts from potential intentional destructive acts, such as those that might result from a terrorist attack. The evaluation involves qualitative comparison to the radiological impacts of the proposed action itself. As the low doses show, the low concentrations of radionuclides in the nickel would deliver very low doses to either workers or members of the public. The evaluation of potential accidents concluded that, because there would be no high-energy sources (e.g., explosives) that could lead to accidents that involved radioactive material during nickel disposition, there would be little potential for offsite radiological consequences from accidents. Therefore, the impacts of sabotage events would have little potential for downwind distribution of significant quantities of radioactive material. The major impact of such events would be to disrupt normal facility operations, and they would have little or no impact on general populations, the environment, or the national economy. Further, the proposed facilities would operate under DOE controls or NRC/Agreement State licenses, which include provisions for security to reduce the potential for sabotage among other events. Finally, the proposed facilities would be unlikely targets of sabotage in comparison to facilities more important to the infrastructure of the United States. Therefore, even in the unlikely event that sabotage occurred at the proposed nickel disposition facilities, the impacts on the regional population, environment, and national economy would be small.

4.2 DISPOSAL AS RADIOACTIVE WASTE

The analysis for this alternative to the proposed action evaluated two options for disposal of the nickel in a DOE-controlled low-level radioactive waste landfill: (1) DOE could transport and directly dispose of the nickel in a classified DOE low-level radioactive waste disposal facility, and (2) DOE could ship the nickel to a facility for melting (similar to Step 1 of the proposed action) before disposal in a DOE-controlled or NRC-licensed low-level radioactive waste disposal facility. There would be no need to decontaminate the nickel because the radionuclide concentrations would be well within the waste acceptance criteria at DOE and NRC-licensed facilities.

The bounding option in terms of impacts would be disposal after melting at a regulated facility because it would require construction, operation, decontamination, and decommissioning of a metal melting facility. The potential impacts for the evaluated resource and subject areas would be less than the impacts for the proposed action because this option would involve fewer facilities and fewer industrial processing steps. For example, construction and operation of a melting facility would have minimal impacts on overall land use because there would be several locations at ETTP, PGDP, or a generic site that have existing industrial locations with existing roads, utility easements, security fences and barriers.

As Section 4.1 describes, and consistent with expected construction and operations, there would be minimal adverse impacts on geology and soils, air quality, and water resources. Sites would be available that would result in minimal adverse impacts on ecological resources or cultural resources because there would be minimal modification to the landscape, which would minimize potential damage to ecological habitats or historical structures. The design, construction, and operation of the melting facility would occur in a manner that would limit the potential for adverse noise impacts. There would be minimal socioeconomic or environmental justice impacts by siting the melting facility at ETTP, PGDP, or a generic location. There would also be minimal impacts to waste management because the facility would be under DOE controls with waste minimization programs in place.

The following sections describe impacts to human health and transportation.

4.2.1 Human Health

In general, the DOE nickel would represent a small fraction of the low-level radioactive waste that DOE site remediation programs generate, and the radionuclide concentrations would be very low in comparison with the established low-level radioactive waste disposal waste acceptance criteria for either DOE-controlled or NRC-licensed facilities. In addition to DOE controls and NRC/Agreement State license requirements, all disposal actions would comply with applicable environmental laws and regulations, including National Environmental Policy Act documentation. For disposal of the DOE nickel in a DOE-controlled or NRC-licensed low-level radioactive waste landfills, all work would occur under conditions the controlling agency would define in its radiation protection programs. Therefore, all worker doses would be maintained at levels below the regulatory limits in 10 CFR Part 835 or 10 CFR Part 20, and could be lower through application of the as low as reasonably achievable process.

DOE has made previous estimates of the potential human health impacts for disposal of the PGDP nickel (DOE 1995) under the assumption that 1 percent of the nickel would be corroded and would uniformly disperse in the soil. The waste barrier would be breached after termination of operations. For this situation, a RESRAD (Yu et al. 2001) computer analysis estimated the peak radiation dose to a member of the public would be 1 millirem (0.01 millisievert) per year. The estimated lifetime latent cancer fatality risk would be about 5×10^{-7}(1 chance in 2 million), which is considerably less than the risk range that the Environmental Protection Agency considers to be acceptable for cleanup actions under Comprehensive Environmental Response, Compensation, and Liability Act, which is from 10^{-4} to 10^{-6} (1 in 10,000 to 1 in 1 million chance). The analysis did not estimate collective dose to members of the public because of the large uncertainties in development of potential exposure scenarios and because of the small individual doses the analysis estimated for the proposed action. There should be little potential for occupational exposures to hazardous chemicals for this alternative, especially because occupational safety controls would be in place. In addition, there would be little potential for sabotage events because DOE or NRC/Agreement State license controls and security procedures would be in place.

4.2.2 Transportation

Under the disposal as low-level radioactive waste alternative, DOE would dispose of the entire inventories of nickel at PGDP and ETTP at a DOE-controlled or NRC-licensed low-level radioactive waste facility. The analysis assumed the facility would be 3,000 miles (about 4,800 kilometers) away. To bound the transportation impacts of this alternative, DOE assumed it would first ship the nickel about 1,000 miles (about 1,600 kilometers) to a melting facility.

4.2.2.1 Nonradiological Impacts

Nonradiological impacts from disposal of the nickel as low-level radioactive waste alternative would include the possible impacts to levels of service on local and national roadways, increased fatalities from vehicles emissions, and increased risk of injuries and fatalities from traffic accidents.

4.2.2.1.1 Impacts to Highway Capacity

For the nickel at PGDP and ETTP, under the assumptions that empty trucks would return for reloading and that the operation would take 1 year, the increased truck traffic on the local roads and highways would be about 280 trucks per year and 486 trucks per year, respectively (Appendix B, Table B-2). Under the further assumption that the increased truck traffic would occur during 250 working days per year, the increase in daily truck traffic on the roads and highways near PGDP and ETTP would be less than 2 vehicles per day. This increase in the daily truck traffic at these facilities would have a small adverse impact on the current levels of service for the regional roads and highways.

Under the assumption that all of the nickel inventory would go to a single melting facility, and that the empty trucks would return for reloading, the increased truck traffic on the local roads and highways near the melting facility would be about 1,500 trucks per year or about 6 trucks per day (Appendix B, Table B-2). If DOE determined a final location for such a facility after deciding to proceed with this option, DOE would evaluate level-of-service impacts as part of future National Environmental Policy Act reviews.

4.2.2.1.2 Vehicle Emissions

Under this alternative, the number of vehicle miles would increase by about 3.1 million miles (4.9 million kilometers) (Appendix B, Table B-3) in comparison with the no-action alternative. Conservatively assuming that these additional miles would occur within a 1-year period, inhalation exposure to vehicle-related emissions could result in an additional 0.036 latent cancer fatality (1 chance in 28; Appendix B, Table B-12). This very small risk would represent a fraction of the more than estimated 33,000 fatalities per year from all causes (CDC 2002) that would otherwise be likely to occur in the affected population of 3.9 million along the transportation routes (Appendix B, Table B-3).

4.2.2.1.3 Traffic Accidents

The analysis estimated that round-trip miles for two-way truck shipments under the disposal as low-level radioactive waste alternative would be about 3.1 million miles (about 4.9 million kilometers) (Appendix B, Table B-3), under the assumption that all trucks would return from the melting and disposal facilities empty for reuse. Based on the predicted mileage and using the national accident injury and fatality rates for trucks (Section 4.1.5.1.3), the potential for injuries and fatalities from local traffic accidents would increase by 1.18 and 0.070, respectively (Appendix B, Table B-13). For traffic fatalities, because the predicted risk is less than 1, no truck-related fatalities would be likely under this alternative. This risk represents a very small fraction of the more than 33,000 estimated fatalities per year from all causes (CDC 2002) that would otherwise be likely to occur in the affected population along the shipping routes. About one injury could occur.

4.2.2.2 Radiological Impacts from Routine Transportation and Transportation Accidents

The shipment of materials under the disposal as low-level radioactive waste alternative would result in an estimated increase in latent cancer fatalities of 9.25×10^{-9} and 2.19×10^{-8} in the affected general population and the truck crews, respectively (Appendix B, Table B-19). The increase in the risk of a latent cancer fatality to the maximally exposed member of the public would be 1.14×10^{-14} (Appendix B, Table B-19). These increases in latent cancer fatalities from the incident-free transportation of radioactive materials would be small in that they would be very small fractions of the likely number of cancer fatalities from all sources in a population similar to the size of the population along the proposed truck transportation corridor (that is, about 3.9 million).

Because the maximum reasonably foreseeable accident under this alternative would be the same as that for the proposed action, the increase in the number of latent cancer fatalities would be the same. That is, the estimated impacts would range from 3.08×10^{-6} to 9.25×10^{-6} latent cancer fatalities for accidents that could occur in rural and suburban areas, respectively, and the increase in the risk of an latent cancer fatality to the maximally exposed individual from exposure to radioactive materials from an accident would be 1.84×10^{-7} (Appendix B, Table B-20).

These increases in potential latent cancer fatalities and accident fatalities would be small in that they would be small fractions of the number of cancer deaths from all sources likely to occur in the affected populations – about 91,000 cancer fatalities from all sources in the affected population of 3.9 million. Long-term indirect effects would be unlikely after a radiological accident because of the requirements for cleanup by local, state, and federal authorities.

4.3 NO ACTION – CONTINUED STORAGE

For all of the resource and subject areas this evaluation considered for ETTP nickel, and for most of the resource and subject areas for PGDP nickel, there would be minimal impacts from continued storage of the DOE nickel because it would not involve facility construction and operation, disposal, or transportation. Therefore, discussion of potential adverse impacts is not required. Potential exceptions for the nickel at PGDP include impacts to geology, soils, and water resources because the nickel is outdoors on a storage pad where there is a potential for soil contamination either from past activities or from future storage of the ingots. Because of the continuing presence of the nickel ingots at this location, it is impracticable to sample soil directly under and around the ingots, so that complete characterization, impact analysis, and remediation of potential impacts are not currently possible. Therefore, there is a potential impact to soils because of the potential for transport of contaminants from the surface of the ingots through the soil to surface water. However, DOE considers this potential to be low because the radioactive contamination is uniform throughout the nickel ingots (not just on the surface), the contamination levels are relatively low and, with the exception of a very thin layer of oxidation on the surface, the nickel is insoluble in water.

4.4 REFERENCES

Anigstein, R., H. J. Chmelynski, D. A. Loomis, S. F. Marschke, J. J. Mauro, R. H. Olsher, W. C. Thurber, and R. A. Meck, 2003, *Radiological Assessments for Clearance of Materials from Nuclear Facilities*, NUREG-1640, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Washington, D.C., June.

BJC (Bechtel Jacobs Company), 2006, *Cultural Resources Survey for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, BJC/PAD-688/R1, Paducah, Kentucky.

BLS (Bureau of Labor Statistics), 2006, "National Census of Fatal Occupational Injuries in 2005," U.S. Department of Labor, available at http://www.bls.gov/iif/osh_nwrl.htm#cases.

CDC (Centers for Disease Control and Prevention), 2002, "Deaths, percent of total deaths, and death rates for the 15 leading causes of death in 10-year age groups by race and sex: United States 2000," National Vital Statistics System, Washington, D.C.

Cheng, J.-J., B. Kassas, C. Yu, D. LePoire, J. Arnish, E. S. Dovel, S. Y. Chen, W. A. Williams, A. Wallo, III, and H. Peterson, 2000, *RESRAD-RECYCLE: A Computer Model for Analyzing the Radiological Doses and Risks Resulting From the Recycling of Radioactive Scrap Metal and the Reuse of Surface-Contaminated Material and Equipment*, ANL/EAD-3, U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

DOE (U.S. Department of Energy), 1995, *Environmental Assessment: Proposed Sale of Radioactively Contaminated Nickel Ingots Located at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/EA-0994, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), 2007a, *Office of Health, Safety and Security, Detailed NAAQS Information for Paducah Gaseous Diffusion Plant*. Available at http://homer.ornl.gov/nuclearsafety/nsea/oepa/guidance/caa/naaqa/showcity.cfm.

DOE (U.S. Department of Energy), 2007b, Office *of Health, Safety and Security, Detailed NAAQS Information for East Tennessee Technology Park*. Available at http://homer.ornl.gov/nuclearsafety/nsea/oepa/guidance/caa/naaqa/showcity.cfm.

DOE (United States Department of Energy), 2002a, *A Resource Handbook on DOE Transportation Risk Assessment*, DOE/EM/NTP/HB-01, Office of Environmental Management, Washington, D.C., July.

DOE (United States Department of Energy), 2002b, *Final Environmental Impact Statement for a Geological Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, DOE/EIS-0250-F, Office of Civilian Radioactive Waste Management, Washington, D.C., February.

Eckerman, K. F., R. W. Leggett, C. B. Nelson, J. S. Puskin, and A. C. B. Richardson, 1999, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Radionuclide-Specific Lifetime Radiogenic Cancer Risk Coefficients for the U.S. Population, Based on Age-Dependent Intake, Dosimetry, and Risk Models*, Federal Guidance Report No. 13, EPA 402-R-99-001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C., September.

EPA (U.S. Environmental Protection Agency), 1993, *Motor Vehicle-Related Air Toxics Study*, EPA 420-R-93-005, Ann Arbor, Michigan.

EPA (U.S. Environmental Protection Agency), 1996, *Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific Technical Information,* EPA-452/R-96-013, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

IAEA (International Atomic Energy Agency), 1992, *Application of Exemption Principles to the Recycle and Reuse of Material from Nuclear Facilities*, Safety Series No. 111-P-1.1, Vienna, Austria.

IAEA (International Atomic Energy Agency), 2004, *Application of the Concepts of Exclusion, Exemption and Clearance,* Safety Guide No. RS-G-1.7, Vienna, Austria.

Nieves, L. A., S. Y. Chen, E. J. Kohout, B. Nabelssi, R. W. Tilbrook, and S. E. Wilson, 1995, *Evaluation of Radioactive Scrap Metal Recycling*, ANL/EAD/TM-50, U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

O'Donnell, F. R., et al., 1978, *Potential Radiation Dose to Man from Recycle of Metals Reclaimed from a Decommissioned Nuclear Power Plant*, NUREG/CR-0313, prepared for the U.S. Nuclear Regulatory Commission, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

SAIC (Science Applications International Corporation), 2001, *ALARA Evaluation of Recycling/Reuse of Metal from the U.S. DOE Gaseous Diffusion Plants at Oak Ridge, Tennessee, Paducah, Kentucky, and Portsmouth, Ohio*, prepared for the National Center of Excellence for Metals Recycle, U.S. Department of Energy, Oak Ridge, Tennessee.

SCA (S. Cohen and Associates), 1997, *Evaluation of the Potential for Recycling of Scrap Metals from Nuclear Facilities*, prepared for the U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, McLean, Virginia.

Yu, C., A. J. Zielen, J.-J Cheng, D. J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo III, W. A. Williams, and H. Peterson, 2001, *User's Manual for RESRAD, Version 6*, ANL/EAD/-4, U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

Yu, C., E. Gnanapragasam, B. M. Biwer, S. Kamboj, J.-J Cheng, T. Klett, D. LePoire, A. J. Zielen, S. Y. Chen, W. A. Williams, A. Wallo, S. Domotor, T. Mo, and A. Schwartzman, 2007, *User's Manual for RESRAD-OFFSITE, Version 2*, ANL/EVS/TM/07-1, U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

CHAPTER 5. CUMULATIVE IMPACTS

Cumulative impacts are defined as "…the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7). This environmental assessment considers impacts on a cumulative basis because significant effects in the same geographic area over the same timeframe could be the result of numerous actions that individually appear to be minor. It also considers cumulative impacts over their lifetimes, rather than the duration of the actions.

Chapter 4 evaluates impacts of the proposed action as well as two other alternatives – disposal as radioactive waste and the no-action alternative – in specific resource areas to serve as a baseline. If a resource area would have no or minimal impacts from the proposed action, there would also be no or minimal cumulative impacts from the action. However, DOE must consider other actions in the same geographic area over the same timeframe that could result in impacts when combined with those of the proposed action.

The preceding discussions of the affected environment and environmental consequences considered a generic site because the exact site for several of the facilities is currently unknown. Because cumulative impacts are highly site specific, cumulative impacts could not be assessed for the generic site because the exact location and conditions are currently unknown. When specific sites are identified, additional analysis would be required to determine cumulative impacts under the National Environmental Policy Act.

This section identifies present and reasonably future actions DOE considers pertinent to the analysis of cumulative impacts, and discusses the potential cumulative impacts by resource area.

5.1 POTENTIAL CUMULATIVE ACTIONS

DOE reviewed the current and proposed industrial actions at PGDP and ETTP to identify those that could contribute to the impacts from the proposed action. The following paragraphs summarize the identified actions for each site.

5.1.1 Potential Cumulative Actions, Paducah, Kentucky

While DOE is no longer enriching uranium at PGDP, that activity continues at the site under control of the United States Enrichment Corporation. DOE focuses its resources and efforts on environmental restoration and the management of waste from previous enrichment and other current activities at PGDP. DOE activities and other industrial activities, including private industry enrichment, at or near the site include (DOE 2002):

- Environmental Management Program. The role of the Environmental Management Program at PGDP is to find, analyze, and correct site contamination problems as quickly and inexpensively as possible. The following ongoing projects have potential environmental impacts: (1) site waste infrastructure, (2) site waste operations, (3) routine surveillance and maintenance, (4) long-term surveillance and maintenance, (5) treatment processes for remediation of low-permeability soils, (6) groundwater fence line action, (7) decontamination and decommissioning of C-410 with removal of trichloroethelene, and (8) site scrap metal removal and disposal.

- Inactive Facility Decontamination and Decommissioning Program. The PGDP Uranium Program was established to provide surveillance and maintenance of unleased inactive DOE facilities and land areas that the Environmental Management Program does not address. There are 15 inactive facilities, and about 200 acres (0.8 square kilometer) of land area that the Uranium Program maintains. The following ongoing projects have potential environmental impacts: (1) completion of cleanup of inactive facilities, (2) maintenance of the de-leased land acreage, and (3) repaving Dyke and McCaw Roads.

- Uranium Hexafluoride Cylinder Storage. The mission of the Uranium Hexafluoride Cylinder Storage Program at PGDP is to maintain safe, long-term storage of the DOE uranium hexafluoride cylinder inventory until its disposition. The cylinder storage facilities are Category II Nuclear Facilities as classified in accordance with the requirements of DOE Order 425.1C, *Startup and Restart of Nuclear Facilities*. The following ongoing projects have potential environmental impacts: (1) restacking of cylinders, (2) annual cylinder inspections, (3) quadrennial cylinder inspections, (4) radiological surveys of cylinders, (5) size reduction of G-yard concrete debris, and (6) monthly sampling and monitoring.

- Depleted Uranium Hexafluoride Conversion Facility. In April 1999, DOE issued a final programmatic environmental impact statement, with a preferred alternative, for long-term management of depleted uranium hexafluoride (DOE 1999). DOE proposed to design, construct, and operate conversion facilities at PGDP and at the Portsmouth Gaseous Diffusion Plant in Ohio. These facilities would convert the DOE inventory of depleted uranium hexafluoride now at Portsmouth and Paducah to a stable chemical form acceptable for transportation, beneficial use, and/or disposal. This facility is currently under construction.

- Disposal of Nonradioactive Wastes Containing Residual Radioactivity at the C-746-U Landfill. DOE conducted an environmental assessment for disposal of nonradioactive waste in the C-746-U Landfill to include the establishment of an Authorized Limits process to allow for disposal of waste with residual activity in the C-746-U Landfill.

- Long-Term Management Plan for DOE's Inventory of Potentially Reusable Uranium. DOE is preparing a programmatic environmental assessment for the implementation of long-term management of its inventory of potentially reusable low-enriched uranium, normal uranium, and depleted uranium that is in excess of national security needs. The DOE inventories of these materials are at more than 100 different sites, including PGDP. The uranium environmental assessment will include a cumulative impacts analysis.

- United States Enrichment Corporation. The United States Enrichment Corporation was created by the Energy Policy Act of 1992 (Public Law 102-486; 106 Stat. 2776) as an initial step in transferring DOE uranium enrichment activities to the private sector. As a wholly owned federal corporation, all of its stock is held by the U.S. Treasury. The Paducah plant is currently the only uranium enrichment facility in the United States. A gaseous centrifuge demonstration plant is being built at Piketon, Ohio, and planned to begin commercial operation in 2009 with full-scale operations beginning in 2012. Because of the commitments to move operations from gaseous diffusion to gaseous centrifuge, there is currently no scheduled new expansion of the Paducah plant.

- Tennessee Valley Authority Shawnee Steam Plant. The Shawnee Fossil Plant is about 10 miles (16 kilometers) northwest of Paducah on the Ohio River. The plant's 10 coal-fired units generate electricity by heating water in a boiler to produce steam to drive turbines. Construction began in 1951 and was complete in 1957. There is currently no additional expansion scheduled for this facility, although upgrades to equipment, including the emissions systems, are ongoing as technology advances.

- Honeywell Metropolis Works. About 2 miles (3 kilometers) from Metropolis, Illinois, across the Ohio River from Paducah, the Honeywell Metropolis Works is the world's largest uranium conversion facility. Although the plant produces a variety of materials, about 80 percent of its work involves refining raw uranium ore into uranium hexafluoride for to supply the uranium enrichment process. In 2004, the plant began installing advanced technology and using complex software to significantly improve performance. Most of the upgrades are complete, and future upgrades will be installed as add-ons to the existing process equipment. Therefore, little additional new industrial actions are anticipated at this time.

- Joppa Power Plant. AmerenEnergy owns and operates the Joppa Power Plant in Joppa, Illinois, which has been the primary supplier of electrical power to PGDP since the 1950s. Although originally a coal-fired plant, the unit now uses natural gas. At present, there are no additional construction projects that are identified for this facility.

5.1.2 Potential Cumulative Actions, Oak Ridge, Tennessee

ETTP is getting a second life through ongoing reindustrialization efforts. Parts of the complex are available for lease and transfer to private industry. Facilities, equipment, and reusable materials are available to companies that are interested in leasing, performing cleanup work, or recycling. ETTP is home to two distinct business centers – Heritage Center, and Horizon Center. In addition, planned industrial operations are scheduled for the greater Oak Ridge area, including areas on the Oak Ridge Reservation. DOE has identified the following industrial actions as potential contributors to cumulative effects (DOE 2007, 2008):

- ETTP (Heritage Center) Reindustrialization. DOE has made some of its underutilized facilities at ETTP available for lease or transfer to the Community Reuse Organization of East Tennessee, which in turn is subleasing or transferring these facilities to private sector firms (DOE 1997). As cleanup progresses, DOE and the Community Reuse Organization are changing the former gaseous diffusion plant to a private industrial park known as the Heritage Center. Heritage Center is a former gaseous diffusion facility that includes 125 main buildings. Businesses that locate at Heritage Center often rehabilitate space in these buildings for reduced lease rates and use existing machinery and other assets to reduce their operating costs. To date, six buildings with over 300,000 square feet (27,870 square meters) have been transferred. Commercial use of these facilities does not constitute a change of the primary use of the property, which has been industrial for about 60 years.

- Horizon Center Industrial Park. DOE has transferred title to the developable portion of Parcel ED-1, approximately 426 acres (1.7 square kilometers) to Horizon Center, a subsidiary of the Community Reuse Organization, for continued development as an industrial and business park for research and development, medical technology, manufacturing, distribution, and corporate headquarters office facilities. DOE maintains ownership of the remainder of the parcel, which includes the Natural Area of approximately 491 acres (2 square kilometers).

- Spallation Neutron Source Project. The Spallation Neutron Source is a state-of-the-art, high-flux, short-pulsed neutron source facility on about 80 acres (0.32 square kilometer) near the Oak Ridge National Laboratory on the Reservation on Chestnut Ridge. DOE has built about 15 permanent buildings with a total of about 600,000 square feet (55,740 square meters) on about 6 acres (0.024 square kilometer) for the project. The facility, which generates subatomic particles called neutrons for materials testing and other research, began operation in April 2006. At full capacity, the facility would employ about 500 people and host over 2,000 visiting scientists and engineers per year.

- Oak Ridge National Laboratory Revitalization Program. DOE is implementing a Facilities Revitalization Program at the Laboratory to modernize some facilities, maintain competitive research and development capabilities, enhance worker health and safety, and reduce operating costs. The Program includes the construction of new facilities on brownfield land and remodeling of many existing facilities to relocate Laboratory staff currently at the Y-12 Complex, other Reservation facilities, and commercial office space. DOE has built new facilities in Bethel Valley near the main Laboratory entrance, near the West Portal in Bethel Valley, and within the footprint for the Spallation Neutron Source. The State of Tennessee and the private sector are funding some of the new construction. DOE has transferred about 20 acres (0.3 square kilometer) of brownfield property in Bethel Valley to the private sector under this proposed action. DOE reviewed the environmental consequences of this project in an environmental assessment and issued a Finding of No Significant Impact on June 1, 2001 (DOE 2001b). Construction of the Joint Institute for Computational Sciences, Research Office Complex, Engineering Technology Facility, and a new facility for the new Laboratory for Comparative and Functional Genomics Program is complete.

- Y-12 Modernization Program. DOE has issued *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex* that includes modernization of facilities (DOE 2001a). Major actions include construction of a Highly Enriched Uranium Materials Facility, which will replace multiple aging facilities in a single state-of-the-art storage facility; a Purification Facility that was completed in 2004; a Uranium Processing Facility, which will replace current enriched uranium and other processing operations; and the Beryllium Capability Project, which will upgrade an existing facility. DOE has demolished many existing facilities to prepare for the construction that began in 2003. By 2013, when the Uranium Processing Facility becomes operational, the Y-12 Complex will have reduced its defense-manufacturing footprint by almost half.

- Roane Regional Business and Technology Park. This industrial park is north of Interstate Highway 40 in Roane County about 3 miles (4.8 kilometers) southwest of the Oak Ridge Science and Technology Project site. The 655-acre (2.65-square-kilometer) site includes areas for industrial development and greenbelt uses. The park will be developed in three phases. Phase I development of 200 acres (0.8 square kilometers) was completed in late 2001 and is expected to house industries that will provide about 500 jobs. Industries at the site include, instrumentation, light metalwork, and materials handling. Additional industries that are expected to locate at the park include information technology, automotive transportation, and corporate administrative offices (TDECD 2006).

- Pine Ridge Development. In 1969, the city of Oak Ridge acquired Site X, a 230-acre (0.93-square kilometer) property, from the U.S. Atomic Energy Commission. The property included the current Valley Industrial Park and a portion of Pine Ridge. In 1999, the city transferred approximately 71 acres (0.29 square kilometers) of Pine Ridge between South Illinois Avenue, Union Valley Road, and Scarboro Road to the Industrial Development Board, which in turn sold the property to a private developer. The developer is constructing office space, light manufacturing, and storage facilities.

- Tennessee Valley Authority Property. Before 1983 the Tennessee Valley Authority partially developed a 1,245-acre (5-square-kilometer) site south of the Heritage Center for the Clinch

River Breeder Reactor. After plans for this reactor were set aside the Tennessee Valley Authority decided to sell the property for industrial use, and it was renamed the Oak Ridge Industrial Center. Approximately 150 acres (0.61 square kilometer) of the property were graded to a slope of less than 2 percent for development purposes; the remainder of the property is rolling to rough terrain with slopes of 8 to 20 percent. The developable land contains tracts with hardwood forests and pine plantations that have been affected by the Southern pine beetle. In addition, the Authority has designated a 103-acre (0.42-square-kilometer) tract along Grassy Creek as the Grassy Creek Habitat Protection Area for protection of bugbane (*Cimicifuga rubifolia*) habitat (TVA 1988). In 2007, the Tennessee Valley Authority announced that the property was no longer for sale and that it would be retained for possible use as a part of the Authority's power generation program. At this time, additional information about the future use of this property is unavailable.

- <u>Parcel ED-6</u>. DOE has determined that the 336-acre (1.4-square-kilometer) Parcel ED-6 is excess property and is considering conveyance to the city of Oak Ridge for new residential development. Under the mixed-development alternative, a portion of the land could also be used for commercial development (offices and retail establishments). The property is west of Wisconsin Avenue, south of Whippoorwill Drive, north of the Oak Ridge Turnpike (State Route 95), and east of the Horizon Center Industrial Park. A portion of the North Boundary Greenway is on the parcel and is maintained by the city under a license from DOE. Parcel ED-6 is part of the area that was included in the Oak Ridge Reservation land use planning process during 2001 and 2002 (Focus Group 2002).

5.2 CUMULATIVE IMPACTS BY RESOURCE AREA FOR THE PROPOSED ACTION

The following discussion provides a qualitative evaluation of cumulative impacts by resource area for the location of the proposed action facilities at PGDP and ETTP. It includes separate discussions for each proposed location and resource area, with the exception of those areas for which DOE can make no distinction based on location. There is a single discussion for those resource areas.

5.2.1 Land Use

<u>PGDP</u>. Land use impacts from the identified DOE and other regional industrial and construction activities have the potential, along with the proposed action, to affect overall land use near PGDP. However, direct incremental impacts of the proposed action on the development of other properties in the region would be unlikely. Therefore, there would be little potential to produce an adverse cumulative impact on land use through the implementation of the proposed action.

<u>ETTP</u>. The continued reindustrialization of ETTP and portions of the Oak Ridge Reservation raise the potential for some concerns over cumulative land use issues in the near future. However, because the proposed facilities would be small in comparison with the available land area, the proposed action would result in a minor cumulative impact to regional land use.

5.2.2 Geology and Soils

<u>PGDP</u>. DOE anticipates no adverse cumulative impacts on regional geology near PGDP with the implementation of the proposed action along with the other identified industrial actions and current construction in the region. Environmental restoration activities at the site have the potential to result in erosion of soils if those activities involved disturbance or removal of vegetation. Such potential impacts would be temporary, and DOE would prevent or mitigate them with the use of best management practices and appropriate engineering controls. These impacts would be offset by the reduction of contamination from remediation activities. Therefore, there would be little potential for adverse cumulative impacts on geology and soils for location of the proposed action facilities at PGDP.

ETTP. DOE anticipates no adverse cumulative impacts on regional geology near ETTP with the implementation of the proposed action along with the other identified industrial actions in the region. Similar to PGDP, ongoing remediation and industrial and residential construction in the ETTP region have the potential to disturb or remove native vegetation, which could lead to the potential for erosion. These potential impacts would be temporary, and DOE would prevent or mitigate them through use of best management practices and engineering controls. Further, accidental spills or releases of radioactive or hazardous materials could contaminate soils; DOE would also prevent or mitigate these impacts by best management practices and appropriate engineering controls. These impacts would be offset by the reduction of contamination from remediation activities. Therefore, there would be little potential to produce adverse cumulative impacts on geology and soils for location of the proposed action facilities at ETTP.

5.2.3 Air Quality and Climate

PGDP. Implementation of the proposed action in combination with other regional actions would be unlikely to cause adverse impacts on either the air quality or the climate in the Paducah region. This is supported by the fact that additional air emissions or changes to air quality as a result of location and operation of the proposed action facilities would be minimal. Engineered emission control systems would be required and would control the required facilities under the proposed action in adherence with applicable regulations and emission limitations.

ETTP. The successful bidder would operate the required facilities under the proposed action in compliance with environmental regulations that require effluent control systems that would ensure compliance with the National Ambient Air Quality Standards. If required, the successful bidder would obtain the appropriate permits before construction and operation of these facilities at ETTP. Therefore, there would be little potential for adverse cumulative effects on air quality in combination with other regional industrial operations. Because of the relatively small size of the facilities under the proposed action and their relatively brief projected operational period, and because of the use of effluent controls at these facilities, there would be little potential for adverse cumulative climate impacts in the ETTP region from their construction and operation.

5.2.4 Water Resources

PGDP. The facility designs for the proposed action would limit possible discharges of industrial effluents that could adversely affect water resources at PGDP. Cleanup of environmental contamination through the environmental restoration projects would have an overall beneficial long-term impact on water resources through the removal of the source of contamination. Therefore, DOE has identified no adverse cumulative impacts on water resources in combination with other regional industrial activities for location of the proposed action facilities at PGDP.

ETTP. Accidental spills of hazardous or radioactive materials, either from the facilities for the proposed action or for other regional industries, could lead to impacts to surface or groundwater resources. However, the facility design would limit possible discharges of industrial effluents that could adversely affect water resources at ETTP. Similar to the PGDP, cleanup of environmental contamination through the environmental restoration projects at the Oak Ridge Reservation would have an overall beneficial long-term impact on water resources through the removal of the source of contamination. Therefore, DOE has identified no adverse cumulative impacts on water resources in combination with other regional industrial activities for location of the proposed action facilities at PGDP.

5.2.5 Ecological Resources

PGDP. Forest fragmentation and its associated impacts on biodiversity are increasing with the development of more land in the PGDP region. However, development of land parcels at PGDP would cause only minor ecological impacts because none of the areas contains habitats or biota that are rare or unique. In addition, there are no known federal- or state-listed threatened and endangered species in the locations of the previously described actions. Emissions and effluents from the operation of the proposed action facilities should not be of sufficient quantity to have a major adverse impact on existing habitats and biota. Accidental releases from ongoing and proposed operations would not greatly affect ecological resources due to the implementation of adequate mitigative measures. In combination with other identified industrial actions in the region, the localized impacts of the proposed action at PGDP would not produce cumulative changes to the region's ecological resources. Therefore, DOE anticipates no adverse cumulative impacts to ecological resources in the PGDP region.

ETTP. Because of the limited land area necessary for construction and operation of the facilities for the proposed action, there would be no significant loss of habitat in the near term. DOE does not expect impacts to surface water or groundwater because it would use best management practices and engineering controls, so there should be no impacts on aquatic habitats. At this time, there are no anticipated cumulative adverse effects on the ecological resources of the region in combination with the other identified industrial actions in the region and the location of the proposed action facilities at ETTP. However, once the procurement process was complete and the successful bidder chose a specific location for the facilities, a review the potential for construction and operation of the facilities would be performed to determine specific cumulative impacts in the region.

5.2.6 Cultural Resources

PGDP. PGDP has recently undergone a complete cultural resources survey that included the prehistoric and historic cultural resources on the site and in its immediate surroundings. Of the more than 35 sites of cultural significance, most prehistoric sites are in the Ohio River floodplain. Six were identified to be on DOE property at the site but are not inside the site fence. None of the sites were included in or nominated to the *National Register of Historic Places*, but at least three prehistoric sites and one historic site were identified as potentially eligible. In 2004 DOE contracted to complete the Cultural Resource Survey of the PGDP Site (BJC 2006). The survey identified a National Register-eligible historic district at PGDP. This district contains properties that are significant under National Register criteria for their significance in Cold War history. Because of the limited facilities necessary for the proposed action, the ability to locate them to avoid identified cultural sites, and with consideration of the other industrial activities in for the region, there would be no anticipated adverse cumulative effects on regional cultural resources at PGDP.

ETTP. In July 2001, the *Cultural Resources Management Plan DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee* (DOE 2001c) was issued to provide the mechanism by which DOE complies with cultural resources statutes, addresses cultural resources in the early planning process of its undertakings, and implements necessary protective measures for its cultural resources before initiating actions. This plan is the basis of the DOE cultural resources management program in Oak Ridge. To fulfill responsibilities under Section 106 of the National Historic Preservation Act and the Advisory Council's regulations, Memoranda of Agreement were prepared for properties at ETTP (Hartman 2003, 2004, 2005). DOE agreed to certain stipulations within the context of each memorandum and is responsible for ensuring that the measures in the memorandum are carried out or that the memorandum is revised accordingly. In light of the existing cultural resources management plan and memoranda, and in combination with the other identified industrial activities in the region, there would be no anticipated adverse cumulative effects on cultural resources for location of the proposed action facilities at the ETTP.

5.2.7 Noise

PGDP. The current noise-producing activities in the vicinity of the PGDP site result from processing and construction activities and local traffic that are similar to those at any other industrial site. Another noise source is rail traffic in and out of the site, particularly train whistle noise at public grade crossings. Rail traffic noise is not a factor in the local noise environment because of infrequent traffic (one train per week). PGDP is in a rural setting, and no residences or other sensitive receptor locations (schools and hospitals for example) are in the immediate vicinity of noisy onsite operations. Ambient noise levels around the site are relatively low. In combination with the identified industrial actions in the region, siting of the proposed action facilities at the PGDP would have no anticipated adverse cumulative effects on noise levels.

ETTP. Noise sources at ETTP are from two major sources– transportation and stationary sources that do not move or that move relatively short distances. Stationary noise sources on and near ETTP include ventilation systems, air compressors, generators, power transformers, and construction equipment. During peak hours, traffic along State Route 58 is a major contributor to traffic noise. Background noise levels at ETTP are mostly from local traffic and are comparable to noise levels in an urban residential area. No sensitive receptor sites such as picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, or hotels are near ETTP. Therefore, in combination with the identified industrial actions in the region, siting the proposed action facilities at the ETTP would have no anticipated adverse cumulative effects on noise levels.

5.2.8 Socioeconomics

PGDP. The creation of new commercial and industrial jobs near PGDP could contribute to cumulative socioeconomic impacts by inducing in-migration of additional population to the area, with corresponding demands for housing and public services. However, such in-migration would be unlikely to result from currently planned activities. Even with the new projects, ongoing downsizing and workforce restructuring would continue, and employment from the facilities for the proposed action would be temporary. In addition to new direct employment in the area, such employment would create the need for goods and services from indirect workers. However, new indirect jobs would be unlikely to stimulate in-migration because unemployed people in the area could fill nearly all of them. DOE does not expect cumulative socioeconomic near PGDP from the proposed action.

ETTP. Socioeconomic impacts are not only important in themselves, but also for the secondary distributional effects they can have. Although economic growth can sometimes attract enough new people to an area that it places pressure on housing, schools, water supply, and other infrastructure, secondary impacts of the proposed action should be minimal because of the relatively small size of the proposed facilities, their relatively small workforce, and the fact that they would process all DOE nickel in about 8 years. DOE anticipates no adverse cumulative socioeconomic impacts in the region near ETTP.

5.2.9 Environmental Justice

PGDP. For the PGDP, this environmental assessment used data from the most recent decennial Census in 2000 to evaluate environmental justice implications of the proposed action and the no-action alternative in relation to minority populations. There is a mixture of these population tracts around PGDP, so the potential impacts of adverse events would be likely to have at least as much effect on all population groups. The same would be true of low- and higher income populations around PGDP. The results of this analysis suggest that there would be no high or adverse human health or environmental impacts near PGDP, and that there would be no adverse cumulative environmental justice impacts in the region with location of the proposed action facilities at PGDP.

ETTP. This analysis suggests that there would be no high or adverse human health or environmental impacts near ETTP; however, actual impacts could depend on the siting and design of the facilities. Because of the mixture of these population tracts around ETTP, the potential impacts of adverse events would be likely to have at least as much effect on all population groups. The same would be true of low- and higher income populations around ETTP. Therefore, DOE expects that any adverse health and environmental impacts that could occur would not have a disproportionate effect on low-income and minority populations, and that there would be no adverse cumulative environmental justice impacts in the region with location of the proposed action facilities at ETTP.

5.2.10 Waste Management

PGDP and ETTP. Operation of the facilities necessary for the proposed action at PGDP or ETTP would occur in full compliance with DOE Orders, Environmental Protection Agency and NRC regulations, and applicable rules and regulations of the Commonwealth of Kentucky or State of Ohio. DOE would dispose of all waste from construction, operation, or decontamination and decommissioning of facilities at an onsite landfill or an appropriate offsite DOE- or NRC-regulated commercial waste disposal facility. The other identified industrial actions in the PGDP and ETTP regions are not likely to generate radioactive or hazardous waste in quantities that would require the development of additional disposal capacity. Because of the limited size of the proposed facilities and given the adequate disposal facilities to receive the waste, DOE anticipates the cumulative impacts from management of wastes from the proposed action would be minimal at either PGDP or ETTP.

5.2.11 Human Health

PGDP. DOE anticipates that cumulative public and occupational health impacts would be roughly equal to those that currently exist in the PGDP area because of the limited size of the proposed action facilities and their limited potential for worker or public health impacts. This analysis determined that the estimated cumulative impacts would be small and well within regulatory limits; however, there would be a certain amount of risk and potential exposure for the workers at the facilities for the proposed action. Emissions and effluents from industrial developments would not be a major source of potential exposure, and DOE, NRC, or other regulatory authorities would control them with the use of proper engineering and administrative controls. Standard industrial accidents would increase in proportion to increases in facility workers and industrial operations. Additional industrial or residential development of the surrounding area could cause an increase in the number of people that could be exposed to offsite releases from accidents. However, DOE determined those accidents would have minimal impacts because of the small quantities of radioactive materials to be handled under the proposed action. Overall, there would be no adverse cumulative effects on human health in comparison with current conditions in the PGDP region.

ETTP. The estimated cumulative public health impacts for siting the proposed action facilities at ETTP would be small and well within regulatory limits, and they would not significantly change from those that currently exist. This conclusion results from the relatively small size of the proposed action facilities, the limited radionuclide concentrations, and the relatively short operational duration for these facilities. Although there would be a certain amount of risk and potential exposure for the workers at the facilities for the proposed action, these impact would be no more significant than currently exist in the region. Because DOE, NRC, or other regulatory authorities would control effluents and emissions with engineering and administrative controls, no cumulative increase in public radiation exposures would be likely. Overall, there would be no adverse cumulative effects on human health in comparison with current conditions in the ETTP region.

5.2.12 Transportation

PGDP. Construction and operation of the facilities for the proposed action at PGDP would nominally increase peak traffic volumes over current levels dependent on total employment numbers. Increases in traffic have the potential for increased numbers of accidents, additional noise and air pollution, and road deterioration and damage. The increase in average daily traffic volumes, in combination with the identified industrial activities in the PGDP region, could result in inconveniences for other vehicles on affected routes and connecting roads. Although noise from increased traffic is not normally harmful to hearing, the public considers increased traffic noise a nuisance. For PGDP, this analysis concluded that the cumulative increase in traffic on the roads and highways would be within the current levels of service and that the associated cumulative impacts on increased accidents, additional noise and air pollution, and road deterioration and damage would be minimal.

ETTP. Siting the proposed action facilities at ETTP would increase peak traffic volumes slightly over current levels, with the associated potential for an increased number of accidents, additional noise and air pollution, and road deterioration and damage. The increase in average daily traffic volumes could result in inconveniences for other vehicles and increased pavement deterioration and damage could increase costs of maintenance or resurfacing of roads. Increased accidents could put an additional strain on local emergency response personnel. However, for ETTP, this analysis concluded that the cumulative increase in traffic on the roads and highways would be within the current levels of service, and that the associated cumulative impacts on increased accidents, additional noise and air pollution, and road deterioration and damage would be minimal.

5.2.13 Intentional Destructive Acts

PGDP and ETTP. The evaluation of potential accidents concluded that, because there would be no high-energy sources (for example, explosives) that could lead to accidents that involved radioactive material during nickel disposition, there would be little potential for offsite radiological consequences from accidents. Therefore, the impacts of sabotage events would also have little potential for distribution of significant quantities of radioactive material downwind of PGDP or ETTP. The major impact of such events would be to disrupt normal facility operations; there would be little or no impact on general populations, the environment, or the national economy. The facilities necessary for the proposed action would be physically isolated from and independent of other regional industries. Further, the proposed facilities would be under DOE controls, NRC/Agreement State licenses, or other regulation, which would include provisions for security to reduce the potential for sabotage or other such events. Therefore, there would be little potential for adverse cumulative impacts in the region from intentional destructive acts for location of the proposed action facilities at either PGDP or ETTP.

5.3 CUMULATIVE IMPACTS FROM DISPOSAL AS RADIOACTIVE WASTE

There are two options for the disposal of the DOE nickel in a DOE-controlled low-level radioactive waste landfill. The Department could transport the nickel and dispose of it directly in a classified DOE low-level radioactive waste disposal facility or could send it to a facility for declassification by melting (similar to Step 1 of the proposed action) before disposal in either a DOE-controlled or an NRC-licensed low-level radioactive waste disposal facility. There would be no need to decontaminate the nickel because the radionuclide concentrations would be well within the waste acceptance criteria at such facilities. The bounding situation would be disposal after processing at a melting facility because that would require construction, operation, and decontamination and decommissioning of a metal melting facility. The potential cumulative impacts for all the resource and subject areas DOE has considered in this evaluation for location of the melting facility at PGDP or ETTP would be less than the total impacts for the preferred action in Section 5.2 because fewer facilities and fewer industrial processing steps would be involved. For example, construction and operations activities of a melting facility would have minimal cumulative impacts on overall land use because DOE could easily place the facility in a location with existing roads, utility easements, security fences, and barriers. As Section 5.2 describes, and consistent with expected construction and operations, there would be minimal adverse cumulative impacts on geology and soils, air quality, and water resources. Further, there would be minimal adverse cumulative impacts on ecological or cultural resources because there would be minimal modification to the landscape, which would minimize potential damage to ecological habitats or historic structures. The design, construction, and operation of the melting facility would occur in a manner that would limit the potential for adverse noise impacts. There would be minimal socioeconomic or environmental justice impacts from location of the melting facility at ETTP, PGDP, or a generic location. Waste management would have minimal impacts because the facility would be under DOE control or NRC or other regulations with waste minimization programs in place.

In addition, the volume of nickel for disposal would not require the construction of a new disposal cell or an expansion to existing facilities. Therefore, the material would be disposed in an existing landfill and the cumulative impacts would be negligible because the other identified industrial actions in the vicinity of PGDP and ETTP would have no additional impacts to this alternative.

Cumulative public and occupational health impacts from the disposal as radioactive waste alternative (with construction of the melting facility) would probably be roughly equal to those that currently exist in the PGDP or ETTP region because the estimated impacts would be a small fraction of regulatory limits. In addition, these impacts would be less than those estimated for the proposed action because there would be fewer industrial facilities. Actions in the regions that involve environmental remediation usually have a positive impact by eliminating or reducing potential exposures to existing contamination. However, there would be a certain amount of risk and potential exposure for the workers at the melting facility. Emissions and effluents from industrial developments would be unlikely to be a major source of potential exposure, and DOE would control them with the use of appropriate engineering and administrative controls. Standard industrial accidents would increase proportionally with the addition of the melting facility in the region, but this increase would be small because of the limited size and operation of the facility. Further, construction and operation of the melting facility would add some development of the surrounding area that could cause an increase in the number of people that could receive exposures to offsite releases from accidents. Overall, there would be no adverse cumulative effects on human health from the construction and operation of the melting facility in comparison with current conditions in either the PGDP or ETTP region.

Construction and operation of the decontamination facility as part of the waste disposal alternative at PGDP or ETTP, and transportation of the nickel as radioactive waste, would increase peak traffic volumes over current levels dependent on total employment numbers. Increases in traffic have the potential for increased numbers of accidents, additional noise and air pollution, and road deterioration and damage. The increase in average daily traffic volumes could result in inconveniences for other vehicles on affected routes and connecting roads. Commercial operations could suffer temporarily reduced business while customers avoided affected areas because of traffic delays. Increased pavement deterioration and damage could increase the costs of maintenance or resurfacing of roads. Although noise from increased traffic is not normally harmful to hearing, the public considers increased traffic noise a nuisance. Increased accidents put an additional strain on local emergency response personnel. In addition, increased vehicular traffic has the greatest potential to increase air pollution in the area.

As Section 5.2 describes for the proposed action, there would be little potential for offsite radiological consequences from accidents. This conclusion is valid for the disposal as radioactive waste alternative; with construction and operation of a melting facility, this alternative requires fewer industrial processes than the proposed action. Therefore, the impacts of sabotage events would have little potential for distribution of significant quantities of radioactive material from PGDP or ETTP. The major impact of such events would be disruption of normal facility operations, with little or no impact on general populations, the environment, or the national economy. The decontamination facility would be physically isolated from and independent of other regional industries. Further, it would be under DOE controls, NRC/Agreement State licenses, or other regulation, which would include provisions for security to reduce the potential for sabotage as well as other events. Therefore, there would be little potential for adverse cumulative impacts in the region from intentional destructive acts at the melting facility under this alternative.

5.4 CUMULATIVE IMPACTS FROM THE NO-ACTION ALTERNATIVE

For all resource and subject areas this environmental assessment considers, and for most of the resource and subject areas for the PGDP nickel, there would be minimal cumulative impacts from continued storage of the nickel because there would be no facility construction, operation, disposal, or transportation. Therefore, a discussion of potential adverse cumulative impacts is not necessary.

5.5 REFERENCES

BJC (Bechtel Jacobs Company), 2006, *Cultural Resources Survey for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, BJC/PAD-688/R1, Paducah, Kentucky.

DOE (U.S. Department of Energy), 1997, *Final Environmental Assessment for Lease of Land and Facilities within the East Tennessee Technology Park, Oak Ridge, Tennessee,* DOE/EA-1175, Oak Ridge Office, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), 1999, *Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride,* DOE/EIS-0269, Office of Environmental Management, Washington, D.C.

DOE (U.S. Department of Energy), 2001a, *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex,* DOE/EIS-0309, Oak Ridge Office, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), 2001b, *Finding of No Significant Impact (FONSI) and Environmental Assessment for the Oak Ridge National Laboratory Facilities Revitalization Project,* DOE/EA-1362, Oak Ridge Office, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), 2001c, *Cultural Resources Management Plan DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee,* DOE/ORO-2085, Oak Ridge Office, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), 2002, *Final Environmental Assessment for Waste Disposition Activities at the Paducah Site, Paducah, Kentucky,* DOE/EA-1339, Paducah, Kentucky.

DOE (U.S. *Department* of Energy), 2007, *Environmental Assessment of U.S. Department of Energy Conveyance of Parcel ED-6 to the City of Oak Ridge, Tennessee*, DOE/EA-1514. Oak Ridge Office, Oak Ridge, Tennessee.

DOE (U.S. Department of Energy), 2008, *Finding of No Significant Impact (FONSI) and Environmental Assessment for the Oak Ridge Science and Technology Project at the Oak Ridge National Laboratory, Oak Ridge, Tennessee,* DOE/EA-1575, Oak Ridge Office, Oak Ridge, Tennessee.

Focus Group, 2002, *Final Report of the Oak Ridge Land Use Planning Focus Group*, Oak Ridge Office, Oak Ridge, Tennessee.

Hartman, G. S., 2003, "National Historic Preservation Act, Section 106 Compliance Final Memorandum of Agreement for the Decontamination and Decommissioning of Buildings K-25 and K-27 Located at the East Tennessee Technology Park," letter to Multiple Addressees, Oak Ridge Office, Oak Ridge, Tennessee, July 18.

Hartman, G. S., 2004, "National Historic Preservation Act, Section 106 Compliance - Final Memorandum of Agreement for Demolition of 108 Buildings/Structures at the East Tennessee Technology Park," letter to Multiple Addressees, Oak Ridge Office, Oak Ridge, Tennessee, May 4.

Hartman, G. S., 2005, "National Historic Preservation Act, Section 106 Compliance, Final Memorandum of Agreement Regarding Site Interpretation of the East Tennessee Technology Park," letter to Multiple Addressees, Oak Ridge Office, Oak Ridge, Tennessee, July 18.

TDECD (Tennessee Department of Economic and Community Development), 2006, "Tennessee Prospector: Available Buildings and Sites," available at http://www.tennesseeprospector.com, accessed March, 2008.

TVA (Tennessee Valley Authority), 1988, *Watts Bar Reservoir Land Management,* August (reprinted September 1992).

Glossary

annual dose	The radiation dose to an individual over the course of 1 year. The units of annual dose are rem and sievert.
As Low As Reasonably Achievable	An approach to radiation protection to manage and control worker and public exposures (both individual and collective) and releases of radioactive material to the environment to as far below applicable limits as social, technical, economic, practicable, and public policy considerations permit. This approach is a process for minimizing radiological doses to as far below limits as is practicable.
attainment area	An area that the U.S. Environmental Protection Agency has designated as being in compliance with one or more of the National Ambient Air Quality Standards for sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and particulate matter. An area can be in attainment for some pollutants but not for others. See *National Ambient Air Quality Standards* and *nonattainment area*.
background radiation	Radiation from (1) cosmic sources, (2) naturally occurring radioactive materials including radon (except as a decay product of source or special nuclear material), and (3) global fallout as it exists in the environment (that is, from the testing of nuclear explosive devices).
becquerel	A unit of radioactivity equal to 1 disintegration per second. A becquerel is approximately 2.7×10^{-11} curie.
bounding analysis	An analysis that uses assumptions and methods to calculate impact or risk estimates such that the result overestimates or describes an upper limit on (that is, bounds) potential impacts or risks.
carbonyl process	A process used for purification (and decontamination) of nickel using chemical reactions with carbon monoxide gas.
collective dose	The total radiation dose to a population. The units of collective dose are person-rem or person-sievert. Annual collective dose is the dose to a population in 1 year, and the collective lifetime dose is the dose to a population over their lifetimes.
committed effective dose equivalent	The internal dose to the body over 50 years from sources internal to the body after inhalation or ingestion of radioactive material. The units of committed effective dose equivalent are rem and sievert.
Comprehensive Environmental Response, Compensation, and Liability Act of 1980	A federal law (also known as Superfund) that was enacted in 1980 and reauthorized in 1986 that provides the legal authority for emergency response and cleanup of hazardous substances released into the environment and for the cleanup of inactive waste sites.

criteria pollutants	Those regulated pollutants for which the Environmental Protection Agency must establish standards included in the National Ambient Air Quality Standards. Criteria pollutants include sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and two size classes of particulate matter, less than 10 micrometers (0.0004 inch) in diameter, and less than 2.5 micrometers (0.0001 inch) in diameter. Primary standards are established to protect public health; secondary standards are established to protect public welfare (for example, visibility, crops, animals, buildings).
curie	A unit of radioactivity equal to 37 billion disintegrations per second. One curie is equal to 3.7×10^{10} becquerels.
declassification	For the DOE nickel, the process of removing the physical attributes that require it to be treated as classified pursuant to DOE Order 475.2.
decommissioning	After decontamination, the release of a facility or land from radiological controls and/or license conditions.
decontamination	The removal or reduction of radioactive or hazardous contamination from facilities, equipment, or soils by washing, heating, chemical or electrochemical action, mechanical cleaning, or other methods to achieve the required end-state contamination level.
dose (radiological)	A generic term meaning dose equivalent, committed effective dose equivalent, total effective dose equivalent, annual dose, lifetime dose, or collective dose as defined elsewhere in this glossary.
dose equivalent	The product of the absorbed dose in tissue, quality factor (to account for different types of ionizing radiation), and all other necessary modifying factors at the location (organ) of interest. The units of dose equivalent are rem and sievert.
ecosystem	A community of organisms and their physical environment that interact as an ecological unit.
electro-winning process	A process for purification (and decontamination) of nickel metal using electrolytic dissolution with subsequent cathode deposition.
environmental justice	The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including racial, ethnic, or socioeconomic groups, should bear a disproportionate share of the negative environmental consequences from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies.

exposure pathway	The course a chemical or physical agent takes from the source to the exposed organism. An exposure pathway describes a mechanism by which chemicals or physical agents at or originating from a release site reach an individual or population. Each exposure pathway includes a source or release from a source, an exposure route, and an exposure point. If the exposure point differs from the source, a transport or exposure medium such as air or water is a part of the pathway.
Finding of No Significant Impact	A public document that is issued by a Federal agency that briefly presents the reasons why an action for which the agency has prepared an environmental assessment has no potential to have a significant effect on the human environment and, thus, will not require preparation of an environmental impact statement.
groundwater	Water below the ground surface in a zone of saturation (40 CFR 192.01.) Subsurface water is all water that exists in the interstices of soil, rocks, and sediment below the land surface, including soil moisture, capillary fringe water, and groundwater. That part of subsurface water in interstices completely saturated with water is called groundwater.
hazardous waste	A category of waste subject to the RCRA. To be considered hazardous, a waste must be a solid waste and must exhibit at least one of four characteristics in 40 CFR 261.20 through 40 CFR 261.24 (i.e., ignitability, corrosivity, reactivity, or toxicity) or be specifically listed by the Environmental Protection Agency in 40 CFR 261.31 through 40 CFR 261.33.
heavy metals	Metallic and semimetallic elements that are generally highly toxic to plants and animals and that tend to accumulate in food chains. Heavy metals include lead, mercury, cadmium, chromium, and arsenic.
High risk	For the DOE nickel, the process of removing the physical attributes that require it to be treated as a "high-risk" property and to be subject to national security concerns in relation to nuclear proliferation.
ingot	A mass of metal shaped into a bar or block, usually through a melting operation.
International Atomic Energy Agency (IAEA)	An agency of the United Nations chartered to provide nuclear and radiation safety recommendations to the member nations.
latent cancer fatality	A fatality from cancer that results from and occurs some time after (generally a year or more) exposure to ionizing radiation or other carcinogens.
lifetime dose	The radiation dose to an individual over the course of a lifetime. The units of lifetime dose are rem and sievert.

low-level radioactive waste	Radioactive waste that is not high-level waste, transuranic waste, spent nuclear fuel, or by-product tailings from processing of uranium or thorium ore. See *radioactive waste*.
maximally exposed individual	A hypothetical individual whose location and habits result in the highest total radiological or chemical exposure (and thus dose) from a particular source for all exposure routes (e.g., inhalation, ingestion, direct exposure).
millirem	One-thousandth of a rem (0.001 rem). See *rem*.
millisievert	One-thousandth of a sievert (0.001 millirem). See *sievert*.
mixed waste	Waste that contains both hazardous waste as defined under the RCRA, and source, special nuclear, or by-product material subject to the Atomic Energy Act.
National Ambient Air Quality Standards	Standards that define the highest allowable levels of certain pollutants in the ambient air (that is, the outdoor air to which the public has access). Because the Environmental Protection Agency must establish the criteria for setting these standards, the regulated pollutants are called criteria pollutants. See *criteria pollutants*.
National Register of Historic Places	The official list of the nation's cultural resources that are worthy of preservation. The National Park Service maintains the list under direction of the Secretary of the Interior. Buildings, structures, objects, sites, and districts are included in the National Register for their importance in American history, architecture, archeology, culture, or engineering. Properties included on the National Register range from large-scale, monumentally proportioned buildings to smaller scale, regionally distinctive buildings. The listed properties are not just of nationwide importance; most are significant primarily at the state or local level. Procedures for listing properties on the National Register are in 36 CFR Part 60.
nonattainment area	An area the Environmental Protection Agency has designated as not meeting (i.e., not being in attainment of) one or more of the National Ambient Air Quality Standards for sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and particulate matter. An area can be in attainment for some pollutants, but not for others. See *attainment area, National Ambient Air Quality Standards*, and *particulate matter*.
person-rem	A unit of collective radiation dose for populations or groups of individuals; that is, a unit for expressing the dose when summed across all people in a specified population or group.
radiation (ionizing)	Particles (alpha, beta, neutrons, and other subatomic particles) or photons (i.e., gamma, x-rays) emitted from the nucleus of unstable atoms as a result of radioactive decay. Such radiation is capable of displacing electrons from atoms or molecules in the target material (such as biological tissues), thereby producing ions.

rem	A unit of dose equivalent. The dose equivalent in rem equals the absorbed dose in rad (1 rad is equal to 0.01 joule per kilogram of absorbed dose) in tissue multiplied by the appropriate quality factor and possibly other modifying factors. Derived from "roentgen equivalent man," rem is the dose of ionizing radiation that will cause the same biological effect as 1 roentgen of x- or gamma-ray exposure.
risk	The probability of a detrimental effect from exposure to a hazard. Risk is often expressed quantitatively as the probability of an adverse event occurring multiplied by the consequence of that event (that is, the product of these two factors).
sievert	A unit of dose equivalent. The unit is the radiation value in gray (equal to 1 joule per kilogram) multiplied by a weighting factor for the type of radiation and a weighting factor for the tissue. One sievert equals 100 rem. See *rem*.
smelting	The act of metal melting, typically to separate (refine) metal components.
surface water	All bodies of water on the surface of the earth and open to the atmosphere, such as rivers, lakes, reservoirs, ponds, seas, and estuaries.
total effective dose equivalent	The sum of the deep dose equivalent for radiation from sources external to the body and the committed effective dose equivalent. The units of total effective dose equivalent are rem and sievert.
wind rose	A circular diagram that shows, for a specific location, the percentage of the time the wind is from each compass direction. A wind rose for use in assessing consequences of airborne releases also shows the frequency of different wind speeds for each compass direction.

APPENDIX A. RADIATION DOSE AND RISK ANALYSIS

This appendix provides the details evaluation of the potential human health impacts from the disposition of DOE nickel in terms of radiation doses and risks. The primary tool for estimation of individual radiation doses and risks was the RESRAD-RECYCLE (Cheng et al. 2000) computer program. Argonne National Laboratory developed RESRAD- RECYCLE as part of the RESRAD (Yu et al. 2001) family of computer programs to assess the doses and risks from decontamination, decommissioning, and remediation activities that involve radioactive and other hazardous materials. The Laboratory designed RESRAD-RECYCLE to provide a comprehensive assessment of radiation doses and risks from recycling and reusing radioactively contaminated metals and equipment. The program uses information from several previous assessments of metal recycling activities (IAEA 1992; Nieves et al. 1995; O'Donnell et al. 1978; SCA 1997). Short-term (total effective dose equivalent from 1 year of exposure), and long-term (lifetime) doses to the users of manufactured products, serve as the basis for estimates of risk.

A.1 RADIONUCLIDE CONCENTRATIONS

To estimate potential human health impacts from exposure to radioactively contaminated nickel, it was necessary to determine the radionuclides present and their concentrations for each of Steps 1 to 5 of the proposed action (Figure 2-1). Table 4-1 in Chapter 4 lists the estimated initial radionuclide concentrations for the nickel at PGDP and ETTP. The total activity is dominated by technetium-99, which makes up over 99 percent of the total radioactivity.

Step 1 of the proposed action would be resizing, which would involve melting, size reduction, and development of a product suitable for either the electro-winning or the carbonyl processes. In addition to the product, melting the nickel inventory would produce slag and baghouse dust. Table A-1 shows the assumed mass partitioning separation factors for the nickel melting process. These values are the default values from RESRAD-RECYCLE (Cheng et al. 2000). Melting the nickel inventory would allow for partitioning of radionuclides among the product, slag, and baghouse dust. The degree to which partitioning occurred would depend on the chemistry of the radioactive element and the operating conditions of the melting process. Table A-2 shows the default percentage values for partitioning from RESRAD-RECYCLE, ranges of NRC-developed values, and the partition factors this assessment used. As the table indicates, the analysis used values within the NRC ranges whenever possible. Tables A-3 and A-4 list the estimated partitioning in terms of radioactivity for melting the PGDP and ETTP nickel.

Table A-1. Assumed[a] mass partitioning factors for nickel.

Component	RESRAD-RECYCLE Default
Amount to product or ingot	~90%*
Amount to slag	~10%*
Amount to baghouse (dust)	~1%

a. Analytical factor assumed to overstate radioactive burden in slag processing and disposal.

Step 2 of the proposed action would be decontamination or purification of the DOE nickel, which must occur before alloying, fabrication, equipment manufacturing, and end use of products in controlled radiological applications. As Chapter 2 describes, the two candidate purification processes DOE has identified are the electro-winning process and the carbonyl process. Again, radionuclides would partition among the product, baghouse ash, and slimes or residues from these processes. Table A-5 shows example elemental partitioning factors for nickel by electro-winning and carbonyl processing. The analysis applied these partitioning factors to determine the activity partitioning for the nickel after decontamination. Tables A-6 and A-7 list the partitioning for the nickel at PGDP and ETTP, respectively.

Table A-2. Elemental partitioning factors for nickel smelting (percent).[a]

	Product			Baghouse (dust)			Slag		
Element	**RESRAD-RECYCLE[b]**	**NUREG-1640[c]**	**This study[d]**	**RESRAD-RECYCLE[b]**	**NUREG-1640[c]**	**This study[d]**	**RESRAD-RECYCLE[b]**	**NUREG-1640[c]**	**This study[d]**
Americium	1	0–1	1	2	0–5	1	97	95–100	98
Cesium	1	0–1	1	97	95–100	96	2	0–5	3
Neptunium	1	0–1	1	2	0–5	1	97	95–100	98
Plutonium	1	0–1	1	2	0–5	1	97	95–100	98
Technetium	10	95–100	98	100	0–2	1	10	0–1	1
Thorium	0	0–1	1	0	0–5	1	97	95–100	98
Uranium	1	0–1	1	2	0–5	1	97	95–100	98

a. For each element in this study, partitioning of values across ingot, dust, and slag does not exceed a sum of 100 percent.

b. Source: Cheng et al. (2000, Table 3-2).

c. Source: Anigstein et al. (2003, Volume 2, Table B.3).

d. Values within the range provided in NUREG-1640 (Anigstein et al. 2003) were considered whenever possible.

Table A-3. Activity partitioning for smelting PGDP nickel.

Radionuclide	PGDP (pCi/g[a])	Partitioning factor to product percent	Activity in product (pCi/g[a])	Partitioning to baghouse (dust) percent	Activity in baghouse dust (pCi/g[a])	Partitioning to slag percent	Activity in slag (pCi/g[a])
Technetium-99	2.59×10^{4}	98	2.54×10^{4}	1	2.59×10^{2}	1	2.59×10^{2}
Cesium-137	4.21×10^{-3}	1	4.21×10^{-5}	96	4.04×10^{-3}	3	1.26×10^{-4}
Thorium-230	6.66×10^{-4}	1	6.66×10^{-6}	1	6.66×10^{-6}	98	6.53×10^{-4}
Uranium-234	9.87×10^{-1}	1	9.87×10^{-3}	1	9.87×10^{-3}	98	9.67×10^{-1}
Uranium-235	4.55×10^{-2}	1	4.55×10^{-4}	1	4.55×10^{-4}	98	4.46×10^{-2}
Uranium-238	1.05	1	1.05×10^{-2}	1	1.05×10^{-2}	98	1.03
Neptunium-237	5.36×10^{-1}	1	5.36×10^{-3}	1	5.36×10^{-3}	98	5.25×10^{-1}
Plutonium-238	1.84×10^{-2}	1	1.84×10^{-4}	1	1.84×10^{-4}	98	1.80×10^{-2}
Plutonium-239	4.11×10^{-2}	1	4.11×10^{-4}	1	4.11×10^{-4}	98	4.03×10^{-2}
Americium-241	1.84×10^{-2}	1	1.84×10^{-4}	1	1.84×10^{-4}	98	1.80×10^{-2}
Total	$\mathbf{2.59 \times 10^{4}}$		$\mathbf{2.54 \times 10^{4}}$		$\mathbf{2.59 \times 10^{2}}$		$\mathbf{2.62 \times 10^{2}}$

a. pCi/g = picocuries per gram; divide by 27 to convert to becquerels per gram.

Table A-4. Activity partitioning for smelting ETTP nickel.

Radionuclide	ETTP (pCi/g[a])	Partitioning factor to product percent	Activity in product (pCi/g[a])	Partitioning to baghouse (dust) percent	Activity in baghouse dust (pCi/g[a])	Partitioning to slag percent	Activity in slag (pCi/g[a])
Technetium-99	3.99×10^{3}	98	3.91×10^{3}	1	3.99×10^{1}	1	3.99×10^{1}
Cesium-137	1.31×10^{-3}	1	1.31×10^{-5}	96	1.26×10^{-3}	3	3.93×10^{-5}
Thorium-230	2.07×10^{-4}	1	2.07×10^{-6}	1	2.07×10^{-6}	98	2.03×10^{-4}
Uranium-234	3.68×10^{-1}	1	3.68×10^{-3}	1	3.68×10^{-3}	98	3.61×10^{-1}
Uranium-235	2.49×10^{-2}	1	2.49×10^{-4}	1	2.49×10^{-4}	98	2.44×10^{-2}
Uranium-238	2.55×10^{-1}	1	2.55×10^{-3}	1	2.55×10^{-3}	98	2.50×10^{-1}
Neptunium-237	5.06×10^{-4}	1	5.06×10^{-6}	1	5.06×10^{-6}	98	4.96×10^{-4}
Plutonium-238	1.88×10^{-5}	1	1.88×10^{-7}	1	1.88×10^{-7}	98	1.84×10^{-5}
Plutonium-239	3.13×10^{-5}	1	3.13×10^{-7}	1	3.13×10^{-7}	98	3.07×10^{-5}
Americium-241	1.31×10^{-5}	1	1.31×10^{-7}	1	1.31×10^{-7}	98	1.28×10^{-5}
Total	$\mathbf{3.99 \times 10^{3}}$		$\mathbf{3.91 \times 10^{3}}$		$\mathbf{3.99 \times 10^{1}}$		$\mathbf{4.05 \times 10^{1}}$

a. pCi/g = picocuries per gram; divide by 27 to convert to becquerels per gram.

Although it is highly likely that the nickel would be used to make alloys, for bounding purposes, the analysis assumed all manufacturing steps and product end use would use pure nickel rather than alloyed products. The process of alloying would typically reduce the radionuclide concentrations to about 10 percent of their concentrations in the nickel after decontamination. Therefore, the assumption of pure nickel products does not underestimate radiation doses.

Table A-5. Example elemental partitioning factors for nickel during decontamination by electro-winning and carbonyl processing (percent).[a]

Element	Product	Baghouse (dust)	Slimes and residues
Americium	1	2	97
Cesium	5	1	94
Neptunium	1	2	97
Plutonium	1	2	97
Technetium	4	2	94
Thorium	1	1	98
Uranium	1	1	98

a. Assumed values based on information from SAIC (2001) and the requirement to meet IAEA clearance levels after processing.

Table A-6. Example activity partitioning for PGDP nickel during decontamination.

Radionuclide	Activity in Oak Ridge feed (pCi/g[a])	Partitioning factor to product percent	Activity in Oak Ridge product (pCi/g[a])	Partitioning to baghouse (dust) percent	Activity in baghouse dust (pCi/g[a])	Partitioning to slimes percent	Activity in slag (pCi/g[a])
Technetium-99	2.54×10^{4}	4	1.02×10^{3}	2	5.08×10^{2}	94	2.39×10^{4}
Cesium-137	4.21×10^{-5}	5	2.11×10^{-6}	1	4.21×10^{-7}	94	3.96×10^{-5}
Thorium-230	6.66×10^{-6}	1	6.66×10^{-8}	1	6.66×10^{-8}	98	6.53×10^{-6}
Uranium-234	9.87×10^{-3}	1	9.87×10^{-5}	1	9.87×10^{-5}	98	9.67×10^{-3}
Uranium-235	4.55×10^{-4}	1	4.55×10^{-6}	1	4.55×10^{-6}	98	4.46×10^{-4}
Uranium-238	1.05×10^{-2}	1	1.05×10^{-4}	1	1.05×10^{-4}	98	1.03×10^{-2}
Neptunium-237	5.36×10^{-3}	1	5.36×10^{-5}	2	1.07×10^{-4}	97	5.20×10^{-3}
Plutonium-238	1.84×10^{-4}	1	1.84×10^{-6}	2	3.68×10^{-6}	97	1.78×10^{-4}
Plutonium-239	4.11×10^{-4}	1	4.11×10^{-6}	2	8.22×10^{-6}	97	3.99×10^{-4}
Americium-241	1.84×10^{-4}	1	1.84×10^{-6}	2	3.68×10^{-6}	97	1.78×10^{-4}
Total	$\mathbf{2.54 \times 10^{4}}$		$\mathbf{1.02 \times 10^{3}}$		$\mathbf{5.08 \times 10^{2}}$		$\mathbf{2.39 \times 10^{4}}$

a. pCi/g = picocuries per gram; divide by 27 to convert to becquerels per gram.

Table A-7. Example activity partitioning for ETTP nickel during decontamination.

Radionuclide	Activity in Oak Ridge feed (pCi/g[a])	Partitioning factor to product percent	Activity in Oak Ridge product (pCi/g[a])	Partitioning to baghouse (dust) percent	Activity in baghouse dust (pCi/g[a])	Partitioning to slimes percent	Activity in slag (pCi/g[a])
Technetium-99	3.91×10^{3}	4	1.56×10^{2}	2	7.82×10^{1}	94	3.68×10^{3}
Cesium-137	1.31×10^{-5}	5	6.55×10^{-7}	1	1.31×10^{-7}	94	1.23×10^{-5}
Thorium-230	2.07×10^{-6}	1	2.07×10^{-8}	1	2.07×10^{-8}	98	2.03×10^{-6}
Uranium-234	3.68×10^{-3}	1	3.68×10^{-5}	1	3.68×10^{-5}	98	3.61×10^{-3}
Uranium-235	2.49×10^{-4}	1	2.49×10^{-6}	1	2.49×10^{-6}	98	2.44×10^{-4}
Uranium-238	2.55×10^{-3}	1	2.55×10^{-5}	1	2.55×10^{-5}	98	2.50×10^{-3}
Neptunium-237	5.06×10^{-6}	1	5.06×10^{-8}	2	1.01×10^{-7}	97	4.91×10^{-6}
Plutonium-238	1.88×10^{-7}	1	1.88×10^{-9}	2	3.76×10^{-9}	97	1.82×10^{-7}
Plutonium-239	3.13×10^{-7}	1	3.13×10^{-9}	2	6.26×10^{-9}	97	3.04×10^{-7}
Americium-241	1.31×10^{-7}	1	1.31×10^{-9}	2	2.62×10^{-9}	97	1.27×10^{-7}
Total	$\mathbf{3.91 \times 10^{3}}$		$\mathbf{1.56 \times 10^{2}}$		$\mathbf{7.82 \times 10^{1}}$		$\mathbf{3.68 \times 10^{3}}$

a. pCi/g = picocuries per gram; divide by 27 to convert to becquerels per gram.

The purified product would have to meet IAEA clearance levels (IAEA 2004). The analysis determined whether the values would be met by using the ratios of the radionuclide concentrations in the purified product to their respective clearance levels and summed those values over all radionuclides in the mixture (i.e., the sum of fractions rule). To be compliant with the clearance levels, the sum of these ratios must be less than or equal to unity (1). To ensure a bounding analysis for human health impacts from the controlled radiological use of nickel products, DOE used the maximum allowable radionuclide concentrations under the clearance levels (Table A-8) for the PGDP and ETTP nickel as the basis of the human health analysis (that is, the concentrations that would result when the sum of fractions equals unity).

Table A-8. Relative radionuclide contributions at IAEA clearance levels.[a]

Radionuclide	Clearance level (Bq/g)	Clearance level (pCi/g)	Relative PGDP contribution at clearance level (pCi/g)	Relative ETTP contribution at clearance level (pCi/g)
Technetium-99	1	27	2.70×10^{1}	2.70×10^{1}
Cesium-137	0.1	2.7	5.60×10^{-8}	1.13×10^{-7}
Thorium-230	1	27	1.77×10^{-9}	3.58×10^{-9}
Uranium-234	1	27	2.63×10^{-6}	6.36×10^{-6}
Uranium-235	1	27	1.21×10^{-7}	4.30×10^{-7}
Uranium-238	1	27	2.79×10^{-6}	4.40×10^{-6}
Neptunium-237	1	27	1.43×10^{-6}	8.74×10^{-9}
Plutonium-238	0.1	2.7	4.89×10^{-8}	3.25×10^{-10}
Plutonium-239	0.1	2.7	1.09×10^{-7}	5.41×10^{-10}
Americium-241	0.1	2.7	4.89×10^{-8}	2.26×10^{-10}
Total			**2.70×10^{1}**	**2.70×10^{1}**

a. Bq/g = becquerels per gram; pCi/g = picocuries per gram.

A.2 RADIATION EXPOSURE SCENARIOS

To evaluate the potential for human health impacts from the proposed action, the analysis used two types of radiation exposure scenarios: (1) industrial workers under radiological controls, and (2) doses to members of the public from airborne effluents from the metal processing facilities.

The analysis selected existing exposure scenarios in RESRAD-RECYCLE that are representative of the steps of the proposed action (Figure 2-1). Numerous scenarios were evaluated for each process step to identify the maximum exposed individual. Although RESRAD-RECYCLE allows modifications of exposure parameters for development of user-defined scenarios, the DOE analysis for the proposed action used default values in the software for most parameters and exposure scenarios to create an easily reproducible and understandable analysis. The exception involved the application of radionuclide partitioning coefficients for the nickel (that is, the fractions of the radionuclide inventory that would become product, slag, or baghouse as a result of melting or the electro-winning or carbonyl processes). In this case, the analysis replaced the RESRAD-RECYCLE default values with values from the recent literature, as Section A.1 discusses. The following paragraphs briefly describe the application of RESRAD-RECYCLE to produce estimated radiation doses and risks for this study.

For dose assessment purposes, the analysis used existing RESRAD-RECYCLE representative scenarios for each of five recycling process steps:

- Scrap delivery,
- Scrap smelting,
- Ingot delivery,
- Product fabrication (initial and final fabrication), and
- Use of finished consumer products.

For evaluation of potential radiation exposures from the DOE nickel, the analysis used industrial radiation worker scenarios to estimate dose and risk to workers who would process the nickel under radiological controls. For the fifth step, use of finished products, the analysis used controlled end-use scenarios for the dose and risk to individuals who would be exposed to residual radioactivity in the products.

For the resizing and decontamination steps, DOE assumed all generated waste (including baghouse dust, slag, and slimes) would be disposed of as radioactive waste. Table A-9 lists the industrial radiation worker scenarios the analysis considered. These scenarios are from the RESRAD-RECYCLE documentation, and DOE tailored them for this analysis to meet controlled end-use conditions. The controlled end-use scenarios include three special scenarios for individuals who would be exposed to shielding structures that contained a large mass of recycled nickel, such as waste canisters that are used in the nuclear fuel industry and large nickel components such as nuclear reactor pressure vessels or steam generators.

Table A-9. Industrial radiation worker scenarios for nickel.

Worker scenarios/ scenario description	Nickel decontamination (melting)	Stainless-steel alloying	Electro-winning or carbonyl processing	Component fabrication
Scrap delivery				
Scrap cutter	●	●	●	
Scrap loader	●	●	●	
Scrap truck driver	(a)	(a)	(a)	
Smelting				
Scrap processor	●	●	●	
Smelter yard worker	●	●	●	
Smelter loader	●	●	●	
Furnace operator	●	●	●	
Baghouse processor	●	●	●	
Small object caster	●	●	●	
Ingot caster				
Slag worker	●	●	●	
Ingot delivery				
Ingot loader	●	●	●	
Truck driver	(a)	(a)	(a)	
Initial fabrication				
Storage yard worker	●	●	●	
Sheet maker	●	●	●	
Final fabrication				
Coil handler				●
Product distribution				
Product loader				●
Truck driver	(a)	(a)	(a)	(a)
Warehouse worker				●

a. Section 4.1.6 and Appendix B describe the analysis for transportation doses.

The analysis used default RESRAD-RECYCLE parameters and assumptions to evaluate doses and risks for these scenarios. For each of the exposure scenarios, the default parameters define the source geometry (for estimation of external exposure); mass, density, thickness, and radius of the material; distance between the exposed individual and the source; exposure duration; exposed medium (ingot, slag, or baghouse dust); medium concentration for internal pathways (ingot, slag, or baghouse dust); default internal pathways (inhalation, ingestion, or none); airborne dust loading; and number of exposed workers at each location.

To bound the estimates of annual doses and risks to workers and risks to the public from airborne effluents, DOE assumed 15,300 tons (13,880 metric tons) of nickel would be processed in 1 year, even though the estimated throughput for the electro-winning and carbonyl processes would be only 2,000 tons (1,814 metric tons) of nickel per year. DOE would limit the total exposure to individual industrial workers by limiting the hours they worked in a year, which relates to the total mass of processed metal.

The following sections summarize the RESRAD-RECYCLE scenarios. Cheng et al. (2000) contains more detail.

A.2.1 INDUSTRIAL RADIATION WORKER SCENARIOS

RESRAD-RECYCLE contains several radiation exposure scenarios that involve industrial workers who could be exposed to radionuclides in recycled nickel. The analysis evaluated these scenarios and the scenarios specific to the controlled radiological disposition of nickel (Table A-9). The analysis used the default parameters and assumptions from the RESRAD-RECYCLE scenarios with the exception of transportation doses. (Section 4.1.6 and Appendix B describe the analysis for transportation doses.)

Scrap Delivery

The analysis used two default industrial worker scenarios for the delivery step for the scrap nickel. These include scenarios for scrap cutters and scrap loaders. Because these scenarios occur before melting, the analysis did not apply the partitioning factors to the assumed input concentrations. For the ETTP nickel, the assumed metal density was less than that found in a furnace or ingot of metal, which accounted for voids in the scrap metal piles. In each of these scenarios, the exposure pathways for calculation of dose included inhalation and incidental ingestion from loose surface contamination in addition to external exposure.

- Scrap cutter. These individuals would prepare the scrap for delivery to a smelter or to the electrowinning and carbonyl processes. The activities would include metal shredding, cutting, smashing, chopping, bailing, and banding loads of scrap nickel. To produce a bounding analysis, the analysis assumed the work would be performed in 1,670 hours over the course of 1 year to process 15,300 tons (13,880 metric tons) of scrap nickel. For external exposure, the scrap cutters would be an average of 6.6 feet (2 meters) from the source.

- Scrap loader. As the title indicates, these individuals would load the scrap metal onto trucks for transport to the smelter. The analysis used parameters for standard loading equipment and estimated that it would take 560 hours to load the scrap nickel during a single year. The scrap loaders would be an average of 13 feet (4 meters) from the source.

Smelting

The analysis included eight default scenarios for industrial radiation workers who would be involved in the smelting step. These included scenarios for a scrap processor, smelter yard worker, smelter loader, furnace operator, baghouse processor, ingot caster, small object caster, and slag worker. The analysis applied the radionuclide partitioning factors in Section A.1 to operations inside the smelter for work activities that occurred after melting. In each of these scenarios, the exposure pathways for calculation of dose included external exposure, inhalation, and incidental ingestion.

- Scrap processor. This scenario represents conditions for a worker who would prepare the scrap for processing. This scenario includes shredding, cutting, smashing, chopping, bailing, and banding the scrap metal as the work activities. Workers would spend 1,670 hours in 1 year to process the scrap nickel. The workers would be an average of 7 feet (2 meters) from the scrap metal during the exposure.

- Smelter yard worker. This scenario represents the conditions for a worker in the storage yard at the smelter. RESRAD-RECYCLE calculated that the yard workers would need to work 1,400 hours during 1 year to process the scrap nickel. Yard workers would be an average of 33 feet (10 meters) from the scrap pile during the exposure duration.

- Smelter loader. The analysis used this scenario to evaluate potential dose to crane operators who would load scrap metal into the furnace. The furnace would have a 110-ton (100-metric-ton) capacity. It would take 700 hours in 1 year to load the material into the furnace. The loaders would be an average distance of 13 feet (4 meters) from the furnace. The operator would be an average of 10 feet (3 meters) from the source.

- Baghouse processor. The smelter baghouse would collect airborne particulates; the baghouse processor must remove the contents and load the material into special dust bags before solidification with grout. The analysis assumed the dust would be sprayed with water to control airborne concentrations. The number of bags to process depends on the furnace throughput, and the radionuclide content was determined using the partitioning factors specific to each element. The baghouse processor would spend 400 hours in 1 year processing the contaminated dust bags at an average distance of 6.6 feet (2 meters).

  Dependent on the final product quality requirements, the metal from the smelting process could require further refinement. The analysis did not further apply the radionuclide partitioning factors because it assumed additional refinement would not result in a substantial loss of metal.

- Ingot caster. This scenario models the potential doses to workers who would be involved in casting metal ingots as industrial products. The workers would spend 350 hours at a distance of 5 feet (1.5 meters).

  In addition to large ingots, workers could cast small objects for use in the electro-winning and carbonyl processes directly from the initial metal melt. The analysis assumed that these workers would spend about 2,000 hours processing 13,770 tons (12,492 metric tons) of nickel, at an average of 3.3 feet (1 meter) from the source.

- Slag worker. The final industrial worker exposure scenario for the scrap smelting step involves workers who would use standard loading and unloading equipment to handle the slag product at the smelting facility. The analysis assumed 10 percent of the scrap nickel mass would partition as slag. The workers would spend 2,000 hours to process 1,530 tons (1,380 metric tons) of slag at an average distance of 4.5 feet (1.5 meters) from the source.

Ingot Delivery

The analysis used one default scenario in the ingot delivery step to model a loader who would load the ingots on trucks. Because these operations would occur outside the smelting facility after the ingot was cooled, there would be no potential for inhalation or incidental ingestion dose. As a result, the only analyzed exposure pathway was external exposure.

- Ingot loader. The analysis assumed radionuclide concentrations would meet IAEA clearance levels (Section A.1). For the ingot loader scenario, the loaders would spend 280 hours to handle 13,770 tons (12,492 metric tons) of nickel ingots. For external exposure, ingot loaders would be an average of 13 feet (4 meters) from the source.

Initial Fabrication

The analysis included two default scenarios for the initial fabrication step for industrial workers. Storage yard workers would receive exposure only through the external exposure pathway; sheet makers would receive exposure through the internal, incidental ingestion, and external exposure pathways. The analysis used the total 13,770 tons (12,492 metric tons) of nickel for these scenarios.

- Storage yard worker. The storage yard workers would process the cast ingots at the storage yard of a fabrication plant. For external exposure, each worker would spend 2,000 hours in 1 year at an average distance of 3.3 feet (1 meter).

- Sheet maker. This scenario modeled doses to industrial workers who would fabricate metal sheets from the cast ingots. The sheet makers would each work 150 hours to process the refined cast ingots at an average distance of 3.3 feet (1 meter) from the source.

Final Fabrication

The analysis used the coil handler default scenario to model the manufacture of end-use equipment and products from recycled nickel. Because this scenario occurs after smelting, the only analyzed exposure pathway was external exposure.

- Coil handler. This scenario considered potential doses to an individual who handled coils of metal sheets produced in the final fabrication step. Each worker would each work 80 hours in 1 year to handle the coils from the nickel at an average distance of 4.8 feet (1.5 meters).

Product Distribution

After manufacture of end-use products, they would be transported and distributed from the fabrication facility. The analysis used two RESRAD-RECYCLE scenarios: a product loader and a warehouse worker. Because these exposure scenarios involve finished products, the only analyzed exposure pathway was external exposure.

- Warehouse worker. The analysis assumed the final products would be stored in a warehouse before distribution to the end-use consumers. Each worker would spend 2,000 hours at an average distance of 20 feet (6 meters) from the source.

- Product loader. These individuals would load the product on trucks for delivery. Each individual would spend 20 hours each loading and unloading trucks at an average of 13 feet (4 meters) from the source.

A.2.2 END-USE PRODUCT SCENARIOS

The proposed action – disposition of nickel for controlled radiological use – requires the definition of special end-use scenarios that are substantially different from the default consumer product scenarios in RESRAD-RECYCLE. For this evaluation, DOE defined three example controlled product scenarios: shielding blocks, radioactive waste containers, and a large component for use in a commercial nuclear reactor. These scenarios represent a broad set of potential products that could be fabricated from the nickel. If other uses were identified, additional analysis under the National Environmental Policy Act would not necessarily be necessary if the impacts would not be greater than those of this environmental assessment. For a bounding analysis, DOE assumed the products would be pure nickel. That is, the analysis did not consider blending of the nickel with steel and chromium to produce stainless steel because this would dilute the radionuclide content to about 10 percent of the concentrations after decontamination. Table A-10 summarizes the parameters for modeling controlled-use products in RESRAD-RECYCLE. The analysis estimated radiation doses and human health risks only for the radioactivity in the nickel products; it did not include those from other sources of radiation in relation to using those products in controlled radiological applications. The following paragraphs define the scenario parameters the analysis used for estimation of radiation doses with RESRAD-RECYCLE.

Shielding Blocks. DOE- or NRC-licensed facilities could use shielding blocks for applications such as high-energy accelerators, in which a typical block is about 4.5 feet (1.37 meters) in each dimension and

Table A-10. RESRAD-RECYCLE parameters for controlled radiological use scenarios.

Scenario	Source geometry	Density (g/cm^2)[a]	Thickness (cm)[b]	Radius (cm)	Distance from source	Exposure duration (hours)
Shielding blocks	1 full cylinder	7.86	1,250	625	100	500
Radioactive waste containers	1 half cylinder	7.86	0.3	100	100	500
Nuclear reactor components	1 full cylinder	7.86	20	200	500	40

a. g/cm^2 = grams per square centimeter; to convert to pounds per square inch, multiply by 0.01422.
b. cm = centimeter; to convert to inches, multiply by 0.3937.

weighs about 20 tons (18 metric tons). For this scenario, a massive shielding wall would use the entire amount of DOE nickel. This assumption bounds the potential exposures because all of the nickel would be at one facility. The analysis modeled individuals who would receive external doses for 100 hours per year at a distance of 3.3 feet (1 meter).

Radioactive Waste Containers. A logical end-use for recycled nickel would be for controlled radioactive waste disposal containers such as those the proposed Yucca Mountain Repository would need for disposal of spent nuclear fuel and high-level radioactive waste. The analysis selected a typical cylindrical radioactive waste drum and assumed an individual would be exposed at a distance of 3.3 feet (1 meter) from an empty container for 500 hours per year. The individuals would be exposed to these empty radioactive waste disposal containers.

Large Nuclear Reactor Components. The third controlled-use product for the analysis would be the production of a large component for use in the nuclear industry. Such components could include reactor pressure vessels, reactor pressure vessel heads, steam generators, large intake piping, or large nuclear reactor compartments. Each component would be about 22 tons (20 metric tons). The analysis assumed an individual would receive exposure at 17 feet (5 meters) from the source for 40 hours per year, which reflects exposure only during annual maintenance operations.

A.3 ESTIMATED RADIATION DOSES AND RISKS

Table A-11 summarizes the bounding assumptions the analysis used with RESRAD-RECYCLE to estimate the radiation doses and probabilities of latent cancer fatalities. Complete summary tables of results at the end of this appendix (Figures A-1 to A-4) include: (1) siting the proposed action Step 1 through 3 facilities at ETTP, PGDP, and a generic site; and (2) siting the proposed action Step 4 end-use scenarios at a generic site. Because all of the proposed action steps would occur at DOE-controlled, NRC-licensed, or otherwise regulated facilities, the workers would be trained radiation workers. The only members of the public that would be exposed would be those who lived downwind near the processing facilities.

The estimated individual worker doses and risks from RESRAD-RECYCLE are the same for all sites for the proposed action Steps 1 through 3. This is because the analysis assumed the same number of workers, work categories, radionuclide concentrations, total mass of nickel, and exposure durations and conditions. The analysis assumed each step would occur in different years, so there would be no additive doses for individual workers from working at more than one facility in a year. This means that all of the bounding individual and worker doses are independent of the site or location of the specific facilities. Table A-12 lists the bounding individual doses and the limiting radiation exposure scenario for the individual doses for all work categories for each step of the proposed action. Because of uncertainties in relation to recovery and disposal of the end-use products, the analysis assumed the doses during end use would bound those of recovery and disposal. As Table A-12 shows, all of the individual radiation worker doses would be a small fraction of the 5 rem (0.05 sievert) annual dose limit for workers. Further, the

Table A-11. Bounding assumptions for the human health radiation dose and risk analysis.

Topic	Discussion
Siting disposition steps	All DOE nickel processed at PGDP, ETTP, or a generic site for disposition Steps 1 to 3, and only at the generic site for Steps 4 and 5.
Pure nickel	All manufacturing and end-use products use pure nickel rather than alloyed products. Alloying would typically reduce the radionuclide concentrations to about 10 percent of their concentrations in the nickel after decontamination.
Radionuclide concentrations	For Steps 1 to 3, the average radionuclide concentrations for the PGDP and ETTP nickel were used for the total tonnage. For Steps 4 and 5, the radionuclide concentrations were assumed to be at the IAEA clearance levels using the sum of fractions method, although actual levels would be lower because decontamination would be less than the clearance levels.
Decontamination throughput	Although decontamination is estimated to take 8 years, bounding worker and public doses and risks were estimated assuming only 1 year.
End-use scenarios	Because external exposure to penetrating radiation would be the only exposure pathway for the end use of manufactured products, doses and risks were bounded by assuming use of large, massive products.

doses for Steps 1 and 2 are higher than the doses for Steps 3 to 5, which occur after decontamination of the nickel to meet the IAEA clearance levels.

Table A-12. Bounding individual worker radiation doses.[a]

Nickel disposition step	MEI workers (millirem/year)	MEI workers limiting scenario
Step 1: Resizing	1.5	Slag worker
Step 2: Decontamination	3.6	Slag worker
Step 3: Fabrication	1.4×10^{-5} (b)	Warehouse worker
Step 4: End use	2.1×10^{-5}	Shielding blocks
Step 5: Disposal	2.1×10^{-5}	Shielding blocks

a. MEI = maximally exposed individual; to convert millirem to millisievert, multiply by 0.01.

b. Where 1.4×10^{-5} equals 0.000014.

Table A-13 summarizes the bounding individual worker lifetime probabilities of latent cancer fatalities.

Table A-13. Bounding estimated worker probabilities of latent cancer fatalities for the Proposed Action.

Nickel disposition step	Individual worker lifetime risk
Step 1: Resizing	8.6×10^{-7}[a]
Step 2: Decontamination	2.1×10^{-6}
Step 3: Fabrication	8.0×10^{-12}
Step 4: End-use shield blocks	1.2×10^{-11}
Step 5: Disposal	1.2×10^{-11}

a. LCFs = latent cancer fatalities and where 8.6×10^{-7} equals 0.00000086.

Consistent with the small radiation doses, the estimated numbers of latent cancer fatalities would be small. These latent cancer fatalities were estimated using the radiation dose-to-risk factors from Federal Guidance Report No. 13 (Eckerman et al. 1999).

For the public, DOE conducted a sensitivity study of potential radiation doses to the maximally exposed individuals for airborne releases using the RESRAD-OFFSITE (Yu et al. 2007) computer program with atmospheric effluents that were estimated with RESRAD-RECYCLE. The results indicated annual doses of less than 1 millirem (less than 0.01 millisievert). These values are an insignificant percentage of the normal background radiation dose, are a small fraction of the dose limit of 40 CFR Part 61, are consistent with current DOE operations, and equate to an individual probability of an latent cancer fatality of less than 0.000001 (1 chance in 1 million). Therefore, the proposed action would not result in quantitative doses or risks to members of the public.

Because there would be no high-energy sources (e.g., explosives) that could lead to radiological accidents during nickel disposition, there would be little potential for offsite radiological consequences from accidents. Further, as demonstrated by the small worker and downwind public doses, the radioactive concentration of radionuclides would be quite low. The analysis of public health impacts concluded that the potential impacts from transportation of radioactive materials, including low-level radioactive waste, would exceed those from any onsite accidents. Therefore, this analysis did not consider specific accidents during nickel disposition activities that could involve exposure of offsite members of the public to radiation.

Decontamination of these facilities would occur under either DOE controls or NRC/Agreement State licenses. These actions would be covered under the appropriate National Environmental Policy Act documentation (that is, use in regulated or licensed facilities, decontamination and decommissioning of those facilities, and license termination actions). However, given the low concentrations of residual radionuclides that would be present, significant radiological impacts to either the facility workers or the downwind public would be unlikely. As a worst case, the radiological impacts in Table A-13 would bound the impacts during facility decontamination.

A.4 REFERENCES

Anigstein, R., H. J. Chmelynski, D. A. Loomis, S. F. Marschke, J. J. Mauro, R. H. Olsher, W. C. Thurber, and R. A. Meck, 2003, *Radiological Assessments for Clearance of Materials from Nuclear Facilities*, NUREG-1640, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Washington, D.C., June.

Cheng, J.-J., B. Kassas, C. Yu, D. LePoire, J. Arnish, E. S. Dovel, S. Y. Chen, W. A. Williams, A. Wallo, III, and H. Peterson, 2000, *RESRAD-RECYCLE: A Computer Model for Analyzing the Radiological Doses and Risks Resulting From the Recycling of Radioactive Scrap Metal and the Reuse of Surface-Contaminated Material and Equipment*, ANL/EAD-3, U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

Eckerman, K. F., R. W. Leggett, C. B. Nelson, J. S. Puskin, and A. C. B. Richardson, 1999, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Radionuclide-Specific Lifetime Radiogenic Cancer Risk Coefficients for the U.S. Population, Based on Age-Dependent Intake, Dosimetry, and Risk Models*, Federal Guidance Report No. 13, EPA 402-R-99-001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C., September.

IAEA (International Atomic Energy Agency), 1992, *Application of Exemption Principles to the Recycle and Reuse of Material from Nuclear Facilities*, Safety Series No. 111-P-1.1, Vienna, Austria.

IAEA (International Atomic Energy Agency), 2004, *Application of the Concepts of Exclusion, Exemption and Clearance,* Safety Guide No. RS-G-1.7, Vienna, Austria.

Nieves, L. A., S. Y. Chen, E. J. Kohout, B. Nabelssi, R. W. Tilbrook, and S. E. Wilson, 1995, *Evaluation of Radioactive Scrap Metal Recycling*, ANL/EAD/TM-50, U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

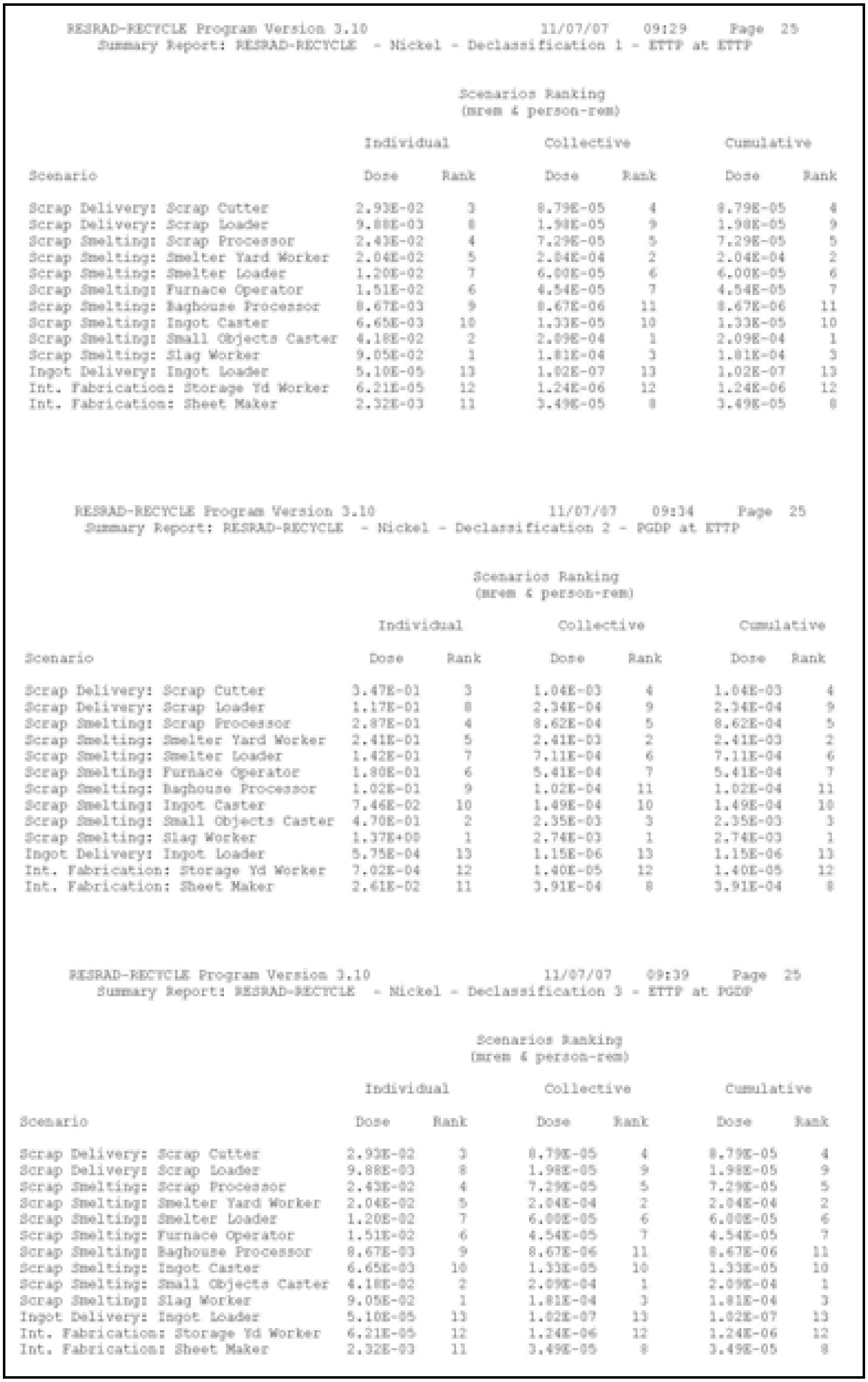
O'Donnell, F. R., et al., 1978, *Potential Radiation Dose to Man from Recycle of Metals Reclaimed from a Decommissioned Nuclear Power Plant*, NUREG/CR-0313, prepared for the U.S. Nuclear Regulatory Commission, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

SAIC (Science Applications International Corporation), 2001, *ALARA Evaluation of Recycling/Reuse of Metal from the U.S. DOE Gaseous Diffusion Plants at Oak Ridge, Tennessee, Paducah, Kentucky, and Portsmouth, Ohio*, prepared for the National Center of Excellence for Metals Recycle, U.S. Department of Energy, Oak Ridge, Tennessee.

SCA (S. Cohen and Associates), 1997, *Evaluation of the Potential for Recycling of Scrap Metals from Nuclear Facilities*, prepared for the U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, McLean, Virginia.

Yu, C., A. J. Zielen, J.-J Cheng, D. J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo III, W. A. Williams, and H. Peterson, 2001, *User's Manual for RESRAD, Version 6*, ANL/EAD/-4, U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

Yu, C., E. Gnanapragasam, B. M. Biwer, S. Kamboj, J.-J Cheng, T. Klett, D. LePoire, A. J. Zielen, S. Y. Chen, W. A. Williams, A. Wallo, S. Domotor, T. Mo, and A. Schwartzman, 2007, *User's Manual for RESRAD-OFFSITE, Version 2*, ANL/EVS/TM/07-1, U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

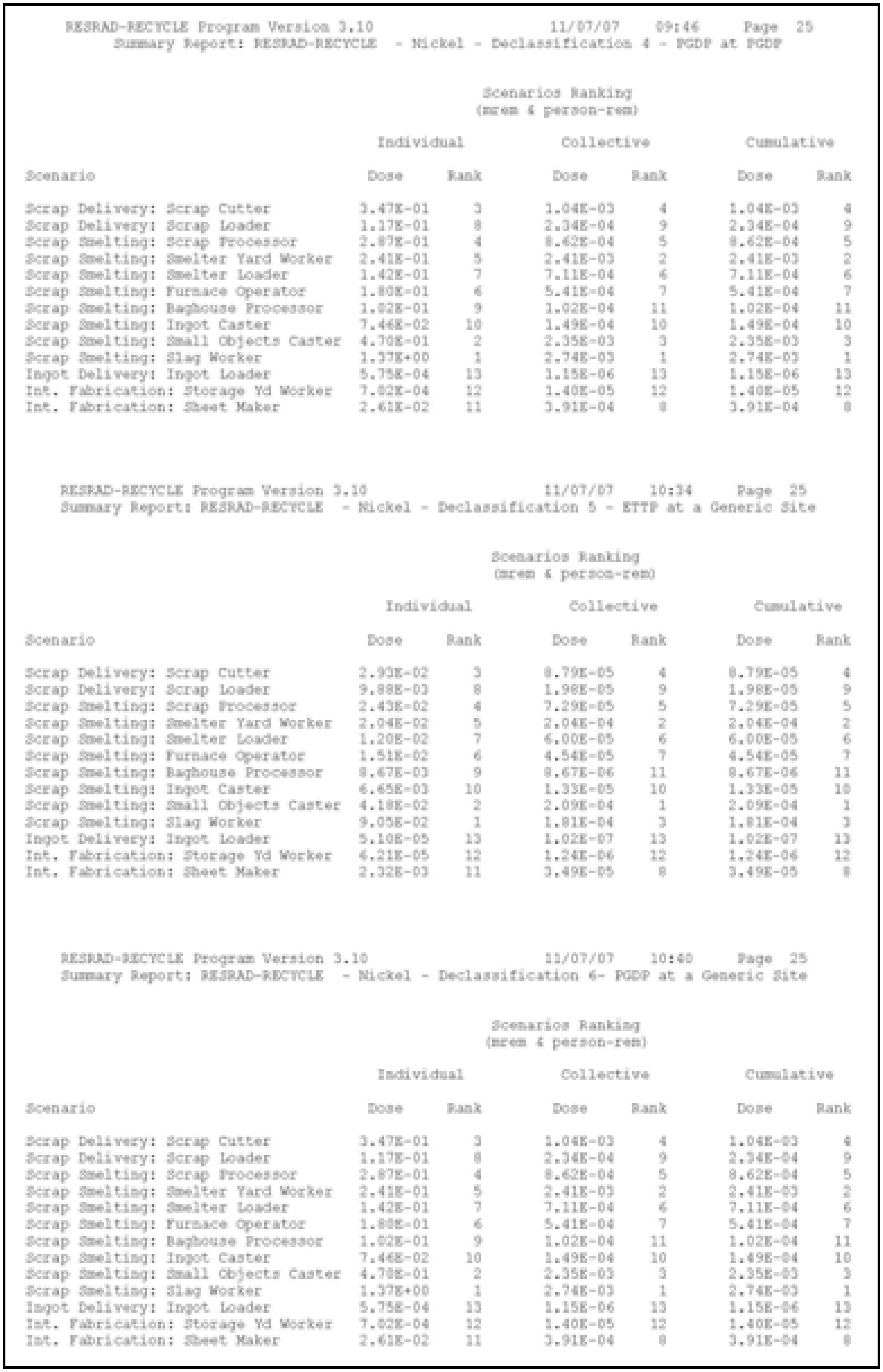


```
     RESRAD-RECYCLE Program Version 3.10                   11/07/07    09:29     Page  25
        Summary Report: RESRAD-RECYCLE  - Nickel - Declassification 1 - ETTP at ETTP


                                                      Scenarios Ranking
                                                      (mrem & person-rem)

                                             Individual           Collective           Cumulative

 Scenario                                    Dose      Rank       Dose      Rank       Dose      Rank

 Scrap Delivery: Scrap Cutter              2.93E-02     3       8.79E-05     4       8.79E-05     4
 Scrap Delivery: Scrap Loader              9.88E-03     8       1.98E-05     9       1.98E-05     9
 Scrap Smelting: Scrap Processor           2.43E-02     4       7.29E-05     5       7.29E-05     5
 Scrap Smelting: Smelter Yard Worker       2.04E-02     5       2.04E-04     2       2.04E-04     2
 Scrap Smelting: Smelter Loader            1.20E-02     7       6.00E-05     6       6.00E-05     6
 Scrap Smelting: Furnace Operator          1.51E-02     6       4.54E-05     7       4.54E-05     7
 Scrap Smelting: Baghouse Processor        8.67E-03     9       8.67E-06    11       8.67E-06    11
 Scrap Smelting: Ingot Caster              6.65E-03    10       1.33E-05    10       1.33E-05    10
 Scrap Smelting: Small Objects Caster      4.18E-02     2       2.09E-04     1       2.09E-04     1
 Scrap Smelting: Slag Worker               9.05E-02     1       1.81E-04     3       1.81E-04     3
 Ingot Delivery: Ingot Loader              5.10E-05    13       1.02E-07    13       1.02E-07    13
 Int. Fabrication: Storage Yd Worker       6.21E-05    12       1.24E-06    12       1.24E-06    12
 Int. Fabrication: Sheet Maker             2.32E-03    11       3.49E-05     8       3.49E-05     8
```

```
      RESRAD-RECYCLE Program Version 3.10                   11/07/07    09:34     Page  25
       Summary Report: RESRAD-RECYCLE  - Nickel - Declassification 2 - PGDP at ETTP


                                                       Scenarios Ranking
                                                       (mrem & person-rem)

                                              Individual          Collective          Cumulative

Scenario                                      Dose      Rank       Dose      Rank       Dose    Rank

Scrap Delivery: Scrap Cutter               3.47E-01     3       1.04E-03     4       1.04E-03     4
Scrap Delivery: Scrap Loader               1.17E-01     8       2.34E-04     9       2.34E-04     9
Scrap Smelting: Scrap Processor            2.87E-01     4       8.62E-04     5       8.62E-04     5
Scrap Smelting: Smelter Yard Worker        2.41E-01     5       2.41E-03     2       2.41E-03     2
Scrap Smelting: Smelter Loader             1.42E-01     7       7.11E-04     6       7.11E-04     6
Scrap Smelting: Furnace Operator           1.80E-01     6       5.41E-04     7       5.41E-04     7
Scrap Smelting: Baghouse Processor         1.02E-01     9       1.02E-04    11       1.02E-04    11
Scrap Smelting: Ingot Caster               7.46E-02    10       1.49E-04    10       1.49E-04    10
Scrap Smelting: Small Objects Caster       4.70E-01     2       2.35E-03     3       2.35E-03     3
Scrap Smelting: Slag Worker                1.37E+00     1       2.74E-03     1       2.74E-03     1
Ingot Delivery: Ingot Loader               5.75E-04    13       1.15E-06    13       1.15E-06    13
Int. Fabrication: Storage Yd Worker        7.02E-04    12       1.40E-05    12       1.40E-05    12
Int. Fabrication: Sheet Maker              2.61E-02    11       3.91E-04     8       3.91E-04     8
```

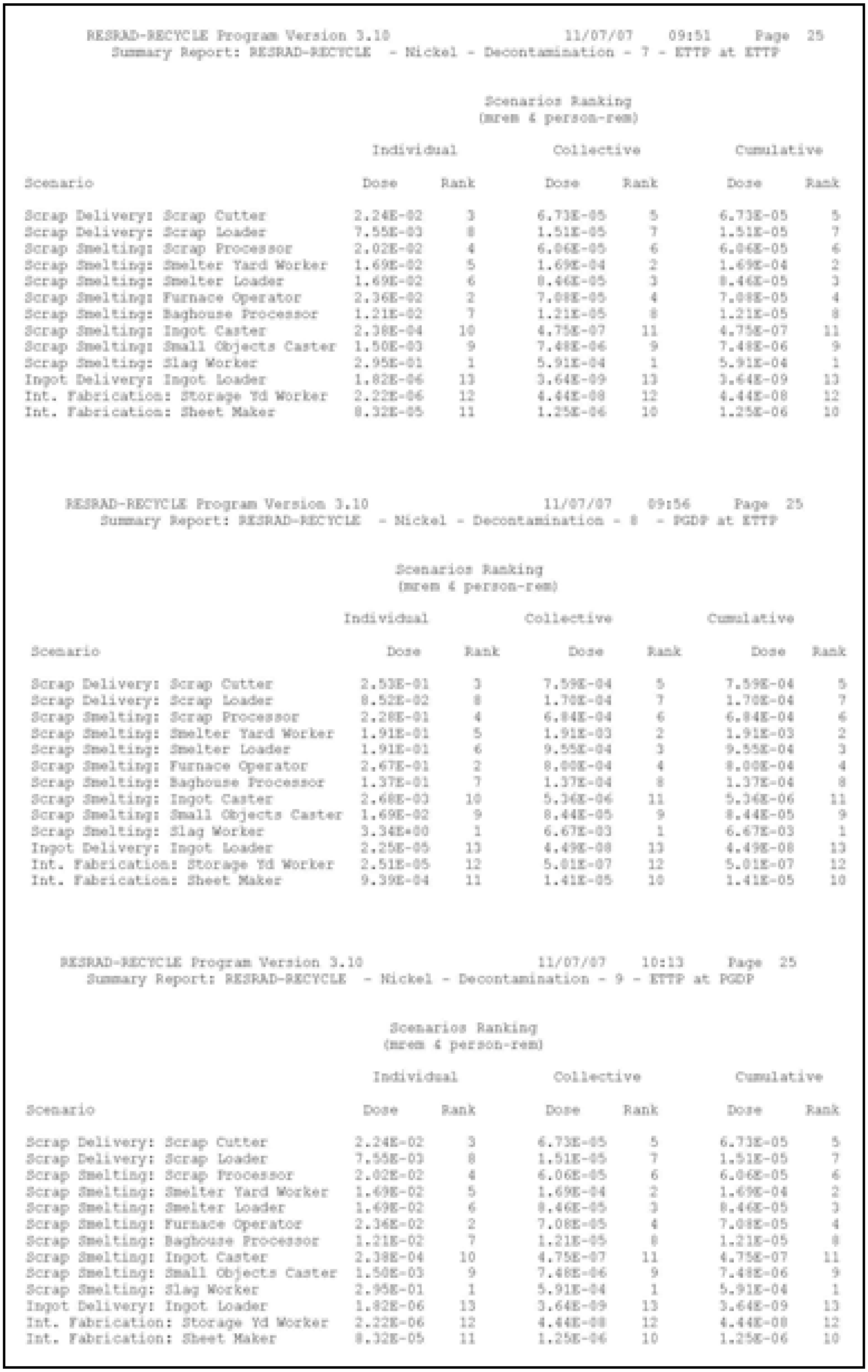
```
      RESRAD-RECYCLE Program Version 3.10                   11/07/07    09:39     Page  25
         Summary Report: RESRAD-RECYCLE  - Nickel - Declassification 3 - ETTP at PGDP


                                                       Scenarios Ranking
                                                       (mrem & person-rem)

                                             Individual           Collective           Cumulative

Scenario                                     Dose      Rank       Dose      Rank       Dose      Rank

Scrap Delivery: Scrap Cutter              2.93E-02     3       8.79E-05     4       8.79E-05     4
Scrap Delivery: Scrap Loader              9.88E-03     8       1.98E-05     9       1.98E-05     9
Scrap Smelting: Scrap Processor           2.43E-02     4       7.29E-05     5       7.29E-05     5
Scrap Smelting: Smelter Yard Worker       2.04E-02     5       2.04E-04     2       2.04E-04     2
Scrap Smelting: Smelter Loader            1.20E-02     7       6.00E-05     6       6.00E-05     6
Scrap Smelting: Furnace Operator          1.51E-02     6       4.54E-05     7       4.54E-05     7
Scrap Smelting: Baghouse Processor        8.67E-03     9       8.67E-06    11       8.67E-06    11
Scrap Smelting: Ingot Caster              6.65E-03    10       1.33E-05    10       1.33E-05    10
Scrap Smelting: Small Objects Caster      4.18E-02     2       2.09E-04     1       2.09E-04     1
Scrap Smelting: Slag Worker               9.05E-02     1       1.81E-04     3       1.81E-04     3
Ingot Delivery: Ingot Loader              5.10E-05    13       1.02E-07    13       1.02E-07    13
Int. Fabrication: Storage Yd Worker       6.21E-05    12       1.24E-06    12       1.24E-06    12
Int. Fabrication: Sheet Maker             2.32E-03    11       3.49E-05     8       3.49E-05     8
```

Figure A-1 (Part 1). Summary of dose from melting of nickel at ETTP, PGDP, and a generic site.



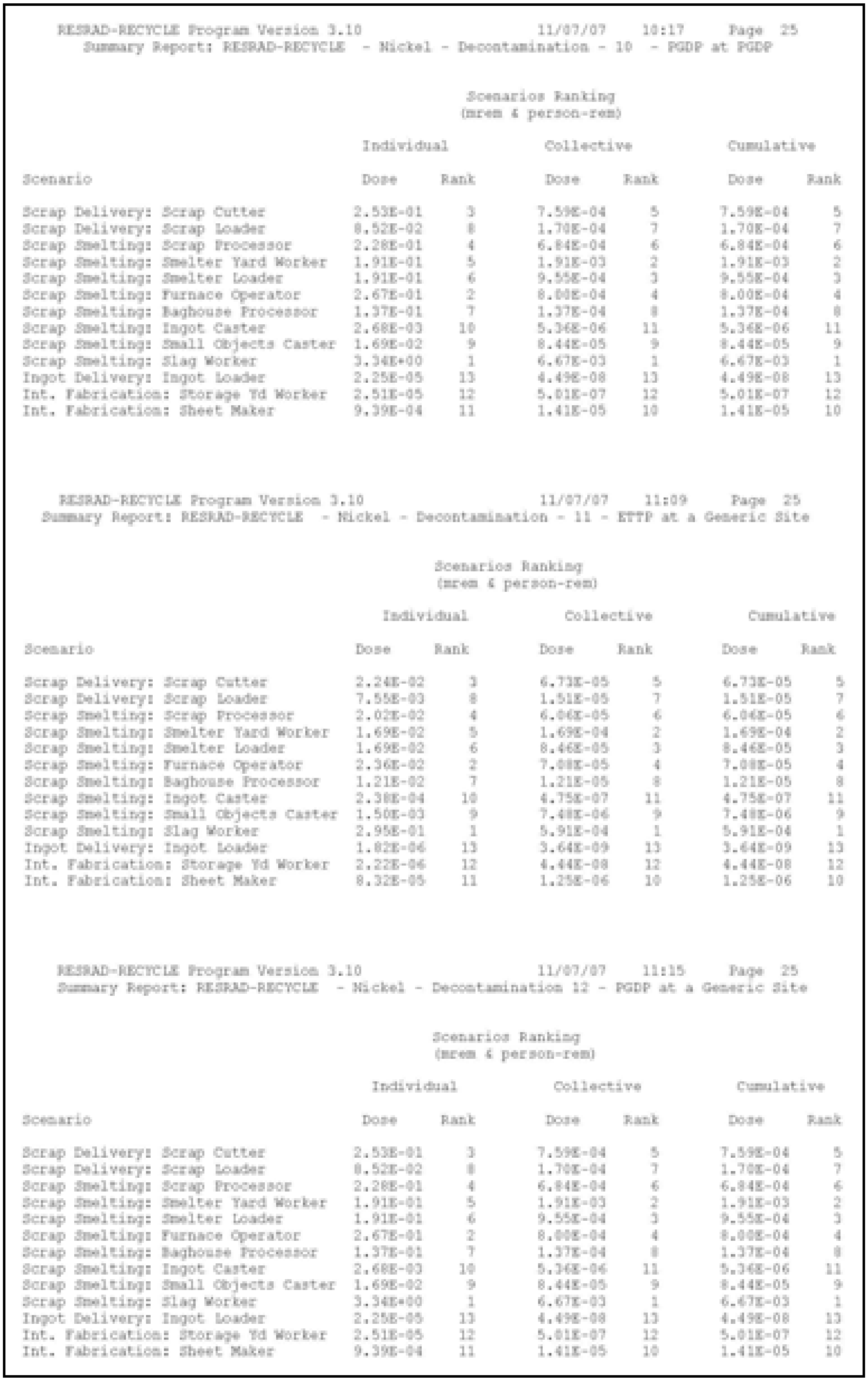
```
     RESRAD-RECYCLE Program Version 3.10                  11/07/07    09:46     Page  25
          Summary Report: RESRAD-RECYCLE  - Nickel - Declassification 4 - PGDP at PGDP


                                                             Scenarios Ranking
                                                            (mrem & person-rem)

                                                  Individual          Collective          Cumulative

 Scenario                                         Dose     Rank       Dose     Rank       Dose     Rank

 Scrap Delivery: Scrap Cutter                  3.47E-01     3      1.04E-03     4      1.04E-03     4
 Scrap Delivery: Scrap Loader                  1.17E-01     8      2.34E-04     9      2.34E-04     9
 Scrap Smelting: Scrap Processor               2.87E-01     4      8.62E-04     5      8.62E-04     5
 Scrap Smelting: Smelter Yard Worker           2.41E-01     5      2.41E-03     2      2.41E-03     2
 Scrap Smelting: Smelter Loader                1.42E-01     7      7.11E-04     6      7.11E-04     6
 Scrap Smelting: Furnace Operator              1.80E-01     6      5.41E-04     7      5.41E-04     7
 Scrap Smelting: Baghouse Processor            1.02E-01     9      1.02E-04    11      1.02E-04    11
 Scrap Smelting: Ingot Caster                  7.46E-02    10      1.49E-04    10      1.49E-04    10
 Scrap Smelting: Small Objects Caster          4.70E-01     2      2.35E-03     3      2.35E-03     3
 Scrap Smelting: Slag Worker                   1.37E+00     1      2.74E-03     1      2.74E-03     1
 Ingot Delivery: Ingot Loader                  5.75E-04    13      1.15E-06    13      1.15E-06    13
 Int. Fabrication: Storage Yd Worker           7.02E-04    12      1.40E-05    12      1.40E-05    12
 Int. Fabrication: Sheet Maker                 2.61E-02    11      3.91E-04     8      3.91E-04     8



    RESRAD-RECYCLE Program Version 3.10                  11/07/07    10:34     Page  25
    Summary Report: RESRAD-RECYCLE  - Nickel - Declassification 5 - ETTP at a Generic Site


                                                              Scenarios Ranking
                                                             (mrem & person-rem)

                                                   Individual          Collective          Cumulative

 Scenario                                         Dose     Rank       Dose     Rank       Dose     Rank

 Scrap Delivery: Scrap Cutter                  2.93E-02     3      8.79E-05     4      8.79E-05     4
 Scrap Delivery: Scrap Loader                  9.88E-03     8      1.98E-05     9      1.98E-05     9
 Scrap Smelting: Scrap Processor               2.43E-02     4      7.29E-05     5      7.29E-05     5
 Scrap Smelting: Smelter Yard Worker           2.04E-02     5      2.04E-04     2      2.04E-04     2
 Scrap Smelting: Smelter Loader                1.20E-02     7      6.00E-05     6      6.00E-05     6
 Scrap Smelting: Furnace Operator              1.51E-02     6      4.54E-05     7      4.54E-05     7
 Scrap Smelting: Baghouse Processor            8.67E-03     9      8.67E-06    11      8.67E-06    11
 Scrap Smelting: Ingot Caster                  6.65E-03    10      1.33E-05    10      1.33E-05    10
 Scrap Smelting: Small Objects Caster          4.18E-02     2      2.09E-04     1      2.09E-04     1
 Scrap Smelting: Slag Worker                   9.05E-02     1      1.81E-04     3      1.81E-04     3
 Ingot Delivery: Ingot Loader                  5.10E-05    13      1.02E-07    13      1.02E-07    13
 Int. Fabrication: Storage Yd Worker           6.21E-05    12      1.24E-06    12      1.24E-06    12
 Int. Fabrication: Sheet Maker                 2.32E-03    11      3.49E-05     8      3.49E-05     8



    RESRAD-RECYCLE Program Version 3.10                  11/07/07    10:40     Page  25
    Summary Report: RESRAD-RECYCLE  - Nickel - Declassification 6- PGDP at a Generic Site


                                                              Scenarios Ranking
                                                             (mrem & person-rem)

                                                  Individual          Collective          Cumulative

 Scenario                                         Dose     Rank       Dose     Rank       Dose     Rank

 Scrap Delivery: Scrap Cutter                  3.47E-01     3      1.04E-03     4      1.04E-03     4
 Scrap Delivery: Scrap Loader                  1.17E-01     8      2.34E-04     9      2.34E-04     9
 Scrap Smelting: Scrap Processor               2.87E-01     4      8.62E-04     5      8.62E-04     5
 Scrap Smelting: Smelter Yard Worker           2.41E-01     5      2.41E-03     2      2.41E-03     2
 Scrap Smelting: Smelter Loader                1.42E-01     7      7.11E-04     6      7.11E-04     6
 Scrap Smelting: Furnace Operator              1.80E-01     6      5.41E-04     7      5.41E-04     7
 Scrap Smelting: Baghouse Processor            1.02E-01     9      1.02E-04    11      1.02E-04    11
 Scrap Smelting: Ingot Caster                  7.46E-02    10      1.49E-04    10      1.49E-04    10
 Scrap Smelting: Small Objects Caster          4.70E-01     2      2.35E-03     3      2.35E-03     3
 Scrap Smelting: Slag Worker                   1.37E+00     1      2.74E-03     1      2.74E-03     1
 Ingot Delivery: Ingot Loader                  5.75E-04    13      1.15E-06    13      1.15E-06    13
 Int. Fabrication: Storage Yd Worker           7.02E-04    12      1.40E-05    12      1.40E-05    12
 Int. Fabrication: Sheet Maker                 2.61E-02    11      3.91E-04     8      3.91E-04     8
```

Figure A-1 (Part 2). Summary of dose from melting of nickel at ETTP, PGDP, and a generic site.



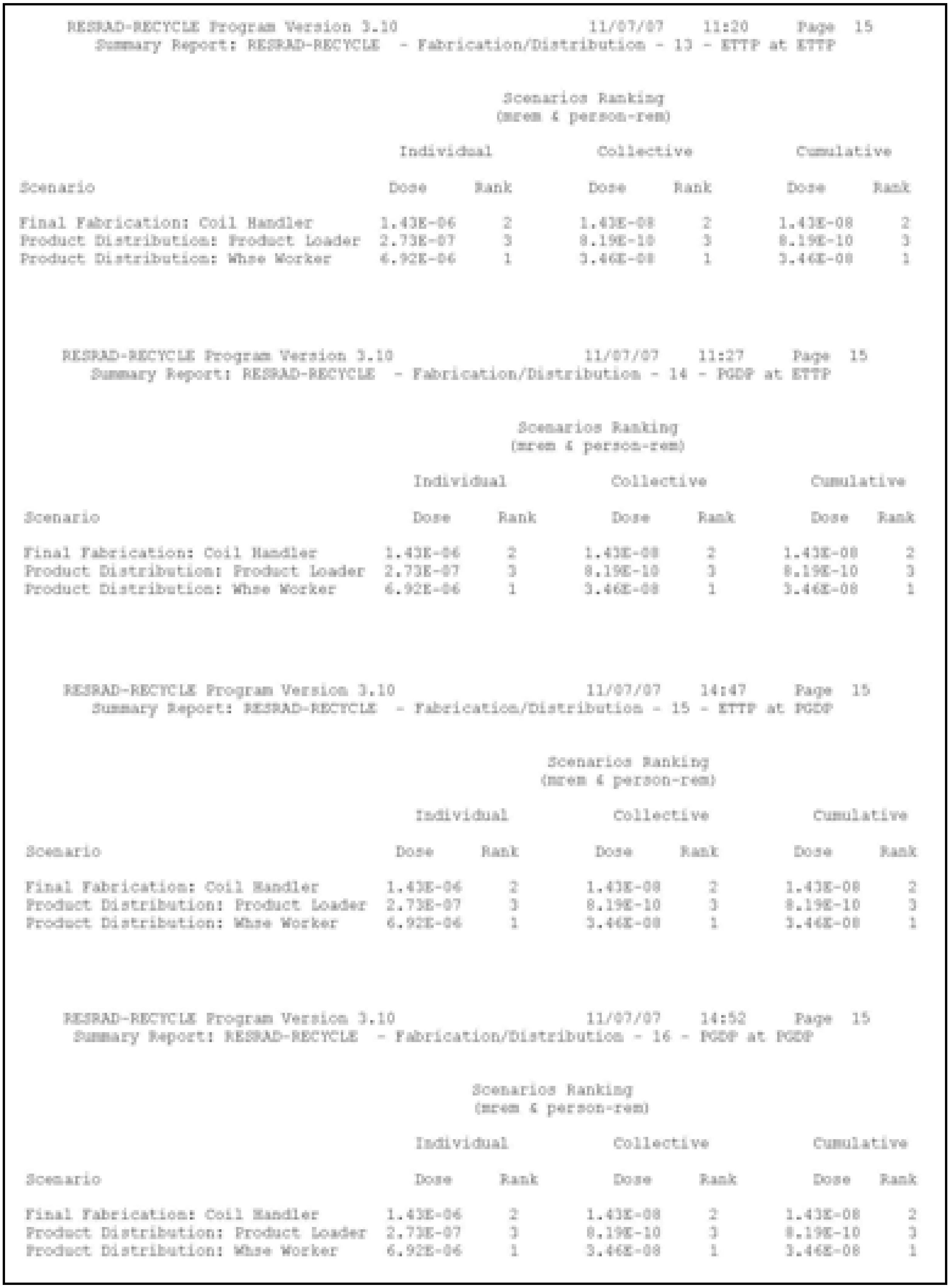
```
      RESRAD-RECYCLE Program Version 3.10                 11/07/07    09:51     Page  25
         Summary Report: RESRAD-RECYCLE  - Nickel - Decontamination - 7 - ETTP at ETTP


                                                        Scenarios Ranking
                                                       (mrem & person-rem)

                                             Individual          Collective          Cumulative

Scenario                                     Dose     Rank       Dose     Rank       Dose     Rank

Scrap Delivery: Scrap Cutter               2.24E-02     3      6.73E-05     5      6.73E-05     5
Scrap Delivery: Scrap Loader               7.55E-03     8      1.51E-05     7      1.51E-05     7
Scrap Smelting: Scrap Processor            2.02E-02     4      6.06E-05     6      6.06E-05     6
Scrap Smelting: Smelter Yard Worker        1.69E-02     5      1.69E-04     2      1.69E-04     2
Scrap Smelting: Smelter Loader             1.69E-02     6      8.46E-05     3      8.46E-05     3
Scrap Smelting: Furnace Operator           2.36E-02     2      7.08E-05     4      7.08E-05     4
Scrap Smelting: Baghouse Processor         1.21E-02     7      1.21E-05     8      1.21E-05     8
Scrap Smelting: Ingot Caster               2.38E-04    10      4.75E-07    11      4.75E-07    11
Scrap Smelting: Small Objects Caster       1.50E-03     9      7.48E-06     9      7.48E-06     9
Scrap Smelting: Slag Worker                2.95E-01     1      5.91E-04     1      5.91E-04     1
Ingot Delivery: Ingot Loader               1.82E-06    13      3.64E-09    13      3.64E-09    13
Int. Fabrication: Storage Yd Worker        2.22E-06    12      4.44E-08    12      4.44E-08    12
Int. Fabrication: Sheet Maker              8.32E-05    11      1.25E-06    10      1.25E-06    10



    RESRAD-RECYCLE Program Version 3.10                 11/07/07    09:56     Page  25
        Summary Report: RESRAD-RECYCLE  - Nickel - Decontamination - 8  - PGDP at ETTP


                                                   Scenarios Ranking
                                                  (mrem & person-rem)

                                           Individual          Collective          Cumulative

Scenario                                        Dose     Rank       Dose     Rank       Dose    Rank

Scrap Delivery: Scrap Cutter               2.53E-01     3      7.59E-04     5      7.59E-04     5
Scrap Delivery: Scrap Loader               8.52E-02     8      1.70E-04     7      1.70E-04     7
Scrap Smelting: Scrap Processor            2.28E-01     4      6.84E-04     6      6.84E-04     6
Scrap Smelting: Smelter Yard Worker        1.91E-01     5      1.91E-03     2      1.91E-03     2
Scrap Smelting: Smelter Loader             1.91E-01     6      9.55E-04     3      9.55E-04     3
Scrap Smelting: Furnace Operator           2.67E-01     2      8.00E-04     4      8.00E-04     4
Scrap Smelting: Baghouse Processor         1.37E-01     7      1.37E-04     8      1.37E-04     8
Scrap Smelting: Ingot Caster               2.68E-03    10      5.36E-06    11      5.36E-06    11
Scrap Smelting: Small Objects Caster       1.69E-02     9      8.44E-05     9      8.44E-05     9
Scrap Smelting: Slag Worker                3.34E+00     1      6.67E-03     1      6.67E-03     1
Ingot Delivery: Ingot Loader               2.25E-05    13      4.49E-08    13      4.49E-08    13
Int. Fabrication: Storage Yd Worker        2.51E-05    12      5.01E-07    12      5.01E-07    12
Int. Fabrication: Sheet Maker              9.39E-04    11      1.41E-05    10      1.41E-05    10



    RESRAD-RECYCLE Program Version 3.10                 11/07/07    10:13     Page  25
       Summary Report: RESRAD-RECYCLE  - Nickel - Decontamination - 9 - ETTP at PGDP


                                                  Scenarios Ranking
                                                 (mrem & person-rem)

                                             Individual          Collective          Cumulative

Scenario                                     Dose     Rank       Dose     Rank       Dose     Rank

Scrap Delivery: Scrap Cutter               2.24E-02     3      6.73E-05     5      6.73E-05     5
Scrap Delivery: Scrap Loader               7.55E-03     8      1.51E-05     7      1.51E-05     7
Scrap Smelting: Scrap Processor            2.02E-02     4      6.06E-05     6      6.06E-05     6
Scrap Smelting: Smelter Yard Worker        1.69E-02     5      1.69E-04     2      1.69E-04     2
Scrap Smelting: Smelter Loader             1.69E-02     6      8.46E-05     3      8.46E-05     3
Scrap Smelting: Furnace Operator           2.36E-02     2      7.08E-05     4      7.08E-05     4
Scrap Smelting: Baghouse Processor         1.21E-02     7      1.21E-05     8      1.21E-05     8
Scrap Smelting: Ingot Caster               2.38E-04    10      4.75E-07    11      4.75E-07    11
Scrap Smelting: Small Objects Caster       1.50E-03     9      7.48E-06     9      7.48E-06     9
Scrap Smelting: Slag Worker                2.95E-01     1      5.91E-04     1      5.91E-04     1
Ingot Delivery: Ingot Loader               1.82E-06    13      3.64E-09    13      3.64E-09    13
Int. Fabrication: Storage Yd Worker        2.22E-06    12      4.44E-08    12      4.44E-08    12
Int. Fabrication: Sheet Maker              8.32E-05    11      1.25E-06    10      1.25E-06    10
```

Figure A-2 (Part 1). Summary of dose from melting of nickel at ETTP, PGDP, and a generic site.



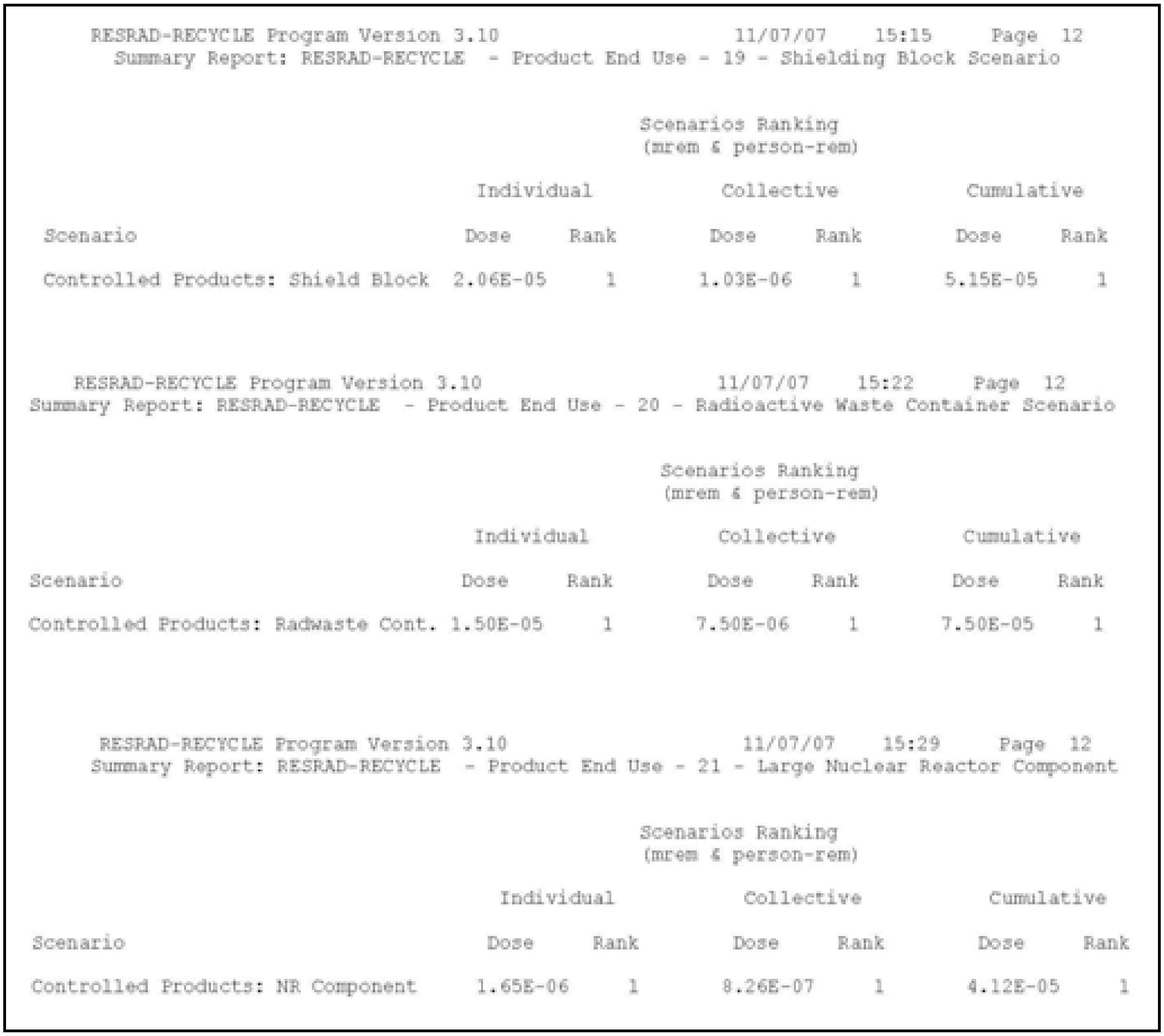
```
     RESRAD-RECYCLE Program Version 3.10                  11/07/07    10:17     Page  25
       Summary Report: RESRAD-RECYCLE  - Nickel - Decontamination - 10  - PGDP at PGDP


                                                     Scenarios Ranking
                                                    (mrem & person-rem)

                                             Individual          Collective          Cumulative

  Scenario                                   Dose     Rank       Dose     Rank       Dose     Rank

  Scrap Delivery: Scrap Cutter             2.53E-01     3      7.59E-04     5      7.59E-04     5
  Scrap Delivery: Scrap Loader             8.52E-02     8      1.70E-04     7      1.70E-04     7
  Scrap Smelting: Scrap Processor          2.28E-01     4      6.84E-04     6      6.84E-04     6
  Scrap Smelting: Smelter Yard Worker      1.91E-01     5      1.91E-03     2      1.91E-03     2
  Scrap Smelting: Smelter Loader           1.91E-01     6      9.55E-04     3      9.55E-04     3
  Scrap Smelting: Furnace Operator         2.67E-01     2      8.00E-04     4      8.00E-04     4
  Scrap Smelting: Baghouse Processor       1.37E-01     7      1.37E-04     8      1.37E-04     8
  Scrap Smelting: Ingot Caster             2.68E-03    10      5.36E-06    11      5.36E-06    11
  Scrap Smelting: Small Objects Caster     1.69E-02     9      8.44E-05     9      8.44E-05     9
  Scrap Smelting: Slag Worker              3.34E+00     1      6.67E-03     1      6.67E-03     1
  Ingot Delivery: Ingot Loader             2.25E-05    13      4.49E-08    13      4.49E-08    13
  Int. Fabrication: Storage Yd Worker      2.51E-05    12      5.01E-07    12      5.01E-07    12
  Int. Fabrication: Sheet Maker            9.39E-04    11      1.41E-05    10      1.41E-05    10




     RESRAD-RECYCLE Program Version 3.10                  11/07/07    11:09     Page  25
   Summary Report: RESRAD-RECYCLE  - Nickel - Decontamination - 11 - ETTP at a Generic Site


                                                  Scenarios Ranking
                                                 (mrem & person-rem)

                                               Individual          Collective          Cumulative

  Scenario                                 Dose     Rank       Dose     Rank       Dose     Rank

  Scrap Delivery: Scrap Cutter             2.24E-02     3      6.73E-05     5      6.73E-05     5
  Scrap Delivery: Scrap Loader             7.55E-03     8      1.51E-05     7      1.51E-05     7
  Scrap Smelting: Scrap Processor          2.02E-02     4      6.06E-05     6      6.06E-05     6
  Scrap Smelting: Smelter Yard Worker      1.69E-02     5      1.69E-04     2      1.69E-04     2
  Scrap Smelting: Smelter Loader           1.69E-02     6      8.46E-05     3      8.46E-05     3
  Scrap Smelting: Furnace Operator         2.36E-02     2      7.08E-05     4      7.08E-05     4
  Scrap Smelting: Baghouse Processor       1.21E-02     7      1.21E-05     8      1.21E-05     8
  Scrap Smelting: Ingot Caster             2.38E-04    10      4.75E-07    11      4.75E-07    11
  Scrap Smelting: Small Objects Caster     1.50E-03     9      7.48E-06     9      7.48E-06     9
  Scrap Smelting: Slag Worker              2.95E-01     1      5.91E-04     1      5.91E-04     1
  Ingot Delivery: Ingot Loader             1.82E-06    13      3.64E-09    13      3.64E-09    13
  Int. Fabrication: Storage Yd Worker      2.22E-06    12      4.44E-08    12      4.44E-08    12
  Int. Fabrication: Sheet Maker            8.32E-05    11      1.25E-06    10      1.25E-06    10




     RESRAD-RECYCLE Program Version 3.10                  11/07/07    11:15     Page  25
     Summary Report: RESRAD-RECYCLE  - Nickel - Decontamination 12 - PGDP at a Generic Site


                                                  Scenarios Ranking
                                                 (mrem & person-rem)

                                              Individual          Collective          Cumulative

  Scenario                                   Dose     Rank       Dose     Rank       Dose     Rank

  Scrap Delivery: Scrap Cutter             2.53E-01     3      7.59E-04     5      7.59E-04     5
  Scrap Delivery: Scrap Loader             8.52E-02     8      1.70E-04     7      1.70E-04     7
  Scrap Smelting: Scrap Processor          2.28E-01     4      6.84E-04     6      6.84E-04     6
  Scrap Smelting: Smelter Yard Worker      1.91E-01     5      1.91E-03     2      1.91E-03     2
  Scrap Smelting: Smelter Loader           1.91E-01     6      9.55E-04     3      9.55E-04     3
  Scrap Smelting: Furnace Operator         2.67E-01     2      8.00E-04     4      8.00E-04     4
  Scrap Smelting: Baghouse Processor       1.37E-01     7      1.37E-04     8      1.37E-04     8
  Scrap Smelting: Ingot Caster             2.68E-03    10      5.36E-06    11      5.36E-06    11
  Scrap Smelting: Small Objects Caster     1.69E-02     9      8.44E-05     9      8.44E-05     9
  Scrap Smelting: Slag Worker              3.34E+00     1      6.67E-03     1      6.67E-03     1
  Ingot Delivery: Ingot Loader             2.25E-05    13      4.49E-08    13      4.49E-08    13
  Int. Fabrication: Storage Yd Worker      2.51E-05    12      5.01E-07    12      5.01E-07    12
  Int. Fabrication: Sheet Maker            9.39E-04    11      1.41E-05    10      1.41E-05    10
```

Figure A-2 (Part 2). Summary of dose from melting of nickel from ETTP and PGDP at ETTP, PGDP, and a generic site.



```
     RESRAD-RECYCLE Program Version 3.10                    11/07/07    11:20     Page  15
        Summary Report: RESRAD-RECYCLE  - Fabrication/Distribution - 13 - ETTP at ETTP


                                                              Scenarios Ranking
                                                             (mrem & person-rem)

                                               Individual          Collective          Cumulative

Scenario                                      Dose      Rank       Dose      Rank       Dose      Rank

Final Fabrication: Coil Handler             1.43E-06      2      1.43E-08      2      1.43E-08      2
Product Distribution: Product Loader        2.73E-07      3      8.19E-10      3      8.19E-10      3
Product Distribution: Whse Worker           6.92E-06      1      3.46E-08      1      3.46E-08      1




     RESRAD-RECYCLE Program Version 3.10                    11/07/07    11:27     Page  15
        Summary Report: RESRAD-RECYCLE  - Fabrication/Distribution - 14 - PGDP at ETTP


                                                              Scenarios Ranking
                                                             (mrem & person-rem)

                                               Individual          Collective          Cumulative

Scenario                                      Dose      Rank       Dose      Rank       Dose      Rank

Final Fabrication: Coil Handler             1.43E-06      2      1.43E-08      2      1.43E-08      2
Product Distribution: Product Loader        2.73E-07      3      8.19E-10      3      8.19E-10      3
Product Distribution: Whse Worker           6.92E-06      1      3.46E-08      1      3.46E-08      1




     RESRAD-RECYCLE Program Version 3.10                    11/07/07    14:47     Page  15
        Summary Report: RESRAD-RECYCLE  - Fabrication/Distribution - 15 - ETTP at PGDP


                                                              Scenarios Ranking
                                                             (mrem & person-rem)

                                               Individual          Collective          Cumulative

Scenario                                      Dose      Rank       Dose      Rank       Dose      Rank

Final Fabrication: Coil Handler             1.43E-06      2      1.43E-08      2      1.43E-08      2
Product Distribution: Product Loader        2.73E-07      3      8.19E-10      3      8.19E-10      3
Product Distribution: Whse Worker           6.92E-06      1      3.46E-08      1      3.46E-08      1




     RESRAD-RECYCLE Program Version 3.10                    11/07/07    14:52     Page  15
      Summary Report: RESRAD-RECYCLE  - Fabrication/Distribution - 16 - PGDP at PGDP


                                                              Scenarios Ranking
                                                             (mrem & person-rem)

                                               Individual          Collective          Cumulative

Scenario                                      Dose      Rank       Dose      Rank       Dose      Rank

Final Fabrication: Coil Handler             1.43E-06      2      1.43E-08      2      1.43E-08      2
Product Distribution: Product Loader        2.73E-07      3      8.19E-10      3      8.19E-10      3
Product Distribution: Whse Worker           6.92E-06      1      3.46E-08      1      3.46E-08      1
```

Figure A-3. Summary of dose from nickel product fabrication at ETTP, PGDP, and a generic site.



```
     RESRAD-RECYCLE Program Version 3.10                    11/07/07    15:15     Page  12
      Summary Report: RESRAD-RECYCLE  - Product End Use - 19 - Shielding Block Scenario


                                                     Scenarios Ranking
                                                     (mrem & person-rem)

                                          Individual          Collective          Cumulative

 Scenario                                Dose     Rank        Dose     Rank        Dose     Rank

 Controlled Products: Shield Block   2.06E-05      1       1.03E-06     1       5.15E-05     1



    RESRAD-RECYCLE Program Version 3.10                    11/07/07    15:22     Page  12
Summary Report: RESRAD-RECYCLE  - Product End Use - 20 - Radioactive Waste Container Scenario


                                                     Scenarios Ranking
                                                     (mrem & person-rem)

                                          Individual          Collective          Cumulative

Scenario                                Dose     Rank        Dose     Rank        Dose     Rank

Controlled Products: Radwaste Cont. 1.50E-05      1       7.50E-06     1       7.50E-05     1



      RESRAD-RECYCLE Program Version 3.10                    11/07/07    15:29     Page  12
     Summary Report: RESRAD-RECYCLE  - Product End Use - 21 - Large Nuclear Reactor Component


                                                     Scenarios Ranking
                                                     (mrem & person-rem)

                                           Individual          Collective          Cumulative

Scenario                                  Dose     Rank        Dose     Rank        Dose     Rank

Controlled Products: NR Component      1.65E-06      1       8.26E-07     1       4.12E-05     1
```

Figure A-4. Summary of dose from end use of nickel products.

APPENDIX B. TRANSPORTATION ANALYSIS METHODOLOGY, ASSUMPTIONS, AND IMPACTS

This appendix documents the assumptions, input data, methods, results, and references for the evaluation of the potential transportation impacts of the disposition of 15,300 tons (13,800 metric tons) of nickel metal scrap from equipment DOE used in the uranium enrichment process. Under the proposed action, the analysis focused on the radiological and nonradiological human health impacts from the shipment of 15,300 tons of nickel to various facilities that would include resizing, decontamination and purification, fabrication, end-use, and disposal facilities. In addition, the analysis evaluated the transportation impacts from disposal of the nickel at a DOE- or NRC-licensed low-level radioactive waste disposal site. The no-action alternative assumes that the nickel would remain in storage at PGDP and ETTP and, because transportation would not occur, that there would be no transportation impacts.

Section B.1 provides (1) nickel inventories for PGDP and ETTP, (2) assumptions about shipping configurations (that is, package characteristics for truck shipments), (3) radiological characteristics of packages (for example, radiological constituent concentrations and radiation dose rates), and (4) the routing assumptions for shipments to disposal facilities. Section B.2 presents the assumptions, methods, and computer programs DOE used to evaluate potential impacts from the incident-free transport of disposal materials and lists the detailed impact estimates. Section B.3 presents the assumptions, methods, and computer programs for evaluation of impacts from potential transportation accidents and lists the results for the maximum reasonably foreseeable radiological accident and the fatalities from vehicle emissions and injuries and traffic accidents. Section B.4 summarizes transportation-related human health impacts.

B.1 SHIPPING INFORMATION

This section describes the information the analysis used to evaluate radiological and nonradiological transportation impacts. If specific information was unavailable, the analysis used conservative assumptions to provide reasonable assurance that it did not underestimate impacts (that is, calculated impacts would be bounding). Section B.1.1 describes the inventories of nickel and waste materials by type for all facilities in the process under the proposed action. Disposal as radioactive waste assumes that DOE would dispose of the entire inventories of nickel currently at PGDP and ETTP after processing at a melting facility.

B.1.1 NICKEL AND RADIONUCLIDE INVENTORIES

Evaluation of transportation impacts requires knowledge of the product and waste material inventories at PGDP and ETTP as well as the other processing facilities. Under the proposed action, disposition of nickel for controlled radiological use would consist of five steps: (1) Resizing, (2) Decontamination (Purification and Alloying), (3) Alloying, Fabricating, and Equipment Manufacturing, (4) End Use of Manufactured Products in Controlled Radiological Applications, and (5) Disposal of Manufactured Products after the end use. The analysis assumed current inventories of nickel of 9,700 tons (8,800 metric tons) and 5,600 tons (5,080 metric tons) at PGDP and ETTP, respectively. The following paragraphs describe the five steps and associated activities.

For Step 1, Tables A-3 and A-4 of Appendix A list input radionuclide inventories for the PGDP and ETTP nickel, respectively, listing the output product concentrations in the slag concentration.

For Step 1, the analysis assumed the shipment of 9,700 tons (8,800 metric tons, about 243 truckloads) of PGDP nickel and 5,600 tons (5,080 metric tons, about 140 truckloads) of ETTP nickel 1,000 miles

(1,600 kilometers) to a melting facility at a generic site. This is a bounding assumption because the initial melt could occur at ETTP or PGDP, due to security requirements.

After melting, the analysis assumed that there would be a 10-percent loss to slag for each inventory. Therefore, there would be 8,730 tons (7,920 metric tons, about 218 truckloads) of PGDP nickel, with 970 tons (880 metric tons, about 24 truckloads) of slag, and 5,040 tons (4,600 metric tons, about 126 truckloads) of ETTP nickel product, with 560 tons (508 metric tons, about 14 truckloads) of slag. The analysis assumed the disposal of the slag as waste at a low-level radioactive waste disposal facility. As part of the bounding analysis, it was assumed that this would occur at the longest shipping distance, or 3,000 miles (4,830 kilometers). The analysis assumed the product would go to a Step 2 decontamination facility 1,000 miles (1,600 kilometers) from the Step 1 melting facility.

For Step 2, the analysis assumed decontamination would result in the radionuclide concentrations in Table A-8 of Appendix A. The values in that tables are the estimated activity in the product [at the IAEA clearance levels]. All waste would be at the activity levels for slag shown in Tables A-3 and A-4.

Again, the analysis assumed 10-percent partitions to slag. Therefore, after decontamination, there would be 7,860 tons (7,130 metric tons, about 196 truckloads) of PGDP nickel product, with 873 tons (792 metric tons, about 22 truckloads) of slimes, and 4,540 tons (4,110 metric tons, about 113 truckloads) of ETTP nickel product, with 504 tons (457 metric tons, about 13 truckloads) of slimes. The analysis assumed the slimes would be disposed of at a low-level radioactive waste facility 3,000 miles (4,830 kilometers) away, and the product would go to the Step 3 smelter, 1,000 miles (1,600 kilometers) away for casting into products.

For Step 3, the analysis assumed all products would be at the clearance levels in Table A-8, and all wastes (slag) would have the radionuclide concentrations in Tables A-3 and A-4.

Again, the analysis assumed a 10-percent loss to slag. Therefore, after fabrication, there would be about 7,070 tons (6,410 metric tons, about 177 truckloads) of PGDP nickel product, with 786 tons (697 metric tons, about 20 truckloads) of slag, and 4,080 tons (3,700 metric tons, about 102 truckloads) of ETTP nickel product, with 454 tons (412 metric tons, about 11 truckloads) of slag. The analysis assumed that DOE would dispose of the slag at a low-level radioactive waste facility at a distance of 3,000 miles (4,830 kilometers), and the product would go to the Step 4 nuclear facility, 3,000 miles (3,830 kilometers) away.

For Step 4, the analysis assumed there would be no transportation.

For Step 5, the analysis assumed all products would be at the clearance levels in Table A-9. The analysis also assumed that the end user would dispose of 7,070 tons (6,410 metric tons, about 177 truckloads) of PGDP nickel products and 4,080 tons (3,700 metric tons, about 102 truckloads) of ETTP nickel products at a low-level radioactive waste facility at a distance of 3,000 miles (4,830 kilometers).

B.1.2 SHIPPING CONFIGURATIONS

The transportation impact analysis evaluated potential radiological and nonradiological impacts on transportation workers and members of the public from incident-free (that is, routine) transportation as well as the postulated maximum reasonably foreseeable radiological transportation accident. Potential radiological impacts from incident-free transportation would depend on, among other things, the level of penetrating radiation that emanated from the complete shipping package, which would include 40-foot (12-meter) tractor-trailer trucks, the total number of shipments, and the distance of each shipment. The analysis used the MicroShield® program (Grove Engineering 1998) to calculate the radiation dose rates based on the radionuclide content, overall size of the package (that is, length, height, and depth), density of the material, and the amount of shielding material (for example, the thickness of the truck side walls).

The analysis conservatively assumed that, under all alternatives, the source, product, and waste materials would be shipped to all locations by truck; this is because shipments by rail would result in lower impacts. The distance for each shipment would depend on the type of material; the analysis assumed the source and product materials would be shipped 1,000 miles (1,600 kilometers) between the processing facilities, and that all waste shipments would be 3,000 miles (4,830 kilometers) to a low-level radioactive waste disposal facility.

To simplify, the analysis assumed that truck shipments would consist of 40-foot (12-meter) tractor-trailers with a total weight of 80,000 pounds (about 36 metric tons; the legal weight limit for nonpermitted multiaxle trucks). Tables B-1 and B-2 summarize the number of truck shipments and distances for the proposed action and disposal as radioactive waste, respectively.

This analysis used a dose rate of 1 milliroentgen per hour at a distance of 3.28 feet (1 meter) from the vehicle to generate unit dose factors. To produce material-specific results, the analysis modified these unit dose rate factors by the estimated dose rates from each radionuclide mixture. The analysis used MicroShield to calculate the dose rates for 40-ton (about 36-metric-ton) truck shipments of source, product, and waste materials (Section B.2.1.1). Tables B-1 and B-2 list both one-way and two-way distances because nonradiological transportation impacts (that is, vehicle emissions and traffic fatalities) would include both loaded and empty trucks moving between the facilities, while incident-free radiological impacts [that is, latent cancer fatalities and increased probability of a latent cancer fatality (Section B.5)] would occur only for trucks loaded with radioactive materials.

B.1.3 ROUTING

To assess the impacts of radioactive materials transportation, the analysis first had to define the characteristics of transportation routes between the origin of the shipments and their destinations. These route characteristics are values such as distance, exposed populations, and weighted population densities.

This type of analysis often divides population density into three zones – rural, suburban, and urban – where rural is defined as an area with a density of less than about 139 people per square mile (54 people per square kilometer), suburban is defined as an area with a density between 139 and 3,326 people per square mile (54 and about 1,284 people per square kilometer), and urban is defined as an area with a density greater than 3,326 people per square mile (1,284 people per square kilometer) (Johnson and Michelhaugh 2003). The analysis typically estimates the distance traveled in each population zone and the total distance.

For shipments, the analysis used the WebTRAGIS computer program (Johnson and Michelhaugh 2003) and 2000 Census data to examine the highway routes. Route characteristics include total shipment distances; the distances traveled in rural, suburban, and urban population density zones; and the weighted population densities in these zones. To simplify and bound the impact analysis, DOE used all of the possible routes in the WebTRAGIS program to determine the percentage of the shipping routes that pass be through rural, suburban, and urban areas in Table B-3 (Johnson 2007a). In addition, the population densities for the rural, suburban, and urban areas in Table B-3 represent the upper limit as defined in WebTRAGIS (Johnson 2007b). However, the cap for the urban population density was 10,000 people per square mile because the routing of radioactive shipments through the densely populated areas of major cities in the United States would be highly unlikely.

Table B-1. Number of trucks for shipments and total distances for the Proposed Action.

	Source quantity		Step 1 Resizing		Step 2 Decontamination		Step 3		Step 4 End-use product	Step 5 Disposal product
Factor	**PGDP**	**ETTP**	**Product**	**Waste[a]**	**Product**	**Waste**	**Product**	**Waste[a]**		
Quantities (tons)[b]	9,700	5,600	13,800	1,530	12,400	1,380	11,200	1,240	11,200	11,200
Trucks (1-way)	243	140	344	38	310	34	280	31	280	280
Distance per trip, (1-way) (miles)[c]	1,000	1,000	1,000	3,000	1,000	3,000	1,000	3,000	1,000	3,000
Total distance, (1-way) (miles)	242,000	140,000	344,000	114,000	310,000	103,000	280,000	93,300	280,000	840,000
Total distance, (2-way) (miles)	485,000	280,000	690,000	230,000	620,000	206,000	560,000	186,000	560,000	1,680,000

a. The 10-percent waste factors were assumed to overstate the radioactivity and exposure for waste processing and disposal. The radioactivity and exposure for the product is overstated by the decision to analyze pure nickel instead of nickel alloy.

b. To convert tons to metric tons, multiply by 0.90718.

c. To convert miles to kilometers, multiply by 1.6093.

Table B-2. Number of trucks required for shipments and total distances for disposal as radioactive waste.

	Source quantity		Step 1 Resizing	
Factor	**ETTP**	**PGDP**	**Product**	**Waste**
Quantities (tons)[a]	5,600	9,700	13,800	1,540
Trucks (1-way)	140	243	344	38
Distance per trip, 1-way (miles)[b]	1,000	1,000	3,000	3,000
Total distance, 1-way (miles)	140,000	242,000	1,030,000	115,000
Total distance, 2-way (miles)	280,000	485,000	2,070,000	230,000

a. To convert tons to metric tons, multiply by 0.90718.

b. To convert miles to kilometers, multiply by 1.6093.

Table B-3. Distance and exposed populations within 2,625 feet (800 meters) of truck routes.[a]

	Proposed Action				Dispose as waste			
Factor	**Rural**	**Suburban**	**Urban**	**Affected population**	**Rural**	**Suburban**	**Urban**	**Affected population**
Percent of route	73.9	21.9	4.21		73.9	21.92	4.21	
Population density[a] (people/mile^2)	139	3,330	10,000		139	3326	10,000	
Total distance, 1-way (miles)[b]	2,030,000	603,000	116,000	14,000,000	1,130,000	336,744	64,700	3,900,000
Total distance, 2-way (miles)	4,070,000	1,210,000	232,000	14,000,000	2,270,000	673,487	129,000	3,900,000

Source: Johnson and Michelhaugh (2003).

a. To convert people per square mile to people per square mile, multiply by 2.59.

b. To convert miles to kilometers, multiply by 1.6093.

B.2 INCIDENT-FREE TRANSPORTATION

This section discusses the calculation of potential radiological exposures from offsite shipments of disposal material. Such shipments can emit some ionizing radiation through the shipping container during routine incident-free transportation. People exposed to this radiation would receive an external radiation dose. The exposed population would include truck crews and members of the public.

Section B.2.1 provides an overview of the methods and assumptions used to calculate collective doses, including the estimated doses, and Section B.2.2 describes the methods and assumptions used to calculate doses to individuals. Section B.2.3 discusses the determination of vehicle emission unit risk factors and their use in the estimation of potential nonradiological impacts.

B.2.1 INCIDENT-FREE COLLECTIVE DOSE

Figure B-1 shows the flow of information through the RADTRAN 5 computer model (Neuhauser and Kanipe 2000; Neuhauser, Kanipe, and Weiner 2000) and the Nickel RiskModel, which was used to estimate radiation doses to receptors.

The analysis calculated incident-free collective doses under the assumption that the external dose rate from the shipping package would be the radiation source that exposed receptors at various distances from the package. MicroShield calculated the radiation exposure from the shipping package based on the radionuclide content of the package. The analysis then used a combination of these estimated exposure rates at 3.28 feet (1 meter; referred to as transport indexes), RADTRAN 5, and the Nickel RiskModel to calculate the doses. The analysis considered exposures from moving and stationary vehicles. RADTRAN 5 calculates incident-free doses to the highest exposed member of the public, to workers (except truck drivers), and members of the general public (public doses). The analysis performed separate calculations for the following receptors:

- The *off-link* population dose applies to members of the general public who resided or were pedestrians along the transportation routes.

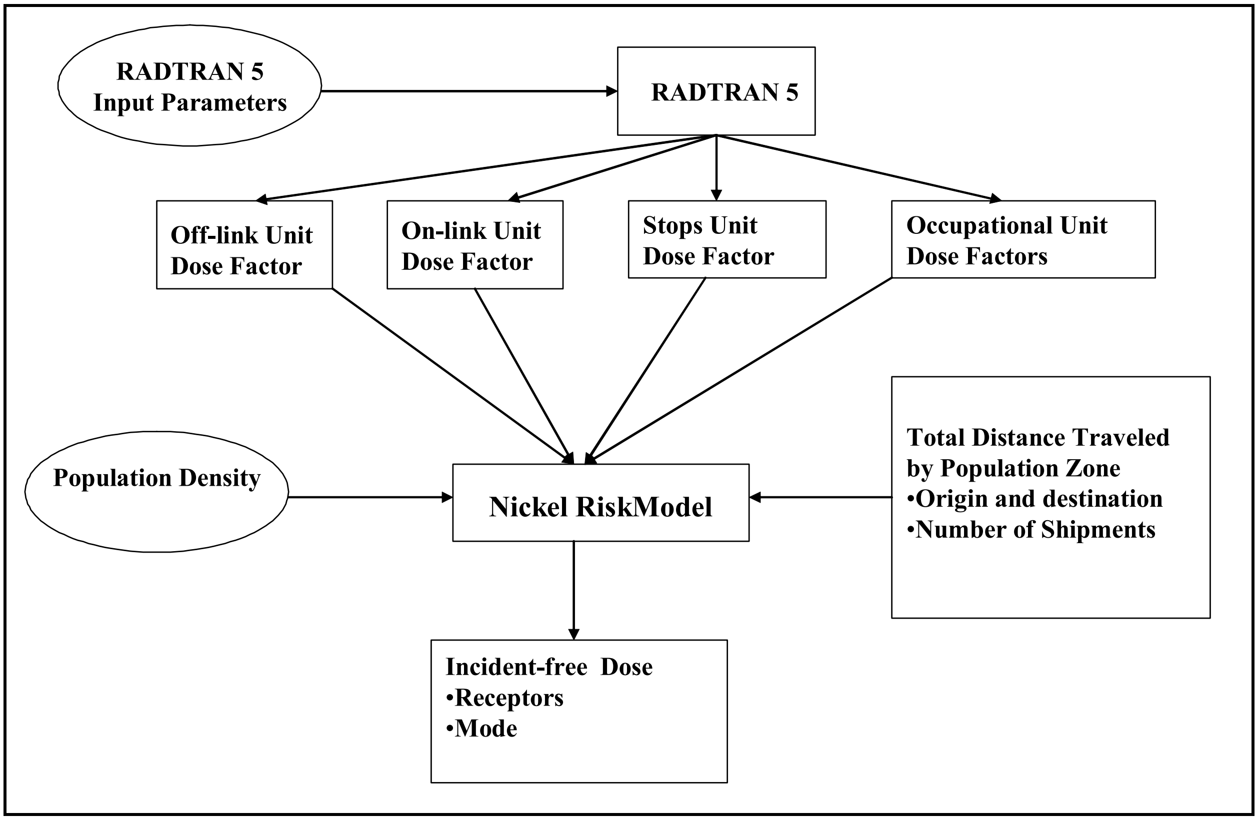


Figure B-1. Information flow for calculation of collective doses from incident-free transportation.

- The *on-link* population dose applies to occupants of motor vehicles that shared the transportation route with the shipment while it was moving.

- The *resident rest stop* dose applies to members of the public who lived within 0.5 mile (800 meters) of a rest stop area where a truck stopped for crew rest or refueling.

- The *crew dose* applies to truck crew members when a truck was moving.

- The *truck driver* dose applies to individuals driving trucks who were 4.9 feet (1.5 meters) from the end of the shipping package.

- The *truck stop* population dose applies to members of the public who were at rest and refueling stops when a truck carrying the shipment stopped for crew rest or refueling.

- The *maximally exposed resident along route* dose applies to a member of the public who lived within 30 meters (98 feet) of a truck route who was exposed to in-transit shipments.

- The *maximally exposed resident at stop* dose applies to a member of the public who lived within 98 feet (30 meters) of locations where trucks shipments stopped (for example, for rest and refuel).

The incident-free dose to a receptor is an external dose and depends on the dose rate external to the package. These external dose rates, or transport indexes, are a function of the radionuclide mix, metal type, and package type. The analysis used conservative assumptions for the estimations to maximize the calculated doses to provide reasonable assurance that incident-free doses would not be underestimated.

B.2.1.1 Assumptions

The model for collective population incident-free doses incorporates several general assumptions. The calculated doses are directly proportional to the number of shipments that would move past the receptor (Neuhauser, Kanipe, and Weiner 2000, p. 23). The collective incident-free population dose is proportional to the number of receptors. For truck transportation, the assumed receptors would occupy a 0.5-mile (800-meter)-wide corridor on either side of the route, and the population density in each corridor reflects the population density of the census block group that abuts or contains the route. Section B.1.3 discusses population assumptions and calculations.

The following sections describe the assumptions and parameters the analysis used with RADTRAN 5 to calculate off- and on-link doses. RADTRAN 5 includes a table of standard parameter values, as well as suggested values for other parameters. This section provides the input parameters for calculation of collective and individual doses from a moving truck and doses to individuals and nearby populations when the truck stopped for refueling and crew rest.

Parameters and Assumptions for Doses from Moving Trucks. Table B-4 lists the assumptions and input parameters, which include national average traffic counts, the analysis used to calculate incident-free doses from moving truck shipments. The model assumed freeway truck speeds would be constant in the absence of rush-hour traffic. Vehicles that shared the route would provide no shielding from the shipping package external radiation. However, buildings in suburban and urban areas would have shielding factors of 0.87 and 0.018, respectively. The model used national average one-way vehicle speeds to calculate the on-link dose for national truck shipments. The incident-free truck transportation analysis evaluated the following receptors along the modeled route:

- Members of the public who resided along the route and pedestrians (off-link),
- Occupants of vehicles that shared the route (on-link), and
- Crew dose (truck drivers).

Parameters and Assumptions for the Calculation of Truck Stop Doses. Section B.2.1.3 describes the rest and refueling stop model. Stop doses are proportional to the exposure time; they are inversely proportional to the distance to nearby receptors and to the square of the distance for distant receptors. Residences near stops would provide no shielding. The receptors at modeled stops in the incident-free truck transportation analysis would be:

- Members of the public at rest and refueling stops (for example, truck stops), and
- Residents of the area in the vicinity of the truck stops.

Table B-5 lists the assumptions about package type and dimensions, external dose rate, and ratio of gamma to neutron radiation (this analysis assumed all radiation would be gamma, so the gamma-to-neutron fraction is 1).

The Nickel RiskModel provides RADTRAN 5 input and output files for the calculation of unit dose factors. In addition, the RiskModel includes the values for route segment lengths, population densities, and numbers of shipments from the source and product facilities to end-use and disposal facilities (Section B.1.3). The RADTRAN 5 calculation includes all other factors in the calculation of the appropriate unit dose factor. Therefore:

- The off-link unit dose factor is per shipment, per kilometer, per unit population density (people per square kilometer), per millirem, and per hour (package transport index). The off-link dose is

Table B-4. Assumptions and parameters for incident-free doses from moving trucks.

Parameter	Value	Comments and reference
Package		
Package dimension	40 feet (12.19 meters)	Length of truck
Dose rate	Assumed to be 1 milliroentgen per hour for calculation of unit dose factors	Actual values used for dose estimations
Fraction of emitted radiation that is gamma	1	
Fraction of emitted radiation that is neutrons	0	
Crew		
Number of crew	2	Analytical assumption
Distance from source to crew	4.92 feet (1.5 meters)	Neuhauser, Kanipe, and Weiner (2000)
Route-specific parameters		
Rural	55 miles (88.5 kilometers) per hour	Neuhauser, Kanipe, and Weiner (2000)
Suburban	25 miles (40.2 kilometers) per hour	Neuhauser, Kanipe, and Weiner (2000)
Urban	15 miles (24.2 kilometers) per hour	Neuhauser, Kanipe, and Weiner (2000)
Number of people per vehicle sharing route	2	
One-way traffic volumes		
Rural	283 vehicles per hour	Neuhauser, Kanipe, and Weiner (2000)
Suburban	590 vehicles per hour	Neuhauser, Kanipe, and Weiner (2000)
Urban	1,575 vehicles per hour	Neuhauser, Kanipe, and Weiner (2000)
Minimum and maximum distances to exposed resident off-link population	98 to 2,600 feet (30 to 800 meters)	Neuhauser, Kanipe, and Weiner (2000)
Population densities[a] (people per square mile)[b]		
Rural	139	
Suburban	3,326	
Urban	10,000	

a. Section B.1.3.

b. To convert people per square mile to people per square kilometer, divide by 2.59.

Table B-5. Assumptions and parameters for incident-free doses at truck stops.

Parameter	Value	Comments and references
Members of the public at truck stops		
Area of public exposure at truck stop	Annulus of inner radius 3.28 feet (1 meter), outer radius 66 feet (20 meters)	DOE (2002a)
Number of members of public exposed at truck stop	25	This is entered in RADTRAN 5 as 51,500 people per square mile (19,900 people per square kilometer) DOE (2002a)
Area of public exposure: residents near truck stop	98 to 2,600 feet (30 to 800 meters) from source	Neuhauser, Kanipe, and Weiner (2000)
Crew		
Crew members exposed at truck stops	2	Analytical assumption
Crew distance to package	6.6 feet (2 meters)	Analytical assumption
Stop time	1.69 hours (104 minutes)	DOE (2002a)
Distance between stops	712 miles (1,206 kilometers)	Sprung et al. 2000

the product of this unit dose factor multiplied by the number of shipments and the appropriate combination of route distance and population density.

- The on-link unit dose factor is per shipment, per kilometer, per millirem, and per hour. The on-link dose is the product of this unit dose factor multiplied by the number of shipments and the appropriate route distance (not the population density).

The unit dose factors do not include the number of shipments, but Section B.1.1 provides those for Steps 1 through 5 under the proposed action. For disposal as radioactive waste, the number of truck shipments to the melting facility would be the same as those for Step 1 under the proposed action (that is, about 243 truckloads of PGDP nickel and about 140 truckloads of ETTP nickel). After processing at the melting facility, the analysis assumed that there would be a 10-percent loss to slag for each inventory. Therefore, there would be 8,730 tons (7,920 metric tons, about 218 truckloads) of PGDP nickel, with 970 tons (880 metric tons, about 24 truckloads) of slag and 5,040 tons (4,570 metric tons, about 126 truckloads) of ETTP nickel product, with 560 tons (508 metric tons, about 14 truckloads) of slag. For disposal as radioactive waste, DOE would ship all the material (that is, product and waste) 3,000 miles (4,830 kilometers) to a low-level radioactive waste disposal facility.

Tables B-6 and B-7 list the Step 1 per-shipment unit dose factors for incident-free truck transportation for the PGDP nickel ingots and the ETTP shredded nickel, respectively. As the tables indicate, the shipment with the highest transport index in the source material would be from the ETTP facility. To simplify and bound the potential impacts, the analysis used this transport index (that is, 4.84×10^{-7} milliroentgen per hour) to calculate the incident-free radiological transportation impacts for all product and waste shipments. This assumption ensures that these impacts will not be underestimated because the actual transport indexes for each of the other types of shipments are lower than the calculated transport index for the ETTP shredded nickel. The ETTP shredded nickel would have the largest transport index because it has the combination of the greatest amount of radioactive material and the lowest density (50 pounds per cubic foot or 3,890 kilograms per cubic meter) of all the other material types.

Table B-8 lists the per-shipment unit dose factors for incident-free truck transportation. In addition to the other multiplying factors in the tables, the Nickel RiskModel multiplies these unit dose factors by the number of shipments appropriate for each alternative.

Table B-9 lists the public and worker population doses, by alternative, for the entire shipping campaign, which would include doses to maximally exposed individuals. The Nickel RiskModel contains a more detailed presentation of consequences (that is, dose) and calculated risks (latent cancer fatalities) (Section B.5).

The analysis used RADTRAN 5 to calculate radiological unit dose factors for entry into the Nickel RiskModel to calculate collective incident-free population doses. The *RADTRAN 5 Technical Manual* and *RADTRAN 5 User Guide* provide detailed descriptions of the theoretical bases and application of this program (Neuhauser, Kanipe, and Weiner 2000; Neuhauser and Kanipe 2000).

B.2.1.2 Analysis of Doses from Moving Vehicles

This section describes the RADTRAN 5 model and deals only with specific details of the application of RADTRAN 5 in the moving-vehicle analysis. The analysis used a dose rate of 1 milliroentgen per hour at a distance of 3.28 feet (1 meter) from the vehicle to generate unit dose factors, then multiplied the unit dose factors by the package-specific external dose (that is, the bounding transport index) rate and other factors (Table B-8 contains details).

Table B-6. Radionuclide-specific activities and transport indexes for PGDP ingots, product, baghouse dust, and waste materials per 40-ton (36-metric-ton) truck shipment.[a,b]

Radionuclide	Activity in ingots (Ci/truck)	PGDP ingots transport index (mR/hr)	Activity in product (Ci/truck)	Product transport index (mR/hr)	Activity in baghouse dust (Ci/truck)	Baghouse dust transport index (mR/hr)	Activity in slag (Ci/truck)	Slag transport index (mR/hr)
Technetium-99	9.41×10^{-1}	2.73×10^{-13}	9.23×10^{-1}	4.47×10^{-8}	9.41×10^{-3}	9.53×10^{-10}	9.41×10^{-3}	1.04×10^{-10}
Cerium-137	1.53×10^{-7}	7.56×10^{-8}	1.53×10^{-9}	6.71×10^{-9}	1.47×10^{-7}	3.86×10^{-7}	4.58×10^{-9}	1.08×10^{-8}
Thorium-230	2.42×10^{-8}	8.88×10^{-14}	2.42×10^{-10}	4.93×10^{-14}	2.42×10^{-10}	4.15×10^{-14}	2.37×10^{-8}	2.51×10^{-12}
Uranium-234	3.58×10^{-5}	1.63×10^{-12}	3.58×10^{-7}	1.00×10^{-11}	3.58×10^{-7}	1.15×10^{-11}	3.51×10^{-5}	4.32×10^{-10}
Uranium-235	1.65×10^{-6}	1.29×10^{-8}	1.65×10^{-8}	4.90×10^{-9}	1.65×10^{-8}	3.80×10^{-9}	1.62×10^{-6}	2.52×10^{-7}
Uranium-238	3.81×10^{-5}	8.28×10^{-23}	3.81×10^{-7}	6.49×10^{-14}	3.81×10^{-7}	5.21×10^{-13}	3.74×10^{-5}	2.71×10^{-13}
Neptunium-237	1.95×10^{-5}	2.47×10^{-9}	1.95×10^{-7}	1.54×10^{-9}	1.95×10^{-7}	1.67×10^{-9}	1.91×10^{-5}	6.93×10^{-8}
Plutonium-238	6.68×10^{-7}	1.47×10^{-33}	6.68×10^{-9}	8.16×10^{-18}	6.68×10^{-9}	3.24×10^{-16}	6.54×10^{-7}	4.31×10^{-18}
Plutonium-239	1.49×10^{-6}	2.14×10^{-14}	1.49×10^{-8}	3.29×10^{-13}	1.49×10^{-8}	4.19×10^{-13}	1.46×10^{-6}	1.29×10^{-11}
Americium-241	6.68×10^{-7}	7.42×10^{-23}	6.68×10^{-9}	4.78×10^{-14}	6.68×10^{-9}	8.42×10^{-13}	6.54×10^{-7}	2.53×10^{-14}
Total	**9.41×10^{-1}**	**9.09×10^{-8}**	**9.23×10^{-1}**	**5.79×10^{-8}**	**9.41×10^{-3}**	**3.92×10^{-7}**	**9.50×10^{-3}**	**3.33×10^{-7}**

a. Ci = curies; to convert to becquerels, multiply by 3.7×10^{10}.

b. mR/hr = milliroentgen per hour.

Table B-7. Radionuclide-specific activities and transport indexes for ETTP shredded nickel, product, baghouse dust, and waste materials per 40-ton (36-metric-ton) truck shipment.

Radionuclide	Activity in ETTP shredded nickel (Ci/truck)	ETTP shredded nickel transport index (mR/hr)	Activity in product (Ci/truck)	Product transport index (mR/hr)	Activity in baghouse dust (Ci/truck)	Baghouse dust transport index (mR/hr)	Activity in slag (Ci/truck)	Slag transport index (mR/hr)
Technetium-99	1.45×10^{-1}	7.03×10^{-9}	1.42×10^{-1}	6.88×10^{-9}	1.45×10^{-3}	1.47×10^{-10}	1.45×10^{-3}	1.60×10^{-11}
Cerium-137	4.76×10^{-8}	2.09×10^{-7}	4.76×10^{-10}	2.09×10^{-9}	4.58×10^{-8}	1.20×10^{-7}	1.43×10^{-9}	3.37×10^{-9}
Thorium-230	7.52×10^{-9}	1.53×10^{-12}	7.52×10^{-11}	1.53×10^{-14}	7.52×10^{-11}	1.29×10^{-14}	7.37×10^{-9}	7.80×10^{-13}
Uranium-234	1.34×10^{-5}	3.74×10^{-10}	1.34×10^{-7}	3.74×10^{-12}	1.34×10^{-7}	4.29×10^{-12}	1.31×10^{-5}	1.61×10^{-10}
Uranium-235	9.04×10^{-7}	2.68×10^{-7}	9.04×10^{-9}	2.68×10^{-9}	9.04×10^{-9}	2.08×10^{-9}	8.86×10^{-7}	1.38×10^{-7}
Uranium-238	9.26×10^{-6}	1.58×10^{-12}	9.26×10^{-8}	1.58×10^{-14}	9.26×10^{-8}	1.27×10^{-13}	9.08×10^{-6}	6.57×10^{-14}
Neptunium-237	1.84×10^{-8}	1.46×10^{-10}	1.84×10^{-10}	1.46×10^{-12}	1.84×10^{-10}	1.57×10^{-12}	1.80×10^{-8}	6.54×10^{-11}
Plutonium-238	6.83×10^{-10}	8.34×10^{-19}	6.83×10^{-12}	8.34×10^{-21}	6.83×10^{-12}	3.31×10^{-19}	6.68×10^{-10}	4.40×10^{-21}
Plutonium-239	1.14×10^{-9}	2.51×10^{-14}	1.14×10^{-11}	2.51×10^{-16}	1.14×10^{-11}	3.19×10^{-16}	1.12×10^{-9}	9.83×10^{-15}
Americium-241	4.76×10^{-10}	3.40×10^{-15}	4.76×10^{-12}	3.40×10^{-17}	4.76×10^{-12}	5.99×10^{-16}	4.65×10^{-10}	1.80×10^{-17}
Total	**1.45×10^{-1}**	**4.84×10^{-7}**	**1.42×10^{-1}**	**1.17×10^{-8}**	**1.45×10^{-3}**	**1.23×10^{-7}**	**1.47×10^{-3}**	**1.42×10^{-7}**

a. Ci = curies; to convert to becquerels, multiply by 3.7×10^{10}.

b. mR/hr = milliroentgen per hour.

Table B-8. Per-shipment unit dose factors, units, and multipliers for incident-free truck transportation.

Receptor	Unit dose factors	Units[a]	Multiply by
Public		**Person-millisievert per external dose rate per**	**External dose rate × …**
Off-link rural	3.16×10^{-8}	Unit population density per kilometer	Rural population density × rural kilometers
Off-link suburban	6.92×10^{-8}	Unit population density per kilometer	Suburban population density × suburban kilometers
Off-link urban	1.15×10^{-7}	Unit population density per kilometer	Urban population density × rural kilometers
On-link rural	4.69×10^{-6}	Per kilometer	Rural kilometers
On-link suburban	4.91×10^{-5}	Per kilometer	Suburban kilometers
On-link urban	3.85×10^{-4}	Per kilometer	Urban kilometers
Residents near rural stop	1.92×10^{-9}(b)	Unit population density per kilometer	Rural population density × rural kilometers
Residents near suburban stop	1.92×10^{-9}(b)	Unit population density per kilometer	Suburban population density × suburban kilometers
Residents near urban stop	1.92×10^{-9}(b)	Unit population density per kilometer	Urban population density × rural kilometers
Public at rural highway rest/refuel stops	1.63×10^{-5}(b)	Per kilometer	Rural kilometers
Public at suburban highway rest/refuel stops	1.63×10^{-5}(b)	Per kilometer	Suburban kilometers
Public at urban highway rest/refuel stops	1.63×10^{-5}(b)	Per kilometer	Urban kilometers
Workers		**Person-millisievert per external dose rate per**	**External dose rate × …**
Truck crew rural rest/refuel	5.12×10^{-5}(b)	Per kilometer	Rural kilometers
Truck crew suburban rest/refuel	5.12×10^{-5}(b)	Per kilometer	Suburban kilometers
Truck crew urban rest/refuel	5.12×10^{-5}(b)	Per kilometer	Urban kilometers
Truck crew rural in-transit	4.07×10^{-4}	Per kilometer	Rural kilometers
Truck crew suburban in-transit	8.90×10^{-4}	Per kilometer	Suburban kilometers
Truck crew urban in-transit	1.48×10^{-3}	Per kilometer	Urban kilometers
Maximally exposed member of the public			**External dose rate × …**
Resident closest to the route	5.12×10^{-7}	Rem per external dose rate per trip	Total trips
Resident near stop	2.08×10^{-7}	Rem per external dose rate per kilometer	Total kilometers

Source: Nickel RiskModel.

a. To convert kilometers to miles, multiply by 0.62137.

b. RADTRAN 5 output for single stop divided by 725 miles (1,206 kilometers) per stop.

Table B-9. Transport indexes, population doses, and doses to maximally exposed individuals for the Proposed Action and disposal as radioactive waste.

	Truck Transport Index	**Public dose (person-rem)[b]**					**Maximally exposed individual (rem)[b]**		**Workers (person-rem)[b]**		
Alternative	**(milliroentgen/ hour at 1 meter)[a]**	**On-link**	**Off-link**	**Residents near stops**	**Public at stops**	**Total public dose**	**Resident near route**	**Resident near stop**	**Truck crew in transit**	**Truck crew at stops**	**Crew total**
Proposed Action	4.84×10^{-7}	6.51×10^{-6}	8.43×10^{-6}	1.99×10^{-7}	3.48×10^{-6}	1.86×10^{-5}	4.90×10^{-11}	1.99×10^{-11}	1.19×10^{-4}	1.09×10^{-5}	1.30×10^{-4}
Dispose of as waste	4.84×10^{-7}	8.63×10^{-6}	4.72×10^{-6}	1.11×10^{-7}	1.95×10^{-6}	1.54×10^{-5}	1.90×10^{-11}	7.71×10^{-12}	6.68×10^{-5}	6.13×10^{-6}	7.30×10^{-5}

a. 1 meter = 3.28 feet.

b. To convert person-rem to person sievert, or rem to sievert, multiply by 0.01.

The analysis used the appropriate input parameters in RADTRAN 5 to calculate unit dose factors. Basic features of the RADTRAN 5 model are (1) the shipping package and truck bed combination are spherically symmetric and (2) while the actual radiation source is the shipping package external dose rate, the model uses an isotropic emission at the center of the sphere as the source (that is, a point source) (Neuhauser, Kanipe, and Weiner 2000, p.20). The dose to a distant receptor is directly proportional to the dose rate buildup, which is the product of a buildup factor and an attenuation factor. For gamma radiation, this product is equal to unity in RADTRAN 5 because it is always less than or equal to 1 (Neuhauser, Kanipe, and Weiner 2000, pp. 29–30).

The dose is inversely proportional to the square of the distance between the receptor and the center of the cargo (the truck bed). When the receptor is within about a package length, which could be the case for crew members and inspectors, the model bases external dose rate on a line source, and the dose to the receptor is inversely proportional to the distance between the receptor and the center of the cargo.

Dose is directly proportional to exposure time. The dose to a stationary receptor from a moving vehicle carrying radioactive cargo, the off-link dose, is inversely proportional to the speed of the vehicle.

This analysis assigned values of 1 to some variables in the RADTRAN 5 input for the calculation of unit dose factors for rural, suburban, and urban segments of the various routes. The products of the resultant table of unit dose factors, multiplied by the applicable shipment kilometers, exposed populations, etc., are the off-link incident-free doses for each segment of each route. This analysis combines these doses to determine total collective dose.

To calculate potential in-transit doses to truck crews, the analysis assumed that the crew would remain at a fixed distance [4.9 feet (1.5 meters)] from the package for the duration of the route. RADTRAN 5 bases the end-on radiation dose rate on the given transport index.

Doses to occupants of other vehicles that shared the transportation corridor, the on-link doses, require a more complex set of assumptions about vehicle speed (Neuhauser, Kanipe, and Weiner 2000, p.42). RADTRAN 5 bases the calculation of on-link doses on Equations 31 to 34 of Neuhauser, Kanipe, and Weiner (2000, pp. 42–45). In RADTRAN 5, the relative speed of vehicles that move in the same direction as the disposal material shipment is twice the disposal material vehicle speed when the vehicle is passing the disposal material vehicle (disposal material vehicle is stationary), and zero if the vehicle is traveling in a lane next to the disposal material vehicle. In addition, the density of vehicles that move in the opposite direction is inversely proportional to the vehicle speed. Overall, the on-link dose is inversely proportional to the square of the vehicle speed (Neuhauser, Kanipe, and Weiner 2000, p. 42).

RADTRAN 5 uses national average vehicle densities to calculate national per-kilometer on-link unit dose factors for each shipment for each population zone. The Nickel RiskModel then multiplied each unit dose factor by route segment length, number of shipments, and package length. Vehicles that shared the route with the radioactive cargo would provide no radiation shielding for their occupants.

B.2.1.3 Analysis of Doses at Stops

Figure B-2 shows the rest and refueling stop model for the analysis for truck shipments.

DOE (2002a) provided the exposure data for members of the public at rest and refueling stops. RADTRAN 5 calculates a population dose per stop. Calculation of a unit dose factor, in units of person-rem per kilometer, requires an estimate of the number of stops per kilometer of travel, which in turn requires an estimate of how many kilometers the trucks travel between rest and refueling stops.

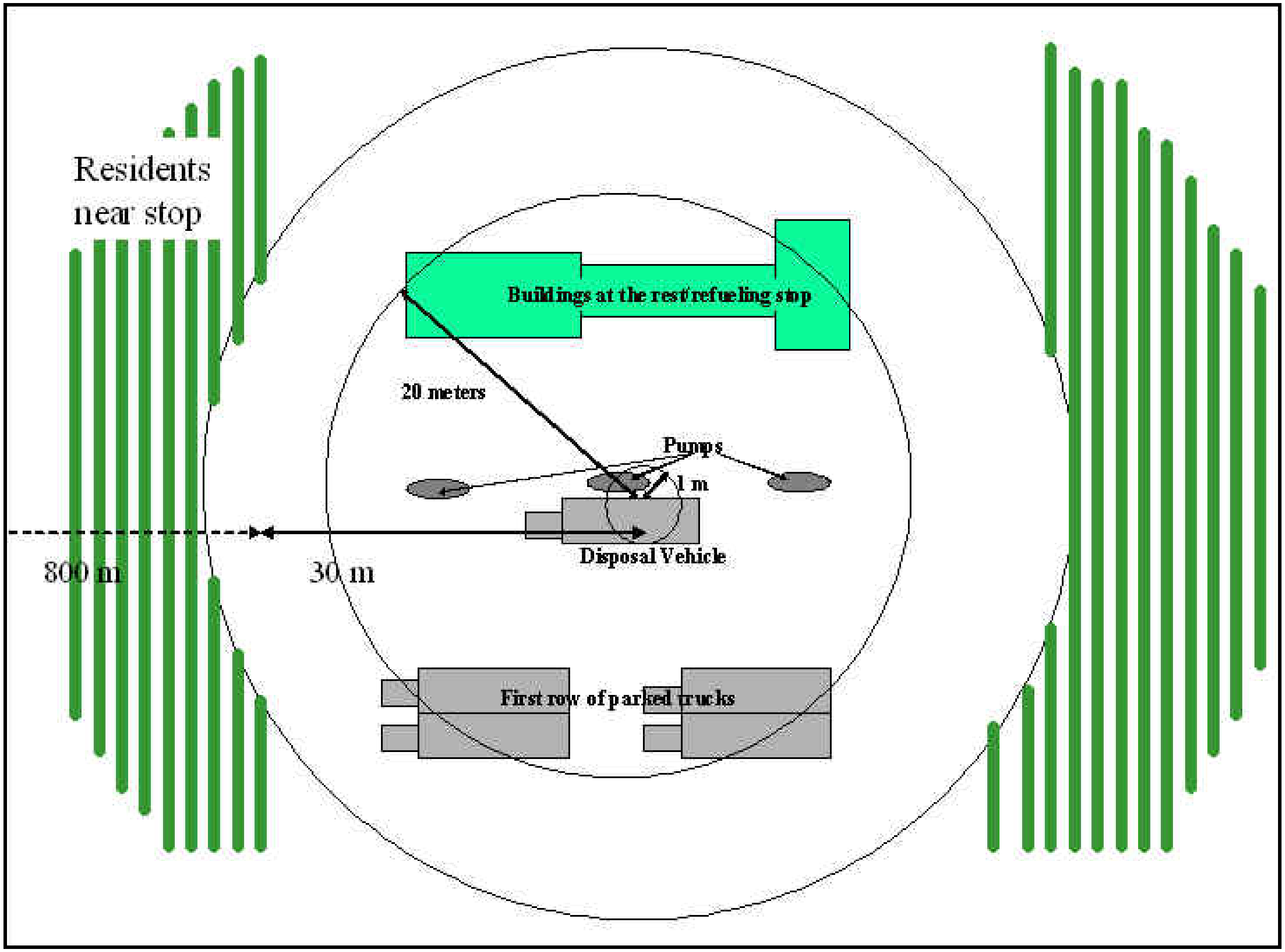


Figure B-2. Rest and refueling truck stop model.

The model uses the appropriate rural, suburban, or urban population density and the same distance from the shipment as that for the off-link dose calculation [about 100 feet to 0.5 mile (30 to 800 meters)] to estimate potential doses to residents who live near the truck stops.

In addition to the model for a rest and refueling stop, for which RADTRAN 5 calculates the dose to a population that is evenly distributed in an area around the source, the RADTRAN 5 stop model allows calculation of dose to receptors at a fixed distance from the source (for example, dose to an individual at an assumed distance from the vehicle).

The Nickel RiskModel uses unit dose factors per kilometer of route length and Equations 37 and 38 or 39 to 41 of Neuhauser, Kanipe, and Weiner (2000, p. 47) to calculate stop dose. The model then divides the result by the average distance between stops to derive a per-kilometer unit dose factor. To convert the unit dose factor to a per-kilometer number, the model divides it by 712 miles (1,206 kilometers) for trucks, which is the average distance between truck stops. The model then multiplies the per-kilometer factor by the distance from each origin to destination and by the number of shipments from each origin site.

B.2.2 INCIDENT-FREE DOSES TO INDIVIDUALS

This section describes the scenarios for and calculation of potential incident-free radiological impacts on individuals during the transportation of source (the ETTP shredded nickel and PGDP ingots), product, and waste materials to their destinations.

The analysis used RADTRAN 5 to estimate exposures to individuals and based them on transportation of the total number of shipments by truck. For public exposures, the analysis assumed an individual would be exposed to all shipments along a route. In addition, the estimates of maximum annual exposures to individuals used the conservative assumption that all shipments would occur during a single year.

The maximally exposed individual is a hypothetical person who would receive the highest dose. Because different individuals could receive the highest doses under different exposure scenarios, the analysis evaluated the following exposure scenarios:

- Truck Driver. A truck driver would be the maximally exposed individual for all alternatives and exposure scenarios. This individual would be 4.9 feet (1.5 meters) from the shipping package during transport. Exposure from transport of the materials would depend on the travel time between the origins and destinations. RADTRAN 5 performed this calculation.

- Resident near Route. The analysis assumed a resident who lived 100 feet (30 meters) from a point where shipments would pass. The resident would be exposed to all truck shipments along a particular route.

- Resident near Truck Stop. The analysis assumed a member of the public would be exposed to shipments for 1.69 hours for each occurrence at a distance of 100 feet (30 meters).

RADTRAN 5 estimates values for exposure to one shipment for each of the individual exposure scenarios. The dose to the maximally exposed individuals is then the product of these estimated exposures and the number of shipments that would pass or stop at the assumed locations. Table B-10 lists potential maximally exposed individual doses for truck shipments for the entire shipping campaign.

Table B-10. Radiation doses to maximally exposed individuals by alternative.[a]

Doses	Proposed Action (rem)	Dispose of as waste (rem)
Truck driver–MEI[b]	6.50×10^{-5}	3.65×10^{-5}
Resident near truck route	4.90×10^{-11}	1.90×10^{-11}
Resident near truck stop	1.99×10^{-11}	7.71×10^{-12}

a. Calculated by RADTRAN 5 and Nickel RiskModel.

b. MEI = maximally exposed individual; assumed two drivers per truck and the same drivers for all shipments.

B.2.3 VEHICLE EMISSION UNIT RISK FACTORS

This section describes the development of unit risk factors for the estimation of potential fatalities from exhaust and fugitive dust emissions from highway transportation. These risk factors, which are from the Yucca Mountain Repository environmental impact statement (DOE 2002b), are appropriate for use in this analysis because they account for heavy truck traffic for any cargo.

Table B-11 lists the unit risk factors in units of fatalities per kilometer per person per square kilometer. The analysis multiplied these factors by the appropriate population-weighted distances and the number of shipments (Table B-1) to calculate the number of potential vehicle emissions fatalities. Table B-12 lists the vehicle emissions fatalities.

Table B-11. Vehicle emission unit risk factors.[a]

Vehicle class	Weight (tons)[b]	Tire/brake particulates (g/km)	Fugitive dust (g/km)	Diesel exhaust (g/km)	Total emissions (g/km)	Unit risk factor (fatalities/km per person/km²)[c]
Class VIIIB trucks	40	0.030	0.26	0.141	0.43	1.5×10^{-11}

Source: DOE (2002a).

a. g/km = grams per kilometer; to convert to ounces per mile, multiply by 0.05677.

b. Assumed 40 tons (36 metric tons) per shipment.

c. km² = square kilometer; to convert to square miles, multiply by 0.3861.

Table B-12. Nonradiological incident-free impacts by alternative.

Alternative	Vehicle emissions fatalities
Proposed Action	6.40×10^{-2}
Dispose of as waste	3.59×10^{-2}

B.3 TRANSPORTATION ACCIDENTS

B.3.1 NONRADIOLOGICAL TRANSPORTATION ACCIDENTS

This section describes the analysis of nonradiological transportation accident impacts (that is, traffic fatalities) that could result from accidents that involved disposal materials. The analysis used truck injury and fatality rates of 3.84×10^{-7} per mile (2.39×10^{-7} per kilometer) and 2.29×10^{-8} per mile (1.42×10^{-8} per kilometer), respectively (DOE 2002a), to estimate the total number of injuries and fatalities that could occur over the entire shipping campaign. The analysis multiplied the distance to be traveled by the national composite injury and fatal accident rates to obtain an estimate of the total number of potential injuries and fatalities for each alternative.

The Nickel RiskModel calculated potential traffic fatalities from disposal material transportation by multiplying the appropriate accident rates by the kilometers per shipment and the number of shipments. Table B-13 lists the calculated estimates of fatalities for each alternative.

Table B-13. Traffic accident injuries and fatalities for the Proposed Action and disposal as radioactive waste.

Alternative	Traffic accidents injuries	Traffic accidents fatalities
Proposed Action	2.11×10^{0}	1.25×10^{-1}
Dispose of as waste	1.18×10^{0}	7.02×10^{-2}

B.3.2 RADIOLOGICAL TRANSPORTATION ACCIDENTS

This section describes the analysis of collective population and individual doses from potential accidents during material transportation. The radiation doses that could result from a transportation accident that involved radioactive material would depend on the amount of radioactive material the accident released to the environment. The amount of released material would depend on (1) the ability of the shipping package to withstand the mechanical and thermal stresses of an accident and (2) the physical behavior of the disposal material in an accident.

Section B.3.2.1 describes the characteristics of the disposal package that the analysis assumed for the accident. Section B.3.2.2 discusses the analysis methods. Section B.3.2.3 discusses the assumptions and presents the results.

B.3.2.1 Radionuclide Content and Source Term

To define the maximum reasonably foreseeable accident, the analysis screened the radionuclide-specific unit dose factors (from RADTRAN 5 unit accident runs in the Nickel RiskModel) to determine the shipping package that could contain the radionuclide mix with the highest potential radiotoxicity, which would represent the highest potential for radiation dose under any accident scenario. The Nickel RiskModel screening analysis determined that shipments of ETTP shredded nickel to the melting facility would have the radionuclide mix and quantities with the highest potential radiotoxicity. Table B-14 lists the potential quantities of radionuclides.

Table B-14. Shipping package radionuclide content for the maximum reasonably foreseeable truck accident.

Radionuclide	Activity per truckload[a] (curies)[b]
Technetium-99	1.45×10^{-1}
Cerium-137	4.76×10^{-8}
Thorium-230	7.52×10^{-9}
Uranium-234	1.34×10^{-5}
Uranium-235	9.04×10^{-7}
Uranium-238	9.26×10^{-6}
Neptunium-237	1.84×10^{-8}
Plutonium-238	6.83×10^{-10}
Plutonium-239	1.14×10^{-9}
Americium-241	4.76×10^{-10}
Total activity	$\mathbf{1.45 \times 10^{-1}}$

a. Assumed 40 tons (36 metric tons) per shipment.
b. To convert to becquerels, multiply by 3.7×10^{10}.

The assumptions of the maximum reasonably foreseeable accident include a release fraction of 1 (that is, all material in the package), an aerosol fraction of 0.1 (DOE 2002a, p. 105, small powder), and a respirable fraction (particles small enough to inhale into the lungs) of the radionuclides of 0.05 (DOE 2002a, loose chunks).

B.3.2.2 Method

The analysis calculated the radionuclide-specific unit dose factors in terms of dose per released curie. The analysis assumed the maximum reasonably foreseeable accident would result in the release of all the radioactive material, of which 10 percent would be in aerosol form, dispersed into the air with 5 percent of respirable particle size. The analysis used RADTRAN 5 to calculate the dose per curie of each radionuclide (that is, the radionuclide-specific unit dose factor).

The analysis calculated inhalation, resuspension, groundshine, and cloudshine unit dose factors for 1 curie of each radionuclide by applying the curie-to-rem, radionuclide-specific dose conversion factors in the RADTRAN 5 internal library. RADTRAN 5 calculated the total accident dose for each pathway and the fraction of that dose attributable to each radionuclide. Section B.3.2.3 discusses other parameters that are part of the unit dose factors.

The analysis modeled the exposed population for a release of radioactive material by assuming that the population density in the 0.5-mile (800-meter)-wide corridor on either side of the route would be the same population density under the entire plume, out to 75 miles (120 kilometers) from the accident. RADTRAN 5 calculates both short- and long-term (50-year) doses; the unit dose factor is the sum of the short- and long-term unit dose factors.

B.3.2.3 Assumptions

To determine the dose factors in terms of dose per curie of a released radionuclide, the analysis calculated atmospheric dispersion to obtain the downwind airborne and ground concentrations from cloud depletion. The analysis made the following major assumptions for the development of dose factors for the radionuclide-specific unit dose factors for the assumed disposal material shipment:

- Meteorological conditions would be U.S. national 95th-percentile meteorology (DOE 2002b, Appendix J, p. J-56).
- Deposition velocity (for groundshine and ingestion doses) would be 0.023 mile per hour (0.01 meter per second) for volatiles and particulates.
- All receptors would breathe outside air that contained radionuclides from the accident.
- Evacuation would occur within 24 hours.
- Interdiction (that is, cleanup) after an accident would prevent additional exposures after evacuation.
- Released and dispersed radioactive material would have a 100-percent release fraction, a 10-percent aerosol fraction, and a 5-percent respirable fraction.

The analysis used RADTRAN 5 default values for other parameters such as breathing rate.

This section describes the development of unit collective dose factors (person-rem per curie released) for each radionuclide. Tables B-15 and B-16 list the unit dose factors for each radionuclide for rural/ suburban and urban accidents, respectively. The analysis developed separate factors to account for the shielding of buildings in suburban and urban areas. Table B-17 lists the total unit dose factors for individual doses, which includes doses from inhalation, cloudshine, and groundshine during evacuation.

Table B-15. Population unit dose factors for rural and suburban accidents by radionuclide and exposure pathway.

	Rural and suburban accident dose factors (person-rem[a] per curie[b] released)				
Radionuclide	**Inhalation[c]**	**Resuspended[d]**	**Groundshine[e]**	**Cloudshine[f]**	**Total**
Technetium-99	2.44×10^{-6}	2.04×10^{-8}	7.76×10^{-6}	5.98×10^{-11}	1.02×10^{-5}
Cerium-137	5.91×10^{-6}	4.94×10^{-8}	3.46×10^{-2}	1.07×10^{-6}	3.46×10^{-2}
Thorium-230	2.62×10^{-2}	2.19×10^{-4}	7.47×10^{-5}	6.43×10^{-10}	2.65×10^{-2}
Uranium-234	2.14×10^{-3}	1.79×10^{-5}	7.44×10^{-5}	2.81×10^{-10}	2.23×10^{-3}
Uranium-235	1.89×10^{-3}	1.58×10^{-5}	1.47×10^{-2}	2.65×10^{-7}	1.66×10^{-2}
Uranium-238	1.76×10^{-3}	1.47×10^{-5}	5.48×10^{-5}	1.26×10^{-10}	1.83×10^{-3}
Neptunium-237	1.40×10^{-2}	1.17×10^{-4}	2.86×10^{-3}	3.80×10^{-8}	1.70×10^{-2}
Plutonium-238	2.80×10^{-2}	2.34×10^{-4}	7.02×10^{-5}	1.81×10^{-10}	2.83×10^{-2}
Plutonium-239	3.05×10^{-2}	2.54×10^{-4}	3.64×10^{-5}	1.57×10^{-10}	3.08×10^{-2}
Americium-241	2.55×10^{-2}	2.13×10^{-4}	2.64×10^{-3}	3.02×10^{-8}	2.84×10^{-2}

Source: RADTRAN 5 calculation.

a. To convert to person-sievert, multiply by 0.01.
b. To convert to becquerels, multiply by 3.7×10^{10}.
c. Inhalation dose: Dose from inhalation of radioactive particles in the plume.
d. Resuspended dose: Dose from inhalation of radioactive particles resuspended from the ground.
e. Groundshine dose: Dose from exposure to radioactive particles deposited on the ground.
f. Cloudshine dose: Dose from exposure to radioactive particles suspended in the plume.

Table B-16. Population unit dose factors for urban accidents by radionuclide and exposure pathway.

	Urban accident dose factors (person-rem[a] per curie[b] released)				
Radionuclide	**Inhalation[c]**	**Resuspended[d]**	**Groundshine[e]**	**Cloudshine[f]**	**Total**
Technetium-99	7.08×10^{-6}	5.91×10^{-8}	2.25×10^{-5}	1.74×10^{-10}	2.97×10^{-5}
Cerium-137	1.72×10^{-5}	1.43×10^{-7}	1.01×10^{-1}	3.10×10^{-6}	1.01×10^{-1}
Thorium-230	7.61×10^{-2}	6.35×10^{-4}	2.17×10^{-4}	1.87×10^{-9}	7.69×10^{-2}
Uranium-234	6.22×10^{-3}	5.20×10^{-5}	2.16×10^{-4}	8.18×10^{-10}	6.49×10^{-3}
Uranium-235	5.50×10^{-3}	4.60×10^{-5}	4.28×10^{-2}	7.71×10^{-7}	4.84×10^{-2}
Uranium-238	5.12×10^{-3}	4.28×10^{-5}	1.59×10^{-4}	3.65×10^{-10}	5.32×10^{-3}
Neptunium-237	4.07×10^{-2}	3.40×10^{-4}	8.30×10^{-3}	1.11×10^{-7}	4.94×10^{-2}
Plutonium-238	8.14×10^{-2}	6.79×10^{-4}	2.04×10^{-4}	5.25×10^{-10}	8.22×10^{-2}
Plutonium-239	8.85×10^{-2}	7.39×10^{-4}	1.06×10^{-4}	4.55×10^{-10}	8.94×10^{-2}
Americium-241	7.42×10^{-2}	6.19×10^{-4}	7.67×10^{-3}	8.79×10^{-8}	8.25×10^{-2}

Source: RADTRAN 5 calculation.

a. To convert to person-sievert, multiply by 0.01.
b. To convert to becquerels, multiply by 3.7×10^{10}.
c. Inhalation dose: Dose from inhalation of radioactive particles in the plume.
d. Resuspended dose: Dose from inhalation of radioactive particles resuspended from the ground.
e. Groundshine dose: Dose from exposure to radioactive particles deposited on the ground.
f. Cloudshine dose: Dose from exposure to radioactive particles suspended in the plume.

The analysis estimated the collective and individual doses from a given accident by multiplying each unit dose factor from Table B-15, B-16, or B-17 (dependent on assumed location and receptor) by the released quantity of that radionuclide (package content multiplied by its release fraction). The sum of these products is the total collective dose in person-rem or the individual dose in rem.

The analysis calculated the collective and individual doses under the conservative assumption that the accident would release all radioactive material in the shipment (Table B-14). Table B-18 summarizes the collective doses for rural and urban locations and the individual doses from the maximum accident.

Table B-17. Individual unit dose factors by radionuclide (rem[a] per curie[b] released).

Radionuclide	Total
Technetium-99	0.00188
Cerium-137	0.00551
Thorium-230	0.23
Uranium-234	1.57
Uranium-235	1.39
Uranium-238	1.33
Neptunium-237	1.8
Plutonium-238	2.28
Plutonium-239	2.02
Americium-241	2.12

Source: RADTRAN 5 calculation.

a. To convert to person-sievert, multiply by 0.01.

b. To convert to becquerels, multiply by 3.7 × 10^{10}.

Table B-18. Collective and individual doses from the maximum reasonably foreseeable accident.[a,b]

Radionuclide	Activity released (curies)	Rural population dose (person-rem)	Urban population dose (person-rem)	Individual dose (rem)
Technetium-99	1.45×10^{-1}	4.92×10^{-3}	1.48×10^{-2}	2.72×10^{-4}
Cerium-137	4.76×10^{-8}	5.48×10^{-6}	1.65×10^{-5}	2.62×10^{-10}
Thorium-230	7.52×10^{-9}	6.63×10^{-7}	1.99×10^{-6}	1.73×10^{-9}
Uranium-234	1.34×10^{-5}	9.91×10^{-5}	2.98×10^{-4}	2.10×10^{-5}
Uranium-235	9.04×10^{-7}	4.99×10^{-5}	1.50×10^{-4}	1.26×10^{-6}
Uranium-238	9.26×10^{-6}	5.64×10^{-5}	1.69×10^{-4}	1.23×10^{-5}
Neptunium-237	1.84×10^{-8}	1.04×10^{-6}	3.12×10^{-6}	3.31×10^{-8}
Plutonium-238	6.83×10^{-10}	6.43×10^{-8}	1.93×10^{-7}	1.56×10^{-9}
Plutonium-239	1.14×10^{-9}	1.16×10^{-7}	3.50×10^{-7}	2.30×10^{-9}
Americium-241	4.76×10^{-10}	4.49×10^{-8}	1.35×10^{-7}	1.01×10^{-9}
Total	**1.45×10^{-1}**	**5.13×10^{-3}**	**1.54×10^{-2}**	**3.07×10^{-4}**

Source: Nickel RiskModel.

a. To convert to person-sievert, multiply by 0.01.

b. To convert to becquerels, multiply by 3.7 × 10^{10}.

B.4 SUMMARY OF TRANSPORTATION IMPACTS

This section discusses the conversion of collective and individual radiation doses to the potential for (or risk of) adverse health effects. Section B.4.1 provides the method for conversion of dose to latent cancer fatalities, and Section B.4.2 summarizes potential radiological and nonradiological transportation impacts.

B.4.1 RADIATION DOSE AND LATENT CANCER FATALITIES

NRC estimates the probability of latent cancer fatalities for members of the public by using a dose-to-risk conversion factor of 6 × 10^{-7} per millirem (6 × 10^{-9} per millisievert) for members of the public. The U.S. Environmental Protection Agency recommends this factor for the general population (Eckerman et al. 1999). This factor considers all age groups in the population, which include infants and children, who are more sensitive to radiation than adults. Because workers would be 18 or more years old, the analysis used a separate, smaller dose-to-risk conversion factor for workers from International Commission on Radiological Protection Publication 60 of 4 × 10^{-7} per millirem (4 × 10^{-9} per millisievert) (ICRP 1991, p. 22).

The analysis used these factors to estimate the effects of exposing a population to radiation. For example, if each of 100,000 people was exposed only to background radiation (0.03 millirem or 0.0003 millisievert per year), an estimated 18 latent cancer fatalities would occur as a result of 1 year of exposure (100,000 people multiplied by 0.03 millirem per year multiplied by 4 × 10^{-7} latent cancer fatality per person-millirem).

This environmental assessment expresses radiological health impacts as incremental changes in the number of expected latent cancer fatalities for the offsite public and for transportation workers. Because of the uncertainties in dose response to low dose rates, the impact estimates provide a general indication of possible health impacts (the potential number of induced cancers), but readers should not interpret these estimates as exact numbers of induced cancers or as an indication of who could contract a cancer.

B.4.2 TRANSPORTATION-RELATED HUMAN HEALTH IMPACTS

The analysis multiplied the population and individual doses (Tables B-9 and B-18) by the dose-to-health-effect conversion factors (Section B.4.1) to estimate (1) the number of fatal cancers in the affected populations and (2) the individual incremental probability of contracting a fatal cancer. Table B-19 lists the estimated radiological impacts for the alternatives from transportation activities for the entire disposal material shipping campaign, which the analysis assumed would last 1 year. It also lists the increased risks of latent cancer fatalities for the maximally exposed individuals (public and workers) by alternative. Table B-20 summarizes collective and individual impacts from the maximum foreseeable accident.

Table B-19. Population impacts and impacts to maximally exposed individuals for the Proposed Action and disposal as radioactive waste.[a]

	General population (LCF)					MEI (increased risk of LCF)		Workers (LCF)		
Alternative	**On-link**	**Off-link**	**Residents near stops**	**Public at stops**	**Total public dose**	**Resident near route**	**Resident near stop**	**Truck crew in transit**	**Truck crew at stops**	**Crew MEI**
Proposed Action	3.90×10^{-9}	5.06×10^{-9}	1.19×10^{-10}	2.09×10^{-9}	1.12×10^{-8}	2.94×10^{-14}	1.20×10^{-14}	7.16×10^{-8}	6.57×10^{-9}	3.91×10^{-8}
Dispose of as waste	5.18×10^{-9}	2.83×10^{-9}	6.68×10^{-11}	1.17×10^{-9}	9.25×10^{-9}	1.14×10^{-14}	4.63×10^{-15}	4.01×10^{-8}	3.68×10^{-9}	2.19×10^{-8}

a. LCF = latent cancer fatality; MEI = maximally exposed individual.

Table B-20. Collective and individual impacts resulting from the maximum reasonably foreseeable accident.[a]

Radionuclide	Rural population dose (LCF)	Urban population dose (LCF)	Individual dose (increased risk of LCF)
Total	3.08×10^{-6}	9.25×10^{-6}	1.84×10^{-7}

a. LCF = latent cancer fatality.

B.5 REFERENCES

DOE (United States Department of Energy), 2002a, *A Resource Handbook on DOE Transportation Risk Assessment*, DOE/EM/NTP/HB-01, Office of Environmental Management, National Transportation Program, Washington, D.C., July.

DOE (United States Department of Energy), 2002b, *Final Environmental Impact Statement for a Geological Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, DOE/EIS-0250, Office of Civilian Radioactive Waste Management, Washington, D.C., February.

Eckerman, K. F., R. W. Leggett, C. B. Nelson, J. S. Puskin, and A. C. B. Richardson, 1999, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report No. 13, EAP 402-R-99-001, prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee, for U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C., September.

Grove Engineering, 1998, *MicroShield User's Manual*, Version 5, Rockville, Maryland.

ICRP (International Commission on Radiological Protection), 1991, *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60, Pergamon Press, New York, New York.

Johnson, P. E., 2007a, personal correspondence with E. M. Rollins on October 30, 2007.

Johnson, P. E., 2007b, personal correspondence with E. M. Rollins on October 30, 2007.

Johnson, P. E., and R. D. Michelhaugh, 2003, *Transportation Routing Analysis Geographic Information System (WebTRAGIS) User's Manual*, ORNL/TM-2000/86, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Neuhauser, K. S., and F. L. Kanipe, 2000, *RADTRAN 5, User Guide*, SAND2000-1257, Sandia National Laboratories, Albuquerque, New Mexico.

Neuhauser, K. S., F. L. Kanipe, and R. F. Weiner, 2000, *RADTRAN 5, Technical Manual*, SAND2000-1256, Sandia National Laboratories, Albuquerque, New Mexico.

Sprung, J. L., D. J. Ammerman, J. A. Koski, and R. F. Weiner, 2000, *Reexamination of Spent Fuel Shipment Risk Estimates*, NUREG/CR-6672, Two Volumes, U.S. Nuclear Regulatory Commission, Washington, D.C.

CONVERSION FACTORS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter	1[a]	Parts/million	Parts/million	1[a]	Milligrams/liter
Micrograms/liter	1[a]	Parts/billion	Parts/billion	1[a]	Micrograms/liter
Micrograms/cu. meter	1[a]	Parts/trillion	Parts/trillion	1[a]	Micrograms/cu. meter
Density					
Grams/cu. cm	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. cm
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F − 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2,118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1,233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

[a] This conversion is only valid for concentrations of contaminants (or other materials) in water.