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Responsible Agency: United States Department of Energy (DOE)

***Cooperating Agency*:** Tennessee Valley Authority (TVA)

Title: Draft Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor

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Abstract: The DOE is responsible for providing the Nation with nuclear weapons and ensuring that these weapons remain safe and reliable. Tritium, a radioactive isotope of hydrogen, is an essential component of every weapon in the current and projected U.S. nuclear weapons stockpile. Unlike other materials utilized in nuclear weapons, tritium decays rapidly, at a rate of 5.5 percent per year. Accordingly, as long as the Nation relies on a nuclear deterrent, the tritium in each nuclear weapon must be replenished periodically. Currently, the U.S. nuclear weapons complex does not have the capability to produce the amounts of tritium that will be required to support the Nation's stockpile. This EIS analyzes the potential consequences to the environment associated with the production of tritium using one or more commercial light water reactors (CLWRs).

This CLWR EIS evaluates the environmental impacts associated with producing tritium at one or more of the following five CLWRs: (1) Watts Bar Nuclear Plant, Unit 1 (Spring City, Tennessee); (2) Sequoyah Nuclear Plant, Unit 1 (Soddy Daisy, Tennessee); (3) Sequoyah Nuclear Plant, Unit 2 (Soddy Daisy, Tennessee); (4) Bellefonte Nuclear Plant, Unit 1 (Hollywood, Alabama); and (5) Bellefonte Nuclear Plant, Unit 2 (Hollywood, Alabama). Specifically, this EIS analyzes the potential environmental impacts associated with fabricating tritium-producing burnable absorber rods (TPBARs), transporting non-irradiated TPBARs from the fabrication facility to the reactor sites, irradiating TPBARs in the reactors, and transporting irradiated TPBARs from the reactors to the proposed tritium extraction facility at the Savannah River Site in South Carolina.

Public Comments: In preparing the CLWR EIS, DOE considered comments received from the public during the scoping process (January 15, 1998 - March 20, 1998). Comments on this CLWR EIS may be submitted during the 60-day comment period (expected to be August 28, 1998 - October 27, 1998). Public meetings on this EIS will also be held during this 60-day comment period. The dates, times, and locations of these meetings will be announced shortly after issuance of this Draft EIS.

SUMMARY

S.1 INTRODUCTION AND BACKGROUND

S.1.1 General

The U.S. Department of Energy (DOE) is responsible for providing the nation with nuclear weapons and ensuring those weapons remain safe and reliable. Tritium, a radioactive isotope of hydrogen, is an essential component of every weapon in the current and projected U.S. nuclear weapons stockpile. Unlike other nuclear materials used in nuclear weapons, tritium, decays rapidly—at a rate of 5.5 percent per year. Accordingly, as long as the nation relies on a nuclear deterrent, the tritium in each nuclear weapon must be replenished periodically.

> ***What is Tritium?***
>
> *Tritium is a radioactive isotope of hydrogen that occurs naturally in the environment in small quantities. However, it must be manufactured to obtain useful quantities. Tritium is not a fissile material and cannot be used by itself to construct a nuclear weapon. It is, however, an essential component of every warhead in the current and projected nuclear weapons stockpile. These warheads depend on tritium to perform as designed. Tritium decays at about 5.5 percent per year; therefore, it requires periodic replacement.*

At present, the U.S. nuclear weapons complex does not have the capability to produce the amounts of tritium that will be required to support the nation's current and future stockpile. Pursuant to the National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. 4321 *et seq*.) and the DOE regulations implementing NEPA (10 CFR 1021), this *Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (CLWR EIS) analyzes the potential consequences to the environment associated with the production of tritium using one or more Commercial Light Water Reactors (CLWRs).

Concurrent with the preparation of this EIS, DOE evaluated the feasibility of various CLWR alternatives through its standard procurement process (see Section 1.1.4). This EIS evaluates the environmental impacts associated with tritium production for all Tennessee Valley Authority (TVA) reactor plants that were offered by TVA during the procurement process (see Section S.1.4 for a list of these reactors).

S.1.2 Proposed Action and Scope

DOE proposes to obtain irradiation services from one or more CLWRs to provide tritium in sufficient quantities to support the nation's nuclear weapons stockpile requirements for at least the next 40 years. The proposed action includes: the manufacture of tritium-producing burnable absorber rods (TPBARs) at a commercial facility; irradiation of the TPBARs at one or more of five operating or partially constructed TVA nuclear reactors; the possible completion of TVA's nuclear reactors; transportation of nonirradiated and irradiated materials; and management of spent nuclear fuel and low-level radioactive waste.

As depicted in **Figure S–1**, this EIS analyzes the potential environmental impacts associated with: (1) fabricating TPBARs; (2) transporting nonirradiated TPBARs from the fabrication facility to the reactor sites; (3) irradiating TPBARs in the reactors; and, (4) transporting irradiated TPBARs from the reactors to the proposed Tritium Extraction Facility at the Savannah River Site in South Carolina. This EIS further analyzes the potential environmental impacts associated with the transportation and management of the low-level radioactive waste generated from CLWR tritium production.

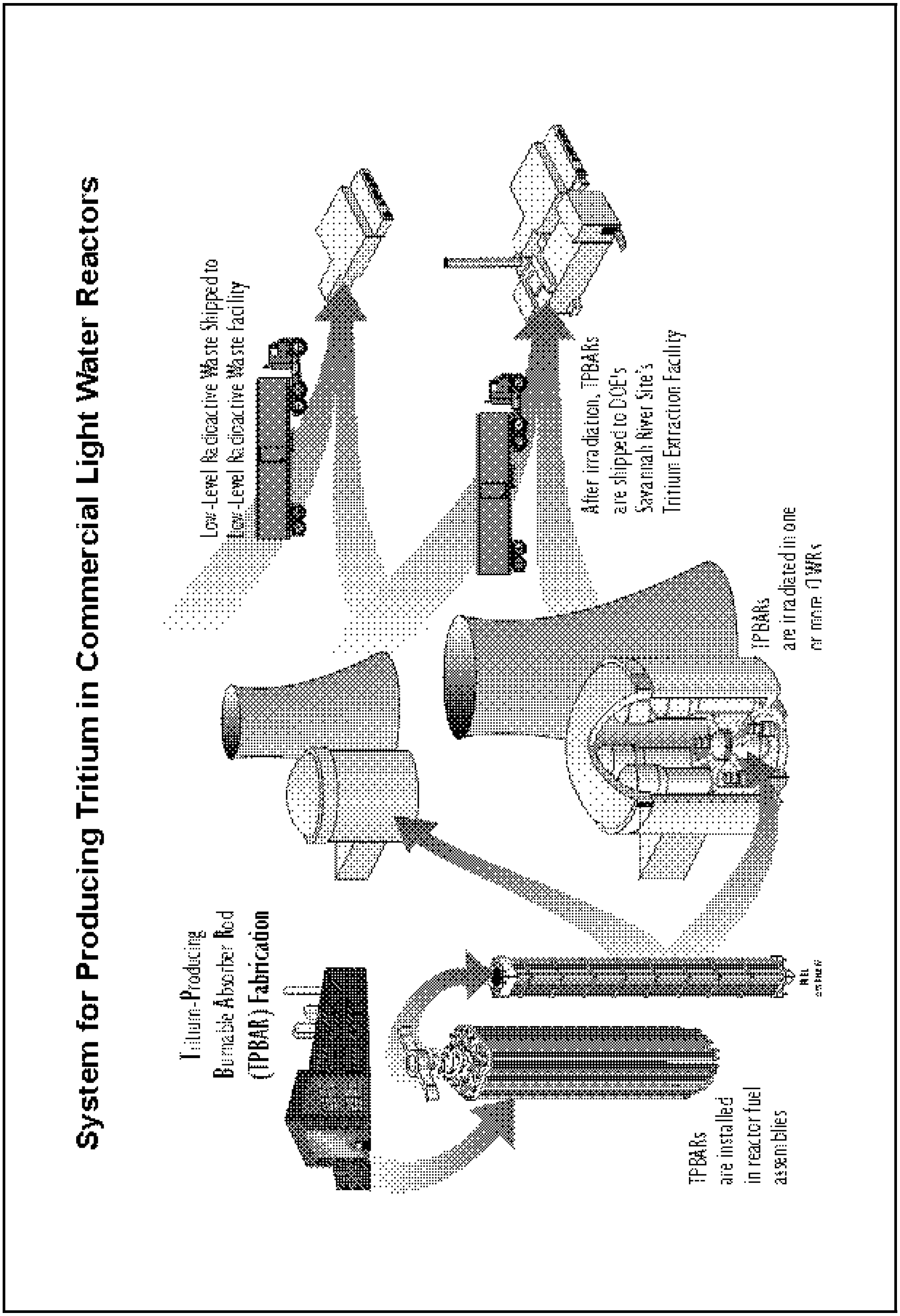


Figure S–1 Schematic of Process for Producing Tritium in CLWRs

In addition, this EIS evaluates the environmental impacts of the No Action Alternative. Under the No Action Alternative, the stockpile requirements for tritium would have to be met by the construction and operation of an accelerator at DOE's Savannah River Site in South Carolina (see Section 1.5.2.1). For the purpose of this EIS a No Action Alternative (i.e., no tritium production at that CLWR) has been evaluated for each candidate reactor facility.

S.1.3 Development of the CLWR EIS

The CLWR EIS is a tiered document which follows the December 1995 Record of Decision (60 FR 63878) for the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling*. In that Programmatic EIS, DOE considered a range of reasonable alternatives for obtaining the required quantities of tritium. In the December 1995 Record of Decision, DOE decided to pursue a dual-track approach on the two most promising tritium-supply alternatives: (1) to initiate purchase of an existing commercial reactor (operating or partially complete) or irradiation services with an option to purchase the reactor for conversion to a defense facility; and (2) to design, build, and test critical components of an accelerator system for tritium production (the Savannah River Site was selected as the location for an accelerator, should one be built).

What is a CLWR?

A CLWR is a nuclear reactor designed and constructed to produce electric power for commercial use. Tritium can be produced during normal operation of a CLWR. The process uses TPBARs which, like the burnable absorber rods that they replace, absorb excess neutrons and help control the power in a reactor. Pressurized water reactors are well suited for the production of tritium because the TPBARs can be inserted into the nonfuel positions of the fuel assemblies. Tritium is generated within the TPBARs as they are irradiated during normal reactor operation.

DOE will select one of these approaches by the end of 1998 to serve as the primary source of tritium. The other alternative, if feasible, would continue to be developed as a backup tritium source. Production of tritium in an accelerator is analyzed in the *Draft Environmental Impact Statement, Accelerator Production of Tritium at the Savannah River Site*, DOE/EIS-0270D (see Section S.1.6.2.1).

S.1.4 The CLWR Procurement Process

The production of tritium in a CLWR would require a contractual agreement between DOE and the owner/operator of the CLWR. Accordingly, on June 3, 1997, DOE issued, in final form, a Request for Proposals from owners/operators for irradiation services or sale of a CLWR. In September 1997, DOE received proposals for producing tritium using operating or partially completed reactors. The proposals for the Watts Bar and Bellefonte Nuclear Plants received from the TVA were the only proposals determined to be responsive to the requirements of the procurement request. Under Federal Procurement Law, a proposal is "responsive" if it meets the criteria set forth in the agency's Request for Proposals. In addition to the responsive bids discussed in this Draft EIS, DOE received one non-responsive bid. That bid did not offer to produce tritium. TVA offered Watts Bar Nuclear Plant, Unit 1 (Watts Bar 1) and Bellefonte Nuclear Plant, Unit 1 (Bellefonte 1). Since Bellefonte 1 was a partially completed unit, in the event that it could not be completed and licensed in time to support DOE's requirements for tritium production, TVA, through the procurement process, offered to make Sequoyah Nuclear Plant, Unit 1 and Unit 2 (Sequoyah 1 and Sequoyah 2) available to meet the need for tritium. In addition, Bellefonte Nuclear Plant, Unit 2 (Bellefonte 2) was considered as a reasonable alternative. These reactors, the location of which are shown in Figure S–2, are owned by the U.S. Government and operated by the TVA. They are as follows:

- Watts Bar Nuclear Plant, Unit 1 (Watts Bar 1), Spring City, Tennessee (operating)
- Sequoyah Nuclear Plant, Unit 1 (Sequoyah 1), Soddy Daisy, Tennessee (operating)
- Sequoyah Nuclear Plant, Unit 2 (Sequoyah 2), Soddy Daisy, Tennessee (operating)
- Bellefonte Nuclear Plant, Unit 1 (Bellefonte 1), Hollywood, Alabama (partially complete)
- Bellefonte Nuclear Plant, Unit 2 (Bellefonte 2), Hollywood, Alabama (partially complete)

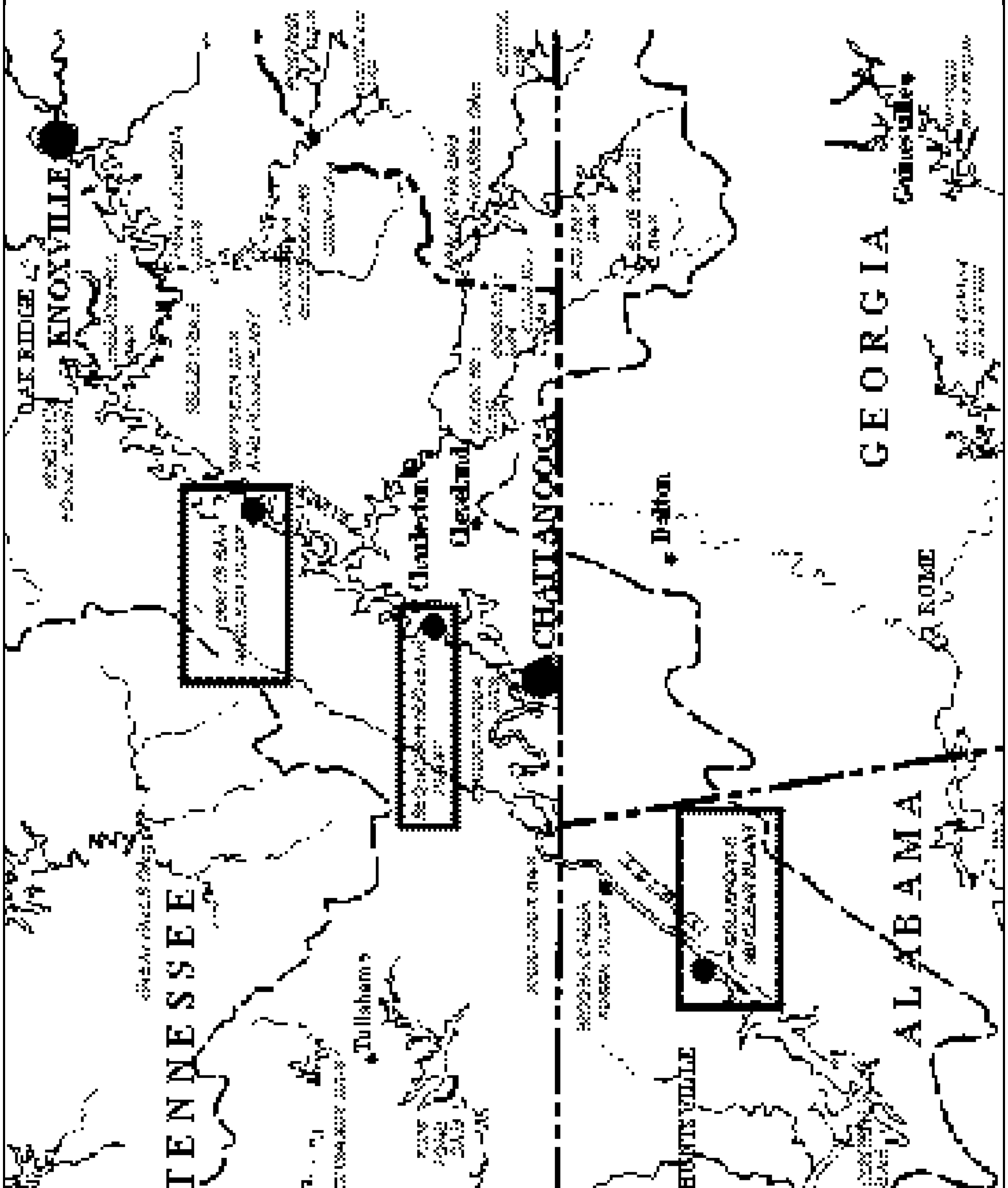


Figure S–2 Candidate CLWRs for Tritium Production

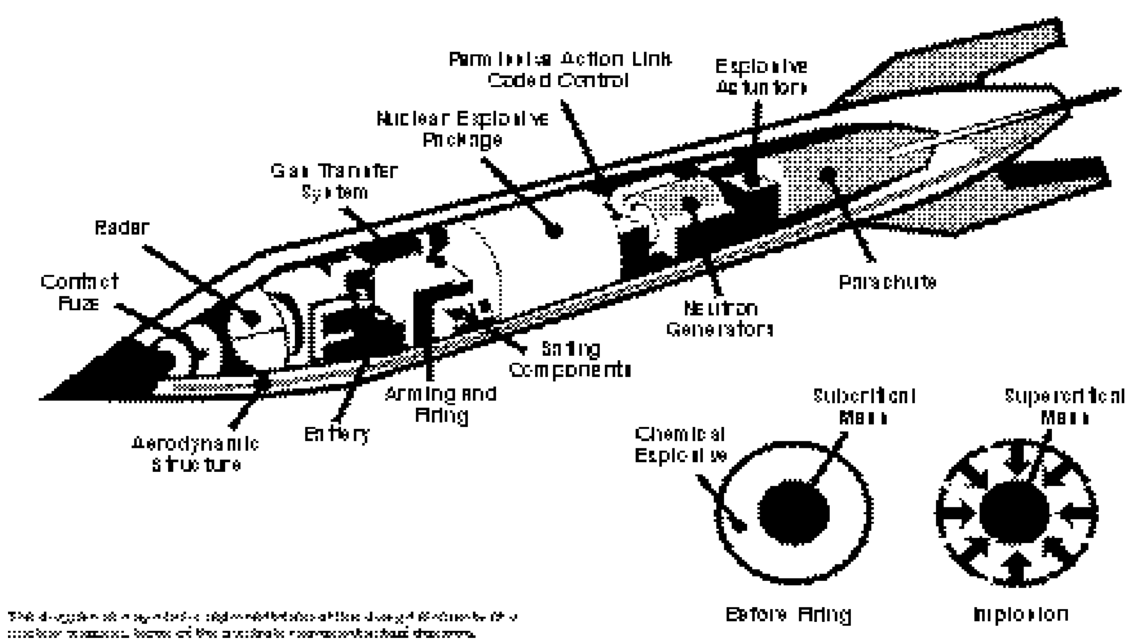
Tritium Use in a Nuclear Weapon

The figure below presents a simplified diagram of a modern nuclear weapon. An actual U.S. nuclear weapon is much more complicated, consisting of many thousands of parts.

The nuclear weapon primary is composed of a central core called a pit, which is usually made of plutonium-239 and/or highly enriched uranium. This is surrounded by a layer of high explosive, which, when detonated, compresses the pit initiating a nuclear reaction. This reaction is generally thought of as the nuclear fission "trigger" which activates the secondary assembly component to produce a thermonuclear hydrogen fusion reaction. The remaining nonnuclear components consist of everything from arming and firing systems, to batteries and parachutes. The assembly of these components into a weapon or the dismantlement of an existing weapon are done at the weapons assembly/disassembly facility.

Tritium is not a fissile material and cannot be used by itself to construct a nuclear weapon. However, tritium is a key component of all nuclear weapons presently in the nation's nuclear weapons arsenal. Tritium enables weapons to produce a larger yield while reducing the overall size and weight of the warhead. This process is called "boosting." Boosting is accomplished by injecting a mixture of tritium gas and deuterium gas, a naturally occurring, nonradioactive hydrogen isotope, into the pit. The deuterium and tritium are stored in reservoirs (which is depicted as the "gas transfer system" in the figure) until the gas transfer system is initiated. The implosion of the pit along with the onset of the fissioning process heats the deuterium-tritium mixture to the point that the atoms undergo fusion. The fusion reaction releases large quantities of very high energy neutrons which flow through the compressed pit material and produce additional fission reactions. Such boosting has allowed for the development of today's sophisticated delivery systems. The key function of tritium is to enhance the fission yield of a nuclear weapon.

Diagram of a Modern Nuclear Weapon



DOE may enter into an interagency agreement with the TVA, contingent on completion of the NEPA process, for production of tritium required to support the nuclear weapons stockpile. Only those actions that are determined to not be irreversible or irretrievable would be permitted prior to the completion of the NEPA process. However, before completion of the CLWR EIS and its associated Record of Decision, DOE and TVA will have taken and will continue to take appropriate actions (e.g., studies, analyses) related to the potential submission of licensing documents to the U.S. Nuclear Regulatory Commission (NRC). The NRC must issue regulatory approval for the use of TPBARs in licensed reactors.

S.1.5 Background

S.1.5.1 Defense Programs Mission

Since the inception of the nuclear weapons program in the 1940s, DOE and its predecessor agencies have been responsible for designing, manufacturing, maintaining, and retiring the nuclear weapons in the nation's stockpile. In response to the end of the Cold War and changes in the world political regime, the emphasis of the United States' nuclear weapons program has shifted dramatically over the past few years from producing weapons to dismantling weapons. Accordingly, the nuclear weapons stockpile is being greatly reduced, the United States is no longer producing new-design nuclear weapons, and DOE has closed or consolidated many former weapons production facilities.

Additionally, in 1991 President Bush declared a moratorium on underground nuclear testing, and in 1995 President Clinton decided to pursue a zero-yield Comprehensive Test Ban Treaty. Despite these significant changes, DOE's responsibilities for the nuclear weapons stockpile continue, and the President and Congress have directed DOE to continue to maintain the safety and reliability of the nuclear weapons stockpile, and to provide the tritium necessary to satisfy national security requirements. As explained in Section S.2, the United States will need a new tritium production source by as early as 2005.

In the absence of new weapons designs and the total redesign of all warheads and delivery systems, the nation requires a reliable source of tritium to maintain a nuclear deterrent. Furthermore, total redesign of all warheads would require nuclear testing which would be contrary to the President's pursuit of a Comprehensive Test Ban Treaty.

S.1.5.2 Brief History of the Production of Tritium

Tritium is so rare in nature that useful quantities must be manufactured. DOE has constructed and operated over a dozen nuclear reactors for the production of nuclear materials at the Savannah River Site, South Carolina, and the Hanford Site, Washington, starting with the early part of the Manhattan Project during World War II. None of these reactors is currently operational. The last one, the K-Reactor at the Savannah River Site was shut down in 1988 for major environmental, safety, and health upgrades, to comply with today's stringent standards. DOE discontinued the K-Reactor Restart Program in 1993 when smaller stockpile requirements delayed the need for tritium. As explained in the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling*, the K-Reactor is not a reasonable alternative for tritium production.

In recent years, international arms control agreements have caused the nuclear weapons stockpile to be reduced in size. Reducing the stockpile has allowed DOE to recycle the tritium removed from dismantled weapons for use in supporting the remaining stockpile. However, due to the decay of tritium, the current inventory of tritium will not meet national security requirements past approximately 2005. Therefore, the most recent Presidential direction, which is contained in the 1996 Nuclear Weapons Stockpile Plan and an accompanying Presidential

Decision Directive, mandates that new tritium be available by approximately 2005 if a CLWR is the selected option for tritium production.

S.1.5.3 Production of Tritium in a CLWR

The production of tritium in a CLWR is technically straightforward and requires no elaborate, complex engineering development and testing program. All the nation's supply of tritium, as mentioned previously, has been produced in reactors. Most existing commercial pressurized water reactors utilize, 12-foot-long rods containing an isotope of boron (boron-10) in ceramic form that are inserted in their fuel assemblies to absorb excess neutrons produced by the uranium fuel in the fission process for the purpose of controlling power in the core at the beginning of an operating cycle. These rods are sometimes called burnable absorber rods. DOE's tritium program has developed another type of burnable absorber rod in which neutrons are absorbed by a lithium aluminate ceramic rather than boron ceramic. They are called tritium producing burnable absorber rods (TPBARs). These TPBARs would be placed in the same locations in the reactor core as the standard burnable absorber rods. There is no fissile material (uranium or plutonium) in the TPBARs. While the two types of rods function in a very similar manner to absorb excess neutrons in the reactor core, there is one notable difference: when neutrons strike the lithium aluminate ceramic material in a TPBAR, tritium is produced. This tritium is captured almost instantaneously in a solid zirconium material in the rod, called a "getter." Thus, there is virtually no free tritium in the rod. In fact, the solid material that captures the tritium as it is produced in the rod is so effective that the rod will have to be heated in a vacuum to temperatures in excess of 1,000
the extraction process to recover the tritium for eventual use in the nuclear weapons stockpile.

S.1.5.4 Nonproliferation

In accordance with the direction provided in the Fiscal Year 1998 National Defense Authorization Act (P.L. 105-85), the Congress requested that the DOE take the lead to identify and assess any policy issues associated with various reactor options for the production of tritium for national security purposes. The Congress requested that this be done in conjunction with other agencies, including the Nuclear Regulatory Commission, the Department of Defense, and the Department of State Arms Control offices through a senior level, interagency process. This process was completed in July 1998 and is documented in a report to Congress entitled, "Interagency Review of the Nonproliferation Implications of Alternative Tritium Production Technologies Under Consideration by the Department of Energy". The principal findings in this report, as related to tritium production in a CLWR, are as follows:

1. The use of CLWRs for tritium production was not prohibited by law or international treaty;

2. That, historically, there have been numerous exceptions to the practice of differentiating between U.S. civil and military facilities (including the operation of the N-Reactor at Hanford, the dual use nature of the U.S. enrichment program, the use of defense program plutonium production reactors to produce radio-isotopes for civilian purposes, and the sale of tritium produced in the defense reactors in the U.S. commercial market);

3. Although the CLWR alternative raised initial concerns because of its implications for the policy of maintaining separation between U.S. civil and military nuclear activities, these concerns could be adequately addressed, given the particular circumstances involved. These included the fact that the reactors would remain eligible for International Atomic Energy Agency safeguards, and the fact that if TVA were the utility selected for the tritium mission, the reactors used for tritium production would be owned and operated by the U.S. Government, making them roughly comparable to past instances of government-owned dual-purpose nuclear facilities.

The report concluded that the nonproliferation policy issues associated with the use of a CLWR are manageable and that DOE should continue to pursue the reactor option as a viable source for future tritium production.

S.1.5.5 Background on the Tennessee Valley Authority

TVA was established by an Act of Congress in 1933 as a Federal corporation to improve the navigability and to provide for the flood control of the Tennessee River; to provide for reforestation and the proper use of marginal lands in the Tennessee Valley; to provide for agricultural and industrial development of the Tennessee Valley, to provide for the national defense, and for other purposes. Within a few years of its establishment, TVA had built a series of multipurpose dams on the Tennessee River system. One of the purposes of these dams was production of abundant, inexpensive electricity. The hydroelectric power generated by these dams met most of the rapidly increasing needs of the region through the 1940s. By the early 1950s, however, the growing demand was quickly outstripping the capacity of the dams and the Watts Bar Fossil Fuel Plant, which had begun operation in 1942. During the next 20 years, TVA built 11 large, coal-fired, electricity-generating plants to meet the region's growing needs. Some of these plants were the largest, first-of-their-kind coal-fired units in the world. The 1960s brought even greater growth to the region. To meet the anticipated need for more power, TVA began an ambitious program of nuclear plant construction.

Today TVA is one of the largest producers of electricity in the United States, generating 4 to 5 percent of all electricity in the nation. TVA's power system serves almost 8 million people in a seven-state region encompassing some 207,200 square kilometers (80,000 square miles). TVA's electricity is distributed to homes and businesses through a network of 159 power distributors, including municipally owned utilities and electric cooperatives. TVA also sells power directly to approximately 60 large industrial customers and Federal facilities.

TVA's power system, which is self-financed, has a generating capacity of 28,000 MWe. Its generating system consists of 11 coal-fired plants (53 percent of total generating capacity), 5 nuclear generating units at three sites (20 percent), 29 hydroelectric dams (15 percent), 48 combustion turbine units at four sites (7 percent), and one pumped-storage facility (5 percent). These plants, although managed by TVA, are owned by the United States government. The TVA power system is linked by 25,750 kilometers (16,000 miles) of transmission lines that carry power to 750 wholesale delivery points, as well as 57 interconnections with 13 neighboring utilities.

In December 1995, with the publication of *Energy Vision 2020, Integrated Resource Plan and Environmental Impact Statement*, TVA projected demands for electricity in the TVA power service area through the year 2020 and evaluated different ways of meeting these projected increases. Since the Integrated Resource Plan was completed in 1995, TVA has continued to evaluate and select the best resource options based on the latest proposals and TVA's forecast of power needs. The total system generating capacity has been increased with the successful completion of Watts Bar 1 and the return to service of Browns Ferry Nuclear Plant, Unit 3. Both units have operated above expectations and have proven to be very reliable.

Current projections show the demand for electricity (including reserves) would exceed TVA's 1998 generating capacity by about 5,200 MWe in 2005; this projection is slightly less than the 1998-2005 medium load forecast of 5,450 MWe in *Energy Vision 2020, Integrated Resource Plan and Environmental Impact Statement*. About 2,800 MWe of additional generating capacity is needed by the year 2001. A portion of this would be met by the proposed Red Hills Power Project. The remainder would be met by option purchase agreements, forward contracts for delivery of electricity to TVA, and internal TVA projects to increase net dependable capacities for TVA's combustion turbines, fossil plants, and pumped storage units. An additional 2,400 MWe of capacity would be required between 2001 and 2005. The completion of the Bellefonte unit(s) would offset some of this planned capacity.

Producing tritium in a TVA reactor would be consistent with the Congressional purposes that established the TVA—namely, to provide for the industrial development of the Tennessee Valley and for national defense. Producing tritium in a TVA reactor would also enable the TVA to maximize the utilization of its resources, and to potentially increase its electricity generating capacity. TVA as a Federal agency, in order to fulfill NEPA responsibilities, chose to be a cooperating agency on this EIS. A cooperating agency is defined by Council on Environmental Quality regulations as any other Federal agency other than a lead agency having jurisdiction by law or special expertise with any environmental issue (40 CFR 1508.5).

S.1.6 NEPA Strategy

DOE's strategy for compliance with NEPA has been, first, to make decisions on programmatic alternatives in the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* and Record of Decision (60 FR 63878), followed by site-specific analyses to implement the programmatic decisions. The decisions made in the December 12, 1995, *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* Record of Decision have resulted in DOE preparing this EIS and the following NEPA documents:

1. *Draft Environmental Impact Statement, Construction and Operation of a Tritium Extraction Facility at the Savannah River Site*

2. *Draft Environmental Impact Statement, Accelerator Production of Tritium at the Savannah River Site*

3. *Environmental Assessment, Lead Test Assembly Irradiation and Analysis, Watts Bar Nuclear Plant, Tennessee and Hanford Site, Richland, Washington*.

The relationship of the CLWR EIS with these, as well as other relevant NEPA documents is explained below.

S.1.6.1 Completed NEPA Actions

S.1.6.1.1 Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling

The *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling*, DOE/EIS-0161, evaluated the alternatives for the siting, construction, and operation of tritium supply and recycling facilities at each of five DOE candidate sites (the Idaho National Engineering Laboratory; the Nevada Test Site; the Oak Ridge Reservation, Tennessee; the Pantex Plant, Texas; and the Savannah River Site, South Carolina) for four different production technologies (heavy water reactor, modular high temperature gas-cooled reactor, advanced light water reactor, and accelerator production of tritium). This Programmatic EIS also evaluated the impacts of using a CLWR, but did not analyze specific locations or reactor sites. Issued in October 1995, the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* was followed by a Record of Decision on December 12, 1995. In the Record of Decision, DOE decided to pursue a dual-track approach on the two most promising tritium supply alternatives: (1) to initiate purchase of an existing commercial reactor (operating or partially complete) or reactor irradiation services with an option to purchase the reactor for conversion to a defense facility; and (2) to design, build, and test critical components of an accelerator system for tritium production (the Savannah River Site was selected as the location for an accelerator, should one be built) (60 FR 63878). The Record of Decision also called for the construction of a proposed new Tritium Extraction Facility at the Savannah River Site. The CLWR EIS is intended to provide the NEPA analysis necessary to implement the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* decision to produce tritium in one or more CLWRs should the Secretary of Energy decide that tritium will be primarily produced in a CLWR.

S.1.6.1.2 Lead Test Assembly Environmental Assessment

> ***Lead Test Assembly Program***
>
> *In September 1997, a confirmatory demonstration using the TPBARs began at Watts Bar 1 following approval by DOE and NRC. The purpose of the confirmatory tests is to provide confidence to the NRC, utilities, and the public that tritium production in a CLWR is both technically straightforward and safe. DOE expects TVA to remove these rods in the Spring of 1999, at which time they will be shipped to a DOE laboratory for examination.*

This NEPA analysis addressed the environmental impacts associated with the fabrication of the Lead Test Assembly TPBARs at Pacific Northwest National Laboratory, Washington; the irradiation of these TPBARs in Watts Bar 1; and post-irradiation examination of the TPBARs at Pacific Northwest National Laboratory and Argonne National Laboratory West, Idaho; and associated impacts of transporting TPBARs to and from the Watts Bar Nuclear Plant. The purpose of the Lead Test Assembly confirmatory demonstration is to confirm and provide confidence to regulators and the public that tritium production in a CLWR is technically straight forward and safe. DOE issued a Finding of No Significant Impact in July 1997. Subsequently, the TPBARs were placed in Watts Bar 1 on September 25, 1997, and they are presently being irradiated during the normal 18-month fuel cycle. Following irradiation, the TPBARs will undergo post-irradiation examination. To meet its own NEPA requirements, TVA adopted the Lead Test Assembly Environmental Assessment and issued a Finding of No Significant Impact on August 14, 1997. Additionally, NRC prepared an independent Environmental Assessment and issued its own Finding of No Significant Impact on September 11, 1997 (62 FR 47835).

S.1.6.1.3 EISs for the Operation of Watts Bar 1, Sequoyah 1, and Sequoyah 2, and for Construction of Bellefonte 1 and 2

EISs analyzing the environmental impacts associated with operation of the Watts Bar and Sequoyah Nuclear Plants and the construction of the Bellefonte Nuclear Plant have been completed and serve to a great extent as a baseline on which the environmental impacts associated with tritium production are assessed. For the partially completed Bellefonte 1 and Bellefonte 2, the CLWR EIS evaluates the environmental impacts associated with their completion and with their subsequent operation for 40 years.

S.1.6.2 Ongoing NEPA Actions

S.1.6.2.1 Draft Environmental Impact Statement, Accelerator Production of Tritium at the Savannah River Site

This EIS analyzes the potential environmental impacts associated with the construction and operation of an accelerator for the production of tritium at the Savannah River Site. On a programmatic level, the accelerator production of tritium at the Savannah River Site represents the No Action Alternative for this CLWR EIS. That is, if DOE decides not to proceed with the proposed action to produce tritium in one or more CLWRs, then DOE would construct and operate the accelerator for the production of tritium at the Savannah River Site. The Draft EIS was issued in December 1997. The Final EIS is expected to be issued in December 1998.

S.1.6.2.2 Draft Environmental Impact Statement, Construction and Operation of a Tritium Extraction Facility

This EIS analyzes the potential environmental impacts associated with the construction and operation of a Tritium Extraction Facility at the Savannah River Site. The Draft EIS was issued in May 1998, a Final EIS is scheduled to be completed in December 1998. The purpose of the Tritium Extraction Facility would be to extract the tritium from the TPBARs or targets of similar design. If the CLWR is selected as the primary tritium technology, TPBARs irradiated at selected CLWRs will be sent to the Tritium Extraction Facility for extraction of the tritium-containing gases. If CLWR is the backup technology, a new extraction capability would still be required either as a stand-alone facility or in combination with the accelerator for production of tritium (APT) technology. A decision on whether to construct and operate a Tritium Extraction Facility is not expected to be made until after the tritium supply technology decision (see Section S.1.1.3).

S.1.6.2.3 Environmental Assessment for the Tritium Facility Modernization and Consolidation Project at the Savannah River Site

This environmental assessment addresses the potential impacts of consolidating the tritium activities currently performed in Building 232-H into the newer Building 234-H. Tritium extraction functions would be transferred to the Tritium Extraction Facility, under the Preferred Alternative. The overall impact would be to reduce emissions by up to 50 percent. Another effect would be to reduce the amount of low-level waste generated. Effects on other resources would be negligible. Therefore, impacts from these actions have not been included in the cumulative impacts of the CLWR EIS.

S.1.6.2.4 Final Environmental Impact Statement for the Bellefonte Conversion Project

This EIS, issued by TVA, addresses the environmental impacts anticipated from: (1) the conversion of partially completed Bellefonte 1 and 2 to fossil fuel electricity generating facilities, and (2) the No Action Alternative of maintaining the facilities as partially completed nuclear facilities. The EIS was completed in October 1997. The issuance of a Record of Decision on the *Final Environmental Impact Statement for the Bellefonte Conversion Project* will not be made until it is determined whether one or both of these reactor plants will be used for tritium production.

S.2 PURPOSE AND NEED

Since nuclear weapons came into existence in 1945, a nuclear deterrent has been a cornerstone of the nation's defense policy and national security. Both President Clinton and Congress have reiterated this principle in public statements and through legislation. The President has stated on a number of occasions his commitment to maintaining a nuclear deterrent capability. Most recently, in May 1997, the President stated in *A National Security Strategy for a New Century* that ". . . our nuclear deterrent posture is one of the most visible and important examples of how U.S. military capabilities can be used effectively to deter aggression and coercion. Nuclear weapons serve as a hedge against an uncertain future, a guarantee of our security commitments to allies, and a disincentive to those who would contemplate developing or otherwise acquiring their own nuclear weapons."

U.S. strategic nuclear systems are based on designs that use tritium gas. Since tritium decays at a rate of about 5.5 percent per year (i.e., every 12.3 years one-half of the tritium has decayed), periodic replacement is required as long as the United States relies on a nuclear deterrent. The nation, therefore, requires a reliable source of tritium to maintain its nuclear weapons stockpile.

As explained in Section S.1.5.1, the size of the nation's nuclear weapons stockpile is determined by the Secretaries of Defense and Energy who, in coordination with the Nuclear Weapons Council, jointly sign and submit to the President the Nuclear Weapons Stockpile Memorandum. This Memorandum transmits the Nuclear Weapons Stockpile Plan to the President for final approval. Many factors are considered in the development of the Nuclear Weapons Stockpile Plan, including the status of the currently approved stockpile, arms control negotiations and treaties, Congressional constraints, and the status of the nuclear material production and fabrication facilities. Under this plan, DOE can determine the amount of tritium necessary to support the approved stockpile.

Over the past 40 years, DOE has built and operated over a dozen nuclear reactors, five of them at the Savannah River Site in South Carolina, to produce tritium and other nuclear materials for weapons purposes. Today, none of these reactors are operational, and DOE has not produced tritium for addition to the stockpile since 1988. According to the Atomic Energy Act of 1954, however, DOE is responsible for developing and maintaining the capability to produce the nuclear materials, such as tritium, that are necessary for the defense of the United States (40 U.S.C. 2011).

Until a new tritium supply source is operational, DOE will continue to support tritium requirements by recycling tritium from weapons retired from the nation's stockpile. However, because of the tritium decay rate, recycling can only meet the tritium demands for a limited time, even with the reduction in stockpile requirements and no identified need for new-design weapons in the foreseeable future. Current projections, derived from the most recently approved, classified projections of future stockpile scenarios, indicate that recycled tritium will support the nation's nuclear weapons stockpile adequately until approximately 2005 **(see Figure S–3)**.

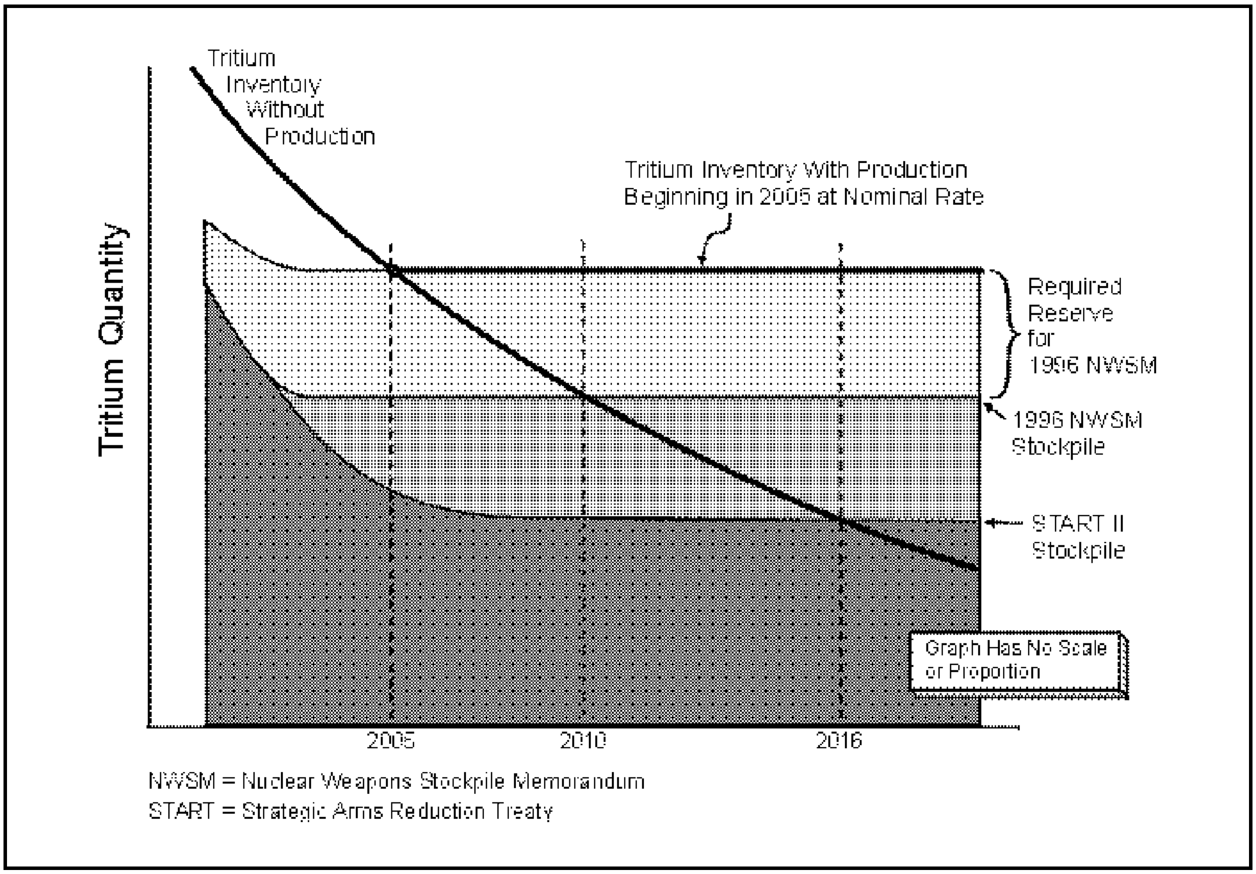


Figure S–3 Estimated Tritium Inventory and Reserve Requirements

Even with a reduced nuclear weapons stockpile and no identified requirement for new nuclear weapons production in the foreseeable future, an ensured long-term tritium supply and recycling capability will be required to maintain the weapons determined to be needed for national defense under the prevailing Nuclear Weapons Stockpile Plan.

Presently, no U.S. source of new tritium is available. The effectiveness of the U.S. nuclear deterrent capability depends not only on the nation's current stockpile of nuclear weapons or the effectiveness of those it can produce, but also on its ability to reliably and safely provide the tritium needed to maintain these weapons.

To meet requirements mandated by the President and supported by the Congress, the United States will need a new source of tritium production by approximately 2005. For planning purposes, the operational life of the new production source would be about 40 years. Without a new supply source, after 2005 the United States would have to use its 5-year reserve of tritium to maintain the readiness of the nuclear weapons stockpile. The 5-year reserve contains a quantity of tritium maintained for emergencies and contingencies. In such a scenario, the complete depletion of the 5-year tritium reserve would degrade the nuclear deterrent capability because not all weapons in the stockpile would be able to function as designed. Eventually, the United States would lose its nuclear deterrent. The purpose of DOE's action is to produce in a CLWR the tritium needed to maintain the nation's nuclear weapons stockpile.

TVA's purpose and need relative to this environmental impact statement is to maximize the utilization of its resources while simultaneously providing support to national defense. National defense support has been one of TVA's historic multi-purpose missions (see Section S.1.5.5).

S.3 COMMERCIAL LIGHT WATER REACTOR PROGRAM ALTERNATIVES

S.3.1 Production of Tritium in a Commercial Light Water Reactor

To produce tritium in a CLWR, TPBARs would be inserted into the reactor core. The TPBARs are long, thin tubes that contain lithium 6, a material that produces tritium when it is exposed to neutrons in the reactor core. The exterior dimensions of the TPBARs are similar to the burnable absorber rods so that they can be installed in fuel assemblies where burnable absorber rods are normally placed. To ease the insertion and removal from fuel assemblies, the TPBARs would be attached to a base plate. See **Figures S–4** and **S–5** for a sketch of a typical TPBAR assembly and components. In addition to producing tritium, TPBARs would fill the same role as burnable absorber rods in the operation of the reactor.

The neutron absorber material in the TPBARs would be enriched in the isotope lithium 6, instead of the boron usually used in the burnable absorber rods. When the TPBARs are inserted into the reactor core, neutrons would be absorbed by the lithium 6 isotope initiating a nuclear process that would turn it into lithium 7. The new isotope would then split to form helium 4 and tritium. The tritium then would be captured in a solid metal nickel-plated zirconium material in the TPBAR called a "getter." The tritium would be chemically bound in the TPBAR "getter" until the TPBAR is removed from the reactor during refueling and transported to the proposed Tritium Extraction Facility at the DOE's Savannah River Site in South Carolina where the tritium would be extracted by heating the TPBARs in a vacuum to temperatures in excess of 1,000
the tritium would be purified.

S.3.1.1 Impacts of Tritium Production on Reactor Operations

The replacement of burnable absorber rods with TPBARs is expected to have some impacts on the normal operation of the reactor, which could result in potential environmental impacts.

The differences between a tritium production reactor and nuclear power plant operation without tritium production are summarized below:

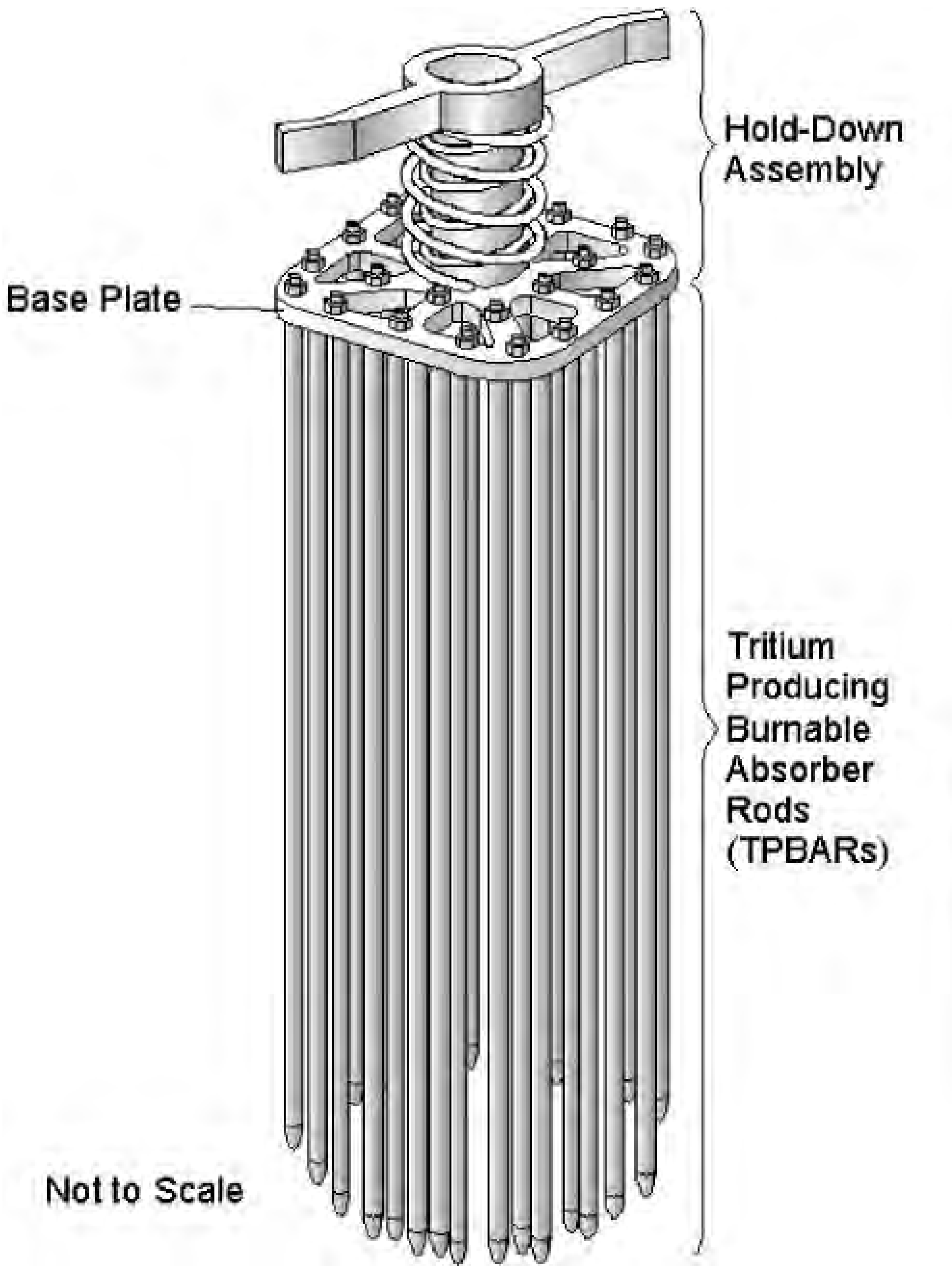


Figure S–4 Typical TPBAR Assembly

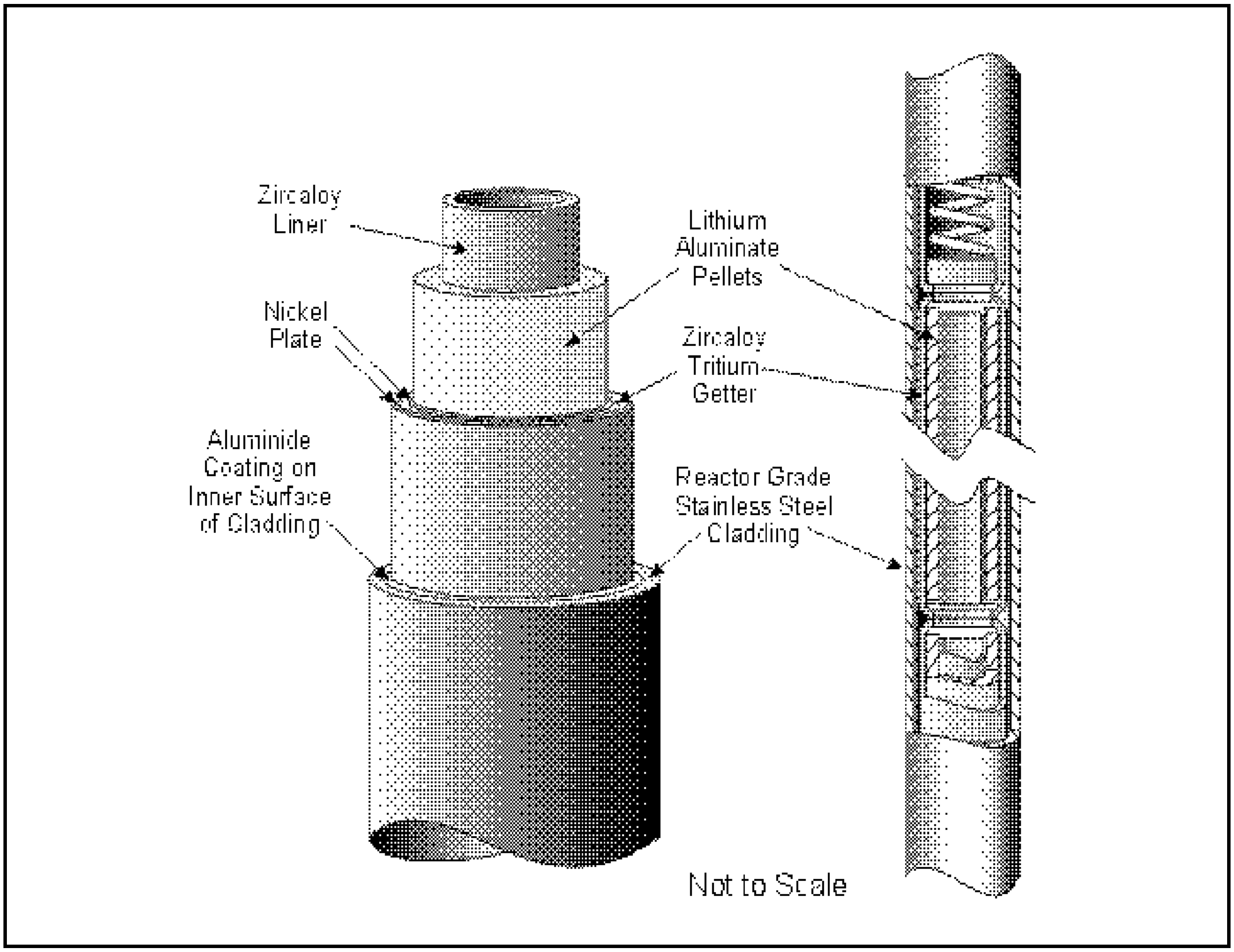


Figure S–5 Sketch of TPBAR Components

- Accident conditions—The physical changes to the reactor core would involve replacing some burnable absorber rods with TPBARs. This change would increase the estimated quantity of radionuclides assumed to be released in the analysis.

- Personnel—Additional TPBAR handling and shipping activities would create new jobs and possibly require the hiring of a few additional personnel at the CLWR sites.

- Effluent—The tritium content in the liquid effluent and gaseous emissions would likely increase as a result of the presence of TPBARs in the reactor.

- Waste—Additional activities associated with handling, processing, and shipping TPBAR assemblies would likely increase the generation of low-level radioactive waste.

- Spent fuel—Additional spent fuel could be generated when a reactor operates in a tritium-producing mode. Depending on existing spent fuel capacity, additional storage for spent fuel could be required.

- Public and worker exposure—The increased levels of tritium in the reactor coolant and the additional activities required in the handling and processing of TPBARs would result in increased radiation exposure of the public, operations workers, and maintenance personnel.

- Transportation and handling—Irradiated TPBAR assemblies would be packaged and transported from the CLWR sites to the Savannah River Site for tritium extraction and purification. Some additional risks of an accident en route would be expected. In addition, low-level radioactive waste associated with the TPBARs would be packaged and transported for disposal at the Barnwell disposal facility or the Savannah River Site.

S.3.2 Development of Alternatives

S.3.2.1 Major Planning Assumptions and Basis for Analysis

The major planning assumptions and considerations that form the basis of the analyses and impact assessments presented in this EIS are listed below.

- For the purposes of analysis in this EIS, DOE assumed that the CLWR program would be designed such that it could produce up to 3 kilograms of tritium per year. Considering the current design of the TPBARs and the efficiency of the tritium extraction process, this would involve the irradiation of up to 6,000 TPBARs in an 18-month refueling cycle (4,000 TPBARs per year). The maximum number of TPBARs that could be irradiated at each reactor unit without significantly disturbing the normal electricity-producing mode of reactor operation is approximately 3,400 TPBARs; the exact number depends on the specific design of the reactor. This EIS evaluates the impacts at each reactor site by considering a range of 1,000 to 3,400 TPBARs.

- The EIS assesses the environmental impacts of tritium production in CLWRs for a period of 40 years, starting with the delivery of irradiated TPBARs at the Tritium Extraction Facility in the year 2005 (approximately). For alternatives involving the partially completed reactor(s), it is assumed that any construction activities needed for the completion of Bellefonte 1 (and any other start-up tests and activities) would take place during the time period between 1999 and 2004, at which time the completed reactor would be fully operational. In the event Bellefonte 2 was also selected for completion, Bellefonte 1 would come on line in approximately 2005 while Bellefonte 2 would begin operation in approximately 2007.

- CLWRs are licensed by NRC to operate for 40 years. Currently operating reactors are not in a position to continue operation beyond 40 years without NRC approval for "life extension." Some of the environmental impacts associated with life extension activities would be attributable to tritium production. The NRC has addressed the generic impacts of life extension in the *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*. The life extension impacts associated with alternatives involving the currently operating units are based on this publication and are addressed generically in the EIS. Tritium production is not expected to affect relicensing. Life extension impacts for a partially completed reactor would not be an issue, since it would be expected to operate for 40 years after its completion.

- Tritium production in a currently operating reactor would not be expected to affect the radiological condition of the reactor at the end of its life. Therefore, environmental impacts associated with decommissioning and decontamination activities would be attributed to the normal operation of the reactor as an electricity-producing unit. For a partially completed reactor, the impacts from decommissioning and decontamination activities are evaluated in this EIS. Decommissioning and decontamination impacts are based on the generic EIS issued by the NRC entitled *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities*.

- Fabrication of the TPBARs would take place in a commercial facility that normally fabricates and assembles the components for the fresh fuel used in the CLWRs.

- Production of tritium in a CLWR would increase the generation rate of spent fuel if more than approximately 2,000 TPBARs are irradiated in a fuel cycle. Normally (i.e., during normal operation with no tritium production), fuel assemblies are used in more than one cycle. However, in order to maximize tritium production, TPBARs would be inserted in fresh fuel assemblies. In accordance with the Nuclear Waste Policy Act of 1982, DOE is planning to manage all spent nuclear fuel at a national repository. Siting and development of a repository is ongoing and the location and opening date for a suitable repository has not been determined. Accordingly, for the purposes of this EIS, the initial management of any additional spent nuclear fuel which may be generated as a result of tritium production is assumed to be stored onsite in a generic dry cask independent spent fuel storage installation (ISFSI) pending the availability of a suitable repository. The environmental impacts from the construction and operation of an ISFSI are addressed in this EIS. However, no decision will be made to either construct or operate an ISFSI as a result of this EIS. Appropriate NEPA documentation would be prepared prior to the construction of a dry cask spent fuel storage facility.

S.3.2.2 Reasonable Alternatives

As discussed in Section S.1.4, DOE issued a Request for Proposals for the CLWR production of tritium. DOE stated in the Request for Proposals its intent to select one or both of two approaches: (1) the acquisition of CLWR irradiation services for tritium production, or (2) the purchase of an operating CLWR by DOE for production of tritium. The only qualified response to DOE's solicitation came from TVA, the operator of Watts Bar 1, Sequoyah 1, and Sequoyah 2. TVA also maintains the partially completed units of Watts Bar 2, Bellefonte 1, and Bellefonte 2. With the exception of Watts Bar 2, which was considered and dismissed, these units form the basis for the Reasonable Alternatives.

To irradiate up to 6,000 TPBARs during an 18-month refueling cycle, DOE could use one or more reactors. Considering that a maximum number of 3,400 TPBARs could be irradiated in a single reactor, at least two reactors would be needed for the 6,000 TPBARs. Considering also that additional spent nuclear fuel generation attributed to tritium production starts approximately with the irradiation of approximately 2,000 TPBARs in a single reactor, DOE could use as many as 3 reactors to irradiate 6,000 TPBARs without increasing the amount of spent nuclear fuel. Mathematically, DOE has the option of selecting 1 of the 18 combinations of reactor units presented in **Table S–1**. These 18 combinations form the Reasonable Alternatives of the irradiation element of the project.

S.3.2.3 No Action Alternative

On the basis of the October 1995 *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling*, the DOE, in its December 12, 1995, Record of Decision (60 FR 63878), selected a dual-track path for tritium production technologies: accelerator production of tritium, and the production of tritium in a CLWR. The Record of Decision further stipulated that one alternative would be selected as the primary source of tritium and that the other alternative, if feasible, would be developed as a backup tritium source. Based on that Record of Decision, if tritium is not produced in a CLWR, it will be produced in an accelerator. Accordingly, for purposes of analysis in this EIS, the No Action Alternative assumes the continued operation of Watts Bar 1, Sequoyah 1, and Sequoyah 2 for the generation of electricity, and the deferral of construction activities necessary for completion of Bellefonte 1 and Bellefonte 2 as nuclear units. Consequently, this No Action Alternative entails the production of tritium in an accelerator. A summary of the environmental impacts associated with the production of tritium in an accelerator is contained in this EIS. That summary is based on the *Accelerator for Production of Tritium at the Savannah River Site Draft Environmental Impact Statement*.

S.3.2.4 Reactor Options

S.3.2.4.1 Watts Bar Nuclear Plant, Unit 1

Watts Bar 1 is located on a 716-hectare (1,770-acre) site in Rhea County, Tennessee, on the Tennessee River at Tennessee River Mile 528, approximately 80 kilometers (50 miles) northeast of Chattanooga, Tennessee. The general arrangement of the Watts Bar Nuclear Plant is shown in **Figure S–6**.

Table S–1 CLWR Tritium Production Program Reasonable Alternatives

Alternative	*Watts Bar 1 Operation*	*Sequoyah 1 Operation*	*Sequoyah 2 Operation*	*Bellefonte 1 Complete Construction and Operation*	*Bellefonte 2 Complete Construction and Operation*[a]
One Reactor[b]					
1					
2					
3					
4					
Two Reactor Combinations					
5					
6					
7					
8					
9					
10					
11					
Three Reactor Combinations					
12					
13					
14					
15					
16					
17					
18					

a Construction on Bellefonte 2 may be completed only if Bellefonte 1 is completed and operated.
b The one-reactor alternative could not produce 3 kilograms of tritium per year. However, it could satisfy reduced tritium requirements.

Watts Bar 1 began commercial power operation in May 1996. The Watts Bar 1 structures include a reactor containment building, a turbine building, an auxiliary building, a service building, a water pumping station for circulating water in the condenser, a diesel generator building, a river intake pumping station, a natural- draft cooling tower, a transformer yard, a 500-kilovolt switchyard and a 161-kilovolt switchyard, a spent nuclear fuel storage facility, and sewage treatment facilities. The reactor containment building houses a pressurized water reactor designed and manufactured by the Westinghouse Electric Corporation. No modifications are expected to be necessary for Watts Bar 1 to irradiate TPBARs. Design equipment and facilities are sufficient to load and unload the TPBAR assemblies. During normal operation with tritium

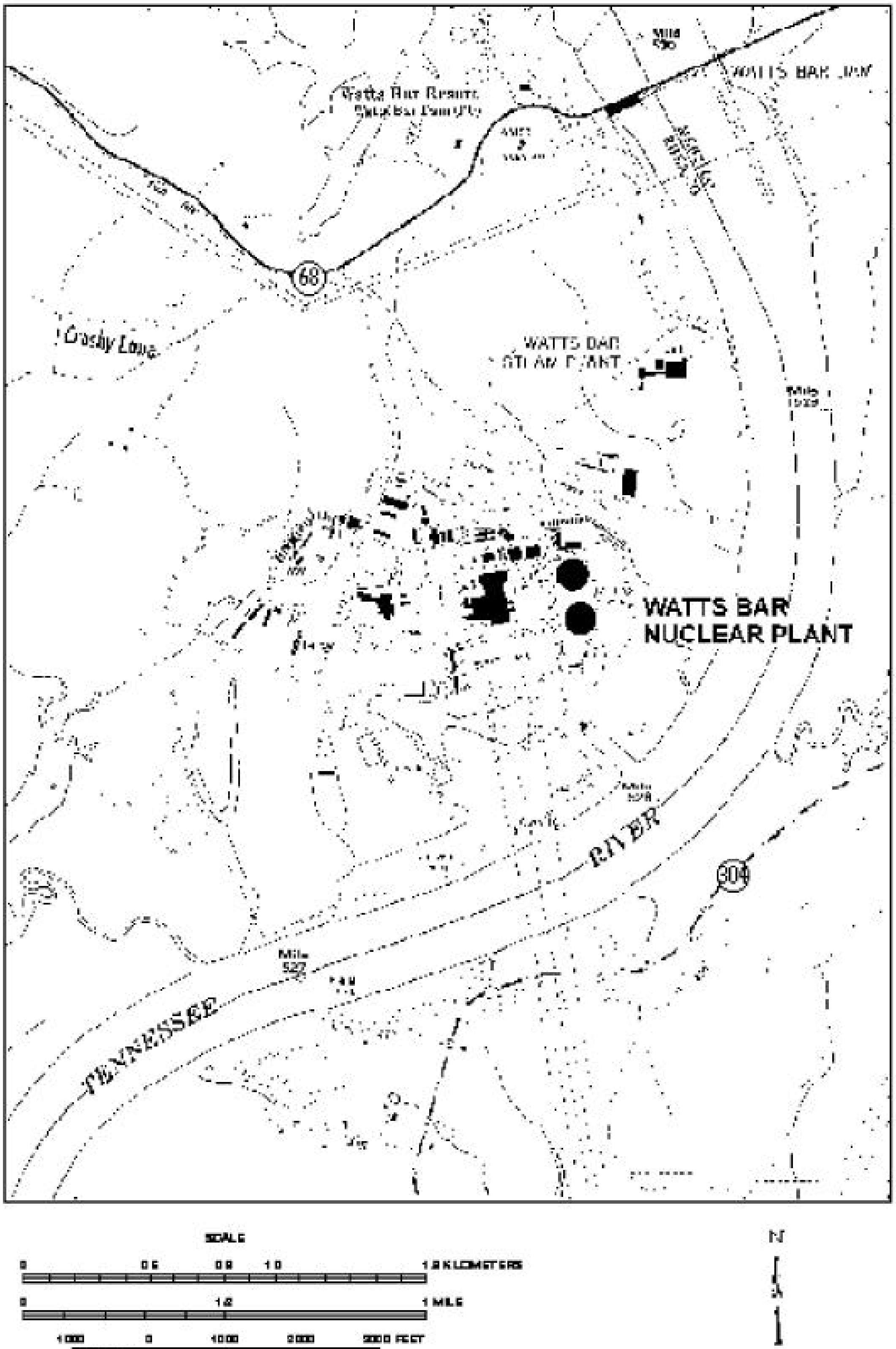


Figure S–6 Watts Bar Nuclear Plant

production, the plant could employ a few more workers (less than 10) in addition to the 809 presently employed. The spent nuclear fuel storage capacity is not sufficient for 40 years of operation with or without TPBARs.

S.3.2.4.2 Sequoyah Nuclear Plant, Units 1 and 2

Sequoyah 1 and Sequoyah 2 are operating, pressurized CLWR nuclear power plants. The units are located on a 212-hectare (525-acre) site in Hamilton County, Tennessee, on the Tennessee River at Tennessee River Mile 484.5, approximately 12 kilometers (7.5 miles) northeast of the nearest city limit of Chattanooga, Tennessee. The general arrangement of the Sequoyah Nuclear Plant is shown in **Figure S–7**.

Sequoyah 1 began commercial operation in July 1981, and Sequoyah 2 began commercial operation in June 1982. The nuclear steam supply systems, designed and manufactured by the Westinghouse Electric Corporation, include the reactor vessel, steam generators, and associated piping and pumps. These are housed in two reactor containment buildings. The balance of the nuclear power plant includes: a turbine building, an auxiliary building, a service and office building, a control building, a condenser circulating water pumping station, a diesel generator building, a river intake pumping station, two natural draft cooling towers, a transformer yard, a 500-kilovolt switchyard and a 161-kilovolt switchyard, spent nuclear fuel storage facilities, and sewage treatment facilities. No modifications are expected to be needed for Sequoyah 1 and Sequoyah 2 to irradiate TPBARs. Equipment and facilities are sufficient to load and unload the TPBAR assemblies. Tritium production could require the addition of a few more employees (fewer than 10 per unit) to the 1,120 employees currently employed at the two-unit site. The spent nuclear fuel storage capacity is not sufficient for 40 years of operation with or without TPBARs.

S.3.2.4.3 Bellefonte Nuclear Plant, Units 1 and 2

Bellefonte 1 and Bellefonte 2 are partially completed reactors. They are situated on approximately 607 hectares (1,500 acres) on a peninsula at Tennessee River Mile 392, on the west shore of Guntersville Reservoir, about 11.3 kilometers (7 miles) northeast of Scottsboro, Alabama. The main land uses of the surrounding area are forestry and agriculture; however, urban-industrial development has grown over the past several years around the plant along the Guntersville Reservoir. The affected environment at the Bellefonte Nuclear Plant site is described in Section 4.2.3. The general arrangement of the Bellefonte Nuclear Plant is shown in **Figure S–8**.

The U.S. Atomic Energy Commission (now NRC) issued the construction permit for the Bellefonte Nuclear Plant in December 1974, and construction started in February 1975. On July 29, 1988, TVA notified NRC that Bellefonte was being deferred as a result of a lower load forecast for the near future. After 3 years of extensive study, TVA notified NRC on March 23, 1993, of its plans to complete Bellefonte 1 and Bellefonte 2. In December 1994, TVA announced that Bellefonte would not be completed as a nuclear plant without a partner, and put further activities on hold until a comprehensive evaluation of TVA's power needs was completed. On April 29, 1996, TVA issued a Notice of Intent to prepare an EIS for the proposed conversion of the Bellefonte Nuclear Plant to a fossil fuel facility. The *Final Environmental Impact Statement for the Bellefonte Conversion Project*, analyzing alternatives for such a conversion, was issued in October 1997. A Record of Decision for that EIS will not be made until it is determined whether Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 will be used for tritium production.

The plant structures presently consist of two reactor containment buildings, a control building, a turbine building, an auxiliary building, a service building, a condenser circulating water pumping station, two diesel generator buildings, a river intake pumping station, two natural-draft cooling towers, a transformer yard, a 500-kilovolt and 161-kilovolt switchyard, a spent nuclear fuel storage pool, and sewage treatment facilities.

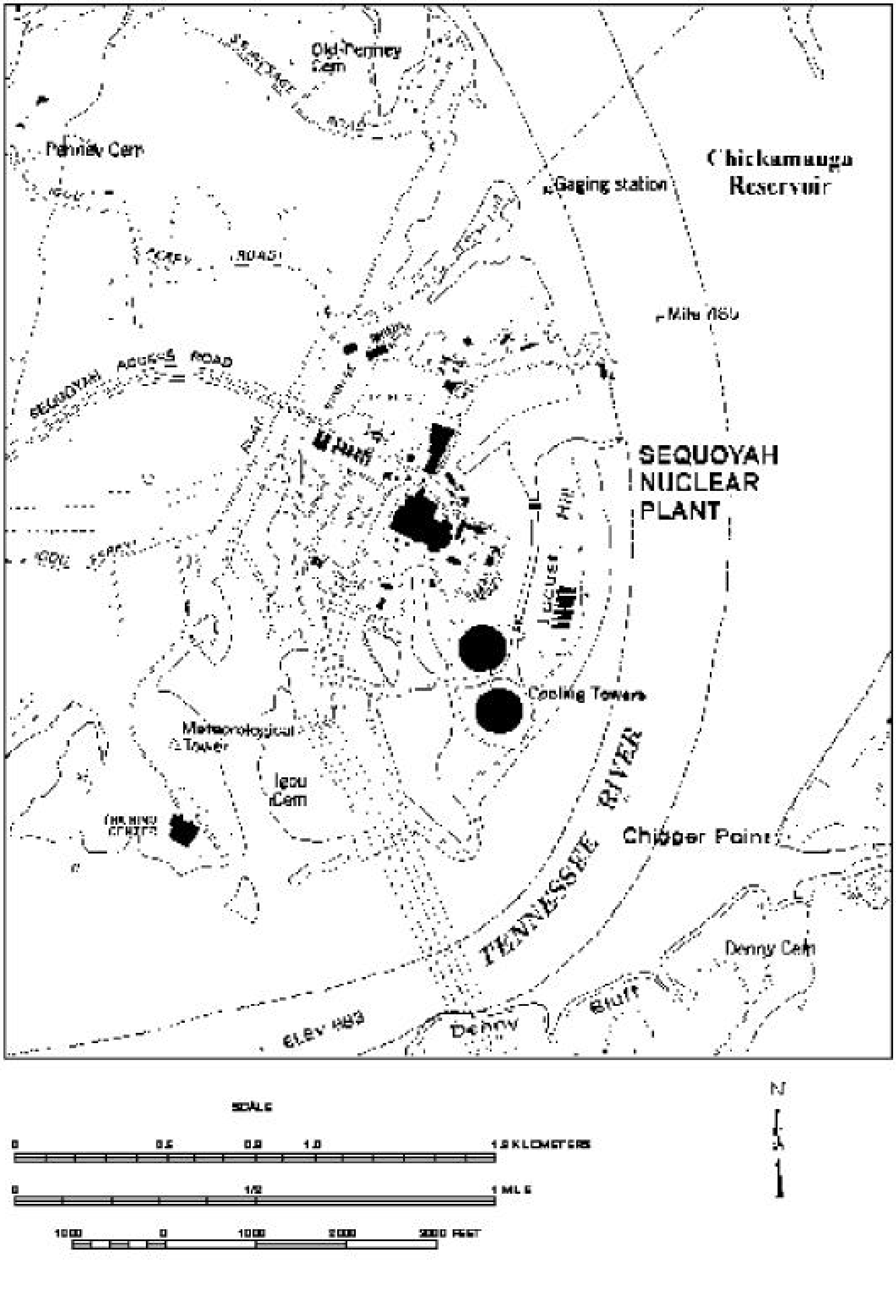


Figure S–7 Sequoyah Nuclear Plant Units 1 and 2

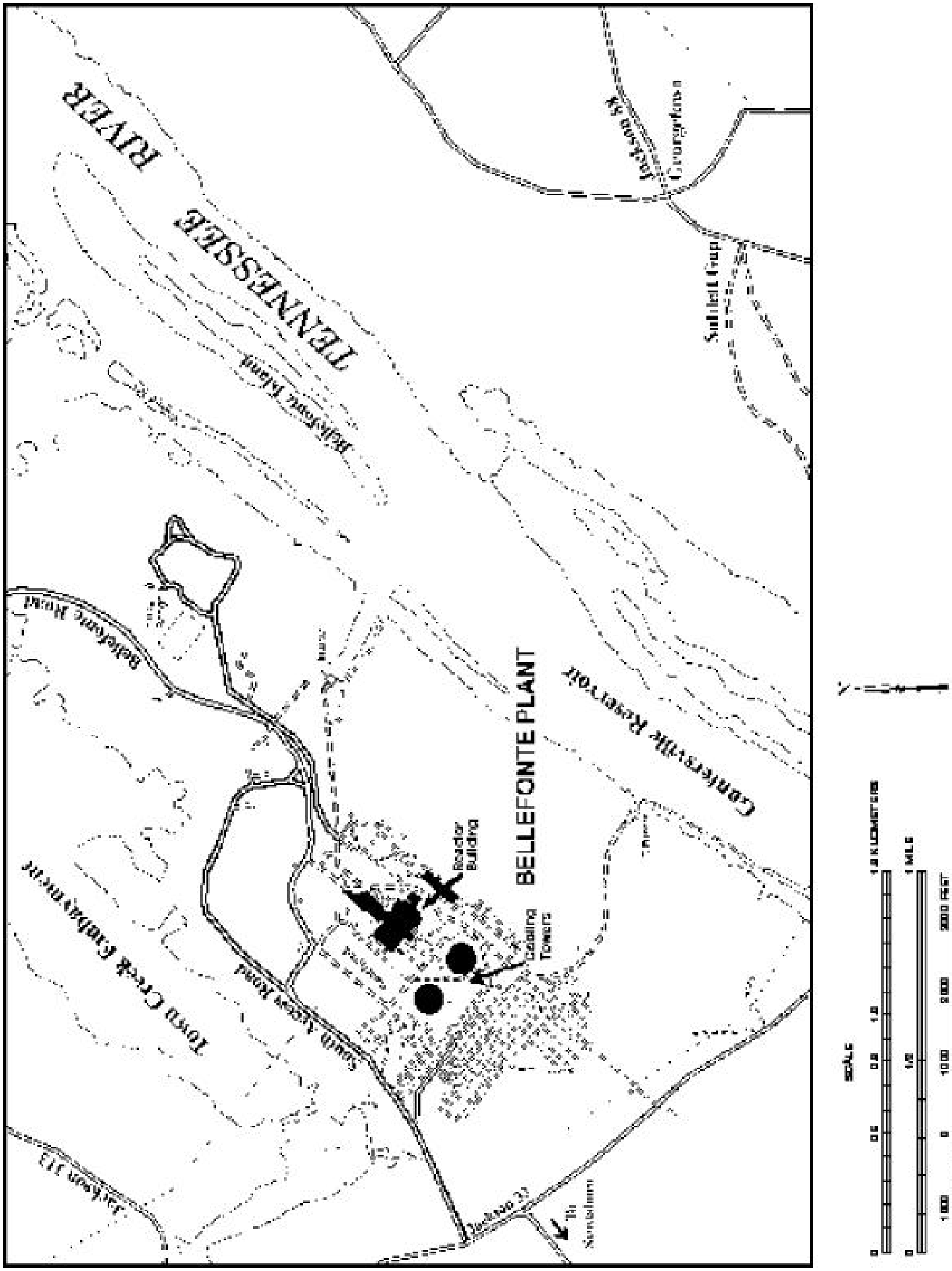


Figure S–8 Bellefonte Nuclear Plant Units 1 and 2

Additionally, there are office buildings to house engineering and other department personnel. Entrance roads, parking lots, railroad spurs, and a helicopter landing pad are in place and are capable of supporting a construction project.

No modifications to the original design would be necessary to complete Bellefonte 1 or Bellefonte 2 for operation, with or without TPBARs.

The plant systems and structures are maintained through active layup and preservation. Program activities include the following:

- Each unit's main turbine generators are rotated every other week.
- The diesel fire pumps are maintained in an operational status and are run monthly.
- The shell and tube sides of the main condensers (heat exchangers) are kept dry, and the tube side is maintained with a flow of warm, dehumidified air.
- The reactor coolant system is kept dry using a flow of warm, dehumidified air.

A workforce of approximately 80 personnel supports layup and preservation of the plant. Of that number, 38 are involved in operations and maintenance.

To complete Bellefonte 1 or both Bellefonte 1 and Bellefonte 2, additional engineering and construction activities would be required. These activities are summarized in the following paragraphs.

Engineering—Engineering for the original Bellefonte Nuclear Plant design is substantially complete. The additional engineering effort consists of completing analysis and design modifications that were not completed prior to deferral; updating the design basis documentation to current industry standards; and supporting construction, start up, and licensing of the plant. More specifically, the remaining engineering effort for Bellefonte 1 and Bellefonte 2 includes, but is not limited to, the following:

- Issuing detailed design modifications for certain mechanical and electrical systems to meet current requirements.
- Updating the main control room drawings into computer-aided design (CAD) electronic format.
- Reviewing the control room design and upgrading the simulator and plant computers.
- Reanalyzing piping and pipe supports.
- Resolving industry issues (e.g., fire protection, electrical equipment qualification, station blackout, site security, communications, motor-operated valves) that were either not completed prior to deferral in 1988 or have arisen since deferral.
- Developing fuel assembly and fuel cycle designs to facilitate the production of tritium.
- Supporting submittals of the Final Safety Analysis Report and completing previous NRC position papers.
- Supporting field change requests by the constructor.

Construction—Construction activities required to complete Bellefonte 1 and Bellefonte 2 include, but are not limited to, the following:

- Completing the application of protective coatings to structures, piping, and components, and the installation of piping insulation.
- Installing the Bellefonte 2 reactor coolant pump internals and motors. [Some (less than 10 percent) of Bellefonte 1 reactor coolant instrumentation and pipe supports would have to be installed.]
- Installing limited major piping and components in the balance of the plant for Bellefonte 2.
- Installing the steam piping for Bellefonte 2.
- Installing and energizing a limited amount of the electric power equipment within the plant. (The 161-kilovolt and 500-kilovolt offsite transmission lines are terminated in the switchyard, which is complete and energized.)
- Completing the Bellefonte 2 main control room. Substantial work would be required because the Bellefonte 1 main control room, although not complete, is functional and manned to monitor the ongoing preservation activities. The recommendations of the Control Room Design review would be factored into efforts to complete construction of both control rooms.
- Preparing the intake structure for operation by desilting the intake water pump.
- Constructing some new support buildings and installing additional equipment.

S.3.2.5 Environmental Consequences

For the five TVA reactors being considered for tritium production (Watts Bar 1, Sequoyah 1, Sequoyah 2, Bellefonte 1, and Bellefonte 2), impacts are presented for the bounding case (i.e., the maximum number of TPBARs that could be irradiated in a reactor). For those resources where impacts would be significantly different for a lesser number of TPBARs, explanation is provided. The impacts of utilizing more than one CLWR for tritium production can be determined by adding the impacts of each individual CLWR together as discussed in Section S.3.2.2. The impacts of not producing tritium at any of these five reactors (the No Action Alternative) are presented first, as a baseline against which to compare the impacts of producing tritium. The summary of the environmental consequences is presented in **Table S-2** at the end of this chapter.

S.3.2.5.1 No Action Alternative

Construction

Watts Bar 1, Sequoyah 1, and Sequoyah 2. Under the No Action Alternative, Watts Bar 1, Sequoyah 1, and Sequoyah 2 would continue to produce electricity and no construction impacts would occur.

Bellefonte 1 and Bellefonte 2. Under the No Action Alternative, Bellefonte 1 and 2 would remain in a deferred status, and no construction impacts would occur. TVA could also convert Bellefonte 1 and 2 to a fossil fuel plant as described in the *Final Environmental Impact Statement for the Bellefonte Conversion Project* (see Section S.1.6.2.4). Such conversion would be independent of this EIS and would not occur until after a decision were made regarding the role of Bellefonte 1 and 2 in tritium production.

Operation

Watts Bar 1, Sequoyah 1, and Sequoyah 2. Under the No Action Alternative, Watts Bar 1, and Sequoyah 1 and 2 would continue to produce electricity for the foreseeable future, and there would be no changes in the type and magnitude of environmental impacts that currently occur. In producing electricity, these reactor plants would continue to comply with all Federal, state, and local requirements. Impacts associated with the continued operation of Watts Bar 1, and Sequoyah 1 and 2 are described in Section S.3.2.5.2 below.

Under the No Action Alternative, water requirements at all three plants would continue to be met by existing water resources, with no additional impacts, and water quality would remain within regulatory limits. Air quality would also remain within regulatory limits. Worker employment should remain steady at each of the sites, with no major changes to the regional economic areas as a result of plant operation. Worker exposure to radiation should remain well within regulatory limits, with the average worker dose at approximately 90 to 100 mrem/yr. Radiation exposure of the public from normal operations would also remain well within regulatory limits for each of the reactor sites. At Watts Bar 1, the total dose to the population within 80 kilometers (50 miles) would be approximately 0.55 person-rem/yr. Statistically, this equates to one fatal cancer approximately every 3,570 years from the operation of Watts Bar 1. At Sequoyah 1 or Sequoyah 2, the total dose to the population within 80 kilometers (50 miles) would be approximately 1.6 person-rem/yr. Statistically, this equates to one fatal cancer approximately every 1,250 years from the operation of Sequoyah 1 or 2. Risks of accidents would remain unchanged.

Under the No Action Alternative, all categories of wastes would continue to be generated at each of the reactor plants and they would be managed in accordance with regulations. Low-level radioactive wastes would continue to be generated at a rate of approximately 40 (Watts Bar 1) to 389 (Sequoyah 1 or 2) m^3/yr and disposed of at the Barnwell disposal facility. For each of the reactors, spent fuel would also continue to be generated at a rate of approximately 80 fuel assemblies per year. Spent fuel would continue to be managed at each of the reactor plants in compliance with all regulatory requirements.

Bellefonte 1 and Bellefonte 2. Under the No Action Alternative, Bellefonte 1 and 2 would remain uncompleted nuclear reactors and there would not be any change on the impacts on the environment.

S.3.2.5.2 Proposed Action Impacts

Construction

Watts Bar 1, Sequoyah 1, and Sequoyah 2. Because this EIS assumes that long-term spent fuel storage would take place at each of the reactor plants, a dry cask spent fuel storage facility could eventually be required for Watts Bar 1, Sequoyah 1, or Sequoyah 2 to support tritium production. This could be the only construction necessary for tritium production. If such a facility were to be constructed, it would consist of three reinforced concrete slabs covering approximately 3.5 acres. Approximately 60-80 horizontal storage modules, each made of reinforced concrete, could be housed on the slabs. These horizontal storage modules would have a hollow internal cavity to accommodate a stainless steel cylindrical cask that would contain the spent nuclear fuel. Constructing such a facility would disturb approximately 5 acres and require approximately 50 construction workers. Premixed concrete would be used and impacts to air quality, water, and biotic resources are expected to be small. Appropriate NEPA documentation would be prepared prior to the construction of a dry cask spent fuel storage facility.

Bellefonte 1 and Bellefonte 2. All major structures (e.g., containment buildings, cooling towers, turbine buildings, support facilities) of Bellefonte 1 and 2 have been constructed. So construction activities would largely consist of internal modifications to the existing facilities. No additional land would be disturbed in completing construction and there would be no impacts on visual resources, biotic resources (including threatened and endangered species), geology and soils, and archaeological and historic resources. Because this EIS assumes that long-term spent fuel storage would take place at each of the reactor plants, a dry cask spent fuel storage facility would eventually be required at Bellefonte 1 and 2. The impacts of constructing such a spent fuel storage facility would be similar to those described above for Watts Bar 1, Sequoyah 1, or Sequoyah 2. Appropriate NEPA documentation would be prepared before to the construction.

Completing construction of Bellefonte 1 would have the greatest impact on socioeconomics, with construction activities taking place between 1999 and 2004. During the peak year of construction (2002), approximately 4,500 direct jobs could be created. As many as 4,500 secondary jobs (indirect jobs) would also be created. The total new jobs (9,000) would cause the regional economic area unemployment rate to decrease to approximately 4 percent, from the current rate of 7.9 percent. Public finance expenditures/revenues would increase by over 30 percent in Scottsboro and about 15 percent in Jackson County. Rental vacancies would decline to near zero, and demand for all types of housing would increase substantially. Rents and housing prices could increase at double-digit percentage levels.

If Bellefonte 2 were also selected for completion, construction activities for both units would be drawn out, taking place between 1999 and 2005. The peak year of construction would shift but the total number of direct and indirect jobs would be the same. The effects, therefore on unemployment, public finance, rents, and housing prices would be the same as for the construction completion of Bellefonte 1.

Operation

Health Effects Risk Factors Used in this EIS

Health impacts of radiation exposure, whether from sources external or internal to the body, are generally identified as "somatic" (i.e., affecting the exposed individual), or "genetic" (i.e., affecting descendants of the exposed individual). Radiation is more likely to produce somatic effects than genetic effects. Except for leukemia, which can have an induction period (time between exposure to carcinogen and cancer diagnosis) of as little as 2 to 7 years, most cancers have an induction period of more than 20 years.

For a uniform irradiation of the body, the incidence of cancer varies among organs and tissues; the thyroid and skin demonstrate a greater sensitivity than other organs. Such cancers, however, also produce relatively low mortality rates because they are relatively amenable to medical treatment. Because of the readily available data for cancer mortality rates, somatic effects leading to cancer fatalities rather than cancer incidence are presented in this EIS. The numbers of cancer fatalities can be used to compare the risks of various alternatives.

Risk factors are used to calculate the statistical expectance of the effects of exposing a population to radiation. For example, in a population of 100,000 people exposed only to natural background radiation (300 millirem per year), it is expected that about 15 latent cancer fatalities per year would be expected (100,000 persons x 0.3 rem per year x 0.0005 latent cancer fatalities per person-rem = 15 latent cancer fatalities per year).

The number of latent cancer fatalities corresponding to a single individual's exposure over a presumed 72-year lifetime to 0.3 rem per year is 0.011 (1 person x 0.3 rem per year x 72 years x 0.0005 latent cancer fatality per person-rem = 0.011 latent cancer fatality). Presented another way, this method estimates that approximately 1.1 percent of the population might die of cancers induced by background radiation.

The health consequences of exposure to radionuclides from normal operation and accidents are converted to estimates of cancer fatality risks using dose conversion factors recommended by the International Commission on Radiological Protection. For individuals, the estimated probability of a latent cancer fatality occurring is reported for the noninvolved worker, the maximally exposed individual, and an average individual in the general population. These categories are defined as follows:

Noninvolved Worker: *An individual 640 meters (0.4 mile) from the radioactive material release point.*

Maximally Exposed Offsite Individual: *A hypothetical individual who could potentially receive the maximum dose of radiation or hazardous chemicals.*

General Population: *Individuals within an 80-kilometer (50-mile) radius of the facility.*

Watts Bar 1, Sequoyah 1, and Sequoyah 2. In a tritium production mode, these operating reactors would continue to comply with all Federal, state, and local requirements. Tritium production would have little or no effect on land use, visual resources, water use and quality, air quality, archaeological and historic resources, biotic resources (including threatened and endangered species), and socioeconomics. It could, however, have some incremental impacts in the following areas: radiation exposure (worker and public), spent fuel generation, and low-level radioactive waste generation. Tritium production could also change the accident and transportation risks associated with these reactors. Each of these areas is discussed below.

Radiation Exposure Tritium production could increase average annual worker radiation exposure by approximately 4–6 millirem. The resultant dose would be well within regulatory limits. Radiation exposure to the public from normal operations could also increase, but would still remain well within regulatory limits at each of the reactor sites. At either Watts Bar 1, Sequoyah 1, or Sequoyah 2, the total dose to the population within 80 kilometers (50 miles) could increase by a maximum of 11 person-rem/yr. Statistically, this equates to one additional fatal cancer approximately every 200 years from operation of Watts Bar 1, Sequoyah 1, or Sequoyah 2.

Spent Fuel Generation Given irradiation of 3,400 TPBARs (the maximum number of TPBARs without changing the reactor's fuel cycle), additional spent fuel would be generated at Watts Bar 1, Sequoyah 1, or Sequoyah 2. In the average 18-month fuel cycle, spent fuel generation could increase from approximately 80 spent fuel assemblies to a maximum of 140, a 71 percent increase in spent fuel generation over the No Action Alternative. Because this EIS assumes that long-term spent fuel storage would take place at each of the reactor plants, a dry cask spent fuel storage facility would eventually be needed. Storing the additional spent fuel should have minor impacts. Radiation exposures would remain below regulatory limits for both workers and the public, and less than 4 cubic feet of low-level waste would be generated annually. The impacts of accidents associated with a dry cask spent fuel storage would be minor. As previously mentioned, appropriate NEPA documentation would be prepared before the construction of a dry cask spent fuel storage facility at Watts Bar 1, Sequoyah 1, or Sequoyah 2. If fewer than approximately 2,000 TPBARs were irradiated, there would be no change in the amount of spent fuel produced by the reactors.

Low-level Radioactive Waste Generation Compared to the No Action Alternative, tritium production at Watts Bar 1, Sequoyah 1, or Sequoyah 2 would generate approximately 0.43 additional m^3/yr of low-level radioactive waste. This would be a 0.1 (Sequoyah 1 or 2) to 1.0 (Watts Bar 1) percent increase in low-level radioactive waste generation over the No Action Alternative. Such an increase would amount to less than 1 percent of the low-level radioactive waste disposed of at the Barnwell disposal facility. The EIS also analyzes the impacts of this low-level radioactive waste disposal at the Savannah River Site. Disposing of 0.43 m^3/yr of low-level radioactive waste would amount to less than 1 percent of the low-level radioactive waste disposed of at the Savannah River Site and less than 1 percent of the landfill's capacity.

Accident Risks Tritium production could change the potential risks associated with accidents at Watts Bar 1, Sequoyah 1, or Sequoyah 2. These changes would be small. Potential impacts from accidents were determined using computer modeling. If a limiting design-basis accident occurred, tritium production at the 3,400 TPBAR level would increase the individual risk of a fatal cancer by 7.5×10^{-9} to an individual living within 80 kilometers (50 miles) of Watts Bar 1. Statistically, this equates to a risk to the individual of one fatal cancer approximately every 130 million years from tritium production. For an individual living within 80 kilometers (50 miles) of Sequoyah 1 or Sequoyah 2, there would be a 1.2×10^{-8} increased likelihood of a cancer fatality to an individual from a design-basis accident as a result of tritium production. Statistically, this equates to a risk to an individual of one additional fatal cancer approximately every 83 million years from tritium production. For a beyond-design-basis accident (an accident which has a probability of occurring approximately once in a million years or less), tritium production would result in small changes in the consequences of an accident. This is due to the fact that the potential consequences of such an accident would be dominated by radionuclides other than tritium.

Transportation

The DOE takes many precautions to ensure the safe transportation of both its radioactive and nonradioactive shipments. These precautions satisfy the U.S. Department of Transportation Regulations, NRC regulations, and DOE Orders. DOE would use Type A packages to transport materials with relatively low levels of radioactivity and Type B packages to transport materials with the highest levels of radioactivity. Type A packages are designed and tested to protect and retain their content under normal transportation conditions. They are tested to survive water spray, dropping during handling, compression by other packages, and penetration by falling objects. Type B packages are designed to protect and retain their contents in both normal and severe accident conditions. In addition, the U.S. Department of Transportation has stringent routing requirements for these shipments. These requirements include reducing the time in transit and the distance traveled, using interstate highways unless the state has designated a preferred alternative, and using beltways around cities where possible. The following are a few of the key safety measures the CLWR project will take to ensure safe shipment.

- *The fuel assemblies with the inserted TPBARs (or the TPBARs themselves) would be transported to the selected reactor(s) according to the fuel manufacturer's current operating practices. The nuclear containers used for fresh fuel shipment would be NRC certified Type A packages and due to security requirements would have an escort.*
- *The transportation of irradiated TPBARs entails very stringent safety measures established by the NRC, the U.S. Department of Transportation, and DOE. TPBARs would be transported from the reactors to the DOE's Savannah River Site in Type B packages that meet the NRC's stringent test requirements.*
- *Low-level radioactive waste would be transported in either certified Type A or Type B packages, depending on the level of the radioactivity of the contents.*

Spent Fuel Storage

The need for additional spent fuel storage is based on the assumption that 3,400 TPBARs would be irradiated in a reactor core for 18-month fuel cycles. However, if approximately 2,000 TPBARs or fewer were irradiated in each fuel cycle, no additional spent fuel would be generated.

The additional spent fuel generated from the tritium production over the duration of the program, would be accommodated at the site at an independent dry cask spent fuel storage installation (ISFSI). The EIS presents the environmental impacts of the construction, operation, and postulated accidents associated with a generic dry cask ISFSI at each of the sites.

The majority of operating ISFSIs are in the form of concrete casks. Concrete casks consist of either a vertical or horizontal concrete structure that houses a metal cask that confines the spent nuclear fuel. A horizontal storage module consists of a rectangular reinforced concrete block that has a hollow internal cavity to accommodate a stainless steel cylindrical cask that contains the spent nuclear fuel. The concrete block is 5.79 meters (19 feet) long, 2.96 meters (9.7 feet) wide, and 4.6 meters (15 feet) high.

The decay heat released from the stored spent fuel would be equal to the heat released to the atmosphere from two to six average cars. NRC regulations require that a minimum distance of 100 meters (328 feet) be maintained as a controlled area around the spent fuel casks. At 100 meters, the direct-scattered total dose rate to an individual was calculated to be in the range of 0.01 to 0.1 mrem/hr.

The environmental consequences of the construction and operation of a generic dry cask storage facility are minor.

Transportation Tritium production at either Watts Bar 1, Sequoyah 1, or 2 would necessitate additional transportation to and from the reactor plants. Most of the additional transportation would involve nonradiological materials. Impacts would be limited to toxic vehicle emissions and traffic fatalities. At each of these reactors, the transportation risks would be less than one fatality per year. Radiological materials transportation impacts would include routine and accidental doses of radioactivity. In all instances the risks associated with radiological materials transportation would be less than one fatality per 100,000 years.

Bellefonte 1 and Bellefonte 2. Because neither Bellefonte 1 or Bellefonte 2 are currently operating, this EIS assesses the impacts of completing construction, and operating these units for tritium production. Consequently, environmental impacts would occur in the following resources: visual resources, water use, biotic resources, socioeconomics, radiation exposure (worker and public), spent fuel generation, and low-level radioactive waste generation. Tritium production would also change the accident and transportation risks associated with these reactors.

During operation, Bellefonte 1 and 2 would produce vapor plumes from cooling towers that would be visible up to 10 miles away. These plumes could create an aesthetic impact on the towns of Pisgah, Hollywood, and Scottsboro, Alabama.

During operation, Bellefonte 1 and 2 would each use less than 0.5 percent of the river flow from Guntersville Reservoir and would not cause any adverse impacts on other users. Discharges from the plants would be treated and monitored before release and would comply with National Pollutant Discharge Elimination System permits. Impacts on water quality would be minimal, and no standards would be exceeded. Operation of either Bellefonte 1 or both Bellefonte 1 and 2 for tritium production would have some effects on ecological resources typical to the operation of a nuclear power plant regardless of tritium production. Impacts on ecological resources from the operation of Bellefonte 1 or both Bellefonte 1 and 2 would result from radioactive and nonradioactive emissions of air pollutants to the atmosphere; thermal, chemical and radioactive effluent releases to surface waters; increases in human activity; and increases in noise levels. These impacts would be small considering that the units would operate in compliance with all Federal, state, and local requirements specifically promulgated to protect environmental resources. The estimated radiological doses to terrestrial and aquatic organisms are well below levels that could have any impact on plants or terrestrial and aquatic animals at the site. Other possible environmental impacts on the aquatic ecosystem of Guntersville Reservoir due to operation of the Bellefonte units would include fish losses at the cooling water intake screens, almost total loss of unscreened entrained organisms, and effects of thermal and chemical discharges. The effects of both thermal and chemical discharges would be small, as these discharges should comply with National Pollutant Discharge Elimination System limitations.

<u>Socioeconomics</u> During operations, approximately 800 direct jobs would be created at Bellefonte 1, along with approximately an equal number of indirect jobs. The total new jobs (approximately 1,600) would cause the regional economic area unemployment rate to decrease to approximately 5.9 percent. Public finance expenditures/revenues would decline from the levels during construction but would remain 10 to 15 percent higher than they would be otherwise at Scottsboro and 5 to 10 percent higher in Jackson county. Housing prices would decline and could fall below the precompletion prices, depending on how much new construction of permanent housing took place during the completion period and how many construction workers chose to remain in the area once construction was completed. If Bellefonte 2 were also completed, a total of approximately 1,000 direct jobs would be created, along with approximately 1,000 indirect jobs.

<u>Radiation Exposure</u> Reactor operation to produce tritium would cause worker radiation exposure to increase from 0 to approximately 110 mrem/yr. This resultant dose would be well within regulatory limits of 5,000 mrem/yr. Radiation exposure to the maximally exposed individual from normal operations would increase from 0 to 0.32 mrem. The total dose to the population within 80 kilometers (50 miles) would increase from approximately 0 to approximately 6.5 person-rem/yr for Bellefonte 1. If Bellefonte 2 were also operating, this dose would be

approximately 13 person-rem. Statistically, this equates to one fatal cancer approximately every 154 years from the operation of Bellefonte 1 and 2.

Spent Fuel Generation Given production of the maximum amount of tritium in the average 18-month fuel cycle, spent fuel generation would increase from 0 up to a maximum of 141 spent fuel assemblies (e.g., 69 fuel assemblies over the normal refueling size). Because this EIS assumes that long-term spent fuel storage would take place at each of the reactor plants, a dry cask spent fuel storage facility could eventually be needed to store the additional assemblies. The impacts of storing the spent fuel in a dry cask spent fuel storage facility are described above for the existing operating reactor plants. As previously mentioned, appropriate NEPA documentation would be prepared before the construction of a dry cask spent fuel storage facility.

Low-Level Radioactive Waste Generation Compared to the No Action Alternative, reactor operation to produce tritium Bellefonte 1 or Bellefonte 2 would generate approximately 40 m^3 (80 m^3 for both units) of low-level radioactive waste. This quantity would be a small fraction of the landfill capacity at the Barnwell disposal facility or the Savannah River Site's low-level radioactive waste disposal facility.

Accident Risks Compared to the No Action Alternative, there is a significant change in potential risks from tritium production. Risks due to accidents would increase during the construction and operation of Bellefonte 1 and 2, and during the operation of these units for production of tritium. Similar to Watts Bar 1, Sequoyah 1, and Sequoyah 2, the potential impacts from the accidents at Bellefonte 1 or 2 were determined using computer modeling. If a limiting design-basis accident occurred, tritium production would increase the individual risk of a fatal cancer by 4.1×10^{-9} additional fatal cancers to an individual living within 80 kilometers (50 miles) of the units. Statistically, this means that for an individual one fatal cancer would occur approximately every 244 million years from tritium production at Bellefonte. If a beyond-design-basis accident occurred (an accident that has a probability of occurring approximately once in a million years or less), tritium production would increase the risk of a fatal cancer by 0.00010 additional fatal cancers to an individual living within 80 kilometers (50 miles) of the Bellefonte Nuclear Plant.

Accident Scenarios

The accident analysis assessment considers a spectrum of potential accident scenarios. The range of accidents considered includes reactor design-basis accidents, nonreactor design-basis accidents, TPBAR-handling accidents, transportation cask-handling accidents, and beyond-design-basis accidents (i.e., severe reactor accidents).

***Reactor Design-Basis Accident**: A reactor design-basis accident is designated a Condition IV occurrence. Condition IV occurrences are faults that are not expected to take place, but are postulated because they have the potential to release significant amounts of radioactive material. The postulated reactor design basis accident for this EIS is a large-break loss-of-coolant accident.*

***Nonreactor Design-Basis Accident**: A nonreactor design- basis accident is designated a Condition III occurrence. The consequences of a Condition III occurrence would be less severe than those of a Condition IV occurrence. The release of radioactivity would not be sufficient to interrupt or restrict public use of those areas beyond the exclusion area. The postulated nonreactor design-basis accident is an unexpected, uncontrolled release of the gases contained in a single gas decay tank due to the failure of the tank or associated piping.*

***TPBAR–Handling Accident**: The postulated TPBAR-handling accident scenario postulated that a TPBAR assembly containing 24 TPBARs was dropped when removing the assembly from an irradiated fuel assembly during the TPBAR consolidation process. The evaluation postulated that all TPBARs would be unprotected and would breach when they impacted the spent fuel pool floor.*

***Transportation Cask–Handling Accident**: Scenarios include loading a truck cask under water in the spent fuel pool cask loading pit with a single TPBAR consolidation container containing a maximum of 289 TPBARs, and loading a rail cask under water in the spent fuel pool cask loading pit with 3 to 12 TPBAR consolidation containers.*

***Beyond-Design-Basis Accident**: The beyond-design-basis accident is limited to severe reactor accidents. Severe reactor accidents are less likely than reactor design basis accidents; however, the consequences of these accidents could be more serious if no mitigative actions were taken. In the reactor design basis accidents, the mitigative systems are assumed to be available. The beyond-design- basis accidents analyzed are reactor core disruptive accidents with containment failure or bypass.*

Transportation Tritium production at either Bellefonte 1 or 2 would necessitate transportation of workers, construction material, and radiological and nonradiological material to and from the reactor plants. The majority of the additional transportation would involve nonradiological materials. Impacts of this transportation are limited to toxic vehicle emissions and traffic fatalities. For Bellefonte 1 or 2, the transportation risks would be significantly lower than one fatality per year. Radiological materials transportation impacts would occur as a result of routine and accidental doses. In all instances the risks associated with radiological materials transportation would be less than one fatality per 100,000 years.

S.3.2.6 Preferred Alternative

The Council on Environmental Quality regulations require that an agency identify its Preferred Alternative(s), if one or more exist, in the Draft EIS (40 CFR 1502.14e). The Preferred Alternative is defined as the alternative that the agency believes would fulfill its statutory mission, giving consideration to environmental, economic, technical, and other factors. Consequently, to identify a Preferred Alternative, DOE is developing information on potential environmental impacts, costs, technical risks, and schedule risks for the alternative under consideration.

This EIS provides information on the environmental impacts. Cost schedule, and technical analyses are also being prepared, and will be considered in the identification of any Preferred Alternative. A Preferred Alternative(s) has not yet been identified. In accordance with the Council on Environmental Quality Regulations, the CLWR Final EIS will identify the Preferred Alternative.

Table S-2 Summary of Environmental Consequences of CLWR Reactor Alternatives

Resource/Material Categories	*Watts Bar 1*	*Sequoyah 1 or Sequoyah 2*	*Bellefonte 1 or Bellefonte 2*
		No Action	
All Resource/Material Categories	No construction or operational changes. Reactor unit continues to produce electricity. No change in environmental impacts.	No construction or operational changes. Reactor units continue to produce electricity. No change in environmental impacts.	No construction or operational changes. Reactor units remain uncompleted. No change in environmental impacts.
		Annual Tritium Production	
Land Resources Land Use	*Construction:* Potential land disturbance - 5.3 acres for dry cask independent spent fuel storage installation (ISFSI) if constructed. *Operation:* Potential permanent land requirement - 3.1 acres for ISFSI if constructed.	*Construction:* Potential land disturbance - 5.47 acres for ISFSI if constructed. *Operation:* Potential permanent land requirement - 3.2 acres for ISFSI if constructed.	*Construction:* Potential land disturbance - 4.9 acres for ISFSI if constructed and additional land for support buildings. *Operation:* Potential permanent land requirement - 3.4 acres for ISFSI if constructed and additional land for support buildings.
Visual Resources	*Construction and Operation:* No additional impact to visual resources.	*Construction and Operation:* No additional impact to visual resources.	*Construction:* No additional impact to visual resources. *Operation:* Vapor plumes would be visible up to 10 miles away.
Noise	*Construction:* No change from current levels. Small impacts if ISFSI is constructed. *Operation:* No change from current levels.	*Construction:* No change from current levels. Small impacts if ISFSI is constructed. *Operation:* No change from current levels.	*Construction:* No change from current levels. Small impacts if ISFSI is constructed. *Operation:* Increase in noise emissions from the plant from 50 dB(A) to 51 dB(A) at nearest receptor. Increase in traffic noise on site access roads from 50 dB(A) to 57 dB(A) due to commuter traffic and truck deliveries.
Air Quality Nonradioactive Emissions	*Construction:* No change from current air quality conditions. Small impacts if ISFSI is constructed. *Operation:* No change from current air quality conditions.	*Construction:* No change from current air quality conditions. Small impacts if ISFSI is constructed. *Operation:* No change from current air quality conditions.	*Construction:* Potential temporary dust emissions during construction. Small impacts if ISFSI is constructed. *Operation:* The increase in nonradioactive emissions would be well within established standards.

Resource/Material Categories	*Watts Bar 1*	*Sequoyah 1 or Sequoyah 2*	*Bellefonte 1 or Bellefonte 2*
Annual Tritium Production (Continued)			
Air Quality Radioactive Emissions	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive emissions of tritium would be 1,650 curies; given 3,400 TPBARs, 1,890 curies (assuming 2 failed TPBARs).	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive emissions of tritium would be 1,650 curies; given 3,400 TPBARs, 1,890 curies (assuming 2 failed TPBARs).	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive emissions of tritium would be 1,656 curies; given 3,400 TPBARs, 1,896 curies, of which 5.6 curies would be from normal operations without tritium production. The release of other radioactive emissions would be 283 curies.
Water Resources Surface Water	*Construction:* No change to current surface water requirements, discharge, or water quality conditions. Small impacts if ISFSI is constructed. *Operation:* No change to current surface water requirements, discharge, or water quality conditions.	*Construction:* No change to current surface water requirements, discharge, or water quality conditions. Small impacts if ISFSI is constructed. *Operation:* No change to current surface water requirements, discharge, or water quality conditions.	*Construction:* Potential for increased storm water runoff. Small amount of surface water requirements. Small impacts if ISFSI is constructed. *Operation:* Increased surface water requirements and discharge. Water usage less than 1% of Tennessee River flow per year. All water quality parameters within limits.
Radioactive Effluent	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive tritium effluents would be 14,850 curies; 3,400 TPBARs, 17,010 curies (assuming 2 failed TPBARs).	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive tritium effluents would be 14,850 curies; and with 3,400 TPBARs, 17,010 curies (assuming 2 failed TPBARs).	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive tritium effluents would be 15,489 curies; 3,400 TPBARs, 17,649 curies (assuming 2 failed TPBARs) of which 639 curies would be from normal operation without tritium production. The release of other radioactive effluents would be 1.32 curies.

Resource/Material Categories	*Watts Bar 1*	*Sequoyah 1 or Sequoyah 2*	*Bellefonte 1 or Bellefonte 2*
Annual Tritium Production (Continued)			
Groundwater	*Construction:* No groundwater requirements or additional impacts to groundwater quality conditions. *Operation:* No groundwater requirements or additional impacts to groundwater quality conditions.	*Construction:* No groundwater requirements or additional impacts to groundwater quality conditions. *Operation:* No groundwater requirements or additional impacts to groundwater quality conditions.	*Construction:* Groundwater would not be used during construction. *Operation:* No groundwater requirements or additional impacts to groundwater quality conditions.
Ecological Resources	*Construction*: No additional impacts on ecological resources. Small impacts if ISFSI is constructed. *Operation*: Small or no impacts to ecological resources from additional tritium releases.	*Construction*: No additional impacts on ecological resources. Small impacts if ISFSI is constructed. *Operation*: Small or no impacts to ecological resources from additional tritium release.	*Construction:* Potential impacts to ecological resources due to the small amount of land disturbance. Small impacts if ISFSI is constructed. *Operation:* Additional impacts on ecological resources including fish impingement and entrainment of aquatic biota during normal plant operation. Small impacts to ecological resources from tritium and other radioactive releases during normal plant operations.
Socioeconomics	*Construction:* No measurable impact. *Operation:* <1% impact on regional economy.	*Construction:* No measurable impact. *Operation:* <1% impact on regional economy.	*Construction:* 4,500 peak new direct jobs due to plant completion. Short-term increased costs and traffic for local jurisdictions. *Operation:* 800 to 1,000 workers per day. Increase in payment-in-lieu of taxes to state and local jurisdictions (approximately $5.5 to $8 million annually), decrease in the unemployment rate (from 7.9% to approximately 5.9%), and minor impacts to school resources.

Resource/Material Categories	*Watts Bar 1*	*Sequoyah 1 or Sequoyah 2*	*Bellefonte 1 or Bellefonte 2*
Annual Tritium Production (Continued)			
Public and Occupational Health and Safety Normal Operation	Annual dose for 1,000 TPBARs: *Workers:* Average dose increase by 5.4 mrem. *MEI:* Dose increase by 0.22 mrem *50-mile population:* Dose increase by 5.5 person-rem.	Annual dose for 1,000 TPBARs: *Workers:* Average dose increase by 3.9 mrem. *MEI:* Dose increase by 0.28 mrem *50-mile population:* Dose increase by 9.4 person-rem.	Annual dose for 1,000 TPBARs: *Workers:* Average dose increase by 109 mrem, of which 104 mrem would be from normal operations without tritium production. *MEI:* Dose increase by 0.31 mrem, of which 0.26 mrem would be from normal operations without tritium production. *50-mile population:* Dose increase by 5.8 person-rem, of which 1.4 person-rem would be from normal operations without tritium production.
	Annual dose for 3,400 TPBARs: *Workers:* Average dose increase by 6.2 mrem. *MEI:* Dose increase by 0.27 mrem *50-mile population:* Dose increase by 6.4 person-rem.	Annual dose for 3,400 TPBARs: *Workers:* Average dose increase by 4.6 mrem. *MEI:* Dose increase by 0.32 mrem *50-mile population:* Dose increase by 10.5 person-rem.	Annual dose for 3,400 TPBARs: *Workers:* Average dose increase by 110 mrem, of which 104 mrem would be from normal operations without tritium production. *MEI:* Dose increase by 0.32 mrem *50-mile population:* Dose increase by 6.5 person-rem.
Design-Basis Accident Risks	Increased likelihood of a cancer fatality per year due to tritium production. For 1,000 TPBARs: *MEI:* 5.5×10^{-7} (1 fatality in 1.8 million years). *Average individual in population:* 6.5×10^{-9} (1 fatality in 150 million years). *Exposed population:* 0.0012 (1 fatality in 833 years). *Noninvolved worker:* 6.8×10^{-9} (1 fatality in 150 million years).	Increased likelihood of a cancer fatality per year due to tritium production. For 1,000 TPBARs: *MEI :* 1.3×10^{-7} (1 fatality in 7.7 million years). *Average individual in population:* 1.0×10^{-8} (1 fatality in 100 million years). *Exposed population:* 0.0025 (1 fatality in 400 years). *Noninvolved worker:* 2.1×10^{-9} (1 fatality in 480 million years).	Increased likelihood of a cancer fatality per year due to tritium production. For 1,000 TPBARs: *MEI:* 3.6×10^{-7} (1 fatality in 2.8 million years). *Average individual in population:* 3.6×10^{-9} (1 fatality in 280 million years). *Exposed population:* 0.00097 (1 fatality in 1,031 years). *Noninvolved worker:* 2.0×10^{-11} (1 fatality in 50 billion years).

Resource/Material Categories	*Watts Bar 1*	*Sequoyah 1 or Sequoyah 2*	*Bellefonte 1 or Bellefonte 2*
Annual Tritium Production (Continued)			
	For 3,400 TPBARs: *MEI:* 6.0×10^{-7} (1 fatality in 1.7 million years). *Average individual in population:* 7.5×10^{-9} (1 fatality in 130 million years). *Exposed population:* 0.0014 (1 fatality in 714 years). *Noninvolved worker:* 8.0×10^{-9} (1 fatality in 130 million years).	For 3,400 TPBARs: *MEI :* 1.5×10^{-7} (1 fatality in 6.7 million years). *Average individual in population:* 1.2×10^{-8} (1 fatality in 83 million years). *Exposed population:* 0.0030 (1 fatality in 333 years). *Noninvolved worker:* 2.5×10^{-9} (1 fatality in 400 million years).	For 3,400 TPBARs: *MEI:* 3.7×10^{-7} (1 fatality in 2.7 million years). *Average individual in population:* 4.1×10^{-9} (1 fatality in 240 million years). *Exposed population:* 0.0011 (1 fatality in 909 years). *Noninvolved worker:* 2.4×10^{-11} (1 fatality in 42 billion years).
Waste Management	*Construction:* Potential non-hazardous waste if ISFSI is constructed. *Operation:* Low-level radioactive waste increase by approximately 0.43 m^3 per year. Other waste types would be unaffected by tritium production.	*Construction:* Potential non-hazardous waste if ISFSI is constructed. *Operation:* Low-level radioactive waste increase by approximately 0.43 m^3 per unit per year. Other waste types are unaffected by tritium production.	*Construction:* Minor amounts of non-hazardous construction material waste generated during the completion of the plant. Potential non-hazardous waste if ISFSI is constructed. *Operation:* Low-level radioactive waste increase by approximately 41 m^3 per unit per year, of which 40 m^3 would be from normal operations without tritium production.
Spent Nuclear Fuel Management	*Operation:* No increase if less than 2,000 TPBARs are irradiated. If 3,400 TPBARs are irradiated, the amount of spent fuel generated would increase, by approximately 60 fuel assemblies per fuel cycle.	*Operation:* No increase if less than 2,000 TPBARs are irradiated. If 3,400 TPBARs are irradiated, the amount of spent fuel generated would increase, by approximately 60 fuel assemblies per fuel cycle.	*Operation:* The amount of spent fuel would increase from zero to approximately 72 spent fuel assemblies for less than 2,000 TPBARs. For 3,400 TPBARs, the amount of spent fuel generated would increase from zero to approximately 140 spent fuel assemblies per fuel cycle, of which 72 would be from normal operations without tritium production.
Transportation	The risk associated with radiological materials transportation would be less than one fatality per 100,000 years.	The risk associated with radiological materials transportation would be less than one fatality per 100,000 years.	The risk associated with radiological materials transportation would be less than one fatality per 100,000 years. Increased traffic volumes on local roads during construction and operations.
Fuel Fabrication	Not applicable for the reactor site.	Not applicable for the reactor site.	Not applicable for the reactor site.

Resource/Material Categories	*Watts Bar 1*	*Sequoyah 1 or Sequoyah 2*	*Bellefonte 1 or Bellefonte 2*
	Annual Tritium Production (Continued)		
Decontamination and Decommissioning	Not applicable	Not applicable	Yes. For a generic discussion on impacts from decontamination and decommissioning see Section 5.2.5.
License Renewal	Yes. For a generic discussion on impacts from licensing renewal see Section 5.2.4.	Yes. For a generic discussion on impacts from licensing renewal see Section 5.2.4.	No

MEI = Maximally Exposed Offsite Individual
ISFSI = Independent Spent Fuel Storage Installation

AVAILABILITY OF THE DRAFT CLWR EIS

Copies of the Draft CLWR EIS may be obtained by calling DOE's Office of Defense Programs at 1-800-332-0801.

General questions concerning the NEPA process, under which EISs are prepared, may be addressed to:

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ACRONYMS AND ABBREVIATIONS

ALARA	As low as is reasonably achievable
Bellefonte 1	Bellefonte Nuclear Plant, Unit 1
Bellefonte 2	Bellefonte Nuclear Plant, Unit 2
CFR	Code of Federal Registrations
CLWR	Commercial light water reactor
DOE	U.S. Department of Energy
EIS	Environmental impact statement
EPA	U.S. Environmental Protection Agency
ISFSI	Independent spent fuel storage installation
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration
PCBs	Polychlorinated byphenyls
RCRA	Resource Conservation and Recovery Act
Sequoyah 1	Sequoyah Nuclear Plant, Unit 1
Sequoyah 2	Sequoyah Nuclear Plant, Unit 2
Superfund	Comprehensive Environmental Response, Compensation, and Liability Act
TPBAR	Tritium-producing burnable absorber rod
TVA	Tennessee Valley Authority
Watts Bar 1	Watts Bar Nuclear Plant, Unit 1
Watts Bar 2	Watts Bar Nuclear Plant, Unit 2

1. INTRODUCTION

Chapter 1 provides an overview of the U.S. Department of Energy's (DOE's) Commercial Light Water Reactor (CLWR) proposal. This chapter discusses the scope and development of the *Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (CLWR EIS), the CLWR procurement process, and the CLWR alternatives. Chapter 1 also includes background information on nuclear weapons; background information on the Tennessee Valley Authority, the operator of candidate CLWRs; the role of tritium in the weapons; DOE's compliance with the National Environmental Policy Act for the CLWR program; and the scoping process used to obtain public input on the issues that are addressed in this EIS. The chapter concludes with a section on the organization of the document and the public scoping process.

1.1 OVERVIEW

1.1.1 General

The U.S. Department of Energy (DOE) is responsible for providing the nation with nuclear weapons and ensuring those weapons remain safe and reliable. Tritium, a radioactive isotope of hydrogen, is an essential component of every weapon in the current and projected U.S. nuclear weapons stockpile. Unlike other nuclear materials used in nuclear weapons tritium, decays rapidly— at a rate of 5.5 percent per year. Accordingly, as long as the nation relies on a nuclear deterrent, the tritium in each nuclear weapon must be replenished periodically.

At present, the U.S. nuclear weapons complex does not have the capability to produce the amounts of tritium that will be required to support the Nation's current and future stockpile. Pursuant to the National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. 4321 *et seq*.) and the DOE regulations implementing NEPA (10 CFR 1021), this *Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (CLWR EIS) analyzes the potential consequences to the environment associated with the production of tritium using one or more CLWRs. In the Record of Decision for this CLWR EIS, DOE anticipates selecting one or more reactors for tritium production.

Concurrent with the preparation of this EIS, DOE evaluated the feasibility of various CLWR alternatives through its standard procurement process (see Section 1.1.4). This EIS evaluates the environmental impacts associated with tritium production for all Tennessee Valley Authority (TVA) reactor plants that were offered by TVA during the procurement process (see Section 1.2 for a list of these reactors). DOE is considering only the purchase of irradiation services, not the purchase of a reactor.

1.1.2 Proposed Action and Scope

The CLWR EIS evaluates the potential direct, indirect, and cumulative environmental impacts associated with producing tritium in one or more CLWRs for a 40-year period. In addition, this EIS evaluates the environmental impacts of the No Action Alternative. Under the No Action Alternative, the stockpile requirements for tritium would have to be met by the construction and operation of an accelerator at DOE's Savannah River Site in South Carolina (see Section 1.5.2.1). For the purpose of this EIS a No Action Alternative (i.e., no tritium production would occur at that CLWR) has been evaluated for each candidate CLWR.

DOE proposes to obtain irradiation services from one or more CLWRs to provide tritium in sufficient quantities to support the Nation's nuclear weapons stockpile requirements for at least the next 40 years. The proposed action includes: the manufacture of tritium-producing burnable absorber rods (TPBARs) at a commercial facility; irradiation of the TPBARs at one or more of five operating or partially constructed TVA nuclear reactors; the possible completion of TVA's nuclear reactors; transportation of nonirradiated and irradiated materials; and management of spent nuclear fuel and low-level radioactive waste.

More specifically, as depicted in **Figure 1–1**, this EIS analyzes the potential environmental impacts associated with the proposed action: (1) fabricating TPBARs; (2) transporting nonirradiated TPBARs from the fabrication facility to the reactor sites; (3) irradiating TPBARs in the reactors; and, (4) transporting irradiated TPBARs from the reactors to the proposed Tritium Extraction Facility at the Savannah River Site. This EIS further analyzes the potential environmental impacts associated with the transportation and management of the low-level radioactive waste generated from CLWR tritium production.

1.1.3 Development of the CLWR EIS

The CLWR EIS is a tiered document which follows the December 1995 Record of Decision (60 FR 63878) for the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (DOE 1995b). In that Programmatic EIS, DOE considered a range of reasonable alternatives for obtaining the required quantities of tritium. In the December 1995 Record of Decision, DOE decided to pursue a dual-track approach on the two most promising tritium-supply alternatives: (1) to initiate purchase of an existing commercial reactor (operating or partially complete) or irradiation services with an option to purchase the reactor for conversion to a defense facility; and (2) to design, build, and test critical components of an accelerator system for tritium production (the Savannah River Site was selected as the location for an accelerator, should one be built).

DOE will select one of these approaches by the end of 1998 to serve as the primary source of tritium. The other alternative, if feasible, would continue to be developed as a backup tritium source. Production of tritium in an accelerator is analyzed in the *Draft Environmental Impact Statement, Accelerator Production of Tritium at the Savannah River Site,* DOE/EIS-0270D (DOE 1997e) (see Section 1.5.2).

1.1.4 The CLWR Procurement Process

The production of tritium in a CLWR would require a contractual agreement between DOE and the owner/operator of the CLWR. Accordingly, on June 3, 1997, DOE issued, in final form, a Request for Proposals from owners/operators for irradiation services or sale of a CLWR (DOE 1997a). In September 1997, DOE received proposals for producing tritium using operating or partially completed reactors. The proposals for the Watts Bar and Bellefonte Nuclear Plants received from the TVA were the only proposals determined to be responsive to the requirements of the procurement request. Under Federal Procurement Law, a proposal is "responsive" if it meets the criteria set forth in the agency's Request for Proposals. In addition to the responsive bids discussed in this Draft EIS, DOE received one non-responsive bid. That bid did not offer to produce tritium. TVA offered Watts Bar Nuclear Plant, Unit 1 (Watts Bar 1) and Bellefonte Nuclear Plant, Unit 1 (Bellefonte 1). Since Bellefonte 1 was a partially completed unit, in the event that it could not be completed and licensed in time to support DOE's requirements for tritium production, TVA, through the procurement process, offered to make Sequoyah Nuclear Plant, Unit 1 and Unit 2 (Sequoyah 1 and Sequoyah 2) available to meet the need for tritium. In addition, Bellefonte Nuclear Plant, Unit 2 (Bellefonte 2) was considered as a reasonable alternative. These reasonable reactor alternatives are identified in Section 1.2. A description of each of these reactor facilities is presented in Section 3.2.5 of this EIS.

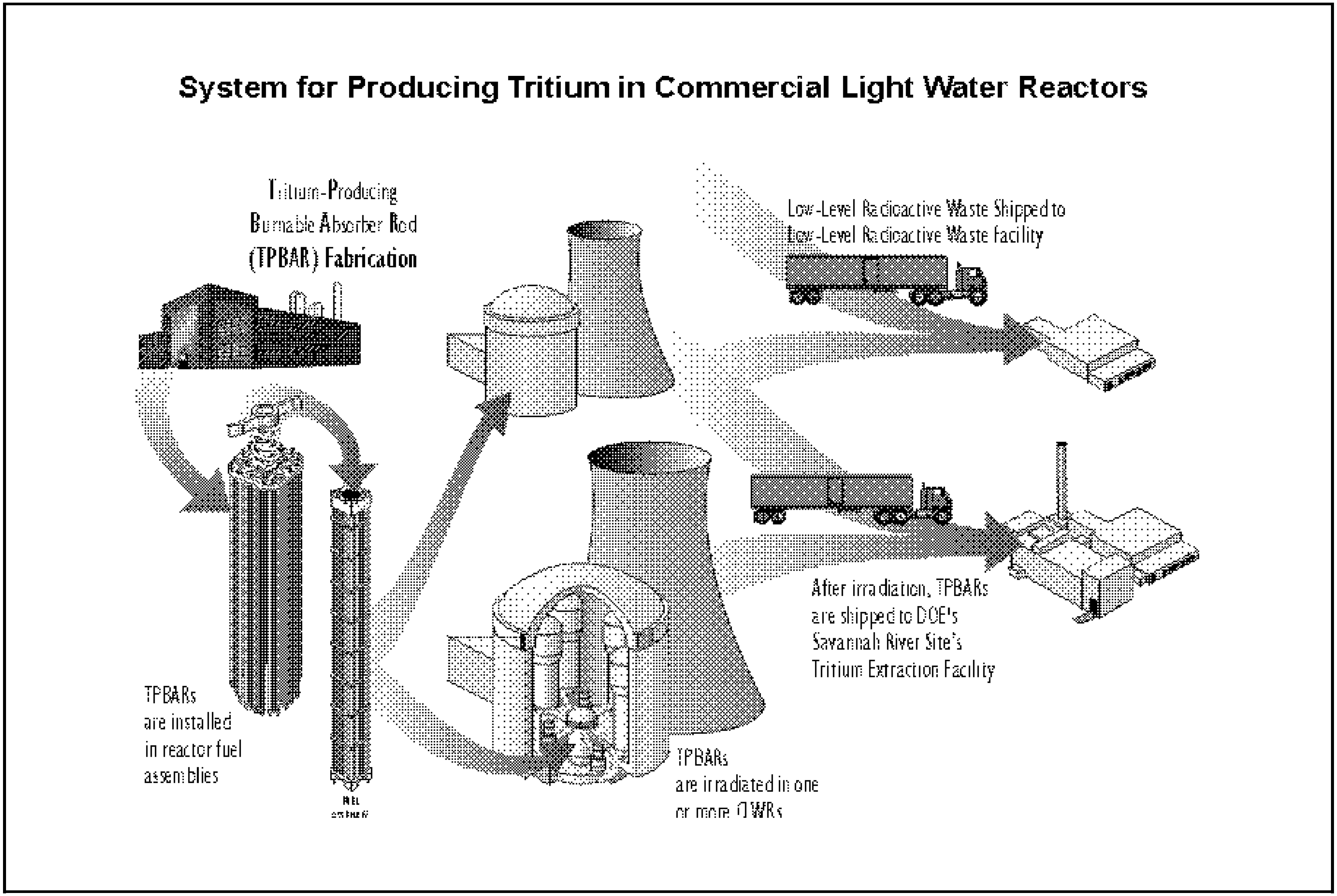


Figure 1–1 Schematic of Process for Producing Tritium in CLWRs

DOE may enter into an interagency agreement with the TVA, contingent on completion of the NEPA process, for production of the tritium required to support the nuclear weapons stockpile. Only those actions that are determined to not be irreversible or irretrievable would be permitted prior to the completion of the NEPA process. However, before completion of the CLWR EIS and its associated Record of Decision, DOE and TVA have taken and will continue to take appropriate actions (e.g., studies, analyses) related to the potential submission of licensing documents to the U.S. Nuclear Regulatory Commission (NRC). The NRC must issue regulatory approval for the use of TPBARs in licensed reactors.

1.2 COMMERCIAL LIGHT WATER REACTOR FACILITIES ANALYZED IN THIS CLWR EIS

This EIS evaluates the environmental impacts associated with producing tritium at one or more of the following reactor facilities:

- Watts Bar Nuclear Plant, Unit 1 (Watts Bar 1), Spring City, Tennessee (operating)
- Sequoyah Nuclear Plant, Unit 1 (Sequoyah 1), Soddy Daisy, Tennessee (operating)
- Sequoyah Nuclear Plant, Unit 2 (Sequoyah 2), Soddy Daisy, Tennessee (operating)
- Bellefonte Nuclear Plant, Unit 1 (Bellefonte 1), Hollywood, Alabama (partially complete)
- Bellefonte Nuclear Plant, Unit 2 (Bellefonte 2), Hollywood, Alabama (partially complete)

These reactors, the locations of which are shown in **Figure 1–2**, are owned by the U.S. Government and operated by TVA. Because tritium production could occur in one or more of these reactor facilities, this EIS evaluates each reactor for the maximum number of TPBARs that could be irradiated in the reactor. This bounds potential environmental impacts associated with any of the reactor facilities. This EIS also qualitatively evaluates the irradiation a lesser number of TPBARs and a TPBAR design with higher tritium production and shorter refueling cycles (see Section 5.2.9).

In accordance with the Council on Environmental Quality regulations, this EIS also evaluates the No Action Alternative. Under the No Action Alternative, DOE would not produce tritium in a CLWR or construct a Tritium Extraction Facility at the Savannah River Site. Consistent with the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* Record of Decision (60 FR 63878), the stockpile demands for tritium would have to be met by construction and operation of an accelerator at the Savannah River Site (see Section 1.5.2.1).

1.3 BACKGROUND

1.3.1 Defense Programs Mission

Since the inception of the nuclear weapons program in the 1940s, DOE and its predecessor agencies have been responsible for designing, manufacturing, maintaining, and retiring the nuclear weapons in the Nation's stockpile. In response to the end of the Cold War and changes in the world political regime, the emphasis of the United States' nuclear weapons program has shifted dramatically over the past few years from producing weapons to dismantling weapons. Accordingly, the nuclear weapons stockpile is being greatly reduced, the United States is no longer producing new-design nuclear weapons, and DOE has closed or consolidated many former weapons production facilities.

Additionally, in 1991 President Bush declared a moratorium on underground nuclear testing, and in 1995 President Clinton decided to pursue a zero-yield Comprehensive Test Ban Treaty. Despite these significant changes, DOE's responsibilities for the nuclear weapons stockpile continue, and the President and Congress have directed DOE to continue to maintain the safety and reliability of the nuclear weapons stockpile, and to provide the tritium necessary to satisfy national security requirements. As explained in Chapter 2, the United States will need a new tritium production source by as early as 2005.

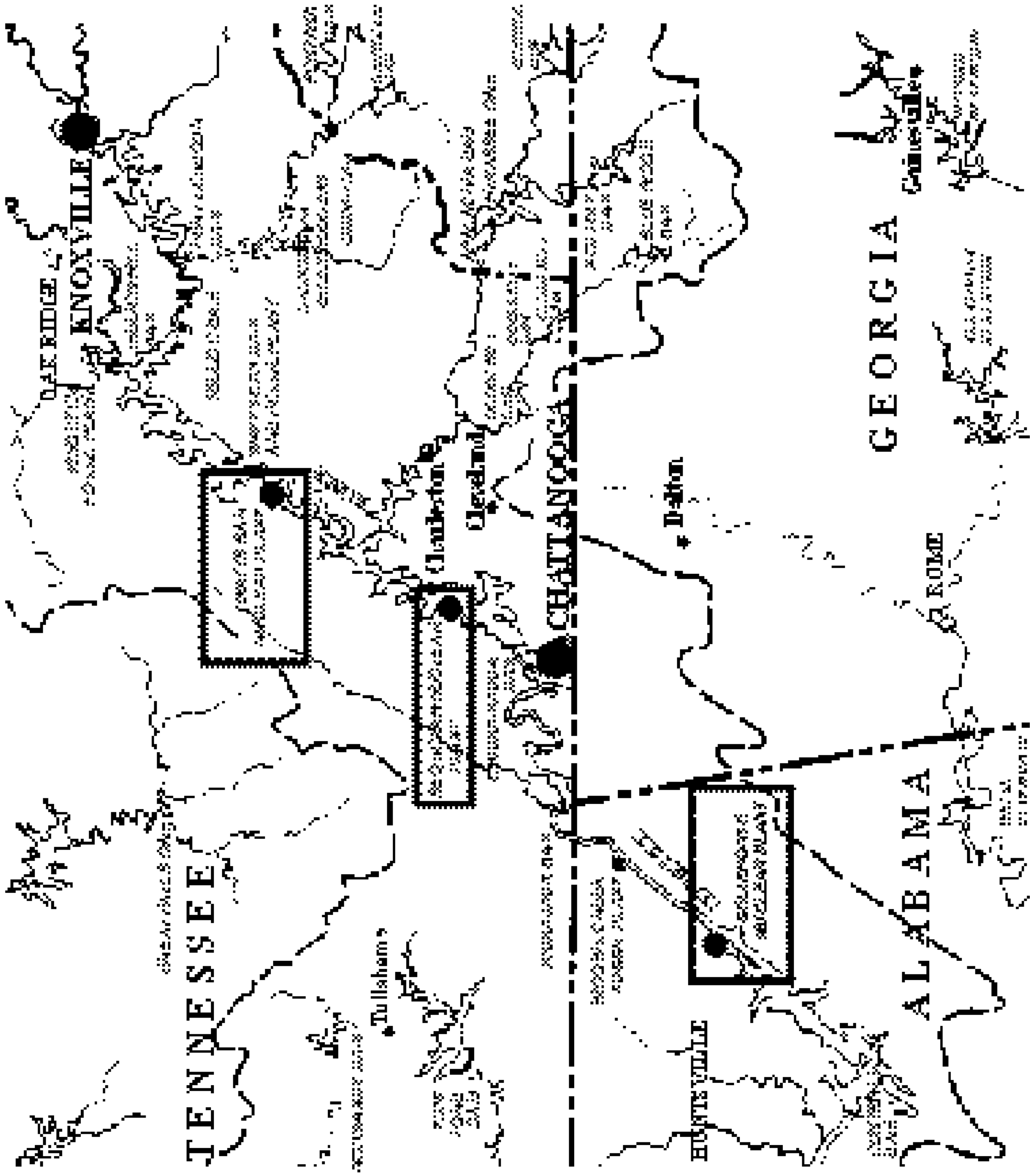


Figure 1–2 Candidate CLWRs for Tritium Production

The size of the Nation's nuclear weapons stockpile is determined by the President through a classified process. The Secretaries of Defense and Energy, in coordination with the Nuclear Weapons Council, jointly sign and submit the Nuclear Weapons Stockpile Memorandum. The Nuclear Weapons Stockpile Memorandum transmits the Nuclear Weapons Stockpile Plan to the President for final approval. **Figure 1–3** depicts this process. The Nuclear Weapons Stockpile Plan covers an 11-year period, specifies the types and quantities of weapons required, and sets limits on the size and nature of stockpile changes that can be made without additional approval from the President. As such, the Nuclear Weapons Stockpile Plan is the basis for all weapons planning in DOE. The President takes the Nuclear Weapons Stockpile Memorandum under advisement and issues a National Security Directive to DOE and the Department of Defense approving the Nuclear Weapons Stockpile Plan for implementation. Based upon this Presidential directive, DOE determines the required tritium requirements. The most recent Presidential direction, which is contained in the 1996 Nuclear Weapons Stockpile Plan and an accompanying Presidential Decision Directive, mandates that new tritium must be available by approximately 2005 if a CLWR is the selected option for tritium production. Chapter 2 provides a description of the tritium requirements that this EIS is intended to support.

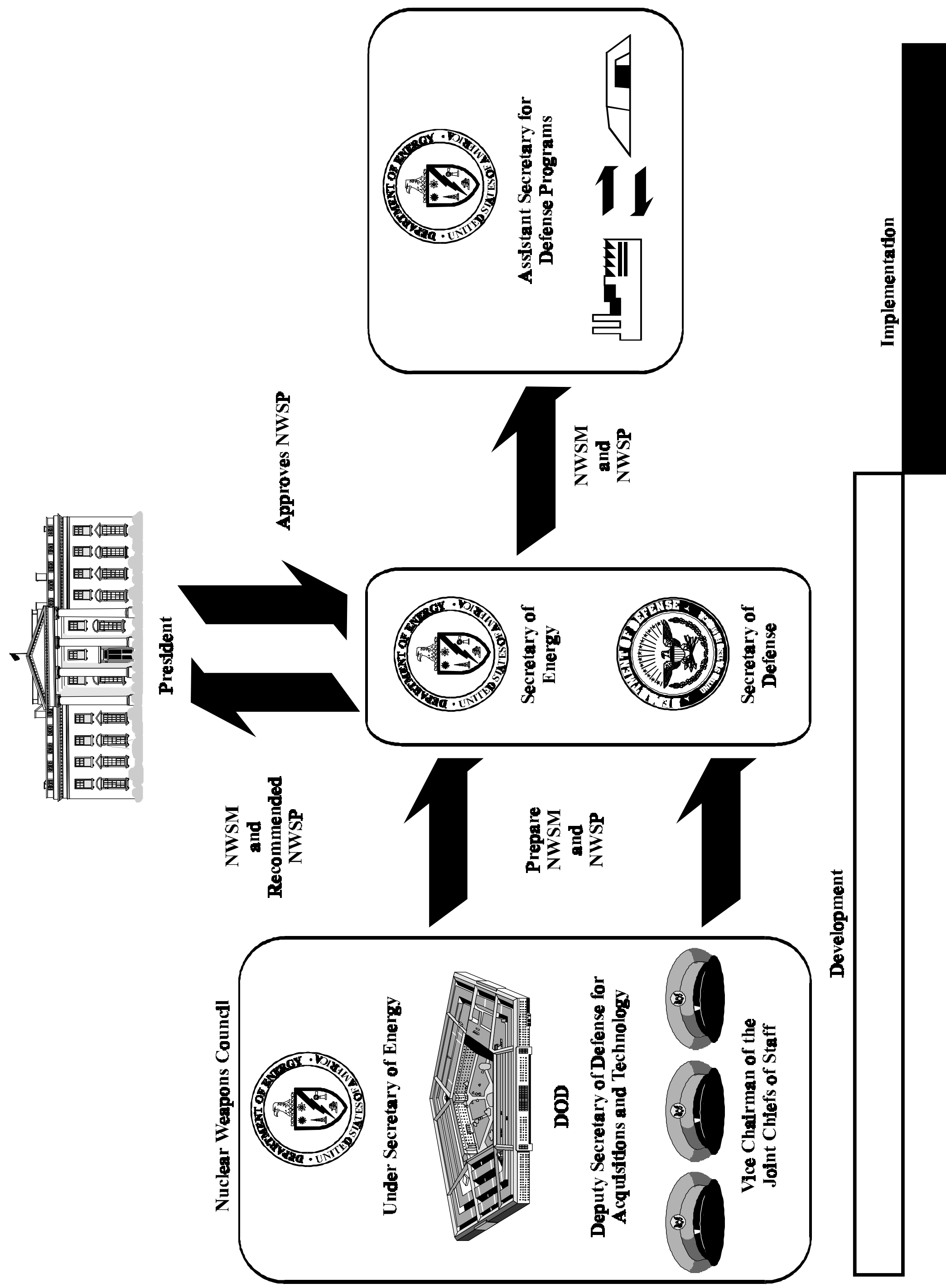
1.3.2 Nuclear Weapons

A general understanding of a nuclear weapon, including the components that make up the weapon and the physical processes involved, is helpful in understanding the purpose and need addressed in this EIS. **Figure 1–4** presents a simplified diagram of a modern nuclear weapon. An actual U.S. nuclear weapon is much more complicated, consisting of many thousands of parts.

The nuclear weapon primary is composed of a central core called a pit, which is usually made of plutonium-239 and/or highly enriched uranium. This is surrounded by a layer of high explosive, which, when detonated, compresses the pit initiating a nuclear reaction. This reaction is generally thought of as the nuclear fission "trigger" which activates the secondary assembly component to produce a thermonuclear hydrogen fusion reaction. The remaining nonnuclear components consist of everything from arming and firing systems, to batteries and parachutes. The assembly of these components into a weapon or the dismantlement of an existing weapon are done at the weapons assembly/disassembly facility.

Tritium is not a fissile material and cannot be used by itself to construct a nuclear weapon. However, tritium is a key component of all nuclear weapons presently in the Nation's nuclear weapons arsenal. Tritium enables weapons to produce a larger yield while reducing the overall size and weight of the warhead. This process is called "boosting." Boosting is accomplished by injecting a mixture of tritium gas and deuterium gas, a naturally occurring, nonradioactive hydrogen isotope, into the pit. The deuterium and tritium are stored in reservoirs (which is depicted as the "gas transfer system" in Figure 1–4) until the gas transfer system is initiated. The implosion of the pit along with the onset of the fissioning process heats the deuterium-tritium mixture to the point that the atoms undergo fusion. The fusion reaction releases large quantities of very high energy neutrons which flow through the compressed pit material and produce additional fission reactions. Such boosting has allowed for the development of today's sophisticated delivery systems. The key function of tritium is to enhance the fission yield of a nuclear weapon.

In the absence of new weapons designs and the total redesign of all warheads and delivery systems, the nation requires a reliable source of tritium to maintain a nuclear deterrent. Furthermore, total redesign of all warheads would require nuclear testing which would be contrary to the President's pursuit of a Comprehensive Test Ban Treaty.



Note: NWSM–Nuclear Weapons Stockpile Memorandum; NWSP–Nuclear Weapons Stockpile Plan.

Figure 1–3 Nuclear Weapons Stockpile Memorandum Process

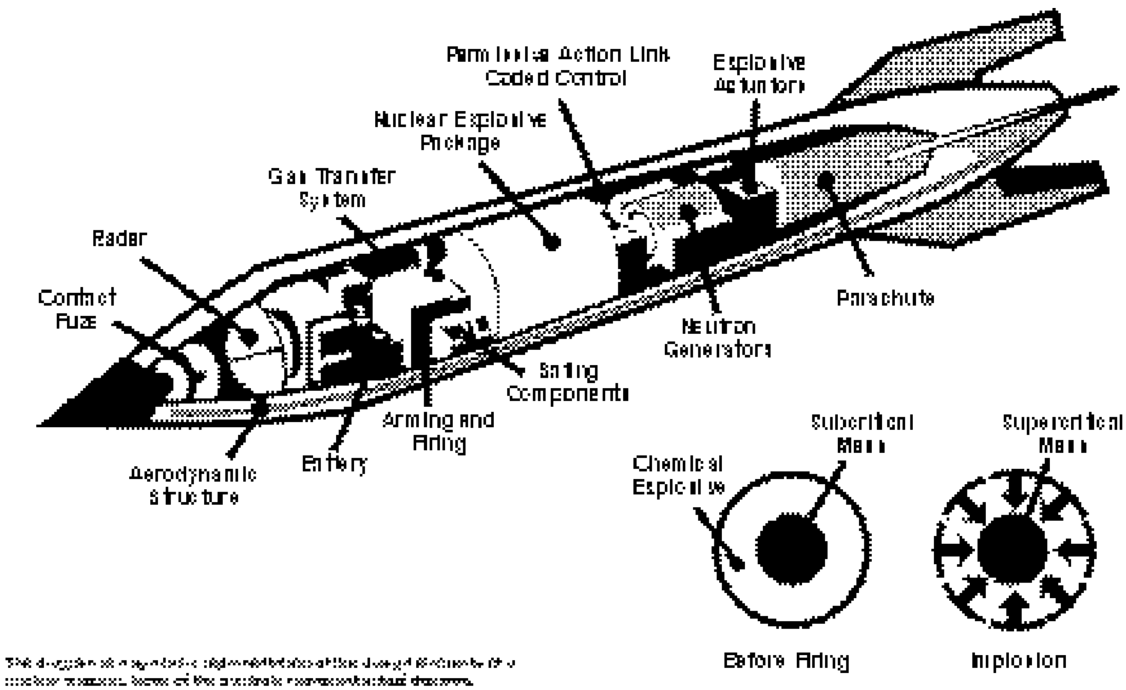


Figure 1–4 Diagram of a Modern Nuclear Weapon

1.3.3 Brief History of the Production of Tritium

Tritium is so rare in nature that useful quantities must be manufactured. DOE has constructed and operated over a dozen nuclear reactors for the production of nuclear materials at the Savannah River Site, South Carolina, and the Hanford Site, Washington, starting with the early part of the Manhattan Project during World War II. None of these reactors is currently operational. The last one, the K-Reactor at the Savannah River Site was shut down in 1988 for major environmental, safety, and health upgrades to comply with today's stringent standards. DOE discontinued the K-Reactor Restart Program in 1993 when smaller stockpile requirements delayed the need for tritium. As explained in the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (DOE 1995b), the K-Reactor is not a reasonable alternative for tritium production.

In recent years, international arms control agreements have caused the nuclear weapons stockpile to be reduced in size. Reducing the stockpile has allowed DOE to recycle the tritium removed from dismantled weapons for use in supporting the remaining stockpile. However, due to the decay of tritium, the current inventory of tritium will not meet national security requirements past approximately 2005. Therefore, the most recent Presidential direction, which is contained in the 1996 Nuclear Weapons Stockpile Plan and an accompanying Presidential Decision Directive, mandates that new tritium be available by approximately 2005 if a CLWR is the selected option for tritium production. If the accelerator is the selected option for tritium production, the Presidential directive mandates that new tritium must be available by 2007. Tritium needs during the period 2005-2007 would be met by using the 5-year tritium reserve or by a contingency tritium supply source.

1.3.4 Production of Tritium in a CLWR

The production of tritium in a CLWR is technically straightforward and requires no elaborate, complex engineering development and testing program. All the Nation's supply of tritium, as mentioned previously, has been produced in reactors. Most existing commercial pressurized water reactors utilize 12-foot-long rods containing an isotope of boron (boron-10) in ceramic form that are inserted in their fuel assemblies to absorb excess neutrons produced by the uranium fuel in the fission process for the purpose of controlling power in the core at the beginning of an operating cycle. These rods are sometimes called burnable absorber rods. DOE's tritium program has developed another type of burnable absorber rod in which neutrons are absorbed by a lithium aluminate ceramic rather than boron ceramic. While the TPBAR design is not complete, the basic parameters have been developed and are not expected to change (see Section 3.1.2). These TPBARs would be placed in the same locations in the reactor core as the standard burnable absorber rods. There is no fissile material (uranium or plutonium) in the TPBARs.

While the two types of rods function in a very similar manner to absorb excess neutrons in the reactor core, there is one notable difference: when neutrons strike the lithium aluminate ceramic material in a TPBAR, tritium is produced. This tritium is captured almost instantaneously in a solid zirconium material in the rod, called a "getter." Thus, there is virtually no free tritium in the rod. In fact, the solid material that captures the tritium as it is produced in the rod is so effective that the rod will have to be heated in a vacuum to temperatures in excess of 1,000

stockpile. Depending upon tritium needs, as many as 3,400 TPBARs could be placed in a CLWR for irradiation.

1.3.5 Nonproliferation

In accordance with the direction provided in the Fiscal Year 1998 National Defense Authorization Act (P.L. 105-85), the Congress requested that the DOE take the lead to identify and assess any policy issues associated with various reactor options for the production of tritium for national security purposes. The Congress requested that this be done in conjunction with other agencies, including the Nuclear Regulatory Commission, the Department of Defense, and the Department of State Arms Control offices through a senior level, interagency process. This process was completed in July 1998 and is documented in a report to Congress entitled, "Interagency Review of the Nonproliferation Implications of Alternative Tritium Production Technologies Under Consideration by the Department of Energy" (DOE 1998d). The principal findings in this report, as related to tritium production in a CLWR, are as follows:

1. The use of CLWRs for tritium production was not prohibited by law or international treaty;

2. That, historically, there have been numerous exceptions to the practice of differentiating between U.S. civil and military facilities (including the operation of the N-Reactor at Hanford, the dual use nature of the U.S. enrichment program, the use of defense program plutonium production reactors to produce radio-isotopes for civilian purposes, and the sale of tritium produced in the defense reactors in the U.S. commercial market);

3. Although the CLWR alternative raised initial concerns because of its implications for the policy of maintaining separation between U.S. civil and military nuclear activities, these concerns could be adequately addressed, given the particular circumstances involved. These included the fact that the reactors would remain eligible for International Atomic Energy Agency safeguards, and the fact that if TVA were the utility selected for the tritium mission, the reactors used for tritium production would be owned and operated by the U.S. Government, making them roughly comparable to past instances of government-owned dual-purpose nuclear facilities.

The report concluded that the nonproliferation policy issues associated with the use of a CLWR are manageable and that DOE should continue to pursue the reactor option as a viable source for future tritium production.

1.3.6 Background on the Tennessee Valley Authority

TVA was established by an Act of Congress in 1933 as a Federal corporation to improve the navigability and to provide for the flood control of the Tennessee River; to provide for reforestation and the proper use of marginal lands in the Tennessee Valley; to provide for agricultural and industrial development of the Tennessee Valley, to provide for the national defense, and for other purposes. Within a few years of its establishment, TVA had built a series of multipurpose dams on the Tennessee River system. One of the purposes of these dams was production of abundant, inexpensive electricity. The hydroelectric power generated by these dams met most of the rapidly increasing needs of the region through the 1940s. By the early 1950s, however, the growing demand was quickly outstripping the capacity of the dams and the Watts Bar Fossil Fuel Plant, which had begun operation in 1942. During the next 20 years, TVA built 11 large, coal-fired, electricity-generating plants to meet the region's growing needs. Some of these plants were the largest, first-of-their-kind coal-fired units in the world. The 1960s brought even greater growth to the region. To meet the anticipated need for more power, TVA began an ambitious program of nuclear plant construction.

Today TVA is one of the largest producers of electricity in the United States, generating 4 to 5 percent of all electricity in the Nation. TVA's power system serves almost 8 million people in a seven-state region encompassing some 207,200 square kilometers (80,000 square miles). TVA's electricity is distributed to homes and businesses through a network of 159 power distributors, including municipally owned utilities and electric cooperatives. TVA also sells power directly to approximately 60 large industrial customers and Federal facilities.

TVA's power system, which is self-financed, has a generating capacity of 28,000 MWe. Its generating system consists of 11 coal-fired plants (53 percent of total generating capacity), 5 nuclear generating units at three sites (20 percent), 29 hydroelectric dams (15 percent), 48 combustion turbine units at four sites (7 percent), and one pumped-storage facility (5 percent). These plants, although managed by TVA, are owned by the United States government. The TVA power system is linked by 25,750 kilometers (16,000 miles) of transmission lines that carry power to 750 wholesale delivery points, as well as 57 interconnections with 13 neighboring utilities.

In December 1995, with the publication of *Energy Vision 2020, Integrated Resource Plan and Environmental Impact Statement* (TVA 1995d), TVA projected demands for electricity in the TVA power service area through the year 2020 and evaluated different ways of meeting these projected increases. Since the Integrated Resource Plan was completed in 1995, TVA has continued to evaluate and select the best resource options based on the latest proposals and TVA's forecast of power needs. The total system generating capacity has been increased with the successful completion of Watts Bar 1 and the return to service of Browns Ferry Nuclear Plant, Unit 3. Both units have operated above expectations and have proven to be very reliable.

Current projections show the demand for electricity (including reserves) would exceed TVA's 1998 generating capacity by about 5,200 MWe in 2005; this projection is slightly less than the 1998-2005 medium load forecast of 5,450 MWe in *Energy Vision 2020, Integrated Resource Plan and Environmental Impact Statement* (TVA 1995d). About 2,800 MWe of additional generating capacity is needed by the year 2001. A portion of this would be met by the proposed Red Hills Power Project. The remainder would be met by option purchase agreements, forward contracts for delivery of electricity to TVA, and internal TVA projects to increase net dependable capacities for TVA's combustion turbines, fossil plants, and pumped storage units. An additional 2,400 MWe of capacity would be required between 2001 and 2005. The completion of the Bellefonte unit(s) would offset some of this planned capacity.

Producing tritium in a TVA reactor would be consistent with the Congressional purposes that established the TVA—namely, to provide for the industrial development of the Tennessee Valley and for national defense. Producing tritium in a TVA reactor would also enable the TVA to maximize the utilization of its resources, and to potentially increase its electricity generating capacity. TVA as a Federal agency, in order to fulfill NEPA responsibilities, chose to be a cooperating agency on this EIS. A cooperating agency is defined by Council on Environmental Quality regulations as any other Federal agency other than a lead agency having jurisdiction by law or special expertise with any environmental issue (40 CFR 1508.5).

1.4 NEPA STRATEGY

DOE's strategy for compliance with NEPA has been, first, to make decisions on programmatic alternatives in the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (DOE 1995b) and Record of Decision (60 FR 63878), followed by site-specific analyses to implement the programmatic decisions. The decisions made in the December 12, 1995, *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* Record of Decision have resulted in DOE preparing this EIS and the following NEPA documents:

1. *Draft Environmental Impact Statement, Construction and Operation of a Tritium Extraction Facility at the Savannah River Site* (DOE 1998c)

2. *Draft Environmental Impact Statement, Accelerator Production of Tritium at the Savannah River Site* (DOE 1997e)

3. *Environmental Assessment, Lead Test Assembly Irradiation and Analysis, Watts Bar Nuclear Plant, Tennessee and Hanford Site, Richland, Washington* (DOE 1997c).

The relationship of the CLWR EIS with these, as well as other relevant NEPA documents is explained in Section 1.5.

1.5 OTHER RELEVANT NEPA REVIEWS

This section explains the relationship between the CLWR EIS and other relevant NEPA documents. Already completed NEPA actions are addressed in Section 1.5.1; ongoing actions, are discussed in Section 1.5.2.

1.5.1 Completed NEPA Actions

1.5.1.1 Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling

The *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling*, DOE/EIS-0161, (DOE 1995b) evaluated the alternatives for the siting, construction, and operation of tritium supply and recycling facilities at each of five DOE candidate sites (the Idaho National Engineering Laboratory; the Nevada Test Site; the Oak Ridge Reservation, Tennessee; the Pantex Plant, Texas; and the Savannah River Site, South Carolina) for four different production technologies (heavy water reactor, modular high temperature gas-cooled reactor, advanced light water reactor, and accelerator production of tritium). This Programmatic EIS also evaluated the impacts of using a CLWR, but did not analyze specific locations or reactor sites. Issued in October 1995, the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* was followed by a Record of Decision on December 12, 1995. In the Record of Decision, DOE decided to pursue a dual-track approach on the two most promising tritium supply alternatives: (1) to initiate purchase of an existing commercial reactor (operating or partially complete) or reactor irradiation services with an option to purchase the reactor for conversion to a defense facility; and (2) to design, build, and test critical components of an accelerator system for tritium production (the Savannah River Site was selected as the location for an accelerator, should one be built) (60 FR 63878). The Record of Decision also called for the construction of a proposed new Tritium Extraction Facility at the Savannah River Site. The CLWR EIS is intended to provide the NEPA analysis necessary to implement the *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* decision to produce tritium in one or more CLWRs should the Secretary of Energy decide that tritium will be primarily produced in a CLWR.

1.5.1.2 Lead Test Assembly Environmental Assessment

This NEPA analysis addressed the environmental impacts associated with the fabrication of the TPBARs at Pacific Northwest National Laboratory, Washington; the irradiation of these TPBARs in Watts Bar 1; and post-irradiation examination of the TPBARs at Pacific Northwest National Laboratory and Argonne National Laboratory West, Idaho; and impacts of transporting TPBARs to and from Watts Bar 1 (DOE 1997c). In the past, the United States produced all necessary tritium in government-owned nuclear reactors. The purpose of the Lead Test Assembly confirmatory demonstration is to confirm and provide confidence to regulators and the public that tritium production in a CLWR is technically straightforward and safe. DOE issued a Finding of No Significant Impact in July 1997 (DOE 1997d). Subsequently, the TPBARs were placed in Watts Bar 1 on September 25, 1997, and they are presently being irradiated during the normal 18-month fuel cycle. Following irradiation, the TPBARs will undergo post-irradiation examination. To meet its own NEPA requirements, TVA adopted the Lead Test Assembly Environmental Assessment and issued a Finding of No Significant Impact on August 19, 1997 (TVA 1998a). Additionally, NRC prepared an independent environmental assessment and its own Finding of No Significant Impact on September 11, 1997 (62 FR 47835).

1.5.1.3 EISs for the Operation of Watts Bar 1, Sequoyah 1 and 2, and for Construction of Bellefonte 1 and 2

EISs analyzing the environmental impacts associated with operation of the Watts Bar and Sequoyah Nuclear Plants and the construction of the Bellefonte Nuclear Plant (NRC 1978; TVA 1974a; AEC 1974) have been completed and serve to a great extent as a baseline on which the environmental impacts associated with tritium production are assessed. For the partially completed Bellefonte 1 and 2, the CLWR EIS also evaluates the environmental impacts associated with their completion and with the subsequent operation of these units for 40 years.

1.5.2 Ongoing NEPA Actions

1.5.2.1 Draft Environmental Impact Statement, Accelerator Production of Tritium at the Savannah River Site

This EIS analyzes the potential environmental impacts associated with the construction and operation of an accelerator for the production of tritium at the Savannah River Site. On a programmatic level, the accelerator production of tritium at the Savannah River Site represents the No Action Alternative for this CLWR EIS. That is, if DOE decides not to proceed with the proposed action to produce tritium in one or more CLWRs, then DOE would construct and operate the accelerator for the production of tritium at the Savannah River Site. A summary of the *Draft Environment Impact Statement, Accelerator Production of Tritium at the Savannah River Site*, DOE/EIS-0270D (DOE 1997e) is presented in Section 5.2.11 of this CLWR EIS. The Draft EIS was issued in December 1997. The Final EIS is expected to be issued in December 1998.

1.5.2.2 Draft Environmental Impact Statement, Construction and Operation of a Tritium Extraction Facility

This EIS analyzes the potential environmental impacts associated with the construction and operation of a Tritium Extraction Facility at the Savannah River Site. The Draft EIS was issued in May 1998, a Final EIS is scheduled to be completed in December1998. The purpose of the Tritium Extraction Facility would be to extract the tritium from the TPBARs or targets of similar design. If the CLWR is selected as the primary tritium technology, TPBARs irradiated at selected CLWRs will be sent to the Tritium Extraction Facility for extraction of the tritium-containing gases. If CLWR is the backup technology, a new extraction capability would still be required either as a stand-alone facility or in combination with the accelerator for production of tritium (APT) technology. A decision on whether to construct and operate a Tritium Extraction Facility is not expected to be made until after the tritium supply technology decision is announced. A summary of the environmental impacts of the *Draft Environmental Impact Statement, Construction and Operation of a Tritium Extraction Facility at the Savannah River Site,* DOE/EIS-0271D (DOE 1998c) is presented in Section 5.3 of this CLWR EIS.

1.5.2.3 Environmental Assessment for the Tritium Facility Modernization and Consolidation Project at the Savannah River Site

This environmental assessment addresses the potential impacts of consolidating the tritium activities currently performed in Building 232-H into the newer Building 234-H. Tritium extraction functions would be transferred to the Tritium Extraction Facility, under the Preferred Alternative. The overall impact would be to reduce emissions by up to 50 percent. Another effect would be to reduce the amount of low-level waste generated. Effects on other resources would be negligible. Therefore, impacts from these actions have not been included in the cumulative impacts of the CLWR EIS (DOE 1998a).

1.5.2.4 Final Environmental Impact Statement for the Bellefonte Conversion Project

This EIS, issued by TVA, addresses the environmental impacts anticipated from: (1) the conversion of partially completed Bellefonte 1 and 2 to fossil fuel electricity generating facilities, and (2) the No Action Alternative of maintaining the facilities as partially completed nuclear facilities. The EIS was completed in October 1997. The issuance of a Record of Decision on the *Final Environmental Impact Statement for the Bellefonte Conversion Project* (TVA 1997f) will not be made until it is determined whether one or both of these reactor plants will be used for tritium production. The No Action Alternative of the CLWR EIS involves the continued deferral of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 while TVA explores arrangements with outside entities to complete the units as nuclear facilities. If these reactor plants will not to be utilized in the CLWR program, one of the five alternatives addressed in the *Final Environmental Impact Statement for the Bellefonte Conversion Project* could be selected in the Record of Decision for that EIS. If the CLWR EIS Record of Decision indicates that Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 will be used for tritium production, then the construction of the reactor(s) would be completed and the reactor(s) would be operated for tritium production in addition to electricity production.

1.6 ORGANIZATION OF THIS EIS

This EIS contains nine chapters and eight appendixes. The main analyses are included in the chapters with additional project information provided in the appendixes. A Summary is available as a separate publication.

Nine chapters provide the following information:

Chapter 1—Introduction: CLWR EIS background and the environmental analysis process.

Chapter 2—Purpose and Need: Reasons why action is needed and the proposed objectives of the action.

Chapter 3—CLWR Program Alternatives: Proposed ways to meet the specified need and achieve the objectives; basic assumptions; and the development of the reasonable alternatives. The chapter also includes a summary of the potential environmental impacts of the reactor alternatives.

Chapter 4—Affected Environment: Aspects of the environment that could be affected by the EIS alternatives.

Chapter 5—Environmental Consequences: Analyses of the potential impacts of the EIS alternatives on the environment.

Chapter 6—Regulatory Requirements: Environmental, safety, and health regulations that would apply for this EIS's alternatives, and agencies consulted for their expertise. The Chapter also contains the regulatory history of TVA's reactors.

Chapters 7-10—References; a list of preparers; a list of agencies, organizations, and persons to whom copies of this EIS are being sent; and a glossary.

Eight appendixes of technical information contain the following information: CLWR tritium production operations, methods for assessing environmental impacts, normal operational impacts on human health, facility accident impacts on human health, evaluation of human health effects of overland transportation, the public scoping process, environmental justice, and contractor disclosure.

1.7 PUBLIC SCOPING PROCESS

Scoping is a process by which the public and stakeholders provide comments directly to the Federal agency on the scope of the EIS. This process is initiated by the publication of the Notice of Intent in the *Federal Register*.

On January 21, 1998, DOE published in the *Federal Register* a Notice of Intent to prepare the CLWR EIS (63 FR 3097). In this Notice of Intent, DOE invited public comment on the CLWR EIS proposal. Subsequent to this notice, DOE held public scoping meetings in Rainsville, Alabama, on February 24, 1998, and in Evansville, Tennessee, on February 26, 1998. The 700 comments received either orally or in writing at these meetings, or received in writing, by facsimile, through the Internet, or over the 1–800 phone line during the public comment period, were reviewed for consideration by DOE in preparing this EIS. A summary of the comments received during the public scoping process, as well as DOE's consideration of these comments, is provided as Appendix F of this EIS.

Approximately 700 comments were received from citizens, interested groups, and Federal, state, and local officials during the public scoping period, including 156 verbal comments made during the public meetings. The remainder of the comments (513) were submitted at the public meetings in written form, or via mail, Internet, fax, or phone over the entire scoping period. Commentors who spoke at the public meetings often read from written statements that were later submitted during or after the meetings. Where this occurred, each comment provided by an individual commentor in both verbal and written form was counted as a single comment. In addition to the comments, four petitions totaling 1,586 signatures were submitted in support of completing the Bellefonte plant for tritium production purposes.

The majority of the verbal and written comments received during the public scoping period favored producing tritium at one or more of TVA's nuclear power plants. Comments from residents of northern Alabama were particularly supportive of completing the Bellefonte plant for tritium production. Reasons given for this support mostly involved potential socioeconomic benefits such as job creation, a greater abundance of inexpensive electricity, attraction of new businesses to the area, and increased local revenues.

Many of the comments received from residents of the local areas near the TVA plants also communicated an understanding that the U.S. will begin producing tritium in the near future–either at the Savannah River Site (the accelerator option) or at one of TVA's nuclear power plants. These commentors expressed confidence in the safety of the TVA plants and the capabilities of area workers to provide the skills needed for tritium production. They also said they believe nuclear power plants are a more sensible choice for tritium production because reactors are a proven technology and the total project cost would be less than the cost of building an accelerator.

A significant number of other comments received during the scoping period opposed tritium production in general and the use of a nuclear power plant for this purpose in particular. This group disagreed with the Presidential and Congressional decision to produce tritium and denied there is any real defense-related need for new tritium production because they believe other options are available. Among the options cited were unilateral disarmament, commercial purchases, recycling the material from deactivated nuclear weapons, and/or extending the half-life of tritium.

Several commentors voiced concerns about the environmental, health, and safety risks they believe are inherent to tritium production. DOE representatives were urged to thoroughly evaluate the potential consequences of the proposed action on local water resources and the health and safety of area residents and wildlife. Concerns also were raised about the safety of TVA's nuclear power plants and how the security of the plants would be managed if tritium production were to begin.

Waste production and disposal was another issue. Some commentors correctly stated that tritium production in a nuclear reactor would increase the amount of spent fuel wastes generated. Questions were posed as to how this additional waste would be dealt with, both onsite and in the long term.

Many commentors also viewed the U.S. Government's decision to produce tritium as a violation of its own policies and commitments under the international Nonproliferation and Strategic Arms Limitation Treaties. They accused the government of hypocrisy and asserted that tritium production in a commercial light water reactor would blur the historical line between U.S. civilian and military nuclear programs. This action, they warned, would encourage other countries to use their own commercial plants to produce weapons materials and to increase their weapons stockpiles.

The public comments and materials submitted during the scoping period were carefully logged as they were received and placed in the Administrative Record of this EIS. Their disposition is described in Appendix F of this EIS.

2. PURPOSE AND NEED

Chapter 2 discusses the U.S. Department of Energy's (DOE's) purpose and need to provide a tritium supply capability. The purpose of DOE's action is to produce in a commercial light water reactor the tritium required to maintain the Nation's nuclear weapons stockpile.

Since nuclear weapons came into existence in 1945, a nuclear deterrent has been a cornerstone of the Nation's defense policy and national security. Both President Clinton and Congress have reiterated this principle in public statements and through legislation. The President has stated on a number of occasions his commitment to maintaining a nuclear deterrent capability. Most recently, in May 1997, the President stated in *A National Security Strategy for a New Century* (White House 1997) that ". . . our nuclear deterrent posture is one of the most visible and important examples of how U.S. military capabilities can be used effectively to deter aggression and coercion. Nuclear weapons serve as a hedge against an uncertain future, a guarantee of our security commitments to allies, and a disincentive to those who would contemplate developing or otherwise acquiring their own nuclear weapons."

U.S. strategic nuclear systems are based on designs that use tritium gas. Since tritium decays at a rate of about 5.5 percent per year (i.e., every 12.3 years one-half of the tritium has decayed), periodic replacement is required as long as the United States relies on a nuclear deterrent. The Nation, therefore, requires a reliable source of tritium to maintain its nuclear weapons stockpile.

As explained in Section 1.3.1, the size of the Nation's nuclear weapons stockpile is determined by the Secretaries of Defense and Energy who, in coordination with the Nuclear Weapons Council, jointly sign and submit to the President the Nuclear Weapons Stockpile Memorandum. This Memorandum transmits the Nuclear Weapons Stockpile Plan to the President for final approval. Many factors are considered in the development of the Nuclear Weapons Stockpile Plan, including the status of the currently approved stockpile, arms control negotiations and treaties, Congressional constraints, and the status of the nuclear material production and fabrication facilities. Under this plan, the U.S. Department of Energy (DOE) can determine the amount of tritium necessary to support the approved stockpile.

Tritium is a radioactive isotope of hydrogen and an essential component of every warhead in the current and projected U.S. nuclear weapons stockpile. These warheads depend on tritium so they can perform as designed. Tritium's relatively short radioactive half-life necessitates the periodic replenishment of tritium in nuclear weapons to ensure that they will function as designed. Over the past 40 years, DOE has built and operated over a dozen nuclear reactors, five of them at the Savannah River Site in South Carolina, to produce tritium and other nuclear materials for weapons purposes. Today, none of these reactors are operational, and DOE has not produced tritium for addition to the stockpile since 1988. According to the Atomic Energy Act of 1954, however, DOE is responsible for developing and maintaining the capability to produce the nuclear materials, such as tritium, that are necessary for the defense of the United States (40 U.S.C. 2011).

Until a new tritium supply source is operational, DOE will continue to support tritium requirements by recycling tritium from weapons retired from the Nation's stockpile. However, because of the tritium decay rate, recycling can only meet the tritium demands for a limited time, even with the reduction in stockpile requirements and no identified need for new-design weapons in the foreseeable future. Current projections, derived from the most recently approved, classified projections of future stockpile scenarios, indicate that recycled tritium will support the Nation's nuclear weapons stockpile adequately until approximately 2005 **(Figure 2–1)**.

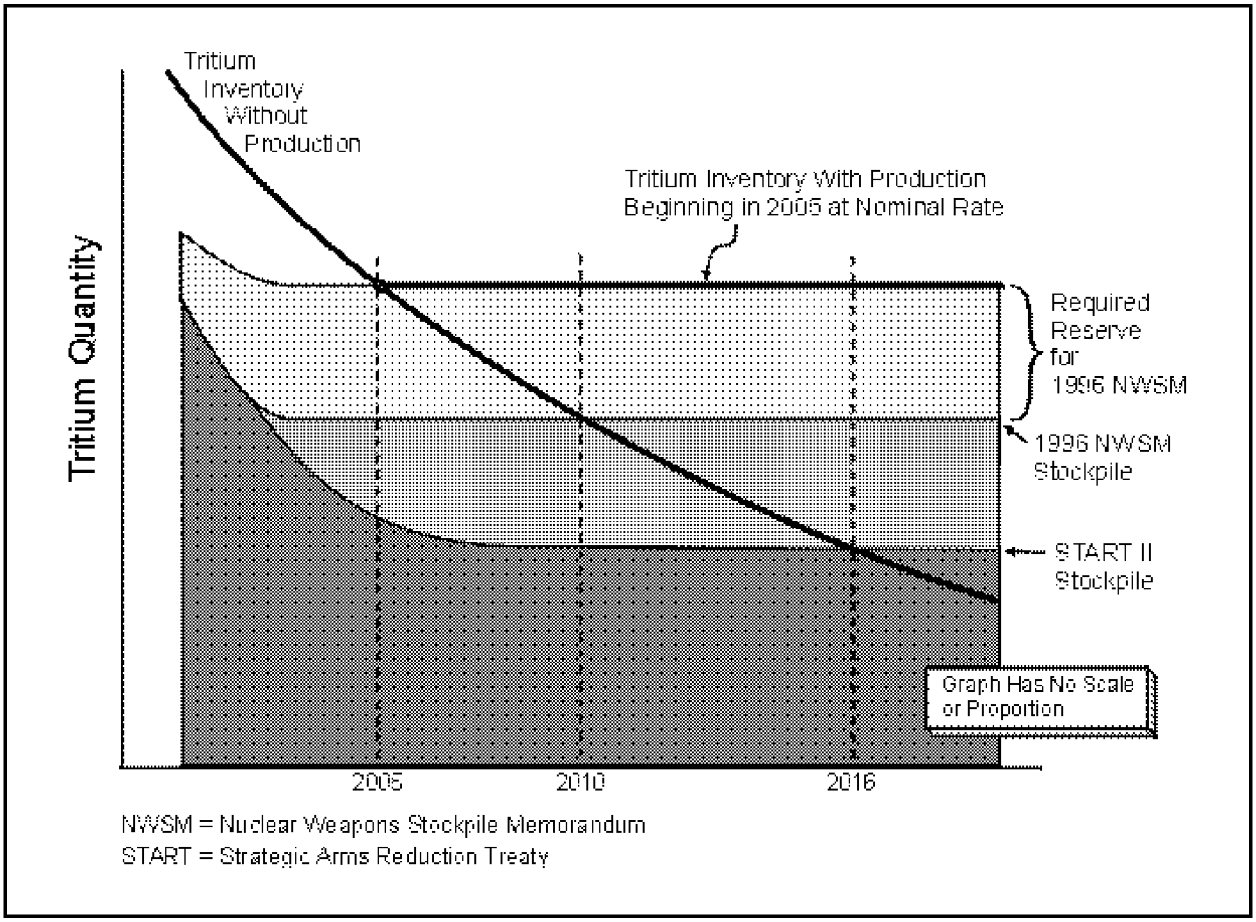


Figure 2–1 Estimated Tritium Inventory and Reserve Requirements

Even with a reduced nuclear weapons stockpile and no identified requirement for new nuclear weapons production in the foreseeable future, an ensured long-term tritium supply and recycling capability will be required to maintain the weapons determined to be needed for national defense under the prevailing Nuclear Weapons Stockpile Plan. Presently, no U.S. source of new tritium is available. The effectiveness of the U.S. nuclear deterrent capability depends not only on the Nation's current stockpile of nuclear weapons or the effectiveness of those it can produce, but also on its ability to reliably and safely provide the tritium needed to maintain these weapons.

To meet requirements mandated by the President and supported by the Congress, the United States will need a new source of tritium production by approximately 2005. For planning purposes, the operational life of the new production source would be about 40 years. Without a new supply source, after 2005 the United States would have to use its 5-year reserve of tritium to maintain the readiness of the nuclear weapons stockpile. The 5-year reserve contains a quantity of tritium maintained for emergencies and contingencies. In such a scenario, the complete depletion of the 5-year tritium reserve would degrade the nuclear deterrent capability because not all weapons in the stockpile would be able to function as designed. Eventually, the United States would lose its nuclear deterrent. The purpose of DOE's action is to produce, in a commercial light water reactor, the tritium needed to maintain the Nation's nuclear weapons stockpile.

TVA's purpose and need relative to this environmental impact statement is to maximize the use of its resources while simultaneously providing support to national defense. National defense support has been one of TVA's historic multipurpose missions (see Section 1.3.6).

3. COMMERCIAL LIGHT WATER REACTOR PROGRAM ALTERNATIVES

Chapter 3 describes the physical process used to produce tritium in a commercial light water reactor (CLWR), the proposed action, the planning assumptions and basis for the environmental impact analysis, and the development of Reasonable Alternatives. The chapter also describes each of the candidate CLWRs, explains the No Action Alternative, and summarizes the environmental impacts associated with the No Action and the Reasonable Alternatives.

3.1 PRODUCTION OF TRITIUM IN A COMMERCIAL LIGHT WATER REACTOR

A commercial light water reactor (CLWR) is a nuclear reactor designed and constructed to produce electric power for commercial sale. As discussed in Section 1.3.4, tritium can be produced during the normal operation of a CLWR. The process uses tritium-producing burnable absorber rods (TPBARs). TPBARs are specially fabricated rods that replace standard burnable absorber rods in the reactor core. Burnable absorber rods absorb excess neutrons and help control the power in a reactor to ensure an even distribution of heat and extend the reactor's fuel cycle. Tritium is produced when the TPBAR is exposed to radiation during the normal operation of the CLWR.

This section provides a general description of the process of producing tritium using a CLWR. It includes: (1) a brief description of the normal process of generating electric power in a typical CLWR plant; (2) a description of the TPBARs that are inserted in the reactor and the standard burnable absorber rods that they replace; and (3) a summary of the operational differences this replacement introduces—differences that would give rise to environmental impacts in addition to those associated with the normal operation of the reactor. A more detailed description of the process of producing tritium in a CLWR and some background information on the operation of CLWRs in a tritium-producing mode are included in Appendix A.

3.1.1 Generation of Electric Power in Nuclear Power Plants

Nuclear, coal-fueled, and oil-fueled power plants all generate electricity by heating water to create steam used to turn a turbine that powers a generator. The principal difference between nuclear and fossil-fueled power plants is that, instead of using a boiler to heat water for steam, the nuclear power plant heats the water with heat generated in the core of the nuclear reactor during nuclear fission.

Nuclear fission is the process of splitting fissionable atoms. When an atom is forced to split, energy is released. Some of this energy is converted to heat. In a nuclear reactor, certain types of uranium atoms are made to fission, or split, and release heat. The amount of heat generated (the power) is controlled by two types of control rods, movable and fixed. The movable control rods are used to start or stop the reactor. The fixed control rods, also called burnable absorber rods, ensure an even distribution of heat and extend the fuel cycle. The term "burnable" in this context means "capable of being consumed," rather than the conventional definition as flammable.

Water is pumped through the reactor core to carry away the heat produced by the nuclear fission. Power reactors in the United States are called light water reactors because they are cooled by ordinary or "light" water. There are two types of light water reactors—boiling water reactors and pressurized water reactors. In boiling water reactors, the water boils to steam in the reactor vessel and goes directly to the turbine. A method to produce tritium in boiling water reactors has not been developed.

In pressurized water reactors, the water is pressurized to prevent it from boiling. As it passes through the pressurized core to cool it, the pressurized water (the primary coolant) is heated. Next, it is pumped to a steam generator where it passes through tubes (heat exchangers) and heats water in a "secondary" system. When this secondary water boils, steam is created. The steam then passes through the turbine, which powers the generator and produces electricity. With both types of reactor plants, the steam, after passing through the turbine, is cooled and condensed by another water system, which is usually supplied from a lake, river, or ocean. See **Figure 3–1** for a schematic drawing of a typical pressurized water reactor.

Light water reactor fuel consists of pellets of uranium dioxide stacked in approximately 12-foot long tubes called fuel rods. Fuel rods are grouped together as fuel assemblies where they are held side-by-side at fixed distances by metal grids. Although power reactor fuel assemblies differ somewhat depending on the design of the reactor, a typical fuel assembly for a pressurized water reactor contains 289 positions: 264 fuel rod and 25 nonfuel rod positions in a 17 x 17 array. The nonfuel positions are used for moveable control rods, instrumentation, neutron source rods, or burnable absorber rods. Pressurized water reactors are suited for the production of tritium because the TPBARs can be inserted into the nonfuel positions of the fuel assemblies to replace standard burnable absorber rods. For this reason, only pressurized water reactors have been considered for the production of tritium in CLWRs. **Figure 3–2** shows cross-sections of a fuel assembly.

3.1.2 Description of Tritium-Producing Burnable Absorber Rods

To produce tritium in a CLWR, TPBARs would be inserted into the reactor core. The TPBARs are long, thin tubes that contain lithium 6, a material that produces tritium when it is exposed to neutrons in the reactor core. The exterior dimensions of the TPBARs are similar to the burnable absorber rods (see **Table 3–1**), so that they can be installed in fuel assemblies where burnable absorber rods are normally placed. To ease the insertion and removal from fuel assemblies, the TPBARs would be attached to a base plate. See **Figures 3–3** and **3–4** for a sketch of a typical TPBAR assembly and components. In addition to producing tritium, TPBARs would fill the same role as burnable absorber rods in the operation of the reactor.

The neutron absorber material in the TPBARs would be enriched in the isotope lithium 6, instead of the boron usually used in the burnable absorber rods. When the TPBARs are inserted into the reactor core, neutrons would be absorbed by the lithium 6 isotope initiating a nuclear process that would turn it into lithium 7. The new isotope would then split to form helium 4 and tritium (see Appendix A for a more detailed discussion of this process). The tritium then would be captured in a solid metal nickel-plated zirconium material in the TPBAR called a "getter." The tritium would be chemically bound in the TPBAR "getter" until the TPBAR is removed from the reactor during refueling and transported to the proposed Tritium Extraction Facility at the U.S. Department of Energy's (DOE's) Savannah River Site in South Carolina where the tritium would be extracted by heating the TPBARs in a vacuum to temperatures in excess of 1,000
the tritium would be purified. More details on the design of the TPBARs are included in Appendix A.

The current DOE TPBAR design is based on the numerous studies and tests performed for an original design to be used in Washington Nuclear Plant Unit-1, a Babcock and Wilcox (now Framatome Technologies, Inc.) reactor design, as part of new production reactor efforts in the early 1990s. The characteristics of a TPBAR design as shown in Table 3–1 show that TPBAR assemblies can be used in either a Westinghouse (Watts Bar or Sequoyah) or a Babcock and Wilcox (Bellefonte) reactor design. The TPBARs, as currently designed, are being irradiated at the Watts bar Nuclear Plant. The final TPBAR design has been completed and is being reviewed by the NRC (62 FR 47835). The analyses of environmental impacts presented in this EIS are based on design parameters for tritium production and a maximum leakage rate of tritium for each TPBAR. These parameters are independent of the type of reactor design used.

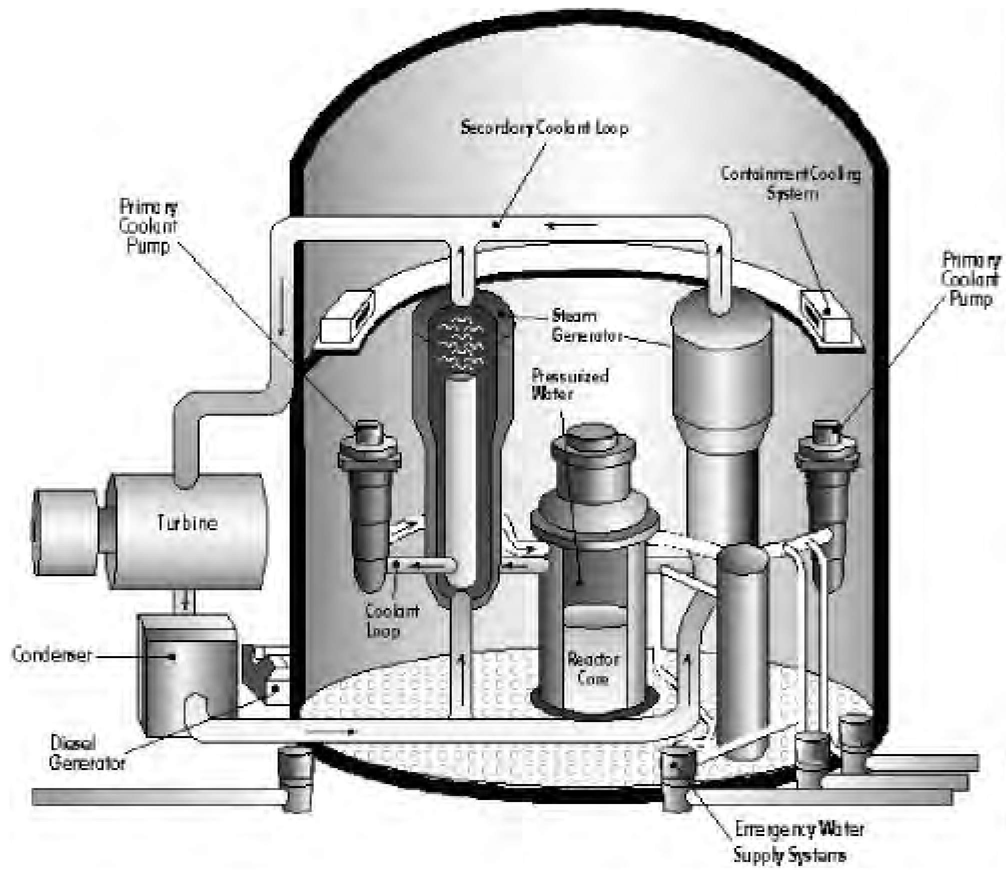


Figure 3–1 Typical Pressurized Water Reactor Schematic

The complete process of producing tritium in a CLWR can be explained in the following way. Nuclear reactors require periodic refueling. In a tritium-producing CLWR, spent fuel would be removed during periodic reactor refueling, and fresh fuel assemblies and TPBARs would be inserted in the reactor core. These new TPBARs would be transported from the TPBAR fabrication facility to the reactor site inside fresh fuel assemblies as part of the regular fresh fuel supply. During the reactor's normal operations cycle, (approximately 18 months), the TPBARs would be irradiated and the tritium generated would be chemically bound in the tritium "getter." During the subsequent refueling period, the fuel assemblies containing the TPBARs would be removed from the reactor core and transferred to the spent fuel pool where the irradiated TPBAR assemblies would be removed from the fuel assemblies. After removal from the fuel assemblies, the TPBARs would be mechanically separated from the hold-down assembly (see Figure 3–3) and placed in a 12-foot long consolidation container. The consolidation container, which in cross-section resembles the 17 × 17 array matrix of the fuel assembly, provides 289 positions for individual TPBARs. The consolidation container with the 289 TPBARs, separated from their hold-down assemblies, would be placed in a shipping cask, sealed, placed on a truck or train, and transported to the proposed Tritium Extraction Facility at the Savannah River Site. The tritium would be extracted in a high-temperature heating/vacuum process. The base plates and any other low-level radioactive waste attributed to tritium production would be placed in a different transportation package and transported to the Barnwell disposal facility for commercial low-level radioactive waste or the Savannah River Site's low-level radioactive waste facility, both in South Carolina. The cycle from TPBAR fabrication and assembly through reactor irradiation and shipment to the Savannah River Site's proposed Tritium Extraction Facility is depicted in Figure 1–1.

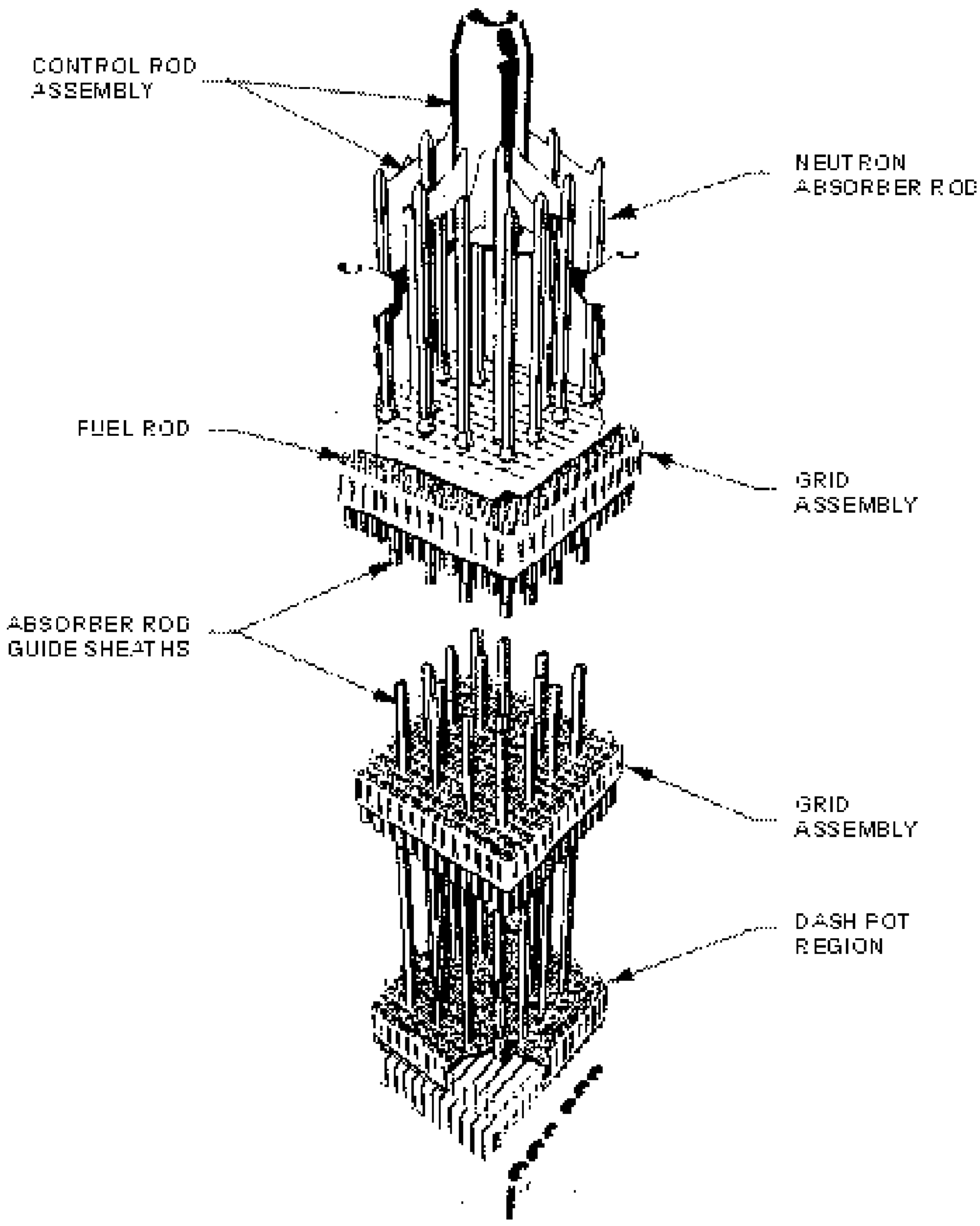


Figure 3–2 Typical Fuel Assembly Cross-Sections

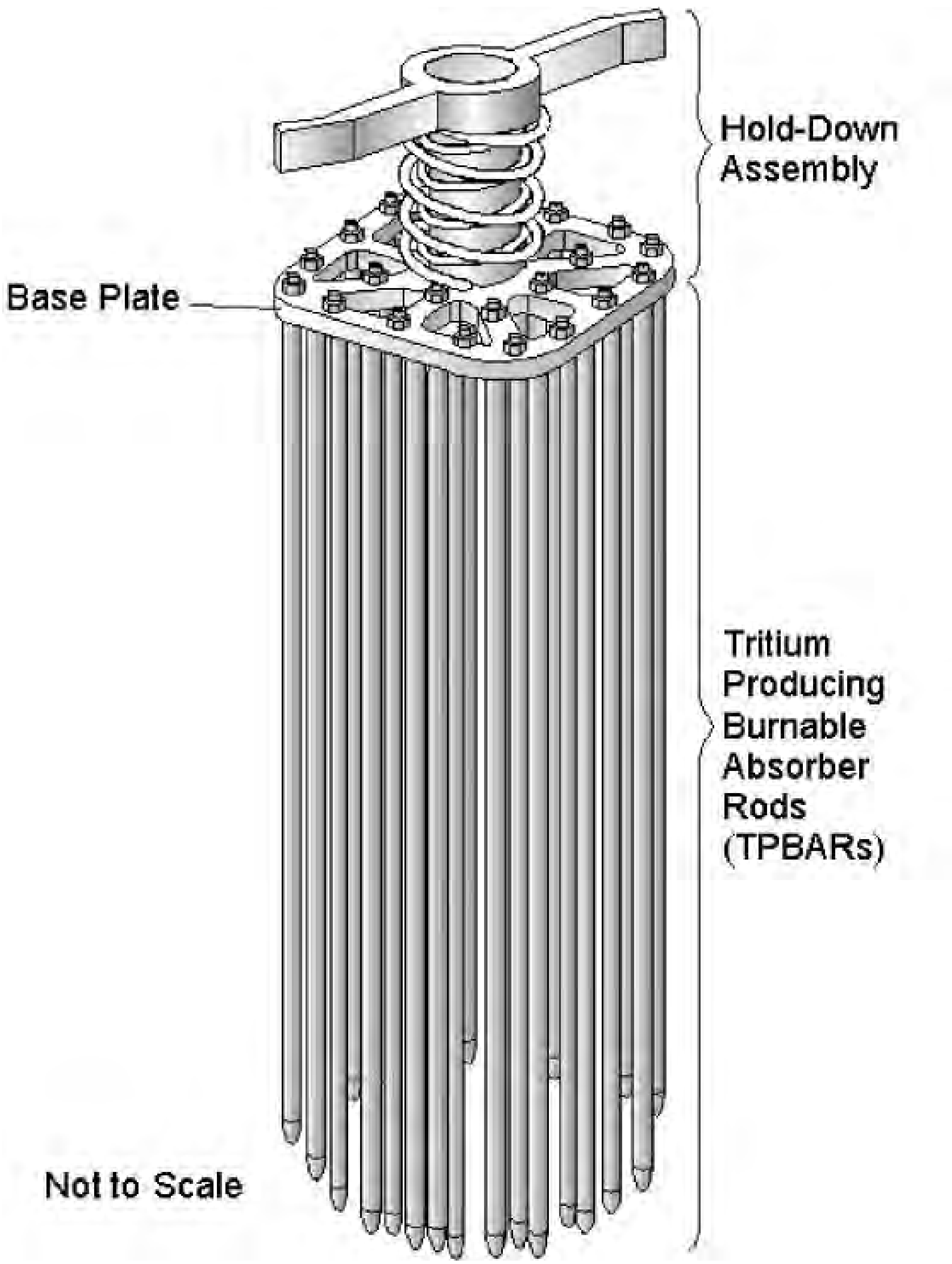


Figure 3–3 Typical TPBAR Assembly

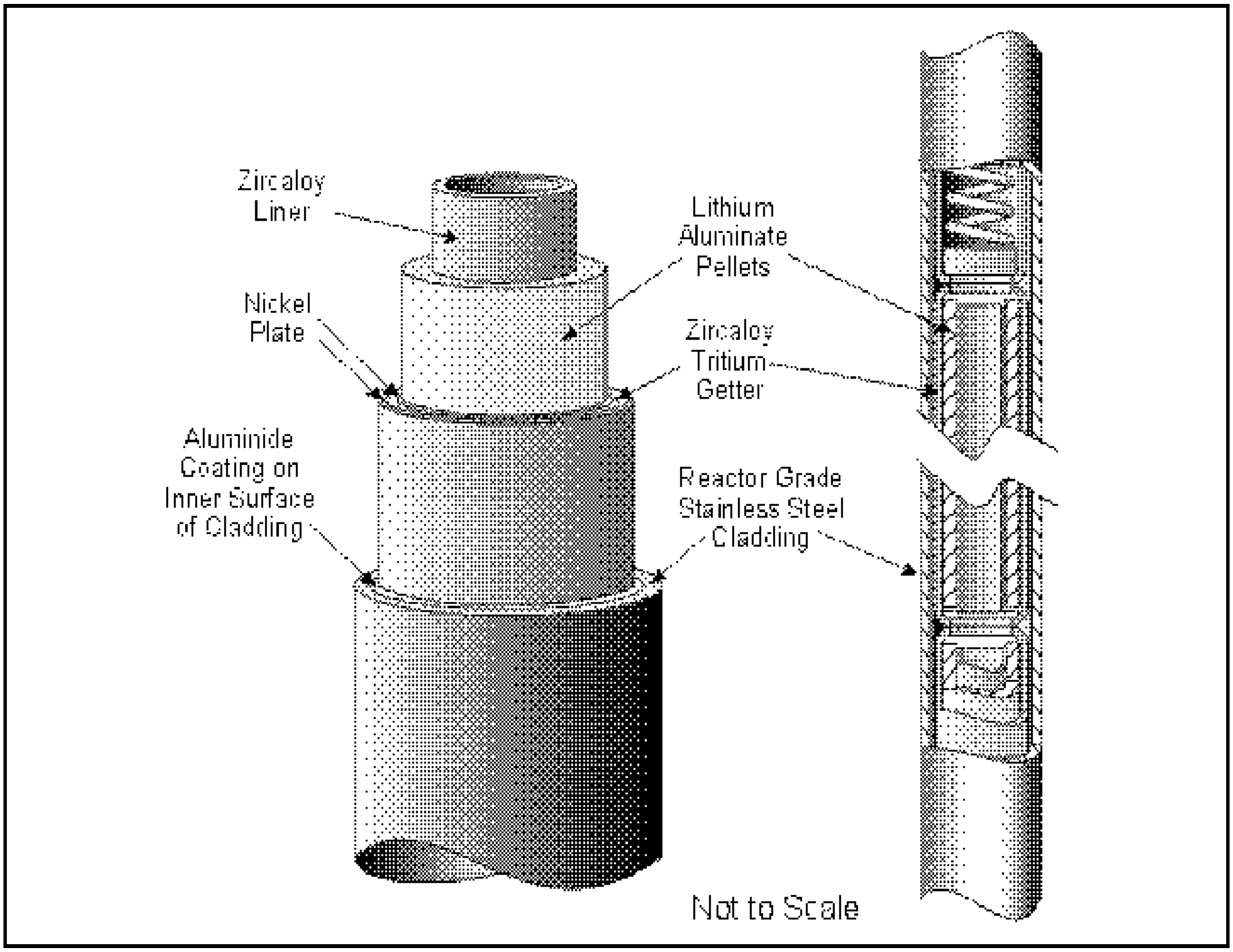


Figure 3–4 Sketch of TPBAR Components

Table 3–1 Comparison of TPBAR with Typical Burnable Absorber Rod Characteristics

Parameter	*Burnable Absorber Rod 17×17 Fuel Assembly*	*TPBAR 17×17 Fuel Assembly*
Overall length (in)	152	152
Total weight (lb)	1.8	2.26
Absorber length (in)	142	~142
Absorber outside diameter (in) Thickness (in)	[ ][a] [ ][a]	0.303 0.040
Absorber material	Silicon-boron oxides (SiO_2-B_2O_3)	Lithium aluminate ($LiAlO_2$)
Outer cladding outside diameter (in)	0.381	0.381
Cladding material	Stainless steel type 304SS	Stainless steel type 316SS

[a] Denotes proprietary data of burnable absorber rod vendor.
Source: PNNL 1997.

3.1.3 Impacts of Tritium Production on Reactor Operations

The replacement of burnable absorber rods with TPBARs should have few impacts on the normal operation of the reactor. The normal power distribution within the core and reactor coolant flow and its distribution within the core would remain within existing technical specification limits. Some tritium is expected to permeate through the TPBARs during normal operation, which would increase the quantity of tritium in the reactor's coolant water system. Since tritium is a type, or isotope, of the hydrogen atom, once the tritium is in the reactor's coolant water system, it could combine with oxygen to become part of a water molecule and could eventually be released to the environment. The impacts associated with this increase in tritium releases are evaluated in this EIS.

The operational differences between a tritium production reactor and nuclear power plant operation without tritium production were determined by evaluating each environmental resource area and identifying the operational parameters that would change in a typical CLWR as a result of operating in a tritium production mode. The summarized operational differences are:

- Accident conditions—The physical changes to the reactor core would involve replacing some burnable absorber rods with TPBARs. This change would increase the estimated quantity of radionuclides assumed to be released in the analysis.

- Personnel—Additional TPBAR handling and shipping activities would create new jobs and possibly require the hiring of extra personnel at the CLWR sites.

- Effluent—The tritium content in the liquid effluent and gaseous emissions is expected to increase as a result of the presence of TPBARs in the reactor.

- Waste—Additional activities associated with handling, processing, and shipping TPBAR assemblies are expected to increase low-level radioactive waste generation rates.

- Spent fuel—Additional spent fuel could be generated when a reactor operates in a tritium-producing mode. Depending on existing spent fuel capacity, additional storage for spent fuel could be required.

- Public and worker exposure—The increased levels of tritium in the reactor coolant and the additional activities required in the handling and processing of TPBARs would result in increased radiation exposure of the public, operations workers, and maintenance personnel.

- Transportation and handling—Irradiated TPBAR assemblies would be packaged and transported from the CLWR sites to the Savannah River Site for tritium extraction and purification. Some additional risks of an accident en route would be expected. In addition, low-level radioactive waste associated with the TPBARs would be packaged and transported for disposal at the Barnwell disposal facility or the Savannah River Site.

The environmental impacts associated with these operational differences are evaluated in Chapter 5 of the CLWR EIS as they affect each environmental resource area (e.g., land resources, air resources, water resources, socioeconomics). In addition, this EIS evaluates the environmental impacts associated with any construction necessary to complete currently unfinished Bellefonte 1 and 2.

3.2 DEVELOPMENT OF ALTERNATIVES

3.2.1 Planning Assumptions and Basis for Analysis

The *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (DOE 1995b) identified two options for producing tritium in a CLWR: (1) the purchase by DOE of an existing operating or partially completed CLWR and conversion of the facility to tritium production for defense purposes; and (2) the purchase of irradiation services from an operating CLWR to produce tritium using DOE-supplied TPBARs. Pursuing these options, on June 3, 1997, DOE issued a Request for Proposal (DOE 1997a) to all pressurized water reactor operators in the United States, delineating the technical requirements and financial conditions necessary for implementing these options.

Under this EIS, DOE proposes to produce, in one or more CLWRs, the tritium needed to maintain the Nation's nuclear stockpile. The CLWRs were identified through a procurement process. The procurement process discussed in Section 1.1.4, identified the following CLWRs where tritium could be produced: the Watts Bar Nuclear Power Plant, Unit 1 (Watts Bar 1); the Sequoyah Nuclear Power Plant, Units 1 and/or 2 (Sequoyah 1 and/or Sequoyah 2); and the Bellefonte Nuclear Power Plant, Units 1 and/or 2 (Bellefonte 1 and/or Bellefonte 2). All of these reactor units are operated by the Tennessee Valley Authority (TVA). Watts Bar 1, Sequoyah 1, and Sequoyah 2 are currently operating units, while Bellefonte 1 and Bellefonte 2 are partially completed units that would have to be completed before tritium could be produced. Based on the procurement process, DOE considers this set of five TVA reactor units to be suitable alternatives for tritium production. Descriptions of these reactor plants are included in Section 3.2.5.

This EIS evaluates the direct, indirect, and cumulative impacts associated with fabrication of the TPBARs, the irradiation and handling of the TPBARs at the reactor facility, and the transportation of all nonirradiated and irradiated materials, including wastes associated with tritium production, to and from the appropriate facilities. The planning assumptions and considerations that form the basis of the analyses and impact assessments presented in this EIS are as follows.

- The purpose of DOE's action is to produce in a CLWR the tritium needed to maintain the Nation's nuclear weapons stockpile. For the purposes of analysis in this EIS, DOE assumed that the CLWR program would be designed such that it could produce up to 3 kilograms of tritium per year. Considering the current design of the TPBARs and the efficiency of the tritium extraction process, this would involve the irradiation of up to 6,000 TPBARs (DOE 1996b) in an 18-month refueling cycle (4,000 TPBARs per year). The maximum number of TPBARs that could be irradiated at each reactor unit without significantly disturbing the normal electricity-producing mode of reactor operation is approximately 3,400 TPBARs; the exact number depends on the specific design of the reactor. This EIS evaluates the impacts at each reactor site by considering a range of 1,000 to 3,400 TPBARs. A sensitivity analysis of the irradiation of fewer than 1,000 TPBARs is also included in Section 5.2.9.

  As explained in Appendix A of this EIS, it is technically feasible to produce larger quantities of tritium in a single reactor by changing some of the design parameters of the TPBARs and some technical parameters of the host reactor core, including shortening the refueling cycle. DOE does not foresee the implementation of this mode of production in any of the reactor units considered in this CLWR EIS. For the purpose of completeness, however, the sensitivity analysis in Section 5.2.9 also addresses the environmental impacts of changing the existing design parameters of the TPBARs and some of the operating parameters of the host reactors to maximize tritium production.

- For alternatives involving currently operating reactor units, this EIS assesses the environmental impacts of the changes to existing operations resulting from the insertion of the TPBARs into the reactors. These environmental impact changes would be in addition to the normal environmental impacts of the ongoing operation of the reactors. For alternatives involving partially completed reactors, the EIS assesses the impacts resulting of construction to complete the reactors and operation of the reactors.

- The EIS addresses the impacts of the No Action Alternative for each of the reactor units by assuming the continuation of the current status and current activities at each site. Because the TVA units are the only potential CLWR units considered as a result of the procurement process, the No Action Alternative means that no tritium would be produced in any CLWR. For this reason, this EIS, consistent with the Record of Decision on the *Final Programmatic Environmental Impacts Statement for Tritium Supply and Recycling*, summarizes the impacts of producing tritium in a linear accelerator (60 FR 63878). The impacts of constructing and operating the accelerator are described in detail in the *Accelerator Production of Tritium at the Savannah River Site Environmental Impact Statement* (DOE 1997e) (see Section 5.2.11).

- The EIS assesses the environmental impacts of tritium production in CLWRs for a period of 40 years, starting with the delivery of irradiated TPBARs at the Tritium Extraction Facility in the year 2005 (approximately). For alternatives involving the partially completed reactor(s), it is assumed that any construction activities needed for the completion of Bellefonte 1 (and any other start-up tests and activities) would take place during the time period between 1999 and 2004, at which time the completed reactor would be fully operational. In the event Bellefonte 2 was also selected for completion, Bellefonte 1 would come on line in approximately 2005 while Bellefonte 2 would begin operation in approximately 2007.

- CLWRs are licensed by NRC to operate for 40 years. Currently operating reactors are not in a position to continue operation beyond 40 years without NRC approval for "life extension." Some of the environmental impacts associated with life extension activities would be attributable to tritium production. The NRC has addressed the generic impacts of life extension in the *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (NRC 1996a). The life extension impacts associated with alternatives involving the currently operating units are based on this publication and are discussed in Section 5.2.4 of this EIS. Tritium production is not expected to affect relicensing. Life extension impacts for a partially completed reactor would not be an issue, since it would be expected to operate for 40 years after its completion.

- Tritium production in a currently operating reactor would not be expected to affect the radiological condition of the reactor at the end of its life. Therefore, environmental impacts associated with decommissioning and decontamination activities would be attributed to the normal operation of the reactor as an electricity-producing unit. For alternatives involving a partially completed reactor, the impacts from decommissioning and decontamination activities are evaluated in this EIS. Decommissioning and decontamination impacts are discussed in Section 5.2.5 of the EIS and are based on the generic EIS issued by the NRC entitled *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities* (NRC 1988).

- Fabrication of the TPBARs would take place in a commercial facility that normally fabricates and assembles the components for the fresh fuel used in the CLWRs. A description of the fabrication process and any differences between fabricating standard burnable absorber rods versus TPBARs and material resources are included in Section 5.2.7. Impacts of the transportation of the nonirradiated TPBARs to the reactor facilities are evaluated in this EIS by considering a number of possible commercial fabrication and assembly facilities.

- An analysis of the environmental impacts of the transportation of nonirradiated and irradiated materials is presented in Section 5.2.8. The analysis for the transportation impacts assumes that 4,000 irradiated TPBARs per year are transported from the tritium production sites to the Savannah River Site. This EIS assumes that the transportation of irradiated TPBARs would be made by truck- or rail-sized casks of the type used to transport spent nuclear fuel in the United States. In addition to the transportation of irradiated TPBARs, the CLWR EIS considers the transportation of the irradiated TPBAR hardware, which would be separated from the rods at the reactor site, and other low-level radioactive waste directly attributed to tritium production. The CLWR EIS assumes that this low-level radioactive waste is transported in separate packages to either the Savannah River Site, where it would be disposed at the low-level radioactive waste facility, or the Barnwell disposal facility, where the low-level radioactive waste of the reactor facilities is normally transported and disposed of. Both truck routes and rail routes are evaluated. Details on the assumptions, method, and consequences of the transportation of TPBARs and low-level radioactive waste are presented in Appendix E.

- The radiological exposures from normal operation and accident conditions are evaluated for the general public and the workers at the reactor sites. For alternatives involving currently operating reactors, the CLWR EIS assesses the exposures from any additional radioactive releases that would result from the irradiation and consolidation of the TPBARs at the reactor. [Note: Consolidation occurs when the TPBARs from several fuel assemblies are inserted into a container for shipment offsite in a transportation cask.] For alternatives involving a partially completed reactor, in addition to irradiation and consolidation of TPBARs, this EIS also assesses the exposures from all radioactive releases that could result from both normal operation and accident conditions. Details on the assumptions used for radiological releases are included in Appendix C for normal operation and Appendix D for accidents.

- Production of tritium in a CLWR would increase the generation rate of spent fuel if more than approximately 2,000 TPBARs are irradiated in a fuel cycle (WEC 1998). Normally (i.e., during normal operation with no tritium production), fuel assemblies are used in more than one cycle. However, in order to maximize tritium production TPBARs would be inserted in fresh fuel assemblies. In accordance with the Nuclear Waste Policy Act of 1982, DOE is planning to manage all spent nuclear fuel of a national repository. Siting and development of a repository is ongoing and the location and opening date for a suitable repository has not yet been determined. Accordingly, for the purposes of this EIS, the initial management of any additional spent nuclear fuel which may be generated as a result of tritium production is assumed to be stored onsite in a generic dry independent spent fuel storage installation (ISFSI) pending the availability of a suitable repository. The environmental impacts from the construction and operation of an ISFSI are addressed in Section 5.2.6. However, no decision will be made to either construct or operate ISFSI as a result of this EIS. Appropriate NEPA documentation would be prepared prior to the construction of a dry cask spent fuel storage facility.

- The methodology used to assess the environmental impacts of tritium production in CLWRs is described in Appendix B.

3.2.2 Reactor Options Considered

Currently, there are 105 CLWRs licensed to operate in the United States, of which 72 are pressurized water reactors. Only pressurized water reactors are suitable for producing tritium with the current TPBAR design. There are also a number of pressurized water reactors for which construction activities have stopped. Construction work on all of the partially completed reactors has been canceled, with the exception of three: Bellefonte 1, Bellefonte 2, and Watts Bar Nuclear Plant, Unit 2 (Watts Bar 2). For these, construction has been deferred indefinitely.

DOE issued a Request for Proposals for the CLWR production of tritium. DOE stated in the Request for Proposals its intent to select one or both of two approaches: (1) the acquisition of CLWR irradiation services for tritium production, or (2) the purchase of an operating CLWR by DOE for production of tritium. As discussed in Section 1.1.4, the only qualified response to DOE's solicitation came from TVA, the operator of Watts Bar 1, Sequoyah 1, and Sequoyah 2. TVA also maintains the partially completed units of Watts Bar 2, Bellefonte 1, and Bellefonte 2.

As a result of DOE's procurement process, all CLWRs except five of the pressurized water reactor units operated by TVA were eliminated from consideration as Reasonable Alternative reactor options. A sixth TVA reactor, Watts Bar 2, was considered but eliminated because, compared to the other five TVA reactor units that have a design suitable for tritium production, utilizing Watts Bar 2 would involve significantly higher construction costs. The cost to complete Watts Bar 2 (which is 50 percent complete) has been estimated to be roughly twice the cost to complete Bellefonte 2 (which is 57 percent complete). Much of the difference in cost between finishing Watts Bar 2 and Bellefonte 2 is attributable to the resolution of design and construction issues which exist on Watts Bar 2 but not on Bellefonte 2. Moreover, construction completion plans for Watts Bar 2 have not reached the level of refinement and reliability associated with those plans for Bellefonte 1 and Bellefonte 2. Consequently, relative to the other five TVA reactor units whose impacts are analyzed in this EIS, Watts Bar 2 is not a reasonable alternative reactor option and has been eliminated from detailed study.

Also, eliminated from detailed study was the completion and operation of Bellefonte 2 without completion and operation of Bellefonte 1. Bellefonte 1 is 90 percent complete; Bellefonte 2 is only 57 percent complete. The costs associated with completion of Bellefonte 1 include all the necessary systems and equipment that would be shared between the two units—equal to approximately 70 percent of the total cost for completion of both units. Therefore, completion of Bellefonte 2 without completion of Bellefonte 1 is economically impractical.

3.2.3 Reasonable Alternatives

The reasonable alternatives presented in the EIS are formed by the options available to DOE in implementing the project. These options include the fabrication facility options, the reactor facility options, and the transportation alternative modes, routes, and destinations.

The fabrication facility options include all commercial facilities that fabricate TPBARs and the pressurized water reactor fuel and its components for the currently operating reactor facilities. These are Framatome-Cogema Fuels, Lynchburg, Virginia; BWX Technologies, Inc., Lynchburg, Virginia; Siemens Power Corporation, Richland, Washington; and Westinghouse Electric, Columbia, South Carolina. These fuel fabrication facilities could fabricate TPBARs immediately without any technology transfers, without a need for startup time, and with quality assurance standards in place and working. Another commercial facility, General Electric in Wilmington, North Carolina, would only manufacture TPBARs. Following the manufacture of TPBARs, final assembly would take place at one of the other facilities. Environmental impacts of the fabrication of TPBARs are discussed in Section 5.2.7.

To irradiate up to 6,000 TPBARs during an 18-month refueling cycle, DOE could use one or more reactors. Considering that a maximum number of 3,400 TPBARs could be irradiated in a single reactor, at least two reactors would be needed for the 6,000 TPBARs. Considering also that additional spent nuclear fuel generation attributed to tritium production starts approximately with the irradiation of approximately 2,000 TPBARs in a single reactor, DOE could use as many as three reactors to irradiate 6,000 TPBARs without increasing the amount of spent nuclear fuel. Mathematically, DOE has the option of selecting 1 of the 18 combinations of reactor units presented in **Table 3–2**. These 18 combinations form the Reasonable Alternatives of the irradiation element of the project. For the purpose of simplicity, the analysis of the environmental impacts for each reactor site is performed using conditions and assumptions that would bracket the impacts at each site. The impacts for each of the 18 irradiation alternatives would be the sum of the impacts at each of the sites involved. For example, the impacts associated with Alternative #7 in Table 3–2 would be the sum of the impacts of the operation of Watts Bar 1 and the completion and operation of Bellefonte 1. The environmental impacts by reactor site are discussed in Section 5.2 and summarized in Section 3.2.6.

Table 3–2 CLWR Tritium Production Program Reasonable Alternatives

Alternative	*Watts Bar 1 Operation*	*Sequoyah 1 Operation*	*Sequoyah 2 Operation*	*Bellefonte 1 Complete Construction and Operation*	*Bellefonte 2 Complete Construction and Operation*[a]
One Reactor[b]					
1					
2					
3					
4					
Two Reactor Combinations					
5					
6					
7					
8					
9					
10					
11					
Three Reactor Combinations					
12					
13					
14					
15					
16					
17					
18					

[a] Construction on Bellefonte 2 may be completed only if Bellefonte 1 is completed and operated.
[b] The one-reactor alternative could not produce 3 kilograms of tritium per year. However, it could satisfy reduced tritium requirements.

The transportation of nonirradiated and irradiated TPBARs presents options in transportation modes (truck versus rail), alternative transportation routes between facilities, alternative fabrication locations, and alternative low-level radioactive waste destinations. The full development of the various transportation options and the associated environmental impacts from these options are discussed in Section 5.2.8 and Appendix E. Transportation impacts are summarized in Section 3.2.6.

3.2.4 No Action Alternative

On the basis of the October 1995 *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling* (DOE 1995b), the DOE, in its December 12, 1995, Record of Decision (60 FR 63878), selected a dual-track path for tritium production technologies: accelerator production of tritium, and the production of tritium in a CLWR. The Record of Decision further stipulated that one alternative would be selected as the primary source of tritium and that the other alternative, if feasible, would be developed as a backup tritium source. Based on that Record of Decision, if tritium is not produced in a CLWR, it will be produced in an accelerator. Accordingly, for purposes of analysis in this EIS, the No Action Alternative assumes the continued operation of Watts Bar 1, Sequoyah 1, and Sequoyah 2 for the generation of electricity, and the deferral of construction activities necessary for completion of Bellefonte 1 and Bellefonte 2 as nuclear units. Consequently, this No Action alternative entails the production of tritium in an accelerator. A summary of the environmental impacts associated with the production of tritium in an accelerator is contained in Section 5.2.11. That summary is based on the *Accelerator for Production of Tritium at the Savannah River Site Draft Environmental Impact Statement* (DOE 1997e).

3.2.5 Reactor Options

3.2.5.1 Watts Bar Nuclear Plant, Unit 1

Watts Bar 1 is located on a 716-hectare (1,770-acre) site in Rhea County, Tennessee, on the Tennessee River at Tennessee River Mile 528, approximately 80 kilometers (50 miles) northeast of Chattanooga, Tennessee (TVA 1976, TVA 1995c). A second, partially completed unit, Watts Bar 2, also is located at this site. Watts Bar 2 was considered and dismissed as an alternative for tritium production in the CLWR EIS, as described in Section 3.2.2. The main land use activities of the surrounding area are described in Section 4.2.1.1. The general arrangement of the Watts Bar Nuclear Plant is shown in **Figure 3–5**.

Watts Bar 1 began commercial power operation in May 1996 (NRC 1997a). The Watts Bar 1 structures include a reactor containment building, a turbine building, an auxiliary building, a service building, a water pumping station for circulating water in the condenser, a diesel generator building, a river intake pumping station, a natural-draft cooling tower, a transformer yard, a 500-kilovolt switchyard and a 161-kilovolt switchyard, a spent nuclear fuel storage facility, and sewage treatment facilities (TVA 1976). The reactor containment building houses a pressurized water reactor designed and manufactured by the Westinghouse Electric Corporation. No modifications are expected to be necessary for Watts Bar 1 to irradiate TPBARs. Design equipment and facilities are sufficient to load and unload the TPBAR assemblies. During normal operation with tritium production, the plant could employ a few more workers (less than 10) in addition to the 809 presently employed (TVA 1998a). The spent nuclear fuel storage capacity is not sufficient for 40 years of operation with or without TPBARs. This EIS evaluates the impacts of a generic dry cask spent nuclear fuel storage facility in Section 5.2.6.

The general design specifications of the unit are provided in **Table 3–3.**

Table 3–3 General Design Specifications of Watts Bar Nuclear Plant Unit 1

Criteria	*Quantity*
Core thermal power level	3,411 MWt
Plant capacity factor	0.80
Total steam flow rate	1.51×10^7 lb/hr
Electrical generation (net)	1,160 MWe
Normal fuel cycle	18 months
Size of full core fuel load	193 fuel assemblies (or 89.5 MTU)

Sources: TVA 1976, TVA 1995d.

In a tritium-producing mode of operation, up to 3,400 TPBARs could be placed in the core, occupying the same fuel assembly locations as the burnable absorber rods now in use. The TPBARs would be irradiated on an 18-month refueling-cycle schedule. During operation, heat released from the fissioning fuel is transported by the reactor cooling water to the steam generators. The overall thermal efficiency of the plant is about 34 percent (TVA 1995c). After passing through the turbine, the steam is condensed by moving through a

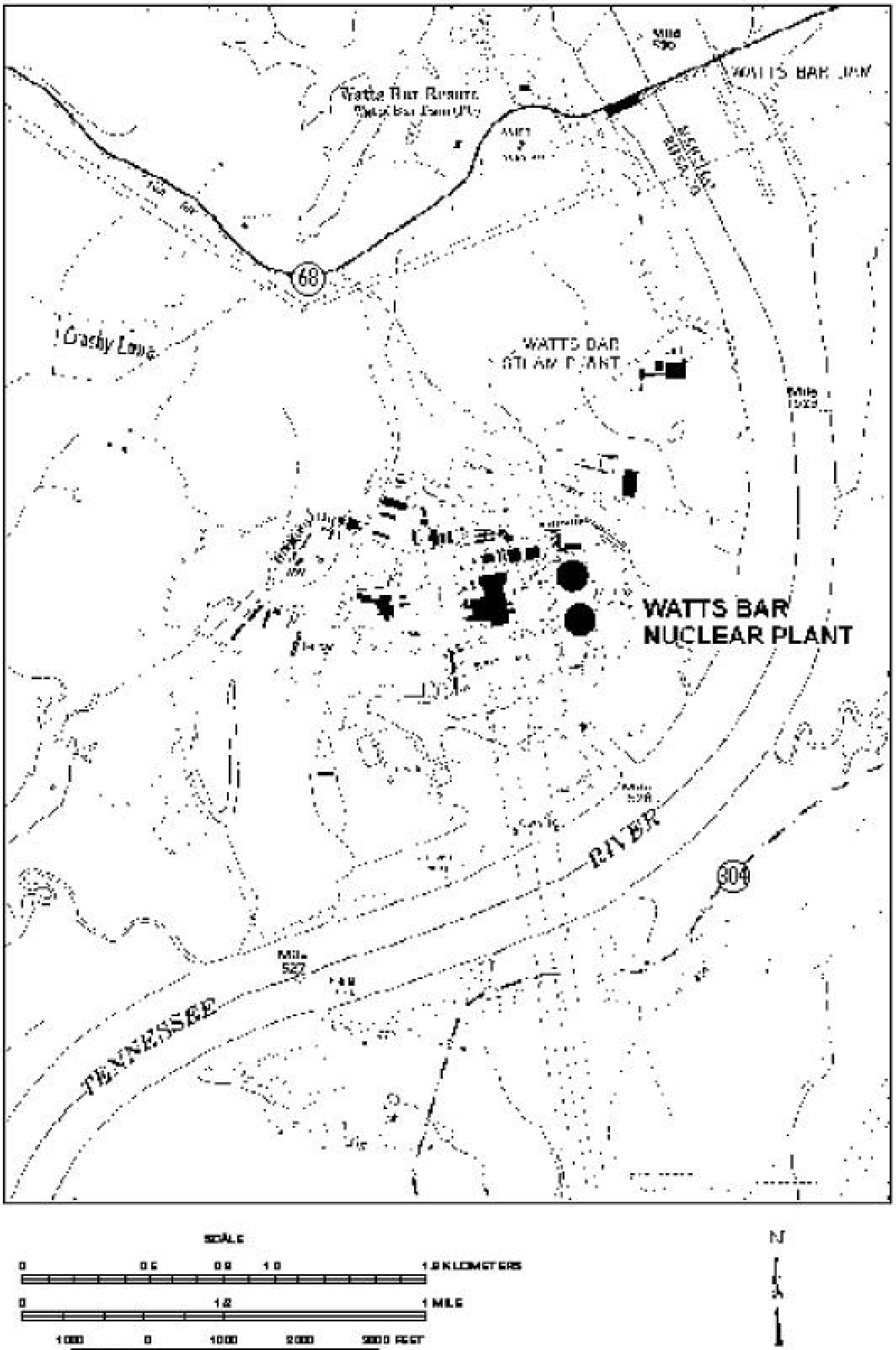


Figure 3–5 Watts Bar Nuclear Plant

condenser cooled with recirculated water. This recirculated condenser water is then cooled by passing it through a natural-draft (without fans), evaporative cooling tower. Although the cooling system is of the so-called "closed type," makeup water from the Tennessee River is needed to replace water losses due to evaporation, drift, and blowdown. Blowdown is a process to remove excess dissolved solids.

At full power, the temperature of the water flowing through the condenser is raised by approximately 20 (36 leaks, and blowdown (mainly associated with cooling tower operation), approximately 156,332 liters per minute (41,300 gallons per minute) (TVA 1976) is withdrawn from the Tennessee River. Blowdown from the natural-draft cooling tower is discharged into the Tennessee River at a normal rate of 106,593 liters per minute (28,160 gallons per minute) (TVA 1976). A diffuser system, disperses the blowdown into the river water, thus limiting the rise in temperature to less than 3 (5 under a National Pollutant Discharge Elimination System (NPDES) Permit (TN DEC 1993b).

The operation of Watts Bar 1 produces radioactive fission products and activates corrosion products in the reactor coolant system. Small amounts of these radioactive products enter the cooling system water. Radionuclides are removed from the cooling water through a chemical water treatment system. The gases and liquids are processed, stored, and monitored within the facility to minimize the radioactive nuclides that could be released to the atmosphere and into the Tennessee River. Radioactive waste is generated in this treatment system. The Watts Bar 1 liquid contaminant releases to the environment during normal operations are identified in **Table 3–4.**

Table 3–4 Annual Liquid Releases to the Environment from Operation of Watts Bar 1

Materials	*Quantity*
Chemicals	1,098,040 kg[a]
Tritium	639 Ci[b]
Other Radionuclides	1.32 Ci[b]

[a] TVA 1995a.
[b] TVA 1998e.

Radioactive gaseous emission releases are controlled by using a ventilation system consisting of gas decay tanks, filter components, and related piping, ductwork, valves, and fans. The main sources of gaseous radioactive emissions are generated in conjunction with degassing of the primary coolant during letdown depressurization of the reactor cooling water into the various process equipment and tanks associated with the makeup water and purification systems. Gases from the reactor are trapped in holding tanks to allow short-lived radioactive gases to decay before they are released to the shield building vent at a controlled rate through high efficiency particulate air filters and charcoal absorbers. Another source of radioactive gaseous emissions is the purging of the reactor containment building, which is also routed through high efficiency particulate air filters and charcoal absorbers prior to release.

Nonradiological criteria and hazardous air pollutant emissions are based on the operation of equipment at Watts Bar 1 at full power. Air pollutant sources include five diesel generators, one diesel generator used for security power, one diesel pump for firefighting, two auxiliary boilers fired with No. 2 fuel oil (0.5 percent sulfur), two natural-draft cooling towers, the lube oil system, two fixed-roof tanks for storing No. 2 fuel oil, the paint shop, and the sandblast shop. Emission factors for both nonradiological criteria and hazardous air pollutants are based on the EPA's *Compilation of Air Pollutant Emission Factors, AP-42* (EPA 1996).

The gaseous waste releases from Watts Bar 1 during normal operations are summarized in **Table 3–5.**

Table 3–5 Summary of Annual Watts Bar 1 Gaseous Emissions

Constituents	*Quantity*
Particulate matter	20,366 kg [a]
Carbon monoxide	21,802 kg [a]
Sulfur dioxide	77,634 kg [a]
Nitrogen dioxide	84,584 kg [a]
Volatile organic compounds	41,602 kg [a]
Hazardous air pollutants	126 kg [a]
Tritium	5.57 Ci [b]
Other radionuclides	282.5 Ci [b]

[a] TVA 1998a.
[b] TVA 1998e.

Several hazardous substances and chemicals are used on a regular basis in the operation of Watts Bar 1. This results in the generation of hazardous waste that is controlled, stored, and managed in accordance with the Resource Conservation and Recovery Act (RCRA) (40 CFR 260). This waste is disposed of offsite at RCRA-permitted treatment and disposal facilities. Solid waste such as noncontaminated clothing, rags, office paper, boxes, and noncontaminated filters is also generated on a regular basis and is disposed of as solid waste.

The waste and spent fuel generation volumes for Watts Bar 1 during normal operation are summarized in **Table 3–6.**

Table 3–6 Summary of Annual Watts Bar 1 Waste and Spent Fuel Generation Rates

Waste Type	*Volume or Mass*
Hazardous waste	1.025 m^3
Nonhazardous solid waste	853,438 kg
Low-level radioactive waste	40 m^3
Mixed low-level radioactive waste	< 1 m^3
Spent fuel (per 18-month cycle)	16 m^3 (or 80 fuel assemblies)

Sources: TVA 1976, TVA 1995c, TVA 1995a.

The reactor is shut down for refueling and maintenance as part of a normal fuel cycle of 18 months. During this shutdown period, the irradiated TPBARs/spent fuel assemblies would be removed from the reactor and placed in the spent fuel pool for cooling. After approximately one to two months, the TPBARs would be removed from the fuel assemblies, loaded into transportation casks, and sent to the proposed Tritium Extraction Facility at the Savannah River Site for tritium extraction and purification.

3.2.5.2 Sequoyah Nuclear Plant, Units 1 and 2

Sequoyah 1 and Sequoyah 2 are operating, pressurized CLWR nuclear power plants. The units are located on a 212-hectare (525-acre) site in Hamilton County, Tennessee, on the Tennessee River at Tennessee River Mile 484.5, approximately 12 kilometers (7.5 miles) northeast of the nearest city limit of Chattanooga, Tennessee (TVA 1996b, TVA 1974a). The main land use activities of the surrounding area are described in Section 4.2.2 The general arrangement of the Sequoyah Nuclear Plant is shown in **Figure 3–6**.

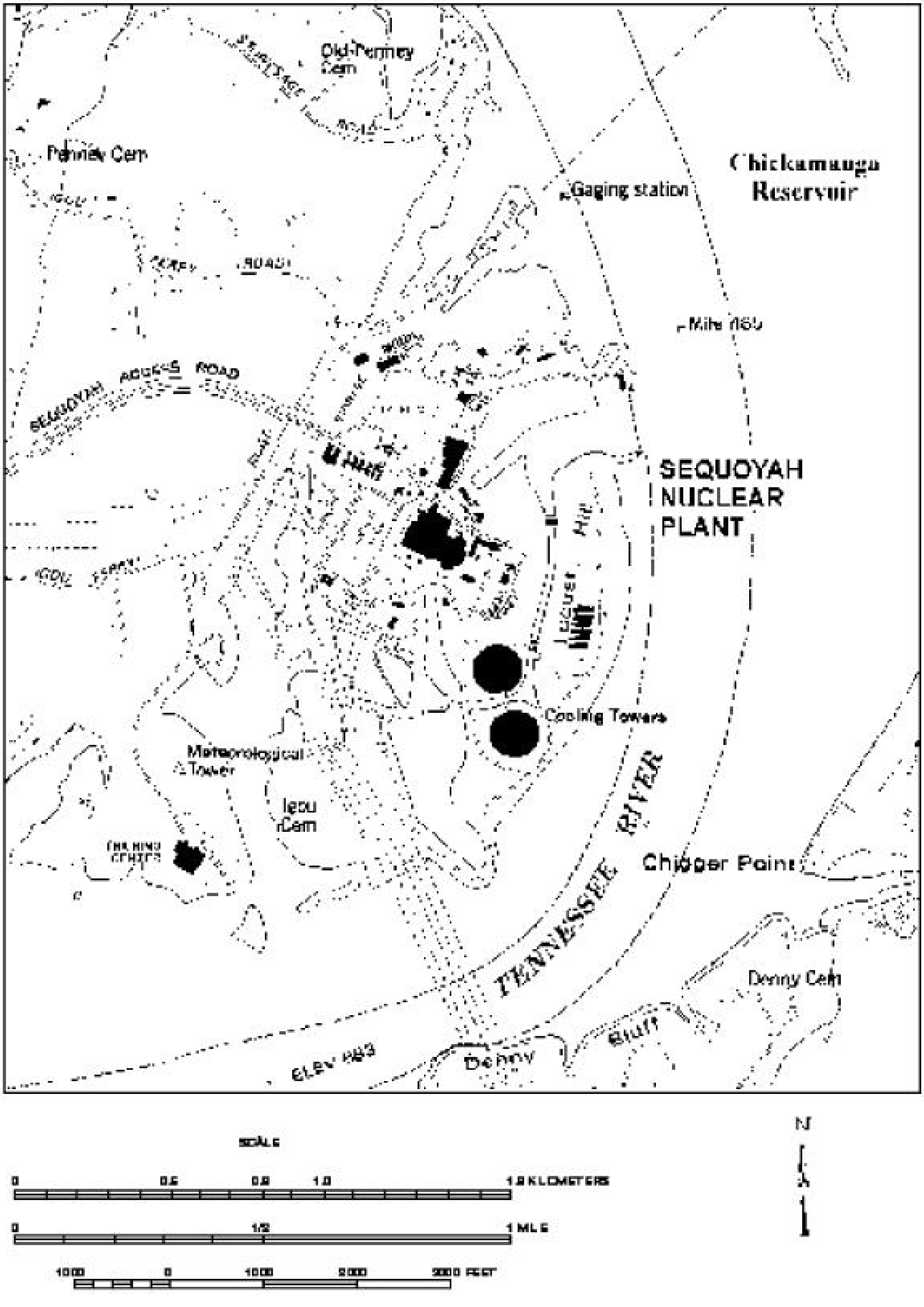


Figure 3–6 Sequoyah Nuclear Plant Units 1 and 2

Sequoyah 1 began commercial operation in July 1981, and Sequoyah 2 began commercial operation in June 1982 (TVA 1996b). The nuclear steam supply systems, designed and manufactured by the Westinghouse Electric Corporation, include the reactor vessel, steam generators, and associated piping and pumps. These are housed in two reactor containment buildings. The balance of the nuclear power plant includes: a turbine building, an auxiliary building, a service and office building, a control building, a condenser circulating water pumping station, a diesel generator building, a river intake pumping station, two natural-draft cooling towers, a transformer yard, a 500-kilovolt switchyard and a 161-kilovolt switchyard, spent nuclear fuel storage facilities, and sewage treatment facilities (TVA 1974a). No modifications are expected to be needed for Sequoyah 1 and Sequoyah 2 to irradiate TPBARs. Equipment and facilities are sufficient to load and unload the TPBAR assemblies. Tritium production could require the addition of a few more employees (fewer than 10 per unit) to the 1,120 employees currently employed at the two-unit site (TVA 1998a). The general design specifications of the plant are provided in **Table 3–7**. The spent nuclear fuel storage capacity is not sufficient for 40 years of operation with or without TPBARs. This EIS evaluates the impacts of a generic dry cask spent fuel storage facility in Section 5.2.6.

Table 3–7 General Design Specifications of Sequoyah 1 or Sequoyah 2

Criteria	*Quantity*
Core thermal power level	3,411 MWt
Plant capacity factor	0.80
Total steam flow rate	1.492×10^7 lb/hr
Net electrical generation (net)	1,183 MWe
Normal fuel cycle	18 Months
Size of full core fuel load	193 Fuel Assemblies (89.5 MTU)

Source: TVA 1996b, TVA 1974a.

In a tritium-producing mode of operation, approximately 3,400 TPBARs could be placed in the reactor core(s) of Sequoyah 1 and/or 2 in the same fuel assembly guide tube locations that now accommodate standard burnable absorber rods. The TPBARs would be irradiated on an 18-month refueling cycle.

During current operations at Sequoyah 1 or Sequoyah 2, heat released from the fissioning fuel is transported by the reactor cooling water to the steam generators. After passing through the turbines, the steam is condensed by moving it through a condenser. The overall thermal efficiency of each unit is about 35 percent (TVA 1996b). The condenser is in turn cooled by a direct open cooling system (or mode) using diffusers supplemented by a helper or closed system (or mode) that uses natural-draft, evaporative cooling towers (TVA 1996b). However, the cooling towers have only been used for approximately 2 percent of the plant's operating time (TVA 1998a) to meet thermal discharge limits. The direct open cooling system uses a diffuser system which discharges cooling water to the Tennessee River from diffuser pipes. One diffuser pipe is 4.9 meters (16 feet) in diameter and extends 107 meters (350 feet) while the other diffuser pipe is 5.2 meters (17 feet) in diameter and extends 213 meters (700 feet). These two pipes are perforated with about twelve thousand 5-centimeter (2-inch) ports through which water is discharged into the river for maximum thermal mixing. This reduces the average river water temperature rise to less than 5.6

Cooling towers can be used in the helper mode, in which they discharge water through the diffuser pipes into the river, or in the closed mode. When the supplemental cooling tower system is used in the closed mode of operation, makeup water from the Tennessee River is needed to replace water losses from evaporation, drift, and blowdown. When the cooling towers are used in the closed mode, cooling is accomplished in the same manner as described for Watts Bar 1 in Section 3.2.5.1.

When the reactor is at full power, the temperature of the water flowing through each condenser is raised by approximately 17
returns 2,123,540 liters per minute (561,000 gallons per minute) (TVA 1974a). In the cooling tower closed cycle cooling mode, water lost through evaporation, small leaks, drift, and blowdown is made up by withdrawing approximately 249,745 liters per minute (65,978 gallons per minute) (TVA 1974a) from the Tennessee River. Blowdown from a natural-draft cooling tower is discharged into the Tennessee River at a normal rate of 120,000 liters per minute (31,700 gallons per minute) (TVA 1974a). Diffusers are used to mix the blowdown with river water, thus limiting the temperature rise after mixing to less than 5.6
discharged under a NPDES Permit (DEC 1993a). Tritium production would not affect the thermal discharge characteristics of the plant.

Operation of the plant produces radioactive fission products and activates corrosion products in the reactor coolant system. Small amounts of these radioactive products enter the plant cooling water. Radionuclides are removed from the cooling water through a chemical water treatment system. The gases and liquids are processed and monitored within the facility to minimize the radioactive nuclides released to the atmosphere and into the Tennessee River. Radioactive waste is produced in this treatment system. The total Sequoyah 1 or Sequoyah 2 liquid contaminant release to the environment during normal operation is identified in **Table 3–8**.

Table 3–8 Annual Liquid Releases to the Environment from Operating Sequoyah 1 or Sequoyah 2

Materials	*Quantity*
Chemicals	294,012 kg[a]
Tritium	738.6 Ci[b]
Other Radionuclides	1.147 Ci[b]

[a] TVA 1996b.
[b] TVA 1998e.

Gaseous wastes are managed in the same manner as described for Watts Bar 1 in Section 3.2.5.1. Gaseous emissions from the plant are summarized in **Table 3–9**.

Table 3–9 Summary of Annual Sequoyah 1 or Sequoyah 2 Gaseous Emissions

Constituent	*Quantity*
Particulate matter	26,225 kg [a]
Carbon monoxide	22,194 kg [a]
Sulfur dioxide	11,335 kg [a]
Nitrogen dioxide	86,928 kg [a]
Volatile organic compounds	2,377 kg [a]
Hazardous air pollutants	171 Ci [a]
Tritium	24.43 Ci [b]
Other radionuclides	119.7 [b]

[a] TVA 1998a.
[b] TVA 1998e.

Several hazardous substances and chemicals are used regularly during plant operation. This results in the generation of hazardous waste, which is controlled, stored, and managed in accordance with RCRA guidelines. This waste is disposed of offsite at RCRA-permitted treatment and disposal facilities. Solid waste such as noncontaminated clothing, rags, waste paper, boxes, and uncontaminated filters is also generated regularly and disposed of as solid waste. The waste generation volumes for Sequoyah 1 or Sequoyah 2 during normal operation are summarized in **Table 3–10**.

Table 3–10 Summary of Annual Sequoyah 1 or Sequoyah 2 Waste and Spent Fuel Generation Rates

Waste Type	*Volume or Mass*
Hazardous waste	1.196 m^3
Nonhazardous solid waste	1,301,966 kg
Low-level radioactive waste	383 m^3
Mixed low-level radioactive waste	< 1 m^3
Spent fuel (per 18-month cycle)	16 m^3 (or 80 fuel assemblies)

Sources: TVA 1974a, TVA 1996b.

The reactors are shut down for refueling and maintenance as part of a normal fuel cycle of 18 months. During this shutdown period, the irradiated TPBARs/spent fuel assemblies would be removed from the reactors and placed in the spent fuel pool for cooling. After approximately one to two months, these TPBARs would be removed from the fuel assemblies, loaded into transportation casks, and sent to the proposed Tritium Extraction Facility at the Savannah River Site for tritium extraction and purification.

3.2.5.3 Bellefonte Nuclear Plant, Units 1 and 2

Bellefonte 1 and Bellefonte 2 are partially completed pressurized water reactors. They are situated on approximately 607 hectares (1,500 acres) (TVA 1997f) on a peninsula at Tennessee River Mile 392, on the west shore of Guntersville Reservoir, about 11.3 kilometers (7 miles) northeast of Scottsboro, Alabama (TVA 1991). The main land uses of the surrounding area are forestry and agriculture; however, urban-industrial development has grown over the past several years around the plant along the Guntersville Reservoir. The affected environment at the Bellefonte Nuclear Plant site is described in Section 4.2.3. The general arrangement of the Bellefonte Nuclear Plant is shown in **Figure 3–7**.

The U.S. Atomic Energy Commission (now NRC) issued the construction permit for the Bellefonte Nuclear Plant in December 1974 (NRC 1990), and construction started in February 1975. On July 29, 1988, TVA notified NRC that Bellefonte was being deferred as a result of a lower load forecast for the near future (TVA 1988). After 3 years of extensive study, TVA notified NRC on March 23, 1993, of its plans to complete Bellefonte 1 and Bellefonte 2 (TVA 1994a). In December 1994, TVA announced that Bellefonte would not be completed as a nuclear plant without a partner, and put further activities on hold until a comprehensive evaluation of TVA's power needs was completed. On April 29, 1996, TVA issued a Notice of Intent to prepare an EIS for the proposed conversion of the Bellefonte Nuclear Plant to a fossil fuel facility. The *Final Environmental Impact Statement for the Bellefonte Conversion Project*, analyzing alternatives for such a conversion, was issued in October 1997 (TVA 1997f). A Record of Decision for that EIS will not be made until it is determined whether Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 will be used for tritium production.

The plant structures presently consist of two reactor containment buildings, a control building, a turbine building, an auxiliary building, a service building, a condenser circulating water pumping station, two diesel generator buildings, a river intake pumping station, two natural-draft cooling towers, a transformer yard, a 500-kilovolt and 161-kilovolt switchyard, a spent nuclear fuel storage pool, and sewage treatment facilities (TVA 1991). Additionally, there are office buildings to house engineering and other department personnel.

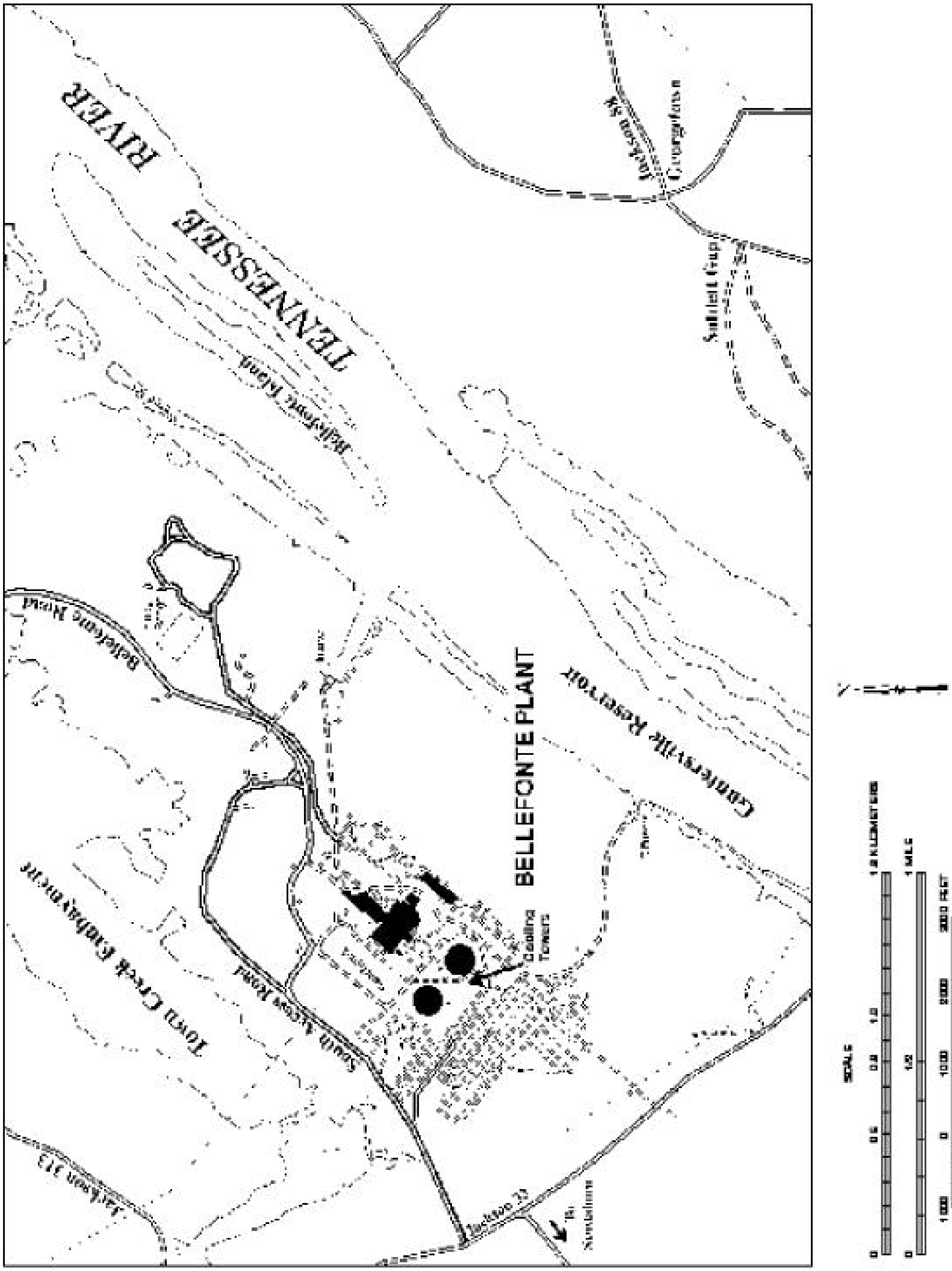


Figure 3–7 Bellefonte Nuclear Plant Units 1 and 2

Entrance roads, parking lots, railroad spurs, and a helicopter landing pad are in place and are capable of supporting a construction project.

No modifications to the original design should be necessary to complete Bellefonte 1 or Bellefonte 2 for operation, with or without TPBARs.

The plant systems and structures are maintained through active layup and preservation. Program activities include the following:

- Each unit's main turbine generators are rotated every other week.

- The diesel fire pumps are maintained in an operational status and are run monthly.

- The shell and tube sides of the main condensers (heat exchangers) are kept dry, and the tube side is maintained with a flow of warm, dehumidified air.

- The reactor coolant system is kept dry using a flow of warm, dehumidified air.

A workforce of approximately 80 personnel supports layup and preservation of the plant. Of that number, 38 are involved in operations and maintenance (TVA 1998e).

To complete Bellefonte 1 or both Bellefonte 1 and Bellefonte 2, additional engineering and construction activities would be required (TVA 1998a). These activities are summarized in the following paragraphs.

Engineering—Engineering for the original Bellefonte Nuclear Plant design is substantially complete. The additional engineering effort consists of completing analysis and design modifications that were not completed prior to deferral, updating the design-basis documentation to current industry standards; and supporting construction, start up, and licensing of the plant. More specifically, the remaining engineering effort for Bellefonte 1 and Bellefonte 2 includes, but is not limited to, the following:

- Issuing detailed design modifications for certain mechanical and electrical systems to meet current requirements.

- Updating the main control room drawings into computer-aided design (CAD) electronic format.

- Reviewing the control room design and upgrading the simulator and plant computers.

- Reanalyzing piping and pipe supports.

- Resolving industry issues (e.g., fire protection, electrical equipment qualification, station blackout, site security, communications, motor-operated valves) that were either not completed prior to deferral in 1988 or have arisen since deferral.

- Developing fuel assembly and fuel cycle designs to facilitate the production of tritium.

- Supporting submittals of the Final Safety Analysis Report and completing previous NRC position papers.

- Supporting field change requests by the constructor.

Construction—Construction activities required to complete Bellefonte 1 and Bellefonte 2 include, but are not limited to, the following:

- Completing the application of protective coatings to structures, piping, and components, and the installation of piping insulation.
- Installing the Bellefonte 2 reactor coolant pump internals and motors [Some (less than 10 percent) of Bellefonte 1 reactor coolant instrumentation and pipe supports would have to be installed.]
- Installing limited major piping and components in the balance of the plant for Bellefonte 2.
- Installing the steam piping for Bellefonte 2.
- Installing and energizing a limited amount of the electric power equipment within the plant. (The 161-kilovolt and 500-kilovolt offsite transmission lines are terminated in the switchyard, which is complete and energized.)
- Completing the Bellefonte 2 main control room. Substantial work would be required because the Bellefonte 1 main control room, although not complete, is functional and manned to monitor the ongoing preservation activities. The recommendations of the Control Room Design review would be factored into efforts to complete construction of both control rooms.
- Preparing the intake structure for operation by desilting the intake water pump.
- Constructing some new support buildings and installing additional equipment.

In addition to the engineering and construction activities, completion and operation of Bellefonte would require NRC licensing, startup testing, and operations staffing and training.

Estimates of the resources required to complete Bellefonte 1 and both Bellefonte 1 and Bellefonte 2 are provided in **Table 3–11**. Bellefonte 2 would require fewer resources than Bellefonte 1 because some facilities constructed for Bellefonte 1 are in common with Bellefonte 2.

Table 3–11 Summary of Resources Required to Complete Construction of Bellefonte 1 and Bellefonte 1 and Bellefonte 2

Resources	*Bellefonte 1*	*Bellefonte 1 and Bellefonte 2*
Employment, peak year	4,500	4,500
Length of time (years)	5	6.5
Electricity (MW-hr)	575,000	1,075,000
Water (m^3)	280,000	440,000
Concrete (m^3)	2,190	3,981
Steel (metric tons)	353	451
Fuel (l)	9.7×10^6	1.4×10^7
Industrial gases (m^3)	500	1,800

Source: TVA 1995b.

For tritium production, approximately 3,400 TPBARs could be placed in the reactor core(s) of Bellefonte 1 or Bellefonte 1 and Bellefonte 2, occupying the same fuel assembly guide tube locations that would otherwise have held standard burnable absorber rods.

During normal operation, one unit would employ approximately 800; both units would employ 1,000 (TVA 1998a). Less than 10 additional employees per unit would be needed for normal operations with tritium production. If either or both units were completed, each reactor containment building would house a pressurized water reactor designed and manufactured by Framatome Technologies, Inc. The general design specifications of the plant are provided in **Table 3–12**.

Table 3–12 General Design Specifications of Bellefonte 1 or Bellefonte 2

Criteria	*Quantity*
Core thermal power level	3,600 MWt
Plant capacity factor	0.80
Total steam flow	1.609×10^7 lb/hr
Electrical generation	1,212 MWe
Normal fuel cycle	18 months
Size of full core fuel load	205 fuel assemblies (93.5 MTU)

Source: TVA 1991.

During operation, heat released from the fissioning fuel would be transported by the reactor cooling water to the steam generators. After passing through the turbines, the steam is condensed by moving it through a condenser cooled by recirculated water. The overall thermal efficiency of an operation unit is expected to be about 34 percent (TVA 1991). This water would in turn be cooled by passing through a natural-draft evaporative cooling tower. Although the cooling system would be of the so-called closed type, makeup water from the Tennessee River (Guntersville Reservoir) would be needed to replace water losses due to evaporation, drift, and blowdown. Cooling would be accomplished in the same manner as described for Watts Bar 1 in Section 3.2.5.1.

At full power, the temperature of the water flowing through a condenser would be raised by approximately 20
(36
evaporation, small leaks, drift, and blowdown would be made up by withdrawing approximately 252,000 liters per minute (66,600 gallons per minute) from the Guntersville Reservoir (TVA 1978). Blowdown from the natural-draft cooling towers would be discharged into the Guntersville Reservoir at a normal rate of 2.1 cubic meters per second (74 cubic feet per second) (TVA 1974b). A diffuser would be used to mix the blowdown with reservoir water and thus limit the temperature rise after mixing to less than 3
water would be discharged under a NPDES Permit (ADEM 1992).

Operation of the plant would produce radioactive fission products and activate corrosion products in the reactor coolant system. Small amounts of these radioactive products would enter the cooling water of the plant. Radionuclides would be removed from the cooling water through a chemical water treatment system. The gases and liquids would be processed and monitored within the facility to minimize the radioactive nuclides released to the atmosphere and into the Guntersville Reservoir. Radioactive waste would be generated in this treatment system.

The gaseous emissions would be managed in the same manner as described for Watts Bar 1 in Section 3.2.5.1. The projected nonradiological gaseous releases at Bellefonte 1 and 2, with the units at full power, would be similar to those for Watts Bar 1, Sequoyah 1, and Sequoyah 2.

Several hazardous substances and chemicals would be used regularly in the operation of the plant. This is expected to result in the generation of hazardous waste that will be controlled, stored, and managed in accordance with RCRA and disposed of offsite at RCRA-permitted treatment and disposal facilities. Solid waste such as noncontaminated clothing, rags, waste paper, boxes, and uncontaminated filters should also be generated regularly and disposed of as solid waste.

The reactors would be shut down for refueling and maintenance after operating for approximately 18 months. During this shutdown period, the irradiated TPBARs would be removed from the reactor and placed in the spent fuel pool for cooling. After 1 to 2 months, these TPBARs separated from the hold-down assemblies would be loaded into transportation casks and sent to the proposed Tritium Extraction Facility at the Savannah River Site for tritium extraction and purification.

3.2.6 Comparison of Alternatives

To aid the reader in understanding the differences among the various alternatives, this section presents a comparison of the environmental impacts associated with tritium production at each of the reactor plants. The comparisons concentrate on those resources that would most likely be impacted.

The information in this section is based on the environmental consequences described in Chapter 5 of this EIS. For the five TVA reactors being considered for tritium production (Watts Bar 1, Sequoyah 1, and Sequoyah 2, Bellefonte 1 and Bellefonte 2), impacts are presented for the bounding case (i.e., the maximum number of TPBARs that could be irradiated in a reactor). For those cases in which impacts would be significantly different for a lesser number of TPBARs, explanation is provided. The impacts of using more than one CLWR for tritium production can be determined by adding the impacts of each individual CLWR together. The impacts of not producing tritium at any of these five reactors (the No Action Alternative) are presented first, as a baseline against which to compare the impacts of producing tritium. A summary of the environmental consequences is presented as **Table 3–13** at the end of this chapter.

3.2.6.1 No Action Alternative Impacts

Construction

Watts Bar 1, Sequoyah 1, and Sequoyah 2. Under the No Action Alternative, Watts Bar 1, and Sequoyah 1, and Sequoyah 2 would continue to produce electricity and no construction impacts would occur.

Bellefonte 1 and Bellefonte 2. Under the No Action Alternative, Bellefonte 1 and 2 would remain in deferred status, and no construction impacts would occur. TVA could also convert Bellefonte 1 and 2 to a fossil fuel plant as described in the *Final Environmental Impact Statement for the Bellefonte Conversion Project* (TVA 1997f) (see Section 1.5.2.4). Such conversion would be independent of this EIS and would not occur until after a decision were made regarding the role of Bellefonte 1 and 2 in tritium production.

Operation

Watts Bar 1, Sequoyah 1, and Sequoyah 2. Under the No Action Alternative, Watts Bar 1, and Sequoyah 1 and 2 would continue to produce electricity for the foreseeable future, and there would be no changes in the type and magnitude of environmental impacts that currently occur. In producing electricity, these reactor plants would continue to comply with all Federal, state, and local requirements. Impacts associated with the continued operation of Watts Bar 1, Sequoyah 1 and 2 are described in the following paragraphs.

Under the No Action Alternative, water requirements at all three plants would continue to be met by existing water resources, with no additional impacts, and water quality would remain within regulatory limits. Air quality would also remain within regulatory limits. Worker employment should remain steady at each of the sites, with no major changes to the regional economic areas as a result of plant operation. Worker exposure to radiation should remain well within regulatory limits, with the average worker dose at approximately 90 to 100 mrem/yr. Radiation exposure of the public from normal operations would also remain well within regulatory limits for each of the reactor sites. At Watts Bar 1, the total dose to the population within 80 kilometers (50 miles) would be approximately 0.55 person-rem/yr. Statistically, this equates to one fatal cancer approximately every 3,570 years from operation of Watts Bar 1. At Sequoyah 1 or Sequoyah 2, the total dose to the population within 80 kilometers (50 miles) would be approximately 1.6 person-rem/yr. Statistically, this equates to one fatal cancer approximately every 1,250 years from the operation of Sequoyah 1 or 2. Risks of accidents would remain unchanged.

Under the No Action Alternative, all categories of wastes would continue to be generated at each of the reactor plants and they would be managed in accordance with regulations. Low-level radioactive wastes would continue to be generated at a rate of approximately 40 (Watts Bar 1) to 389 (Sequoyah 1 or 2) m^3/yr and disposed of at the Barnwell disposal facility. For each of the reactors, spent fuel would also continue to be generated at a rate of approximately 80 fuel assemblies per year. Spent fuel would continue to be managed at each of the reactor plants in compliance with all regulatory requirements.

Bellefonte 1 and Bellefonte 2. Under the No Action Alternative, Bellefonte 1 and 2 would remain uncompleted nuclear reactors and there would not be any change on the impacts on the environment.

3.2.6.2 Proposed Action Impacts

Construction

Watts Bar 1, Sequoyah 1, and Sequoyah 2. Because this EIS assumes that long-term spent fuel storage would take place at each of the reactor plants, a dry cask spent fuel storage facility could eventually be required for Watts Bar 1, Sequoyah 1, or Sequoyah 2 to support tritium production. This could be the only construction necessary for tritium production. If such a facility were to be constructed, it would consist of three reinforced concrete slabs covering approximately 3.5 acres. Approximately 60-80 horizontal storage modules, each made of reinforced concrete, could be housed on the slabs. These horizontal storage modules would have a hollow internal cavity to accommodate a stainless steel cylindrical cask that would contain the spent nuclear fuel. Constructing such a facility would disturb approximately 5 acres and require approximately 50 construction workers. Premixed concrete would be used and impacts to air quality, water, and biotic resources are expected to be small. Appropriate NEPA documentation would be prepared prior to the construction of a dry cask spent fuel storage facility.

Bellefonte 1 and Bellefonte 2. All major structures (e.g., containment buildings, cooling towers, turbine buildings, support facilities) have been constructed. So, construction activities would largely consist of internal modifications to the existing facilities. No additional land would be disturbed in completing construction and there would be no impacts on visual resources, biotic resources (including threatened and endangered species), geology and soils, and archaeological and historic resources. Because this EIS assumes that long-term spent fuel storage would take place at each of the reactor plants, a dry cask spent fuel storage facility would eventually be required at Bellefonte 1 and 2. The impacts of constructing such a spent fuel storage facility would be similar to those described above for Watts Bar 1, Sequoyah 1, or Sequoyah 2. Appropriate NEPA documentation would be prepared before the construction.

Completing construction of Bellefonte 1 would have the greatest impact on socioeconomics, with construction activities taking place between 1999 and 2004. During the peak year of construction (2002), approximately 4,500 direct jobs could be created. As many as 4,500 secondary jobs (indirect jobs) would also be created. The total new jobs (9,000) would cause the regional economic area unemployment rate to decrease to approximately 4 percent, from the current rate of 7.9 percent. Public finance expenditures/revenues would increase by over 30 percent in Scottsboro and about 15 percent in Jackson County. Rental vacancies would decline to near zero, and demand for all types of housing would increase substantially. Rents and housing prices could increase at double-digit percentage levels.

If Bellefonte 2 were also selected for completion, construction activities for both units would be drawn out, taking place between 1999 and 2005. The peak year of construction would shift but the total number of direct and indirect jobs would be the same. The effects, therefore on unemployment, public finance, rents, and housing prices would be the same as for the construction completion of Bellefonte 1.

Operation

Watts Bar 1, Sequoyah 1, and Sequoyah 2. In a tritium production mode, these operating reactors would continue to comply with all Federal, state, and local requirements. Tritium production would have little or no effect on land use, visual resources, water use and quality, air quality, archaeological and historic resources, biotic resources (including threatened and endangered species), and socioeconomics. It could, however, have some incremental impacts in the following areas: radiation exposure (worker and public), spent fuel generation, and low-level radioactive waste generation. Tritium production could also change the accident and transportation risks associated with these reactors. Each of these areas is discussed below.

<u>Radiation Exposure</u> Tritium production could increase average annual worker radiation exposure by approximately 4–6 mrem/yr. The resultant dose would be well within regulatory limits. Radiation exposure to the public from normal operations could also increase, but would still remain well within regulatory limits at each of the reactor sites. At either Watts Bar 1, Sequoyah 1, or Sequoyah 2, the total dose to the population within 80 kilometers (50 miles) could increase by a maximum of 11 person-rem/yr. Statistically, this equates to one additional fatal cancer approximately every 200 years from the operation of Watts Bar 1, Sequoyah 1, or Sequoyah 2.

<u>Spent Fuel Generation</u> Given irradiation of 3,400 TPBARs (the maximum number of TPBARs without changing the reactor's fuel cycle), additional spent fuel would be generated at Watts Bar 1, Sequoyah 1, or Sequoyah 2. In the average 18-month fuel cycle, spent fuel generation could increase from approximately 80 spent fuel assemblies to a maximum of 140, a 71 percent increase in spent fuel generation over the No Action Alternative. Because this EIS assumes that long-term spent fuel storage would take place at each of the reactor plants, a dry cask spent fuel storage facility would eventually be needed. Storing the additional spent fuel should have minor impacts. Radiation exposures would remain below regulatory limits for both workers and the public, and less than 4 cubic feet of low-level radioactive waste would be generated annually. The impacts of accidents associated with dry cask spent fuel storage would be small. As previously mentioned, appropriate NEPA documentation would be prepared before the construction of a dry cask spent fuel storage facility at Watts Bar 1, Sequoyah 1, or Sequoyah 2. If fewer than approximately 2,000 TPBARs were irradiated, there would be no change in the amount of spent fuel produced by the reactors.

<u>Low-Level Radioactive Waste Generation</u> Compared to the No Action Alternative, tritium production at Watts Bar 1, Sequoyah 1, or Sequoyah 2 would generate approximately 0.43 additional m^3/yr of low-level radioactive

waste. This would be a 0.1 (Sequoyah 1 or 2) to 1.0 (Watts Bar 1) percent increase in low-level radioactive waste generation over the No Action Alternative. Such an increase would amount to less than 1 percent of the low-level radioactive waste disposed of at the Barnwell disposal facility. The EIS also analyzes the impacts of this low-level radioactive waste disposal at the Savannah River Site. Disposing of 0.43 m^3/yr of low-level radioactive waste would amount to less than 1 percent of the low-level radioactive waste disposed of at the Savannah River Site and less than 1 percent of the landfill's capacity.

Accident Risks Tritium production could change the potential risks associated with accidents at Watts Bar 1, Sequoyah 1, or Sequoyah 2. As described in the following text, these changes would be small. Potential impacts from accidents were determined using computer modeling. If a limiting design-basis accident occurred, tritium production at the 3,400 TPBAR level would increase the individual risk of a fatal cancer by 7.5×10^{-9} to an individual living within 80 kilometers (50 miles) of Watts Bar 1. Statistically, this equates to a risk to the individual of one fatal cancer approximately every 130 million years from tritium production. For an individual living within 80 kilometers (50 miles) of Sequoyah 1 or Sequoyah 2, there would be a 1.2×10^{-8} increased likelihood of a cancer fatality to an individual from a design-basis accident as a result of tritium production. Statistically, this equates to a risk to an individual of one additional fatal cancer approximately every 83 million years from tritium production. For a beyond-design-basis accident (an accident which has a probability of occurring approximately once in a million years or less), tritium production would result in small changes in the consequences of an accident. This is due to the fact that the potential consequences of such an accident would be dominated by radionuclides other than tritium.

Transportation Tritium production at either Watts Bar 1, Sequoyah 1, or Sequoyah 2 would necessitate additional transportation to and from the reactor plants. Most of the additional transportation would involve nonradiological materials. Impacts would be limited to toxic vehicle emissions and traffic fatalities. At each of these reactors, the transportation risks would be less than one fatality per year. Radiological materials transportation impacts would include routine and accidental doses of radioactivity. In all instances the risks associated with radiological materials transportation would be less than one fatality per 100,000 years.

Bellefonte 1 and Bellefonte 2. Because neither Bellefonte 1 or Bellefonte 2 are currently operating, this EIS assesses the impacts of completing construction, and operating these units for tritium production. Consequently, environmental impacts would occur in the following resources: visual resources, water use, biotic resources, socioeconomics, radiation exposure (worker and public), spent fuel generation, and low-level radioactive waste generation. Tritium production would also change the accident and transportation risks associated with these reactors.

During operations Bellefonte 1 and 2 would produce vapor plumes from cooling towers that would be visible up to 10 miles away. These plumes could create an aesthetic impact on the towns of Pisgah, Hollywood, and Scottsboro, Alabama.

During operation, Bellefonte 1 and 2 would each use less than 0.5 percent of the river flow from Guntersville Reservoir and would not have any adverse impacts on other users. Discharges from the plants would be treated and monitored before release and would comply with NPDES permits. Impacts on water quality would be minimal, and no standards would be exceeded. Operation of either Bellefonte 1 or both Bellefonte 1 and 2 for tritium production would have some effects on ecological resources typical to the operation of a nuclear power plant regardless of tritium production. Impacts on ecological resources from the operation of Bellefonte 1 or both Bellefonte 1 and 2 would result from radioactive and nonradioactive emissions of air pollutants to the atmosphere; thermal, chemical and radioactive effluent releases to surface waters; increases in human activity; and increases in noise levels. These impacts would be small considering that the units would operate in compliance with all Federal, state, and local requirements specifically promulgated to protect environmental resources. The estimated radiological doses to terrestrial and aquatic organisms are well below levels that could have any impact on plants or terrestrial and aquatic animals at the site. Other possible environmental impacts on the aquatic ecosystem of Guntersville Reservoir due to operation of the Bellefonte units would include fish losses at the cooling water intake screens, almost total loss of unscreened entrained organisms, and effects of thermal and chemical discharges. The effects of both thermal and chemical discharges would be small, as these discharges should comply with NPDES limitations.

Socioeconomics During operations, approximately 800 direct jobs would be created at Bellefonte 1, along with approximately an equal number of indirect jobs. The total new jobs (approximately 1,600) would cause the regional economic area unemployment rate to decrease to approximately 5.9 percent. Public finance expenditures/revenues would decline from the levels during construction but would remain 10 to 15 percent higher than they would be otherwise at Scottsboro and 5 to 10 percent higher in Jackson county. Housing prices would decline and could fall below the precompletion prices, depending on how much new construction of permanent housing took place during the completion period and how many construction workers chose to remain in the area once construction was completed. If Bellefonte 2 were also completed, a total of approximately 1,000 direct jobs would be created, along with approximately 1,000 indirect jobs.

Radiation Exposure Reactor operation to produce tritium would cause worker radiation exposure to increase from 0 to approximately 110 mrem/yr. This resultant dose would be well within regulatory limits of 5,000 mrem/yr. Radiation exposure to the maximally exposed individual from normal operations would increase from 0 to 0.32 millirem. The total dose to the population within 80 kilometers (50 miles) would increase from approximately 0 to approximately 6.5 person-rem/yr for Bellefonte 1. If Bellefonte 2 were also operating, this dose would be approximately 13 person-rem/yr. Statistically, this equates to one fatal cancer approximately every 154 years from the operation of Bellefonte 1 and 2.

Spent Fuel Generation Given production of the maximum amount of tritium in the average 18-month fuel cycle, spent fuel generation would increase from 0 up to a maximum of 141 spent fuel assemblies (e.g., 69 fuel assemblies over the normal refueling size). Because this EIS assumes that long-term spent fuel storage would take place at each of the reactor plants, a dry cask spent fuel storage facility could eventually be needed to store the additional assemblies. The impacts of storing the spent fuel in a dry cask spent fuel storage facility are described above for the existing operating reactor plants. As previously mentioned, appropriate NEPA documentation would be prepared before the construction of a dry cask spent fuel storage facility.

Low-Level Radioactive Waste Generation Compared to the No Action Alternative, reactor operation to produce tritium Bellefonte 1 or Bellefonte 2 would generate approximately 40 m^3 (80 m^3 for both units) of low-level radioactive waste. This quantity would be a small fraction of the landfill capacity at the Barnwell disposal facility or the Savannah River Site's low-level radioactive waste disposal facility.

Accident Risks Compared to the No Action Alternative, there is a significant change in potential risks from tritium production. Risks due to accidents would increase during the construction and operation of Bellefonte 1 and 2, and during the operation of these units for production of tritium. Similar to Watts Bar 1, Sequoyah 1, and Sequoyah 2, the potential impacts from the accidents at Bellefonte 1 or 2 were determined using computer modeling. If a limiting design-basis accident occurred, tritium production would increase the individual risk of a fatal cancer by 4.1×10^{-9} additional fatal cancers to an individual living within 80 kilometers (50 miles) of the units. Statistically, this means that for an individual one fatal cancer would occur approximately every 244 million years from tritium production at Bellefonte. If a beyond-design-basis accident occurred (an accident that has a probability of occurring approximately once in a million years or less), tritium production would increase the risk of a fatal cancer by 0.00010 additional fatal cancers to an individual living within 80 kilometers (50 miles) of the Bellefonte Nuclear plant.

Transportation Tritium production at either Bellefonte 1 or 2 would necessitate transportation of workers, construction material, and radiological and nonradiological material to and from the reactor plants. Most of the additional transportation would involve nonradiological materials. Impacts of this transportation are limited to toxic vehicle emissions and traffic fatalities. For Bellefonte 1 or 2, the transportation risks would be significantly lower than one fatality per year. Radiological materials transportation impacts would occur as a result of routine and accidental doses. In all instances the risks associated with radiological materials transportation would be less than one fatality per 100,000 years.

3.2.7 Preferred Alternatives

The Council on Environmental Quality regulations require that an agency identify its Preferred Alternative(s), if one or more exist, in the Draft EIS (40 CFR 1502.14e). The Preferred Alternative is defined as the alternative that the agency believes would fulfill its statutory mission, giving consideration to environmental, economic, technical, and other factors. Consequently, to identify a Preferred Alternative(s), DOE is developing information on potential environmental impacts, costs, technical risks, and schedule risks for the alternatives under consideration.

This EIS provides information on the environmental impacts. Cost schedule, and technical analyses are also being prepared, and will be considered in the identification of any Preferred Alternative(s). A Preferred Alternative has not yet been identified. In accordance with the Council on Environmental Quality Regulations, the CLWR Final EIS will identify the Preferred Alternatives.

Table 3–13 Summary of Environmental Consequences for the CLWR Reactor Alternatives

Resource/Material Categories	*Watts Bar 1*	*Sequoyah 1 or Sequoyah 2*	*Bellefonte 1 or Bellefonte 2*
No Action			
All Resource/Material Categories	No construction or operational changes. Reactor unit continues to produce electricity. No change in environmental impacts.	No construction or operational changes. Reactor units continue to produce electricity. No change in environmental impacts.	No construction or operational changes. Reactor units remain uncompleted. No change in environmental impacts.
Annual Tritium Production			
Land Resources Land Use	*Construction:* Potential land disturbance - 5.3 acres for dry cask independent spent fuel storage installation (ISFSI) if constructed. *Operation:* Potential permanent land requirement - 3.1 acres for ISFSI if constructed.	*Construction:* Potential land disturbance - 5.47 acres for ISFSI if constructed. *Operation:* Potential permanent land requirement - 3.2 acres for ISFSI if constructed.	*Construction:* Potential land disturbance - 4.9 acres for ISFSI if constructed and additional land for support buildings. *Operation:* Potential permanent land requirement - 3.4 acres for ISFSI if constructed and additional land for support buildings.
Visual Resources	*Construction and Operation:* No additional impact to visual resources.	*Construction and Operation:* No additional impact to visual resources.	*Construction:* No additional impact to visual resources. *Operation:* Vapor plumes would be visible up to 10 miles away.
Noise	*Construction:* No change from current levels. Small impacts if ISFSI is constructed. *Operation:* No change from current levels.	*Construction:* No change from current levels. Small impacts if ISFSI is constructed. *Operation:* No change from current levels.	*Construction:* No change from current levels. Small impacts if ISFSI is constructed. *Operation:* Increase in noise emissions from the plant from 50 dB(A) to 51 dB(A) at nearest receptor. Increase in traffic noise onsite access roads from 50 dB(A) to 57 dB(A) due to commuter traffic and truck deliveries.
Air Quality Nonradioactive Emissions	*Construction:* No change from current air quality conditions. Small impacts if ISFSI is constructed. *Operation:* No change from current air quality conditions.	*Construction:* No change from current air quality conditions. Small impacts if ISFSI is constructed. *Operation:* No change from current air quality conditions.	*Construction:* Potential temporary dust emissions during construction. Small impacts if ISFSI is constructed. *Operation:* The increase in nonradioactive emissions would be well within established standards.

Resource/Material Categories	*Watts Bar 1*	*Sequoyah 1 or Sequoyah 2*	*Bellefonte 1 or Bellefonte 2*
Annual Tritium Production (Continued)			
Air Quality Radioactive Emissions	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive emissions of tritium would be 1,650 curies; given 3,400 TPBARs, 1,890 curies (assuming 2 failed TPBARs).	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive emissions of tritium would be 1,650 curies; given 3,400 TPBARs, 1,890 curies (assuming 2 failed TPBARs).	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive emissions of tritium would be 1,656 curies; 3,400 TPBARs, 1,896 curies, of which 5.6 curies would be from normal operations without tritium production. The release of other radioactive emissions would be 283 curies.
Water Resources Surface Water	*Construction:* No change to current surface water requirements, discharge, or water quality conditions. Small impacts if ISFSI is constructed. *Operation:* No change to current surface water requirements, discharge, or water quality conditions.	*Construction:* No change to current surface water requirements, discharge, or water quality conditions. Small impacts if ISFSI is constructed. *Operation:* No change to current surface water requirements, discharge, or water quality conditions.	*Construction:* Potential for increased storm water runoff. Small amount of surface water requirements. Small impacts if ISFSI is constructed. *Operation:* Increased surface water requirements and discharge. Water usage less than 1% of Tennessee River flow per year. All water quality parameters within limits.
Radioactive Effluent	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive tritium effluents would be 14,850 curies; 3,400 TPBARs, 17,010 curies (assuming 2 failed TPBARs).	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive tritium effluents would be 14,850 curies; 3,400 TPBARs, 17,010 curies (assuming 2 failed TPBARs).	*Construction:* No radioactive emissions. *Operation:* Given 1,000 TPBARs, the maximum potential increase in annual radioactive tritium effluents would be 15,489 curies; 3,400 TPBARs, 17,649 curies (assuming 2 failed TPBARs), of which 639 curies would be from normal operation without tritium production. The release of other radioactive effluents would be 1.32 curies.

Resource/Material Categories	***Watts Bar 1***	***Sequoyah 1 or Sequoyah 2***	***Bellefonte 1 or Bellefonte 2***
Annual Tritium Production (Continued)			
Groundwater	*Construction:* No groundwater requirements or additional impacts to groundwater quality conditions. *Operation:* No groundwater requirements or additional impacts to groundwater quality conditions.	*Construction:* No groundwater requirements or additional impacts to groundwater quality conditions. *Operation:* No groundwater requirements or additional impacts to groundwater quality conditions.	*Construction:* Groundwater would not be used during construction. *Operation:* No groundwater requirements or additional impacts to groundwater quality conditions.
Ecological Resources	*Construction*: No additional impacts on ecological resources. Small impacts if ISFSI is constructed. *Operation*: Small or no impacts to ecological resources from additional tritium releases.	*Construction*: No additional impacts on ecological resources. Small impacts if ISFSI is constructed. *Operation*: Small or no impacts to ecological resources from additional tritium release.	*Construction:* Potential impacts to ecological resources due to the small amount of land disturbance. Small impacts if ISFSI is constructed. *Operation:* Additional impacts on ecological resources including fish impingement and entrainment of aquatic biota during normal plant operation. Small impacts to ecological resources from tritium and other radioactive releases during normal plant operations.
Socioeconomics	*Construction:* No measurable impact. *Operation:* <1% impact on regional economy.	*Construction:* No measurable impact. *Operation:* <1% impact on regional economy.	*Construction:* 4,500 peak new direct jobs due to plant completion. Short-term increased costs and traffic for local jurisdictions. *Operation:* 800 to 1,000 workers per day. Increase in payment-in-lieu of taxes to state and local jurisdictions (approximately $5.5 to $8 million annually), decrease in the unemployment rate (from 7.9% to approximately 5.9%), and minor impacts to school resources.

Resource/Material Categories	***Watts Bar 1***	***Sequoyah 1 or Sequoyah 2***	***Bellefonte 1 or Bellefonte 2***
	Annual Tritium Production (Continued)		
Public and Occupational Health and Safety Normal Operation	Annual dose for 1,000 TPBARs: *Workers:* Average dose increase by 5.4 mrem. *MEI:* Dose increase by 0.22 mrem *50-mile population:* Dose increase by 5.5 person-rem. Annual dose for 3,400 TPBARs: *Workers:* Average dose increase by 6.2 mrem. *MEI:* Dose increase by 0.27 mrem *50-mile population:* Dose increase by 6.4 person-rem.	Annual dose for 1,000 TPBARs: *Workers:* Average dose increase by 3.9 mrem. *MEI:* Dose increase by 0.28 mrem *50-mile population:* Dose increase by 9.4 person-rem. Annual dose for 3,400 TPBARs: *Workers:* Average dose increase by 4.6 mrem. *MEI:* Dose increase by 0.32 mrem *50-mile population:* Dose increase by 10.5 person-rem.	Annual dose for 1,000 TPBARs: *Workers:* Average dose increase by 109 mrem, of which 104 mrem would be from normal operations without tritium production. *MEI:* Dose increase by 0.31 mrem, of which 0.26 mrem would be from normal operations without tritium production. *50-mile population:* Dose increase by 5.8 person-rem, of which 1.4 person-rem would be from normal operations without tritium production. Annual dose for 3,400 TPBARs: *Workers:* Average dose increase by 110 mrem, of which 104 mrem would be from normal operations without tritium production. *MEI:* Dose increase by 0.32 mrem *50-mile population:* Dose increase by 6.5 person-rem.
Design-Basis Accident Risks	Increased likelihood of a cancer fatality per year due to tritium production. For 1,000 TPBARs: *MEI:* 5.5×10^{-7} (1 fatality in 1.8 million years). *Average individual in population:* 6.5×10^{-9} (1 fatality in 150 million years). *Exposed population*: 0.0012 (1 fatality in 833 years). *Noninvolved worker:* 6.8×10^{-9} (1 fatality in 150 million years).	Increased likelihood of a cancer fatality per year due to tritium production. For 1,000 TPBARs: *MEI :* 1.3×10^{-7} (1 fatality in 7.7 million years). *Average individual in population:* 1.0×10^{-8} (1 fatality in 100 million years). *Exposed population*: 0.0025 (1 fatality in 400 years). *Noninvolved worker:* 2.1×10^{-9} (1 fatality in 480 million years).	Increased likelihood of a cancer fatality per year due to tritium production. For 1,000 TPBARs: *MEI:* 3.6×10^{-7} (1 fatality in 2.8 million years). *Average individual in population:* 3.6×10^{-9} (1 fatality in 280 million years). *Exposed population*: 0.00097 (1 fatality in 1,031 years). *Noninvolved worker:* 2.0×10^{-11} (1 fatality in 50 billion years).

Resource/Material Categories	*Watts Bar 1*	*Sequoyah 1 or Sequoyah 2*	*Bellefonte 1 or Bellefonte 2*
		Annual Tritium Production (Continued)	
	For 3,400 TPBARs: *MEI:* 6.0x10^{-7} (1 fatality in 1.7 million years). *Average individual in population:* 7.5x10^{-9} (1 fatality in 130 million years). *Exposed population*: 0.0014 (1 fatality in 714 years). *Noninvolved worker:* 8.0x10^{-9} (1 fatality in 130 million years).	For 3,400 TPBARs: *MEI :* 1.5x10^{-7} (1 fatality in 6.7 million years). *Average individual in population:* 1.2x10^{-8} (1 fatality in 83 million years). *Exposed population*: 0.0030 (1 fatality in 333 years). *Noninvolved worker:* 2.5x10^{-9} (1 fatality in 400 million years).	For 3,400 TPBARs: *MEI:* 3.7x10^{-7} (1 fatality in 67 million years). *Average individual in population:* 4.1x10^{-9} (1 fatality in 244 million years). *Exposed population*: 0.0011 (1 fatality in 909 years). *Noninvolved worker:* 2.4x10^{-11} (1 fatality in 42 billion years).
Waste Management	*Construction:* Potential non-hazardous waste if ISFSI is constructed. *Operation:* Low-level radioactive waste increase by approximately 0.43 m^3 per year. Other waste types would be unaffected by tritium production.	*Construction:* Potential non-hazardous waste if ISFSI is constructed. *Operation:* Low-level radioactive waste increase by approximately 0.43 m^3 per unit per year. Other waste types would be unaffected by tritium production.	*Construction:* Minor amounts of non-hazardous construction material waste generated during the completion of the plant. Potential non-hazardous waste if ISFSI is constructed. *Operation:* Low-level radioactive waste increase by approximately 41 m^3 per unit per year, of which 40 m^3 would be from normal operations without tritium production.
Spent Nuclear Fuel Management	*Operation:* No increase if less than 2,000 TPBARs are irradiated. If 3,400 TPBARs are irradiated, the amount of spent fuel generated increases by a maximum of 56 fuel assemblies per fuel cycle.	*Operation:* No increase if less than 2,000 TPBARs are irradiated. If 3,400 TPBARs are irradiated, the amount of spent fuel generated would increase by a maximum of 60 fuel assemblies per fuel cycle.	*Operation:* The amount of spent fuel would increase from zero to approximately 72 spent fuel assemblies for less than 2,000 TPBARs. For 3,400 TPBARs, the amount of spent fuel generation could increase from zero to a maximum of 141 spent fuel assemblies per fuel cycle, of which 72 would be from normal operations without tritium production.
Transportation	The risk associated with radiological materials transportation would be less than one fatality per 100,000 years.	The risk associated with radiological materials transportation would be less than one fatality per 100,000 years.	The risk associated with radiological materials transportation would be less than one fatality per 100,000 years. Increased traffic volumes on local roads during construction and operations.

Resource/Material Categories	*Watts Bar 1*	*Sequoyah 1 or Sequoyah 2*	*Bellefonte 1 or Bellefonte 2*
		Annual Tritium Production (Continued)	
Fuel Fabrication	Not applicable for the reactor site.	Not applicable for the reactor site.	Not applicable for the reactor site.
Decontamination and Decommissioning	Not Applicable	Not Applicable	Yes. For a generic discussion on impacts from decontamination and decommissioning see Section 5.2.5.
License Renewal	Yes. For a generic discussion on impacts from licensing renewal see Section 5.2.4.	Yes. For a generic discussion on impacts from licensing renewal see Section 5.2.4.	No

MEI = Maximally Exposed Offsite Individual
ISFSI = Independent Spent Fuel Storage Installation

4. AFFECTED ENVIRONMENT

Chapter 4 describes the affected environment associated with the production of tritium in commercial light water reactors (CLWRs). The chapter begins with a brief introduction, followed by descriptions of the affected environment at each of the alternative reactor sites being considered for tritium production.

4.1 INTRODUCTION

In accordance with Council on Environmental Quality regulations, the affected environment is "interpreted comprehensively to include the natural and physical environment and the relationship of people with that environment" (40 CFR 1508.14).

The descriptions of the affected environment provide bases for understanding the direct, indirect, and cumulative effects of the alternatives. The localities and characteristics of each potentially affected environmental resource are described for each site. The scope of the discussions varies with each resource to ensure that all relevant issues are included. The level of detail in the description of each resource also varies with the expectation of a potential impact to the resource. Resources expected to be impacted by the proposed action are discussed in more detail than those resources that are not likely to be affected. For instance, the descriptions of land resources, geology and soils, and archaeological and historic resources that are not expected to be impacted because of limited, if any, construction activities are less detailed. On the other hand, ambient conditions are described in greater detail for air and water resources that could be affected by the plant's intake and discharges at each site. This information serves as a basis for analyzing key air and water quality parameters to obtain results that can be compared with regulatory standards.

Socioeconomic conditions are described for the counties and communities that could be affected by regional population changes associated with the proposed program. The affected environment discussions include projections of regional growth and related socioeconomic indicators. Each region is large enough to encompass any growth related to direct project employment, as well as any secondary jobs that may be created by the program. As for other environmental resources, the level of detail is commensurate with the expected socioeconomic impact from the proposed action. For the currently operating units, only the socioeconomic impacts associated with incremental, tritium-related changes to the plants are considered. This environmental impact statement (EIS) provides less detail concerning current conditions for the operating units, Watts Bar Nuclear Plant Unit 1 (Watts Bar 1) and Sequoyah Nuclear Plant Units 1 and 2 (Sequoyah 1 and Sequoyah 2). However, more detail is provided for the partially constructed Bellefonte Nuclear Plant Units 1 and 2 (Bellefonte 1 and Bellefonte 2).

In addition to the natural and human environmental resources discussed above, the affected environment sections include a number of issues related to the ongoing activities at each site. These issues involve effluents from facility operations, waste and spent nuclear fuel management, and radiological and hazardous impacts during normal operation and from potential accidents.

4.2 AFFECTED ENVIRONMENT

4.2.1 Watts Bar Nuclear Plant, Unit 1

As discussed in Section 3.2.5, one of the reactor options under consideration is the irradiation of tritium-producing burnable absorber rods (TPBARs) at the Watts Bar 1. This option is based on the assumption that Watts Bar 1 would operate at its licensed full power output for the generation of electricity, with no reduced operability attributable to the production of tritium. The tritium production activity would be considered a secondary mission of the unit.

Preliminary construction of Watts Bar 1 started in spring 1973 (TVA 1995a). The major construction elements were largely completed by 1985. From 1985 to 1992, Watts Bar 1 underwent extensive reviews and modifications. Construction work was put on hold in December 1990. Work was resumed in November 1991 and, after extensive site review, the U.S. Nuclear Regulatory Commission (NRC) gave the site permission to resume full construction activities in May 1992. Watts Bar 1 was granted a full power operating license on February 7, 1996, and began commercial operation in May 1996. In October 1997, four lead test assemblies (fuel assemblies containing TPBARs) were inserted in the Watts Bar 1 reactor core in a demonstration to provide confidence to regulators and confirm that tritium production in a CLWR is both technically reasonable and safe. The status and results of this demonstration are described in Section 1.5.1.2.

Watts Bar 1 is described briefly in Section 3.2.5.1. Detailed descriptions of the site, buildings, structures, systems, and operations are provided in the licensing and environmental documents for the plant, which are listed below.

TVA (Tennessee Valley Authority), *Watts Bar Nuclear Plant, Final Safety Analysis Report, through Amendment 91*, Chattanooga, Tennessee, October (TVA 1995c)

NRC (U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Regulation), *Final Environmental Statement Related to the Operation of Watts Bar Nuclear Plant, Units 1 and 2, Tennessee Valley Authority 1995, NUREG-0498, Supplement No. 1, Docket Nos. 50-390 and 50-391,* April (NRC 1995b)

NRC (U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation), *Final Environmental Statement Related to Operation of Watts Bar Nuclear Plant Unit Nos. 1 and 2, Tennessee Valley Authority 1978,* NUREG-0498, Docket Nos 50-390 and 50-391, December (NRC 1978)

The regional and local climatology and meteorology of the Watts Bar 1 site described in the *Final Environmental Statement Related to Operation of Watts Bar Nuclear Plant Units 1 and 2* (NRC 1978) was re-evaluated in 1995 (NRC 1995b) with consideration of additional data accumulated in the intervening years. It was determined that the records used for the 1978 Final Environmental Statement provide an adequate representation of regional climatic conditions. This information was updated with the inclusion of more recent climatological and meteorological data for Chattanooga, Tennessee.

The following sections describe the affected environment at the Watts Bar 1 site for land resources, air quality, noise, water resources, geology and soils, ecology, cultural resources, and socioeconomics. In addition, the radiation and hazardous chemical environment, the waste management conditions, and spent nuclear fuel considerations at Watts Bar 1 are described.

4.2.1.1 Land Resources

Land Use

Watts Bar 1 is in the Watts Bar Reservation in Rhea County, Tennessee, approximately 80 kilometers (50 miles) northeast of Chattanooga, Tennessee, 50 kilometers (31 miles) north northeast of the Sequoyah Nuclear Plant site (TVA 1995c). The location of the site is shown on **Figure 4–1**. The Watts Bar Reservation on which Watts Bar 1 is located is a 716-hectare (1,770-acre) area on the west bank of the Chickamauga Reservoir. Watts Bar 1 is on the Tennessee River at River Mile 528 (River Mile refers to the distance along the Tennessee River measured from its mouth). The site layout is shown on **Figure 4–2.** The Watts Bar Nuclear Plant site is already dedicated to power generation.

The region of influence for land use includes lands within 3.2 kilometers (2 miles) of the Watts Bar Reservation. Land uses in the vicinity of Watts Bar 1 are classified as industrial, agricultural, forest, and recreational. The reservation that encloses the Watts Bar 1 site is maintained by the Tennessee Valley Authority (TVA) for the U.S. Government. In addition to Watts Bar 1, the reservation contains the Watts Bar Steam Plant, which has not operated since 1983 and has been deleted from the air emission permit for the area; the Watts Bar Dam and Hydroelectric Plant; the TVA Central Maintenance Facility; and the Watts Bar Resort Area (TVA 1995c).

Industry

The only significant industrial facility in the vicinity of Watts Bar, even though it is not operating at the present time, is the Watts Bar Steam Plant, a 240-megawatt coal-fired power plant that was shut down and placed in standby mode by TVA in 1983.

Agriculture

The total area of Rhea County and nearby Meigs County is approximately 1,290 square kilometers (498 square miles), of which about 34 percent, or 440 square kilometers (170 square miles), is unforested and used for agriculture (GISP 1998d, GISP 1998e).

Forest

Forests in the two-county area amount to 84,800 hectares (209,500 acres). They tend to be scattered along narrow ridges. Approximately 14 percent of forested land consists of Virginia and loblolly pine. Hardwood forests, chiefly of the oak-hickory type, cover 66 percent of the forested land. The remainder supports mixtures of pine, cedar, and hardwoods (DOA 1998a, DOA 1998b).

Recreation

The Watts Bar Reservation and the adjacent Watts Bar Resort are major recreation attractions in the immediate vicinity of the plant. In general, the Watts Bar and Chickamauga Reservoirs attract a high level of water-based recreation. The peak usage time is April 15 through October 15 (TVA 1971). Demand for recreation results in a large influx of daytime and overnight users.

Nature Reserves

The Hiwassee Waterfowl Refuge, Ocoee Wildlife Management Area, and the Yellow Creek Wildlife Management Area are located within 64 kilometers (40 miles) of the Watts Bar Reservation. There are three

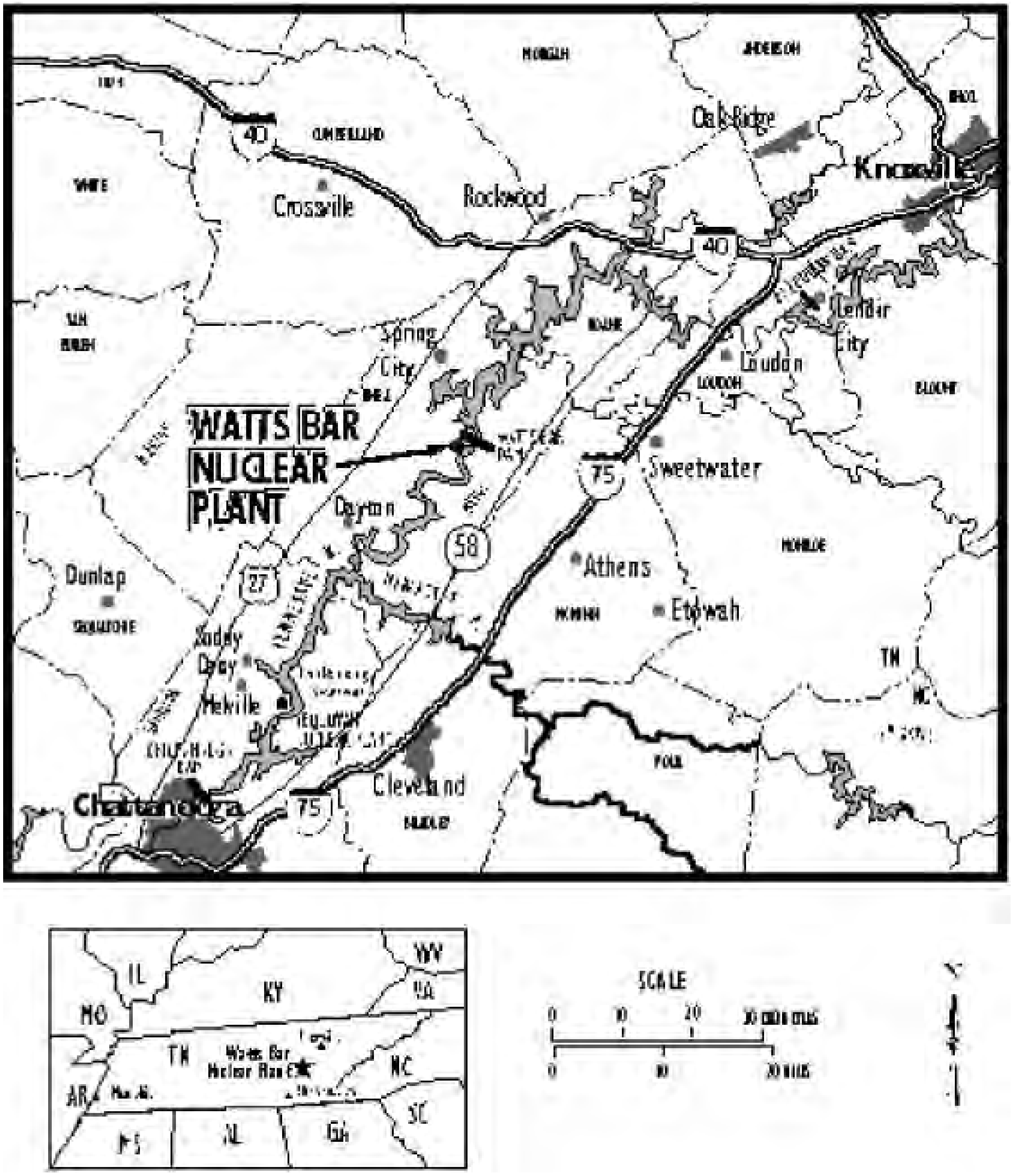


Figure 4–1 Location of Watts Bar Nuclear Plant Site

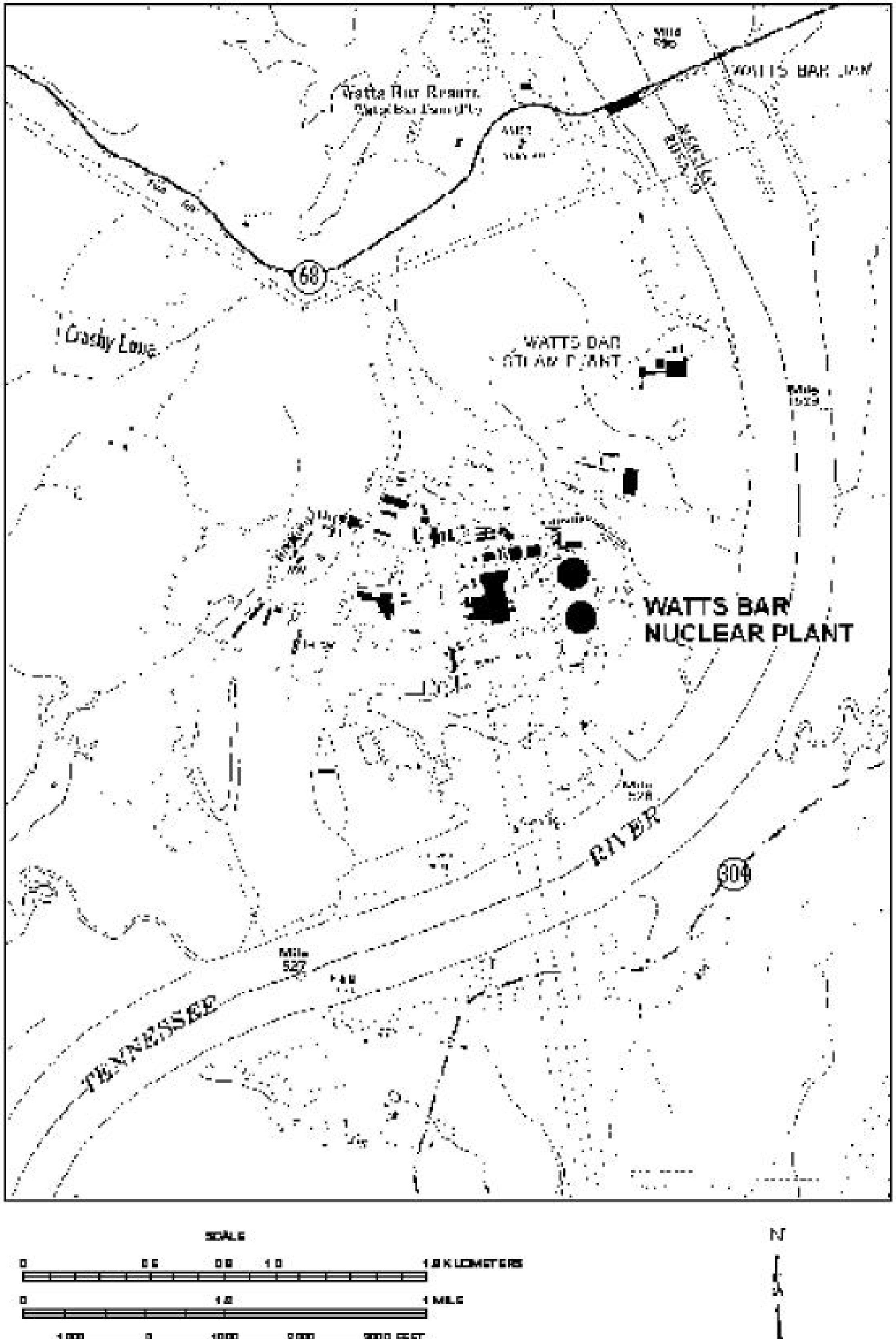


Figure 4–2 Watts Bar Nuclear Plant Site

state forests and one national forest within 48 kilometers (30 miles) of the site: Falls Creek State Park and Forest, Bledsoe State Forest, Mt. Roosevelt State Forest, and the Cherokee National Forest.

Visual Resources

The region of influence for visual resources includes those lands from which the site is visible. The major visual elements of the plant already exist, including the cooling towers, containment structures, turbine building, and the transmission lines. Views of Watts Bar 1 from passing river traffic on the Tennessee River are partially screened by the wooded area east of the plant. Distant glimpses of the plant site can be seen from the coves and hollows along the river, as well as from various area roads such as State Route 68 (TVA 1995c).

Based on the Bureau of Land Management Visual Resource Management method, the existing landscape at the site would be classified as Class 3 or 4. Class 3 includes areas where there has been a moderate change in the landscape and these changes may attract attention, but do not dominate the view of the casual observer. Class 4 includes areas where major modifications to the character of the landscape have occurred. These changes may be both dominant features of the view and the major focus of viewer attention (DOI 1986a).

During operation of Watts Bar 1, the vapor plume associated with the cooling towers can be visible up to 16 kilometers (10 miles) away. The plume length and frequency of occurrence varies with atmospheric conditions, being most visible during cooler months and after the passage of weather fronts. Plumes would be less visible during the summer months, when hazy conditions persist and morning fog is more common. Vapor plumes are visible at times from nearby residential areas, State Route 68, and other nearby roads (TVA 1972).

4.2.1.2 Noise

The most common measure of environmental noise impact is the day-night average sound level. The day-night average sound level is a 24-hour sound level with a 10-dBA penalty added to sound levels between 10:00 p.m. and 7:00 a.m. to account for increased annoyance due to noise during nighttime hours. The U.S. Environmental Protection Agency (EPA) has developed noise level guidelines for different land-use classifications based on day-night average and equivalent sound levels. The U.S. Department of Housing and Urban Development has established noise impact guidelines for residential areas based on day-night average sound levels. Some states and localities have established noise control regulations or zoning ordinances that specify acceptable noise levels by land-use category. The State of Tennessee has not developed a noise regulation that specifies the numerical community noise levels that are acceptable.

For the purpose of this document, a day-night average sound level of 65 dBA is the level below which noise levels would be considered acceptable for residential land and outdoor recreational uses. Estimated sound levels at the three residences nearest the site boundary at distances between 900 meters (3,000 feet) to 1,800 meters (6,000 feet) from the transformers and cooling towers, including the noise from the plant and background noise, are between day-night average sound levels of 53 and 63 dBA. Intermittent sound levels at these locations range from 84 to 103 dBA as a result of operating air-blast circuit breakers and steam venting (NRC 1995b). Generally the noise levels at these residences are below a day-night average sound level of 65 dBA and are considered acceptable. Watts Bar 1 is a licensed, operating nuclear power reactor. Testing of the emergency warning siren system occurs on a regular basis and results in outdoor noise levels of about 60 dBA in areas within a radius of about 16 kilometers (10 miles) of the site. TVA typically tests siren systems on a given day of the month at noon.

4.2.1.3 Air Quality

Watts Bar 1 is located in the Eastern Tennessee/Southwestern Virginia Interstate Air Quality Control Region. Baseline air quality data for the Watts Bar Site has been collected since 1969, prior to the start of construction of Watts Bar 1. Ambient concentrations of criteria pollutants, determined by measuring air quality in the vicinity of Watts Bar 1, are shown in **Table 4–1** with the applicable National Ambient Air Quality Standards and Tennessee State Ambient Air Quality Standards.

Table 4–1 Comparison of Baseline Watts Bar 1 Ambient Air Concentrations with Most Stringent Applicable Regulations and Guidelines

Criteria Pollutant	*Averaging Time*	*Most Stringent Regulation or Guideline[a] ($\mu g/m^3$)*	*Baseline Concentration ($\mu g/m^3$)[b]*
Carbon monoxide	8-hour 1-hour	10,000[c] 40,000[c]	1,270 1,270
Lead	Calendar quarter	1.5 [c]	0.03
Nitrogen dioxide	Annual	100 [c]	26.3
Ozone	8-hour (4th highest, averaged over 3 years)	157 [c,d]	e
Particulate matter[d]	PM_{10} Annual (3-year average) 24-hour (interim) 24-hour 99th percentile (3-year average) $PM_{2.5}$ Annual (3-year average) 24-hour (98th percentile average over 3-years)	 50 [c] 150 [c] 150 [c] 15[c] 65[c]	 20.3 39 35 f f
Sulfur dioxide	Annual 24-hour 3-hour	80 [c] 365 [c] 1,300 [c]	10.5 65.5 204
Other Regulated Pollutants			
Gaseous fluoride (as hydrogen fluoride)	30-day 7-day 24-hour 12-hour 8-hour	1.2[g] 1.6[g] 2.9[g] 3.7[g] 250[g]	h h h h h
Total suspended particulates (TSP)	24-hour	150 [g]	39 [i]

[a] The more stringent of Federal and state standards are presented if both exist for the averaging time. Tennessee State and National Ambient Air Quality Standards are the same for the criteria pollutants. The National Ambient Air Quality Standards (40 CFR 50), other than those for ozone, particulate matter, lead, and those based on annual averages, are not to be exceeded more than once per year. The 1-hour ozone standard is attained when the expected number of days per year with maximum hourly average concentrations above the standard is inment areas. The 8-hour ozone standard is attained when the 3-year average of the annual fourth-highest daily maximum 8-hour average concentration is less than or equal to 157 $\mu g/m^3$. The interim 24-hour PM_{10} standard is attained when the expected number of days with a 24-hour average concentration above the standard is The annual arithmetic mean particulate matter standard is attained when the expected annual arithmetic mean concentration is less than or equal to the standard.

[b] Based on ambient air quality monitoring data at a Loudon County location for 1996 and 1997 except for lead that is from the Rockwood monitor in Roane County (1996) and PM_{10} from Bradley County (1994 and 1995). Concentrations shown are maximums for the averaging period.

[c] Federal standard.

[d] EPA recently revised the ambient air quality standards for particulate matter and ozone. The new standards, finalized on July 18, 1997, change the ozone primary and secondary standards from a 1-hour concentration of 235 $\mu g/m^3$ (0.12 ppm) to an 8-hour concentration of 157 $\mu g/m^3$ (0.08 ppm). During a transition period while states are developing state implementation plan revisions for attaining and maintaining these standards the 1-hour ozone standard would continue to apply in nonattainment areas (62 FR 38855). For particulate matter, the current PM_{10} (particulate matter size less than or equal to 10 micrometers) annual standard is retained and two $PM_{2.5}$ (particulate matter size less than or equal to 2.5 micrometers) standards are added. These standards are set at 15 $\mu g/m^3$ for the 3-year annual average arithmetic mean based on community-oriented monitors and 65 $\mu g/m^3$ for the 3-year average of the 98th percentile of 24-hour concentrations at population-oriented monitors. The current 24-hour PM_{10} standard is revised to be based on the 3-year average of the 99th percentile of 24-hour concentrations. The existing PM_{10} standards would continue to apply in the interim period (62 FR 38652).

[e] There is insufficient data to compare to the 8-hour standard for ozone.

[f] Compliance with the new $PM_{2.5}$ standards was not evaluated since current emissions data for $PM_{2.5}$ are not available.

[g] State standard.

[h] No local monitoring data is available for gaseous fluoride.

[i] PM_{10} value is presented and would underestimate the TSP concentration. No monitoring data available for total suspended particulates.

Source: 62 FR 38855, 62 FR 38652, TN DEC 1994, TVA 1998a.

The area in which Watts Bar 1 is located is designated by EPA as an attainment area with respect to the National Ambient Air Quality Standards for criteria pollutants (40 CFR 81). For locations that are in an attainment area for criteria pollutants, prevention of significant deterioration regulations limit pollutant emissions from new sources and establish allowable increments of pollutant concentrations. Class I areas include national wilderness areas, memorial parks larger than 2,020 hectares (5,000 acres), national parks larger than 2,340 hectares (6,000 acres), and any areas redesignated as Class I. The Class I areas closest to Watts Bar 1 are the Joyce Kilmer–Slickrock National Wilderness Area and the Great Smoky Mountains National Park. These Class I areas are located approximately 80 kilometers (50 miles) from Watts Bar 1 (TVA 1998e).

Sources of criteria nonradiological air pollutant emissions at Watts Bar 1 include five diesel-powered emergency generators; two diesel generators for security power and fire protection pumps; site and employee vehicles; two auxiliary boilers; two natural-draft cooling towers; a lube oil system; two fixed-roof, No. 2 fuel oil storage tanks; a paint shop; and a sandblast shop. Small quantities of toxic chemicals and metals are emitted from testing and operation of the diesel fuel-fired equipment, resulting in contributions to offsite concentrations of less than 0.0001 percent of the threshold limit value of any of these pollutants. One-tenth of the threshold limit value often is used as a guideline in identifying pollutants that may be of concern and should be evaluated in more detail. Ozone is produced by corona discharge (ionization of air) in the operation of transmission lines and substations, particularly at the higher voltages, and by operation of electrical equipment such as motors and generators. TVA minimizes corona discharges by optimizing, to the extent practicable, the design and construction of its transmission facilities (TVA 1997c).

The calculated concentrations of carbon monoxide, nitrogen dioxide, particulate matter, and sulfur dioxide from operation of the auxiliary steam boilers are two or more orders of magnitude below the ambient standards shown in Table 4–1 (NRC 1995b). Compliance with the new $PM_{2.5}$ standards was not evaluated since current emissions data for $PM_{2.5}$ are not available. When the calculated concentrations from onsite sources are combined with concentrations from offsite sources, the ambient air quality standards for carbon monoxide, nitrogen oxide compounds, particulate matter, and sulfur dioxide continue to be met.

The occurrence of visible plumes has been evaluated for Watts Bar 1. Naturally occurring fog with visibility equal to or less than 0.4 kilometer (0.25 mile) occurs in the vicinity of Watts Bar 1 about 35 days per year (TVA 1995c). Occurrences of the plume descending to the ground or causing localized surface fogging are expected to be rare. Some localized fog may occur on rare occasions on top of Walden Ridge, about 13 kilometers (8 miles) to the west-northwest (TVA 1995c).

Gaseous Radioactive Emissions

Watts Bar 1 has three primary sources of gaseous radioactive emissions:

Discharges from the gaseous waste management system

Discharges associated with the exhaust of noncondensable gases in the main condenser if a primary to secondary leak exists

Radioactive gaseous discharges from the building ventilation exhaust, including the reactor building, reactor auxiliary building, and fuel-handling building

The gaseous waste management system collects fission product gases (mainly noble gases) that accumulate in the primary coolant. A portion of the primary coolant is continually diverted to the primary coolant purification, volume, and chemical control system to remove contaminants and adjust the chemistry and volume. Noncondensable gases are stripped and sent to the gaseous waste management system, a series of gas storage tanks where the extended holdup time allows short half-life radioactive gases to decay, leaving only a small quantity of long half-life radionuclides to be released to the atmosphere. The annual gaseous radioactive emissions from Watts Bar 1 normal operation are shown in **Table 4–2**.

Table 4–2 Annual Radioactive Gaseous Emissions at Watts Bar 1

Emission	***Quantity***
Fission gases	282.5 Ci
Tritium	5.6 Ci

Source: TVA 1998e.

Meteorology and Climatology

The regional and local climatology and meteorology of the Watts Bar site, described in the *Final Environmental Statement Related to Operation of Watts Bar Nuclear Plant Units 1 and 2* (NRC 1978), was re-evaluated in 1995 (NRC 1995b) with consideration of additional data accumulated in the intervening years. It was determined that the records used for the 1978 Final Environmental Statement provide an adequate representation of regional climatic conditions. This information has been updated with more recent data for Chattanooga, Tennessee.

Regional Climate

The Great Tennessee Valley, located between the Cumberland Plateau to the west and the Appalachian Mountains to the east, is an area of complex local terrain. This results in localized variations in temperatures and winds.

As a whole, the area experiences a moderate climate with cool winters averaging 1
than plateau areas to the west. In the winter, severe weather is rare. Snowfall is variable from year to year, ranging from none to heavy snowfall. Appreciable accumulations seldom last more than a few days. Occasional ice storms may be severe enough to cause some damage.

The summer temperature rises to as high as 35
temperatures by 5 rature determined from data recorded from
1961 to 1990 at the Chattanooga Airport is 15.2

January is -2.2
(NOAA 1997a).

Precipitation is fairly uniform throughout the year. The average annual precipitation is approximately 133.5 centimeters (52.57 inches). Severe thunderstorms may result in hail and damaging winds. Prevailing winds are from the south-southwest. The average annual wind speed is 1.82 meter per second (4.07 miles per hour) (TVA 1995c).

Severe Weather

The current estimate of tornado strike probability at the Watts Bar site is 0.00018 per year (18 chances in 100,000 in a given year) with a recurrence interval of 5,400 years (NRC 1995b). The maximum sustained windspeed reported in Chattanooga was 132 km/hr (82 mi/hr).

Thunderstorms occur on approximately 50 day/yr. Freezing precipitation occurs, on the average, every other year. Air stagnation within the site area is expected to occur for about six days annually (TVA 1995c, TVA 1998e).

Local Meteorological Conditions

Winds tend to be light. The direction of flow is up and down the Tennessee River Valley. Nighttime stable atmospheric conditions with light winds are driven by local conditions. Neutral atmospheric stability conditions are prevalent during the transition between day and night. The frequencies of calm winds during extremely unstable atmospheric conditions (stability classes A and B) are lower than expected. Although unusual, this shift in stability class is not significant because it occurs infrequently and under conditions associated with relatively good dispersion.

4.2.1.4 Water Resources

Surface Water

The Watts Bar Reservation is located on the Tennessee River at River Mile 528.0 at the northern end of the Chickamauga Reservoir (TVA 1998e). Chickamauga Reservoir is TVA's sixth largest reservoir. The reservoir is 95 kilometers (59 miles) long on the Tennessee River and 51 kilometers (32 miles) long on the Hiwassee River, covering an area of 14,300 hectares (35,350 acres), with a volume of 775 million cubic meters (628,000 acre-feet). At the Watts Bar 1 site, the reservoir is about 335 meters (1,100 feet) wide, with cross-sectional depths ranging between 5.5 meters (18.0 feet) and 7.9 meters (26 feet).

The Tennessee River above Chattanooga is one of the most highly regulated rivers in the United States. The TVA reservoir system is operated for flood control, navigation, and power generation, with flood control a prime purpose. Particular emphasis is placed on protection of Chattanooga, 66 kilometers (41 miles) downstream from the Watts Bar Site.

During the steam cycle, heat from the Watts Bar 1 turbine is released when the steam passes through a condenser cooled with recirculated water from the Tennessee River. This water is cooled by passing it through a natural-draft evaporative cooling tower. Although the system is designated as a closed type, makeup water from the Tennessee River is needed to replace water losses from evaporation, drift, and blowdown.

At full power, the temperature of the water flowing through the condenser is raised by approximately 20
(36 n (66,600 gal/min of water is withdrawn from the Tennessee River to make up for water lost in the cooling system. Blowdown from the natural-draft cooling tower is discharged into the river at

a normal rate of 125,600 l/min (33,200 gal/min). "Blowdown" is a maintenance process to remove excess dissolved solids left after the water evaporates.

On the Watts Bar 1 site, two temporary chemical holding ponds are available for use to retain and treat chemicals from the turbine building. The smaller pond is lined and holds 3,800 cubic meters (1 million gallons). The larger, unlined pond has a volume of 19,000 cubic meters (5 million gallons). The ponds discharge via outfall pipe 103 to the large outdoor holding pond. This discharge is monitored in accordance with the plant's National Pollutant Discharge Elimination System (NPDES) State of Tennessee 1993 Permit (NRC 1995b).

Blowdown from the natural-draft cooling towers is routed to a multiport diffuser system (outfall pipe 101) in the main channel of the Tennessee River at River Mile 527.9 in accordance with the NPDES Permit. Makeup water and other water supply requirements are taken from an intake channel and pumping station at Tennessee River Mile 528. When there is low flow from the Watts Bar Dam, cooling tower blowdown is routed to a holding pond. The maximum intake pumping flow rate is approximately 4.5 m^3/s (160 ft^3/s) (TVA 1997b). At this flow, the diffuser exit jet velocity would be 2 m/s (6.6 ft/s). The discharge temperature varies depending on the cooling tower performance, which is a function of the ambient air temperature, from 5
(91 in July. With a 35
difference between the discharge and the river temperature varies from -5.8
to 22.3

TVA has completed an environmental assessment of a proposed modification to Watts Bar 1 called the supplemental condenser cooling water project (TVA 1997g). As previously discussed, the Watts Bar 1 condenser circulating cooling water system uses a natural-draft cooling tower to reject waste heat from the steam cycle. The cooling capability of the tower is significantly affected by site meteorological conditions. As the ambient temperatures become higher, the tower-cooled water temperature also increases. The warmer water from the tower results in a decrease in the net megawatt-electric power output of Watts Bar 1 due to an increase in the condenser backpressure above the optimum design value. If the temperature of the water to the main condenser could be reduced, the efficiency and output of Watts Bar 1 could be improved. Therefore, TVA investigated the feasibility of supplementing cooling tower thermal performance by routing cooler water from upstream of the Watts Bar Dam to mix with and lower the temperature of the water from the tower.

The proposed project would provide between 435,313 and 511,020 l/min (115,000 and 135,000 gal/min) from the Watts Bar Reservoir to Watts Bar 1, depending on the pool elevation, to supplement the cooling capacity of the existing cooling tower. The proposed project would use some of the existing structures and components at the Watts Bar Fossil Plant to take advantage of the gravity flow and eliminate the need for new pumps. This project would use the existing intake structure at the Watts Bar Dam and most of the existing large diameter pipe from the dam to the Watts Bar Fossil Plant to supply supplemental cooling water to Watts Bar 1. New pipe between the Watts Bar Fossil Plant and the Watts Bar 1 cooling towers would be installed. The discharge structure at the Watts Bar Fossil Plant would be integrated into the project.

The environmental assessment of this proposed supplemental condenser cooling water project for Watts Bar 1 concluded that the construction and operation of this system would have no significant adverse environmental impacts with the appropriate implementation of the commitments delineated in the environmental assessment. Special emphasis was placed on the thermal discharge limits, and relevant analyses were performed to demonstrate no significant thermal impacts. TVA has not yet made a decision regarding the construction of this proposed supplemental condenser cooling water system.

Surface Water Quality

The Tennessee Department of Environment and Conservation classifies the streams and creeks of Tennessee based on water quality, stream uses, and resident aquatic biota. Classifications are defined in the State of Tennessee water quality standards. Monitoring data are presented in **Table 4–3**. Surface water quality measurements made during the period of operation of Watts Bar 1, when compared with preoperational monitoring values, show that Watts Bar 1 operations have no significant effect on surface water quality (TVA 1997b).

Table 4–3 Summary of Surface Water Quality Monitoring in the Vicinity of the Watts Bar Site

Parameter	*Unit of Measure*	*Water Quality Criteria*	*Average Water Body Concentration*
Radiological			
Alpha (gross)	pCi/l	15[a]	0.433
Beta (gross)	pCi/l	50[b]	3.75
Tritium	pCi/l	20,000[a]	<300[c]
Nonradiological			
Manganese	mg/l	0.05[d]	0.060
Nitrate (as N)	mg/l	10.0[a]	0.253
Arsenic	mg/l	0.05[e]	0.001
Barium	mg/l	2.0[e]	0.142
Cadmium	mg/l	0.005[e]	0.00014
Chromium	mg/l	0.1[e]	0.0012
Lead	mg/l	0.005[e]	0.0046
Mercury	mg/l	0.002[e]	0.00021
pH	pH units	6.0 - 9.0[e]	7.8

[a] National Primary Drinking Water Regulations (40 CFR 141).
[b] Proposed National Primary Drinking Water Regulation.
[c] Below lower limit of detection of 300 pCi/l
[d] National Secondary Drinking Water Regulations (40 CFR 143).
[e] Tennessee General Water Quality Criteria for Domestic Water Supply (TN DEC 1995)
Source: TVA 1998a, TVA 1998b, Tennessee 1998, TVA 1997b.

Surface Water Use and Rights

There are 20 surface water users within 80 kilometers (50 miles) downstream of the Watts Bar 1 site; 6 are water utility districts and 14 are industrial users. The continued operation of the plant is not expected to affect surface water use.

The Watts Bar 1 site can use a maximum of approximately 389,000 cubic meters (103 million gallons) of process water per day. The average quantity of water flowing by the site is 66,270,000 cubic meters (17,500 million gallons) per day. Under average flow conditions, Watts Bar 1 uses 0.6 percent of the total flow of the Tennessee River (TVA 1997b).

The major public water uses of the Chickamauga Reservoir are for water supplies and recreation. There are two municipal drinking water intakes downstream from the Watts Bar Site on the Chickamauga Lake. The closest downstream public water supply is Dayton, Tennessee, 39 kilometers (24.2 miles) downstream, which serves 6,900 people.

In Tennessee, the State's water rights laws are codified in the Water Quality Control Act. In effect, the water rights are similar to riparian rights in that the designated usage of a water body cannot be impaired. In order to construct intake structures for the purpose of withdrawing water from available supplies, U.S. Army Corps of Engineers and TVA permits are required.

Liquid Chemical and Radioactive Effluents

The radionuclide contaminants in the primary coolant are the source of liquid radioactive waste at Watts Bar 1. Liquid radioactive wastes vary considerably in composition. They may include nonradioactive contaminants and chemical constituents depending on the history and collection point of the liquid. Each source of liquid waste receives an individual degree and type of treatment before storage for reuse or discharge to the environment under the Watts Bar 1 NPDES permit. To increase the efficiency of waste processing, wastes of similar characteristics are grouped together before treatment. The Watts Bar 1 liquid effluents to the environment during normal operation are shown in **Table 4–4**.

Table 4–4 Annual Chemical and Radioactive Liquid Effluents Released to the Environment from Operation of Watts Bar 1

Materials	*Quantity*
Chemicals	1,098,040 [a] kg
Tritium Other radionuclides	639 [b] Ci 1.32 [b] Ci

[a] TVA 1996a.
[b] TVA 1998e.

Floodplains and Flood Risk

At Watts Bar 1, the 100-year floodplain for the Tennessee River varies from elevation 212.3 meters (696.6 feet) above mean sea level at river mile 527.0 to elevation 212.6 meters (697.6 feet) at River Mile 529.0. The TVA Flood Risk Profile elevation on the Tennessee River varies from elevation 213.5 meters (700.5 feet) at River Mile 527.0 to elevation 213.8 meters (701.5 feet) at River Mile 529.0. The Flood Risk Profile is used to control flood damageable development for TVA projects. At this location, the Flood Risk Profile elevation is based on the 500-year flood elevation (TVA 1998e).

The safety-related facilities, systems, and equipment are housed in structures that provide protection from flooding for all flood conditions up to plant grade at 222 meters (728 feet). Rainfall floods exceeding this elevation would require plant shutdown. The situation producing the maximum plant site flood level was determined to be one of two events: (1) a sequence of March storms producing maximum precipitation on the watershed above Chattanooga or (2) a sequence of March storms centered and producing maximum precipitation in the basin to the west of the Appalachian Divide and above Chattanooga. Seismic and flood events could cause dam failure surges above plant grade elevation 222 meters (728 feet). Flood waves from landslides into upstream reservoirs required no special analysis (TVA 1995c).

Groundwater

Groundwater at Watts Bar 1 is derived principally from infiltration of local precipitation and from lateral underflow from the area north of the plant site. All groundwater flow from the site is to Chickamauga Lake, either directly or via Yellow Creek. The plant site is located above the Conasauga Shale, a formation made up of about 84 percent shale and 16 percent limestone. The shales and limestones are essentially impervious to water, and the majority of the groundwater flows through the terrace deposits overlying bedrock.

Groundwater Quality

Preoperational monitoring of groundwater was performed by analyzing data from six wells tapped into the Conasauga Shale aquifer to verify that the flow gradient was toward the Chickamauga Reservoir. The operational groundwater monitoring program uses two wells in the Conasauga Shale aquifer: one upgradient and one downgradient of the plant. Quarterly samples are taken to monitor for the consistency of groundwater constituents (NRC 1995b).

Groundwater Availability, Use, and Rights

Potable water for plant use is obtained from the Watts Bar Utility District. The utility district's water is obtained from three wells located 4 kilometers (2.5 miles) northwest of the plant (TVA 1995c). Single family wells are common in adjacent rural areas not served by the public water supply system. Industrial and drinking water supplies in the area are primarily taken from surface water sources.

Groundwater rights in the State of Tennessee are traditionally associated with the Reasonable Use Doctrine. Under this doctrine, landowners can withdraw groundwater to the extent that they exercise their rights reasonably in relation to the similar rights of others.

4.2.1.5 Geology and Soils

Geology

The Watts Bar 1 site is located in the Tennessee Section of the Valley and Ridge Province of the Appalachian Highlands (TVA 1995c). The distinguishing geological feature of the province is the series of folded and faulted mountains and valleys that overlie Paleozoic sedimentary formations totaling 12.2 kilometers (40,000 feet) in thickness. The plant is located on alluvial terrace deposits on a bend of the Tennessee River. Below these deposits lies the Middle Cambrian Conasauga, a shale formation of 84 percent shale and interbedded limestone. The shales and limestones are generally low permeability formations. The majority of the groundwater flows through the terrace deposits overlying the bedrock.

The controlling feature of the geologic structure at the site is the Kingston thrust fault that developed 250 million years ago. The fault has been inactive for many millions of years, and recurrence of movement is not expected. The fault lies to the northwest of the site area and is not involved in the foundation of any of the major plant structures (TVA 1995c).

Seismology

Watts Bar 1 was designed based on the largest historic earthquake to occur in the Southern Appalachian Tectonic Province—the 1897 Giles County, Virginia, earthquake (Intensity: Modified Mercalli VIII and Richter magnitude of 6 to 7). The safe-shutdown earthquake for the plant has been established at a maximum horizontal acceleration of 0.18g (g = acceleration due to gravity) and a simultaneous maximum vertical acceleration of 0.12g (TVA 1995c). The "safe-shutdown earthquake" is defined as the earthquake that produces the maximum ground vibration for which the reactor coolant pressure boundary, the capability to shut down the reactor and maintain it in the shutdown mode, and the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the guideline exposures—are designed to remain functional (10 CFR 100, Appendix A).

Soils

Extensive evaluation was made of the soils on the Watts Bar 1 site, and foundation requirements were devised for all of the plant structures related to the specific location and safety classification of each. The unconsolidated deposits overlying bedrock were primarily alluvial deposits consisting of fine grained, finely sorted soils and clays with micaceous sand and some quartz gravel. The general requirements for Safety Category I structures involved use of in-situ soil, compacted granular fill, or in-situ rock as foundation material (TVA 1995c).

4.2.1.6 Ecological Resources

Terrestrial Resources

The Watts Bar Reservation is located within the Ridge and Valley Physiographic Province. This province lies between the Blue Ridge Mountains and the Cumberland Plateau and is characterized by prominent, northwest trending ridges and adjacent valleys. The Tennessee River flows through this province, roughly paralleling the alignment of the valleys. The Watts Bar 1 Site is located in an area heavily impacted by agricultural activities. The site was further altered during its conversion to an industrial site. Terrestrial biological communities outside the immediate plant area have not been substantially impacted by the existing power plant. No areas onsite are identified as critical areas for terrestrial plant and animal species protected under state or Federal laws.

Terrestrial Wildlife

The Watts Bar 1 site vicinity, as a result of exclusion control, serves the function of an informal preserve and continues to support a variety of terrestrial plant and animal communities. No further expansion of the current operations area is anticipated. Game species in the vicinity of the site include white-tailed deer, gray squirrel, raccoon, wild turkey, ruffed grouse, cottontail rabbit, and bobwhite quail. Good squirrel populations occur in large stands of hardwoods, while raccoons and rabbits are most common in the wide, rolling valleys between the ridges.

The mixture of forest and open vegetative types of terrain, and the large degree of openness within the forest provide an abundance of niches favoring a diverse bird population. The diverse habitat sites surrounding the plant site support varied and abundant populations of snakes, frogs, salamanders, and other reptiles.

Wetlands

Potential wetland areas identified in the vicinity of the Watts Bar 1 site are: (1) palustrine, bottom land hardwood, deciduous temporarily flooded, and (2) fringe wetlands. They are indicated in **Figure 4–3** (TVA 1994b).

Aquatic Resources

The Watts Bar 1 Site (at Tennessee River Mile 528.0) is in the riverine portion of Chickamauga Reservoir, approximately 3.2 kilometers (2 miles) downstream of Watts Bar Dam. The quality of the water at the Watts Bar 1 intake was generally satisfactory, but negatively influenced, particularly in summer and fall, by water releases from Watts Bar Reservoir, 3.2 kilometers (2 miles) upstream. Water standing at the face (the forebay) of the Watts Bar Dam becomes stratified, particularly in warmer weather, and consequently becomes oxygen deficient. In 1996, an aerator was installed in the forebay of the Watts Bar Reservoir to reduce stratification and provide higher dissolved oxygen levels in reservoir releases.

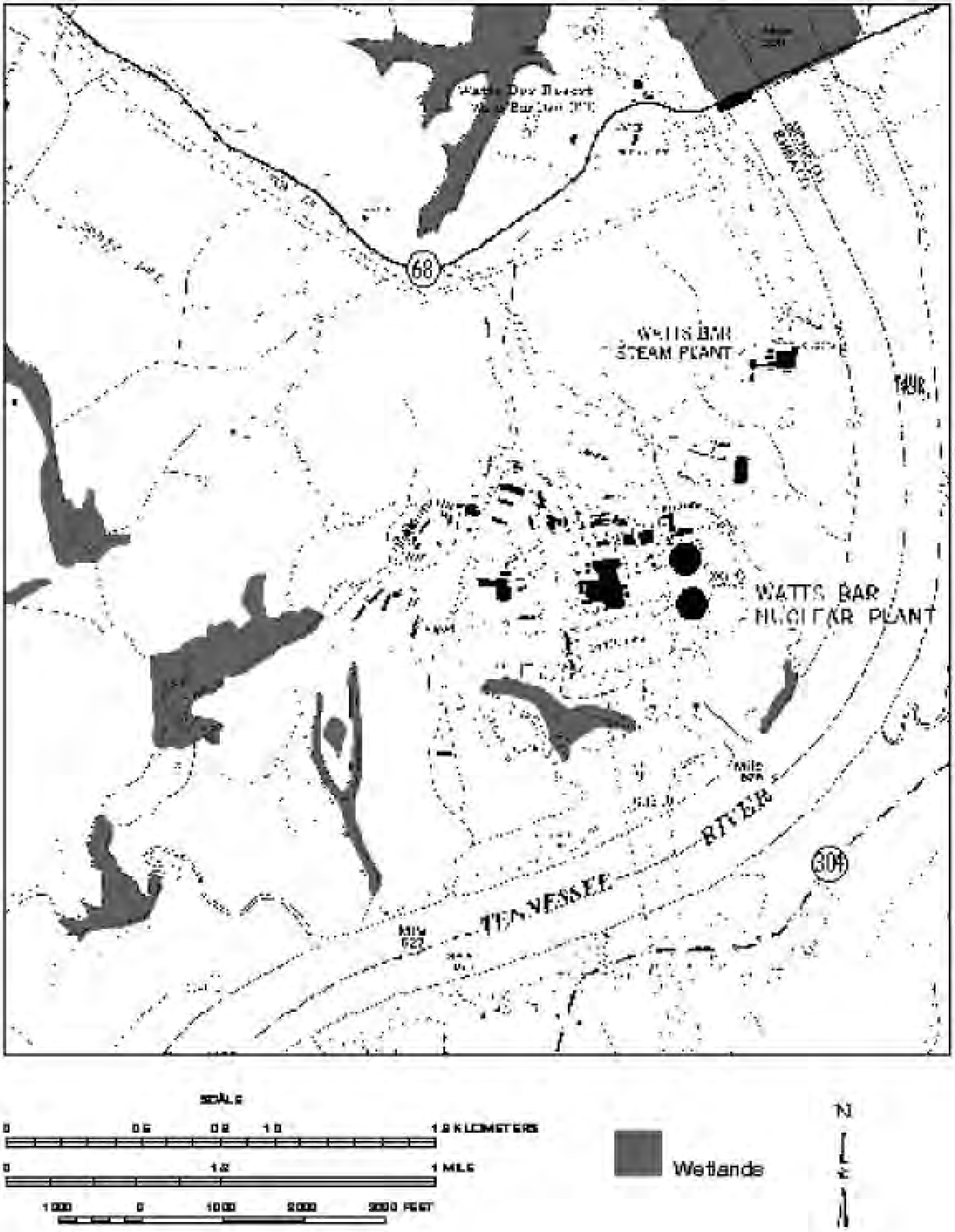


Figure 4–3 National Wetlands Inventory Map of Watts Bar Nuclear Plant Site Vicinity

Watts Bar 1 began commercial generation on May 27, 1996, and operated at an 84 percent capacity factor through its first cycle. Trends and similarities noted during preoperational monitoring, and comparisons with operational data, were used to determine potential plant-induced effects to aquatic communities and water quality.

Plankton

Evaluation of the entrainment of icthyoplankton (fish eggs and larvae) during the first year of operation of Watts Bar 1 revealed the presence of only a few varieties and at low densities (TVA 1997d). Eggs and larvae passing the Watts Bar 1 water intake are primarily spawned in the Watts Bar Reservoir and exposed to passage through the hydroelectric generation turbines at Watts Bar Dam. Very few eggs or larvae of species known to spawn in tailwaters (downstream side of the dam) were collected, indicating that most spawning in Chickamauga Reservoir occurs downstream of the Watts Bar Site (TVA 1997d). The entrainment of eggs and larvae by Watts Bar 1 is characterized as extremely low (counts of 449 and 267 during the period sampled). These low-levels are largely attributed to the low use of water (0.6 percent) passing the plant (TVA 1997b).

Fish Communities

Fish community sampling results after Watts Bar 1 began operation were found to be consistent with the preoperational results (TVA 1997d). The slight differences were attributed to the difference in the sample design. The 1977–1985 data was collected on a monthly basis throughout the year and 1990–1995 data being collected only once during the fall of each year. Important species evaluated in the comparison of preoperational and operational conditions were largemouth bass, spotted bass, redear sunfish, white bass, emerald shiner, common carp, brook silversides, log perch, bluegill, smallmouth bass, spotted sucker, and yellow bass.

Results of the first year's monitoring compared with preoperational data indicate that operation of Watts Bar 1 has not adversely impacted the tailwater fish population below Watts Bar Dam. Fish impingement on the Watts Bar 1 water intake traveling screens was virtually nonexistent.

Aquatic Macrophytes

Aquatic plants in the Watts Bar Reservoir covered 0.04 square kilometer (10 acres) during the late 1970s. Coverage increased to about 2.8 square kilometers during the 1980s but decreased back to the 1970s levels by the early 1990s. An extended drought in the mid- to late 1980s enhanced conditions for growth of aquatic macrophytes. A return to more normal rainfall and runoff conditions resulted in a return to early 1980s densities. Eurasian watermilfoil *Myriophyllum spicatum* and spiny-leafed naiad *Najas minor* remain the dominant species. Populations of aquatic macrophyte species in the Chickamauga Reservoir fluctuated similarly over the same period, primarily in response to river flow conditions (NRC 1995b).

Mussel and Clam Communities

The Tennessee River downstream from Watts Bar Dam is inhabited by a relatively diverse native mussel community. Sampling conducted several times during the last 14 years indicates that 31 species are present; however, the 5 most abundant species account for 90 percent of the total. Many of the mussels present in this part of the Tennessee River are quite old, and most species may not have reproduced successfully in the last 30 or more years. The long-term trend is a reduction in abundance and species richness (TVA 1997b; NRC 1995b).

The 16-kilometer (9.9-mile) reach of the Tennessee River from Watts Bar Dam (Tennessee River Mile 529.9) downstream to Hunter Shoal (Tennessee River Mile 520.0) has been designated a mollusk sanctuary by the State of Tennessee. While commercial harvest of mussels is prohibited within the sanctuary, the age and species composition of the surviving mussel stocks in this river reach do not support any commercial harvest, even outside of the sanctuary (NRC 1995b).

In addition to the native mussels, this part of the Tennessee River is inhabited by a large population of the Asiatic clam *Corbicula fluminea* and an increasing population of the zebra mussel *Dreissena polymorpha*. The Asiatic clam has been present in the Watts Bar Dam tailwater for at least 25 years, but the zebra mussel was first found there in 1993 (TVA 1997b).

Threatened and Endangered Species

Several terrestrial and aquatic species that occur in the vicinity of the Watts Bar 1 site are listed as endangered or threatened by the U.S. Fish and Wildlife Service and/or state agencies in Tennessee (**Table 4–5**). The status and biology of federally listed species in the vicinity of the Watts Bar site was described in detail in the Biological Assessment included in the 1995 NRC Final EIS (NRC 1995b), which is incorporated here by reference. More current information on the status of the federally listed species is included, where available, in the following discussion.

Table 4–5 Listed Threatened or Endangered Species Potentially On or Near the Watts Bar Site

Common Name	*Scientific Name*	*Federal*	*State*
Mollusks			
Dromedary Pearlymussel	*Dromus dromas*	Endangered	Endangered
Pink Mucket	*Lampsilis abrupta/Lampsilis orbiculata*	Endangered	Endangered
Rough Pigtoe	*Pleurobema Plenum*	Endangered	Endangered
Fanshell	*Cyprogenia stegaria*	Endangered	Endangered
Fish			
Blue Sucker	*Cyprogenia stegaria*	a	Threatened
Snail Darter	*Percina tanasi*	Threatened	Threatened
Amphibians			
Eastern Hellbender	*Cryptobranchus a. alleganiensis*	a	NMGT[b]
Birds			
Bald Eagle	*Haliaeetus leucocephalus*	Threatened	Threatened
Osprey	*Pandion haliaetus*	a	Threatened
Mammals			
Gray Bat	*Myotis grisescens*	Endangered	Endangered

[a] Not listed.
[b] NMGT = In Need of Management
Source: NRC 1995b, TVA 1998a, Tennessee 1994, DOI 1998a.

Plants

No federally or state-listed plants are known to occur on or in the immediate vicinity of the Watts Bar site.

Terrestrial Animals

Bald eagles, listed as threatened, visit the Watts Bar site during the winter where they roost on trees near the reservoirs and forage for fish. The nearest reported eagle nest is about 6.4 kilometers (4 miles) south-southwest of the plant. This nest site was first used in 1994 and has been inactive since 1996. Gray bats roost in caves throughout the year and primarily feed over water on adult insects. The nearest cave in which gray bats have been found is located about 6 kilometers (3.7 miles) downstream from the Watts Bar site. Because of frequent human visitation, this cave is not regularly occupied by bats. Gray bats have also been reported from three other caves between 15 and 30 kilometers (10 and 20 miles) from the Watts Bar site. Only one of these three caves is, at present, regularly occupied by gray bats. Gray bats may also forage over the reservoir adjacent to and downstream from the plant site.

The State of Tennessee lists the osprey as threatened. Ospreys feed primarily on fish and regularly occur along the Tennessee River adjacent to the Watts Bar site (NRC 1995b). Ospreys have also recently nested in the immediate vicinity of Watts Bar Dam.

Aquatic Animals

Five aquatic species found in the Tennessee River near the Watts Bar site are on the Federal lists of endangered or threatened wildlife. Four of these species are endangered mussels (dromedary pearlymussel, pink mucket, rough pigtoe, and fanshell) and the other species is a threatened fish (the snail darter). Of these species, only the pink mucket and snail darter have been observed in this part of the river within the last decade. The State of Tennessee has listed the blue sucker as a threatened species and the hellbender to be In Need of Management. Both of these species have been observed only on rare occasions in the Watts Bar Dam tailwater (NRC 1995b).

Three other aquatic species, all federally listed as endangered, were found in preimpoundment surveys of nearby portions of the Tennessee River. These species are the birdwing pearlymussel *Conradilla caelata*, white wartyback pearlymussel, *Plethobasus cicatricosus*, and the Cumberland monkeyface pearlymussel, *Quadrula intermedia.* They all inhabit gravel riffles in medium to large rivers, and have not been found in the Watts Bar tailwater or in Chickamauga Reservoir for 25 years.

4.2.1.7 Archaeological and Historic Resources

For the past 12,000 years, through changing climates and environmental conditions, the Tennessee River Valley has attracted humans because of its system of water routes and its abundance of natural resources. Surveys of the Watts Bar 1 site and vicinity have identified numerous archaeological resources (Schroedl 1978, Calabrese 1976). Data recovery excavations were undertaken in 1971. Other archaeological sites exist along the reservoir shoreline downstream from the Watts Bar 1 site. However, it is important to note that no systematic archaeological survey was conducted to identify buried sites that could be present in the area of potential effect.

No sites listed in the *National Register of Historic Places* are located at or near the Watts Bar 1 site. Sites that are potentially eligible for listing in the National Register within the Watts Bar Reservation include the Watts Bar Steam Plant and the Watts Bar Dam.

Construction of Watts Bar 1 is complete, and the reactor has operated since May 1996. The operation experience to date indicates that there is no impact on archaeological or historic resources on or near the Watts Bar site.

4.2.1.8 Socioeconomics

Watts Bar 1 is located near the town of Spring City, Rhea County, in eastern Tennessee. The precise location is latitude 35 and longitude 84
(17 miles) northeast of Dayton, Tennessee, and 80 kilometers (50 miles) northeast of Chattanooga, Tennessee. Highway access to Spring City is via Route 27 and nearby Route 68. Route 27 links the town to Dayton (Rhea

County seat) and Route 68, both to the south; to Chattanooga, to the southwest, and to Interstate Highway 40, about 24 kilometers (15 miles) north. Route 68 links Spring City to Interstate Highway 75.

Demography

The region of influence had an estimated overall population of about 890,600 in 1990 (DOC 1992). The number of households in the region of influence was about 343,000 in 1990; while the number of families, about 254,000. **Table 4–6** shows the population distribution by ethnic group in Spring City, Rhea County, and the Watts Bar region of influence in 1990.

Table 4–6 General Demographic Characteristics of Spring City, Rhea County, and the Watts Bar 1 Region of Influence 1990

Demographic Measure	*Spring City*	*Rhea County*	*Region of Influence*
Total population (1990)	2,199	24,344	890,617
Total population (1995/96, as noted)	2,381 (1996)	26,833 (1995)	NA
Families (1990)	614	6,976	254,317
Households (1990)	867	9,128	343,067
Male (1990)	982	11,728	428,137
Female (1990)	1,217	12,616	462,480

Sources: DOC 1992, DOC 1998c.

For Spring City, the population increased approximately 8 percent from 1990 to 1996. Rhea County had an estimated population of 26,833 in 1995, up from 24,344 in 1990 (Dayton/Rhea EDC 1998). The county is projected to continue growing to a population of 30,000 in the year 2000, and 35,000 in 2010. **Table 4–7** shows general demographic data for Spring City, Rhea County, and the Watts Bar 1 region of influence. The Watts Bar region of influence was defined as the area within 80 kilometers (50 miles) of the Watts Bar Nuclear Plant.

Figure 4–4 shows the racial and ethnic composition of the projected population residing in the affected area projected for the year 2025. Data for low-income households from the 1990 Census are presented on **Figure 4–5**. Low-income households are those with incomes of 80 percent or lower than the median income for the counties. As indicated on this figure, approximately 40 percent of the total households are low-income households (see also Appendix G).

Table 4–7 Population Distribution by Ethnic Group in Spring City, Rhea County, and the Watts Bar 1 Region of Influence (1990 U.S. Census)

Ethnic Group or Subgroup (U.S. Census Definitions)	***Spring City***		***Rhea County***		***Watts Bar Region of Influence***	
	Population	***Percentage of Total Population***	***Population***	***Percentage of Total Population***	***Population***	***Percentage of Total Population***
White not of Hispanic origin	2,033	92.45	23,472	96.42	804,523	90.33
Black not of Hispanic origin	139	6.32	528	2.17	72,936	8.19
American Indian, Aleut, or Eskimo not of Hispanic origin	10	0.45	72	0.30	2,838	0.32
Asian or Pacific Islander not of Hispanic origin	8	0.36	33	0.14	4,527	0.51
Other race not of Hispanic origin	0	0.00	56	0.23	275	0.03
White of Hispanic origin	0	0.00	103	0.42	3,770	0.42
Black of Hispanic origin	0	0.00	4	0.02	163	0.02
American Indian, Aleut or Eskimo of Hispanic origin	0	0.00	12	0.05	84	0.01
Asian or Pacific Islander of Hispanic origin	0	0.00	0	0.00	81	0.01
Other race of Hispanic origin	9	0.41	64	0.26	1,421	0.16
Hispanic total	9	0.41	183	0.75	5,519	0.62
Total population (all ethnic groups)	2,199	100.00	24,344	100.00	890,617	100.00

Sources: DOC 1992, DOC 1998c.
Note 1: Sum of items may not add up to population total due to rounding error.

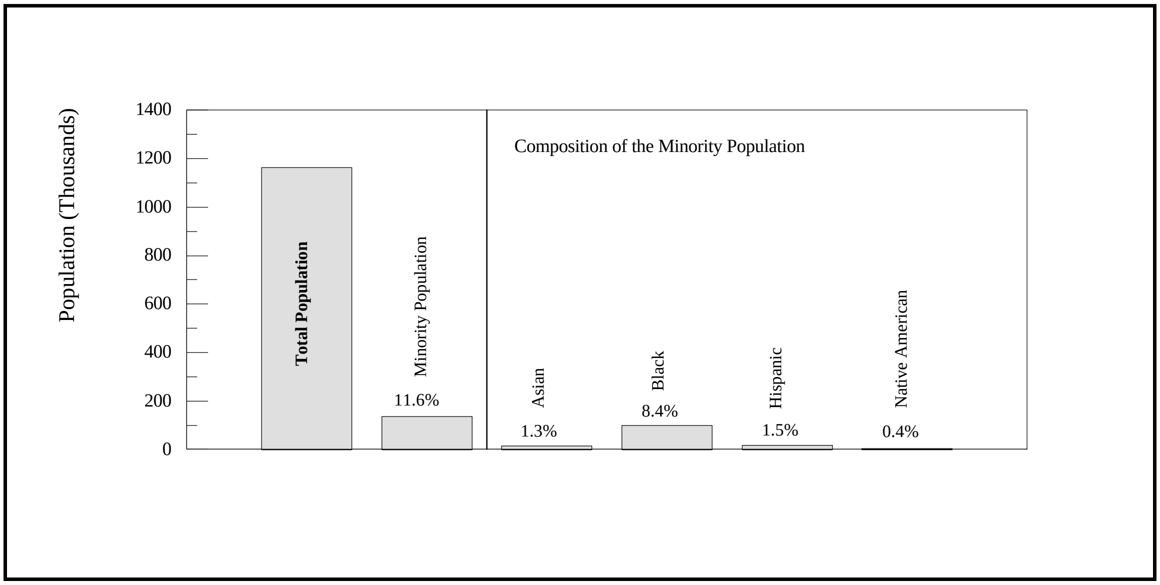


Figure 4–4 Racial and Ethnic Composition of the Minority Population Residing Within 80 Kilometers (50 Miles) of Watts Bar 1 Projected for the Year 2025

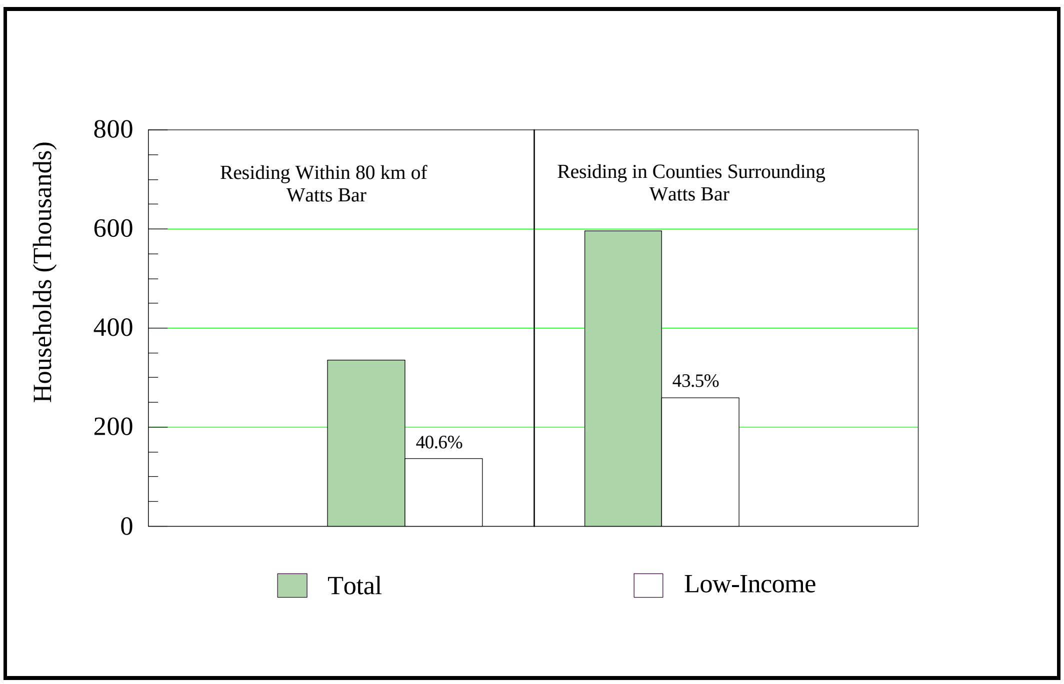


Figure 4–5 Low-Income Households Residing Within 80 Kilometers (50 Miles) of Watts Bar (1990)

Income

Total personal income in Rhea County was $417 million in 1996, up from $404 million in 1995 (DOC 1998a). Comparable figures for neighboring Meigs County were $132 million in 1996 and $127 million in 1995. Per capita income in Rhea County was $15,323 in 1996, up from $15,078 in 1995. Rhea and Meigs counties were respectively ranked seventy-first and eighty-fourth in the State of Tennessee in terms of per capita income in 1996. **Table 4–8** summarizes income data for Spring City and Rhea County.

Table 4–8 Income Data Summary for Spring City and Rhea County (1989)

Income Measure	*Spring City*	*Rhea County*
Per capita income	$9,412	$9,333
Median household income	$19,757	$19,915
Median family income	$24,028	$23,789
Median housing value	$41,300	$45,100

Source: DOC 1998c.

Community Services

Education, public safety, and health care were examined to determine the level of community services for the region of influence.

Education

There are 418 schools with a capacity for 130,107 students within an 80-kilometer (50-mile) radius of the Watts Bar 1 site. The average student-to-teacher ratio is approximately 17:1.

Public Safety

City, county, and state law enforcement agencies provide police protection to residents of the region of influence. The average officer-to-population ratio is 1.3:1,000 persons. Fire protection services are provided by both paid and volunteer firefighters. The ratio of firefighters to population is 0.6:1,000.

Health Care

The region of influence includes 34 hospitals with a total of 4,861 beds. All of the hospitals are operating below capacity.

Local Transportation

The nearest land transportation route is State Route 68, about 1.6 kilometers (1 mile) north of the site. Other surface roads in the Watts Bar 1 site vicinity are State Route 58, 4.8 kilometers (3 miles) southeast; State Route 30, 9.7 kilometers (6 miles) south; U.S. Highway 27, 11.3 kilometers (7 miles) northwest; and Interstate Highway 75, 12.9 kilometers (8 miles) southeast. A main line of the CNO&TP Railroad (Norfolk Southern Corporation) passes about 11.3 kilometers (7 miles) west of the site. A TVA railroad spur connects with the main line and serves Watts Bar 1. The spur from Spring City to the Watts Bar 1 site would require refurbishment prior to use. On the site, several hundred feet of rail that have been removed would have to be replaced if rail spent fuel shipping casks were to be accommodated (TVA 1998a). The Tennessee River is navigable past the site and is used as a major barge route (TVA 1995c). These transportation routes are shown in **Figure 4–6**.

The major surface roads mentioned above and the network of local roads connecting with them adequately serve the needs of the local communities and TVA employees at the Watts Bar 1 site.

4.2.1.9 Public and Occupational Health and Safety

Radiation Environment

Background radiation exposure to individuals in the vicinity of the Watts Bar site is presented in **Table 4–9**. The annual doses to individuals from background radiation are expected to remain constant over time. Thus, any incremental change in the total dose to the population would be a function only of a change in the size of the population.

Table 4–9 Sources of Background Radiation Exposure to Individuals in the Vicinity of the Watts Bar Site

Source	*Committed Effective Dose Equivalent (mrem/yr)*
Natural Background Radiation	
Cosmic and cosmogenic radiation	28
External terrestrial radiation	28
In the body	39
Radon in homes (inhaled)	200
Total	295
Other Background Radiation	
Release of radioactive material in natural gas, mining, ore processing, etc.	5
Diagnostic x-rays and nuclear medicine	53
Air travel	0.28
Consumer and industrial products	0.03
Total	355

Source: TVA 1998b.

Radionuclides released in emissions and effluents from Watts Bar 1 are a potential source of radiation exposure to individuals in the vicinity of Watts Bar 1 and are additive to the background radiation values listed. Calculations of radiation doses to individuals and the population surrounding the plant were performed by TVA using measurements from the various radiological monitoring points around the plant during operation in 1996, as well as conservative assumptions regarding both individual and population exposure time. The doses are presented in **Table 4–10**.

Radiation doses to the onsite worker include the background dose plus an additional dose from working in the facility.

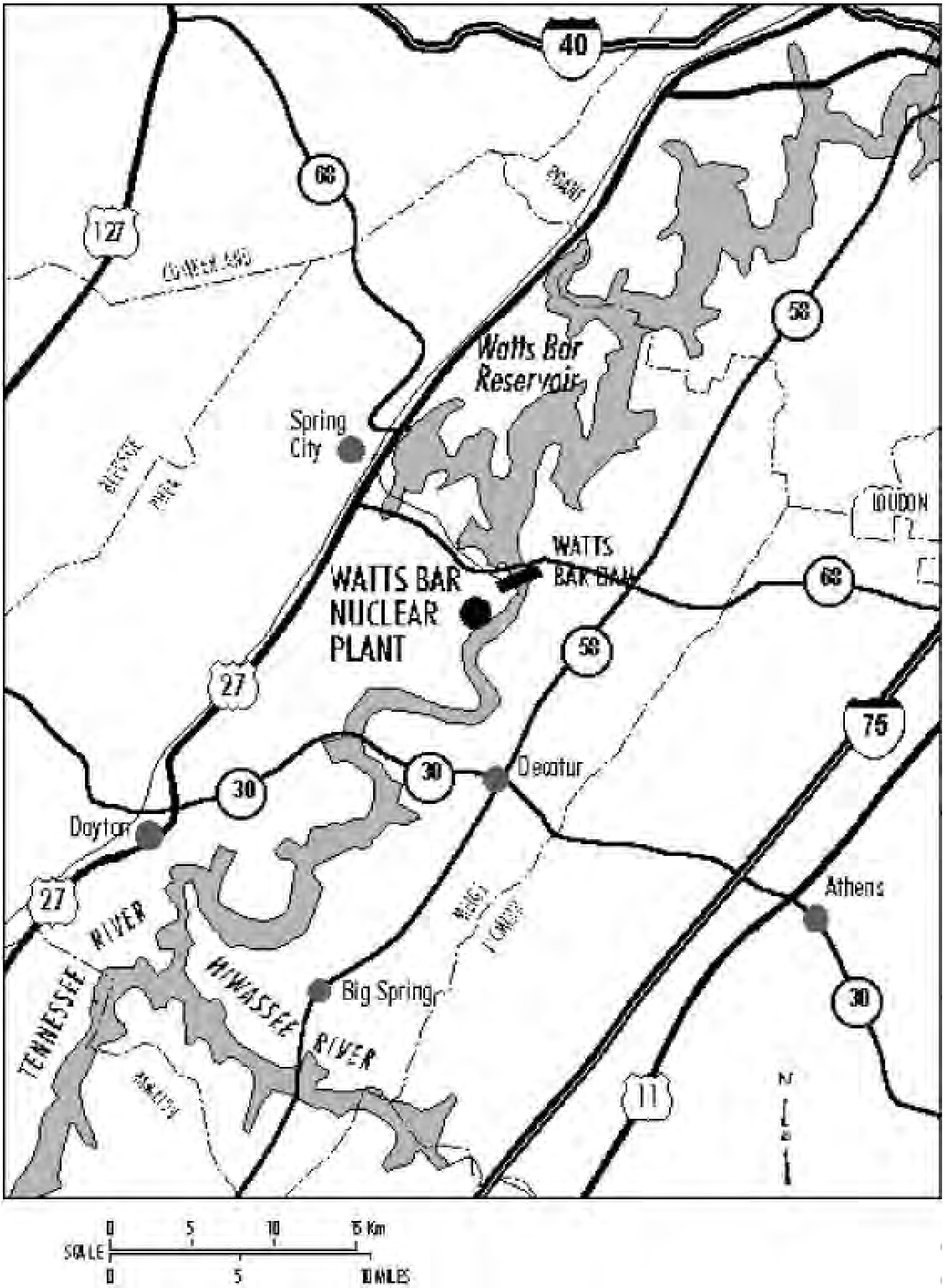


Figure 4–6 Transportation Routes in the Vicinity of the Watts Bar Nuclear Plant Site

Table 4–10 Annual Doses to the General Public during 1997 from Normal Operation at Watts Bar 1, (Total Effective Dose Equivalent)

Affected Environment	*Airborne Releases*		*Liquid Releases*		*Total*	
	Most Stringent Standard [a]	*Based on Actual Measurements*	*Most Stringent Standard* [a]	*Based on Actual Measurements*	*Most Stringent Standard* [a]	*Based on Actual Measurements*
Maximally exposed offsite individual (mrem)	5	0.036	3	0.25	25	0.29
Population within 80 kilometers (person-rem)[b]	None	0.068	None	0.44	None	0.51
Average dose to an individual within 80 kilometers (mrem)[c]	None	0.000063	None	0.00042	None	0.00048

[a] The standards for individuals are given in 10 CFR 50, Appendix I. The standard for maximally exposed offsite individual (25 mrem/yr total body from all pathways) is given in 40 CFR 190.
[b] Population used: 1,066,600.
[d] The average is obtained by dividing the population dose by the population living within an 80-kilometer (50-mile) radius of Watts Bar 1.

Source: TVA 1998e.

Direct Radiation

Radiation fields are produced in nuclear plant environments as a result of radioactivity contained within the reactor and its associated components. Doses from sources within the plant are primarily due to nitrogen 16, a radionuclide produced in the reactor core. Since the primary coolant of pressurized water reactors is contained in a heavily shielded area of the plant, dose rates in the vicinity of pressurized water reactors are generally less than 5 mrem/yr.

Low-level radioactive storage containers outside the plant are estimated to contribute less than 0.01 mrem/yr at the site boundary (NRC 1978).

The plant operator committed to design features and operating practices that ensure that individual occupational radiation doses are within the occupational dose limits defined in 10 CFR 20 and that individual and total plant population doses would be as low as reasonably achievable. The combined radiation doses received by the onsite worker are shown in **Table 4–11**.

Table 4–11 Annual Worker Doses from Normal Operation of Watts Bar 1 during 1997

Affected Environment	*Standard* [a]	*Dose* [b]
Average worker (mrem)	None	104
Maximally exposed worker (mrem)	5,000	1,269
Total workers (person-rem)	None	112

[a] NRC regulatory limit from 10 CFR 20.
[b] Based on 1073 badged workers.

Source: TVA 1998e.

Chemical Environment

Nonradioactive chemical wastes from Watts Bar 1 include boiler blowdown water treatment wastes (sludges and high saline streams whose residues are disposed of as solid wastes and biocides), boiler metal cleaning, floor and yard drains, and stormwater runoff.

Regeneration (chemical removal of radioactive waste) of ion exchange resins accounts for 596,000 kg/yr (657 ton/yr) of neutralized sulfate and sodium salts. Other water purification processes produce 196,500 kg/yr (217 ton/yr) phosphate and aluminum hydroxide residue. Processes for defouling facility piping produce 22,000 kg/yr (24 ton/yr) of organic residue byproducts and halites (oxygenated chlorine and bromine ions).

Operation of Watts Bar 1 takes into account the storage of process chemicals and disposal of waste products. Adverse health impacts to the public are minimized through administrative and design controls to decrease hazardous chemical releases to the environment and achieve compliance with permit requirements (such as air emissions and NPDES Permit requirements). The effectiveness of these controls is verified by monitoring information and inspecting compliance with mitigation measures.

Section 4.2.1.3, Table 4–1, and Section 4.2.1.4, Table 4–3, contain data on quantities of concentrated chemical concentrations in ambient air and surface water in the vicinity of Watts Bar 1.

Emergency Preparedness

The license issued by the NRC for the operation of Watts Bar 1 is based in part on a finding that there is reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency. This finding by NRC is based on: (1) a review of the Federal Emergency Management Agency findings, (2) determinations that state and local emergency plans are adequate with reasonable assurance that they can be implemented, and (3) the NRC assessment that the applicant's onsite emergency plans are adequate and give reasonable assurance that they can be implemented.

The plan establishes that evacuation is the most effective protective action that can be taken to cope with radiological incidents. The Watts Bar 1 emergency plan provides details of an evacuation plan. Risk Counties, identified as McMinn, Meigs, and Rhea, are tasked with preparing evacuation plans for citizens within the 16-kilometer (10-mile) emergency planning zone and determining the number of people to be evacuated from the zone. Host Counties, identified as Hamilton, Roane, Cumberland, and McMinn, are assigned responsibility to identify suitable shelters for evacuees. A State Emergency Operation Center would provide the focus for emergency reaction (e.g., notifications, protective action, evacuation implementation). Fixed sirens would alert residents and transients within the 16-kilometer (10-mile) emergency planning zone with backup provided, if needed, by emergency vehicle sirens and loud speakers. The State Emergency Operation Center Director would involve Counties' Emergency Management Directors as required.

The Emergency Alert System and the National Oceanic and Atmospheric Administration Weather Radio would be used to provide emergency information and instructions.

The evacuation would be ordered and accomplished by designated sectors. The designated evacuation routes would be patrolled by Traffic Assistance Teams.

The American Red Cross would operate mass care shelters in the Host Counties. Shelter Information Points would be established on each evacuation route to help direct evacuees to their assigned shelters.

Considerable planning is involved in evacuation planning. Training, education, and practice runs are used to further the probability of successful evacuation in the event it is ever required.

4.2.1.10 Waste Management

As with any major industrial activity, Watts Bar 1 generates waste as a consequence of its normal operation. The wastes fall into four broad categories: hazardous waste, nonhazardous solid waste, low-level radioactive waste, and sanitary liquid waste. No high-level waste, as it is defined by Nuclear Waste Policy Act of 1992, is generated at the Watts Bar 1 site. **Table 4–12** summarizes the annual amount of waste generated at the Watts Bar 1 site in each category.

Table 4–12 Annual Waste Generation at Watts Bar 1

Category	*Volume or Mass Per Year*
Hazardous waste	1.025 m^3
Non-hazardous solid waste	863,438 kg
Low-level radioactive waste	40 m^3
Mixed waste	<1 m^3

Source: TVA 1998e

Hazardous Waste

Hazardous wastes typically generated at Watts Bar 1 include paints, solvents, acids, oils, radiographic film and development chemicals, and degreasers. Neutralization is the only waste treatment performed onsite. Hazardous wastes are normally stored in polyethylene containment systems during accumulation. An approved storage building is utilized to store hazardous wastes for either 90 or 180 days depending on the plant's hazardous waste generator status (i.e., Small Quantity or Large Quantity Generator) at the time. Waste is transported to an offsite hazardous waste storage facility or disposal facility prior to exceeding the 90- or 180-day storage limit.

Low-Level Radioactive Waste

During the fission process, an inventory of radioactive fission and activation products builds up within the reactor (in the fuel and the materials of construction). A small fraction of these radioactive materials escape and contaminate the reactor coolant. The primary coolant system also receives radioactive contaminants. These contaminants are removed from the coolant by a radioactive waste treatment system. Watts Bar 1 uses separate radioactive waste treatment systems for gaseous, liquid, and solid waste treatment. Residues from the gaseous and liquid waste treatment systems (filters, resins, dewatered solids) are combined and disposed of with the solid, low-level radioactive waste. The other important category of low-level radioactive waste is the solidified and dewatered product of treatment of gaseous and liquid waste treatment systems. Contaminated protective clothing, paper, rags, glassware, compactible and noncompactible trash, and reactor components and equipment comprise the majority of solid low-level radioactive waste at Watts Bar 1.

Before disposal, compactible trash with the exception of irradiated metals is shipped to a commercial processor where it is compacted to a lesser volume and shipped to the Barnwell, South Carolina, low-level radioactive waste disposal facility. Incineratable trash is shipped to a commercial waste incinerator in Oak Ridge, Tennessee, where the material is burned to ashes before disposal at the Barnwell disposal facility. Metal waste is either decontaminated and recycled or melted to form shielding blocks. TVA does not send irradiated metals for volume reduction due to its excessive dose rate. This material would be accumulated until a sufficient amount is on hand to ship directly to the Barnwell disposal facility. Any radioactive waste from these processes is shipped for disposal at the Barnwell disposal facility (TVA 1998a).

Mixed Waste

Mixed waste is material that is both hazardous and radioactive. Typical sources of mixed low-level radioactive waste at Watts Bar 1 are: beta-counting fluids (e.g., zylene, toluene) for use in liquid scintillation detectors, polychorinated biphenyls (PCBs) susceptible to contact with radioactive contamination as a result of an accidental transformer spill or explosion, isopropyl alcohol used for cleaning radioactive surfaces, chelating agents, and various acids.

Waste Minimization Practices

The Watts Bar 1 site has an active waste minimization program that consists of the following practices:

- Useful portions of construction and demolition materials are salvaged for resale.
- Segregated storage areas are maintained for each type of recoverable material.
- Scrap treated lumber is sold or placed in dumpsters for disposal by the solid-waste disposal contractor at an offsite permitted landfill.
- Inert construction and demolition wastes are collected for disposal at the onsite permitted landfill.
- Waste paper is placed in bins or dumpsters and sold to an offsite recycle facility.
- Aluminum cans are recycled and sold.
- Nonrecoverable solid wastes are placed in dumpsters for disposal by the solid waste disposal contractor.
- Special wastes (e.g., desiccants, oily wastes, insulation) are collected and stored and then disposed by incineration. Asbestos is sent to an approved special waste landfill for disposal.
- Used oil, fluorescent tubes, and antifreeze are collected and stored in drums and tanks and recycled.
- Medical wastes are collected and disposed of in accordance with the Medical Waste Disposal Procedure for TVA Medical Facilities.
- Plant sanitary wastewater is routed to the sanitary wastewater treatment plant and then treated for release in accordance with the NPDES Permit.
- Metal-cleaning wastewater (i.e., trisodium phosphate, acetic acid, etc.) is discharged into approved storage ponds for future disposal in accordance with the NPDES Permit.
- Wastewater from floor and equipment drains in nonradiation areas is routed through sumps to the turbine building sump for discharge in accordance with the NPDES Permit.
- Surplus chemicals are sold; lead acid batteries are recycled; refrigerant is recovered and recycled; and solvent recovery equipment is used for painting operations.
- Steps to use biodegradable solvents and cleaners to replace hazardous chemicals in various cleaning operations have been incorporated to the extent practical.

4.2.1.11 Spent Nuclear Fuel Management

When nuclear reactor fuel has been irradiated to the point that it no longer contributes to the operation of the reactor, or when it is found to have cladding leaks that allow radioactive gaseous emissions, the fuel assembly is termed “spent nuclear fuel” and is removed from the reactor core and stored in the spent fuel storage pool or basin. The Nuclear Waste Policy Act of 1982, as amended, assigned the Secretary of the Department of Energy the responsibility for the development of a repository for the disposal of high-level radioactive waste and spent nuclear fuel. When such a repository is available, spent nuclear fuel would be transported for disposal from the nuclear power reactors to the repository. Until a repository is available, spent nuclear fuel would be stored in the reactor pools or in other acceptable, NRC-licensed storage locations. Because of the uncertainty associated with opening a repository, this EIS assumes spent fuel would be stored at the reactor facility for the duration of the proposed action (i.e., 40 years).

Storage Capacity

Storage cells have been provided in the Watts Bar 1 spent fuel storage pool to hold 1,383 fuel assemblies. A reserve capacity is required for a full-core discharge (193 fuel assemblies), in the event it becomes necessary to remove fuel from the reactor vessel. The remaining storage capacity is 1,190 fuel assemblies. As of January 1998, the spent fuel inventory of Watts Bar 1 was 84 assemblies, leaving a usable storage capacity of 1,106 fuel assemblies.

Management Practice

The normal (projected equilibrium average) refueling batch size is 80 fuel assemblies, with refueling frequency established at 18 months. The current capacity for storing spent nuclear fuel is adequate through the year 2016 (fuel cycle number 14). However, Watts Bar 1 is already licensed for a total spent nuclear fuel storage pool capacity of 1,607 fuel assemblies, an increase of 224 fuel assemblies over the present capacity. As it becomes necessary, dry storage facilities can be added to extend the plant life.

4.2.2 Sequoyah Nuclear Plant, Units 1 and 2

As discussed in Section 3.2.5 one of the reactor options under consideration is the irradiation of TPBARs in the Sequoyah Nuclear Plant, Units 1 and 2 (Sequoyah 1 and 2). This option is based on the assumption that Sequoyah 1 and 2 would operate at their licensed full power output for the generation of electricity, with no reduced operability attributable to the production of tritium. The tritium production activity would be considered a secondary mission of the units.

The TVA Board authorized the construction of the Sequoyah Nuclear Plant in August 1968. On October 15 1968, an application to construct the plant was filed with the U.S. Atomic Energy Commission. A provisional construction permit was granted on May 27, 1970. Unit 1 began commercial operation on July 1, 1981. Unit 2 began commercial operation on June 1, 1982. The units were shut down in 1985 and resumed operation in 1988. Sequoyah 1 and 2 are described briefly in Section 3.2.5.2. Detailed descriptions of the site, building structures, systems, and operations are provided in the following licensing and environmental documentation:

> TVA, *Final Environmental Statement, Sequoyah Nuclear Plant Units 1 and 2*, Chattanooga, Tennessee (Letter of Transmittal dated February 21, 1974) (TVA 1974a).
>
> TVA, *Sequoyah Nuclear Plant Updated Final Safety Analysis Report*, Amendment 12, Chattanooga, Tennessee, December (TVA 1996b).

The following sections describe the affected environment at the Sequoyah Nuclear Plant site for land resources, noise, air quality, water resources, geology and soils, biotic resources, cultural resources, and socioeconomics. In addition, radiation and hazardous chemical environment, and the waste management conditions and spent nuclear fuel considerations at Sequoyah 1 and 2, are described.

4.2.2.1 Land Resources

Land Use

The Sequoyah Nuclear Plant site is on a 212-hectare (525-acre) site near the center of Hamilton County, Tennessee, on a peninsula on the western shore of Chickamauga Lake at River Mile 484.5, as shown in

Figure 4–7. The site is shown in **Figure 4–8**. The Sequoyah Nuclear Plant site is approximately 12 kilometers (7.5 miles) northeast of the nearest city limit of Chattanooga, Tennessee. The corridor to the

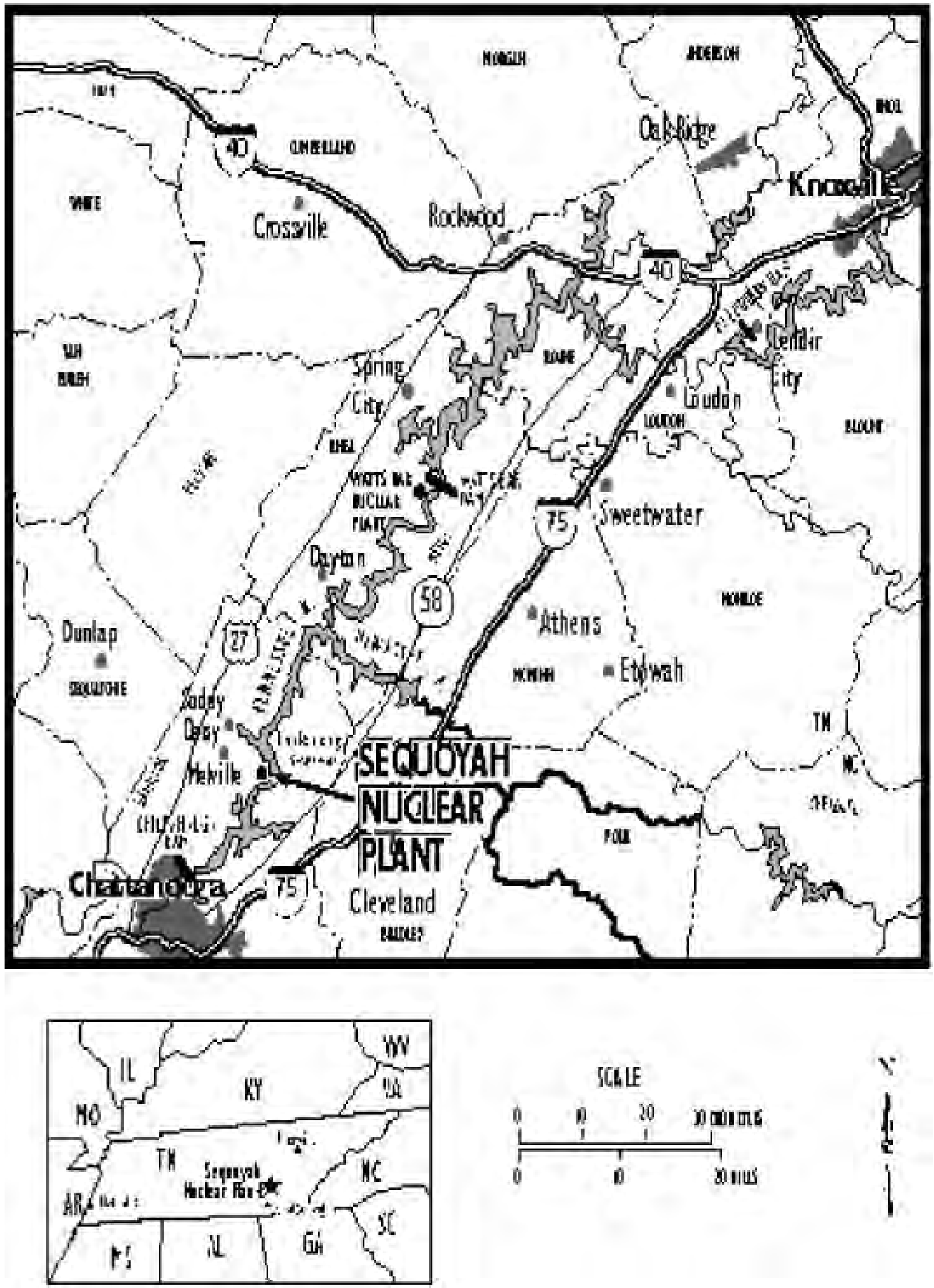


Figure 4–7 Location of the Sequoyah Nuclear Plant Site

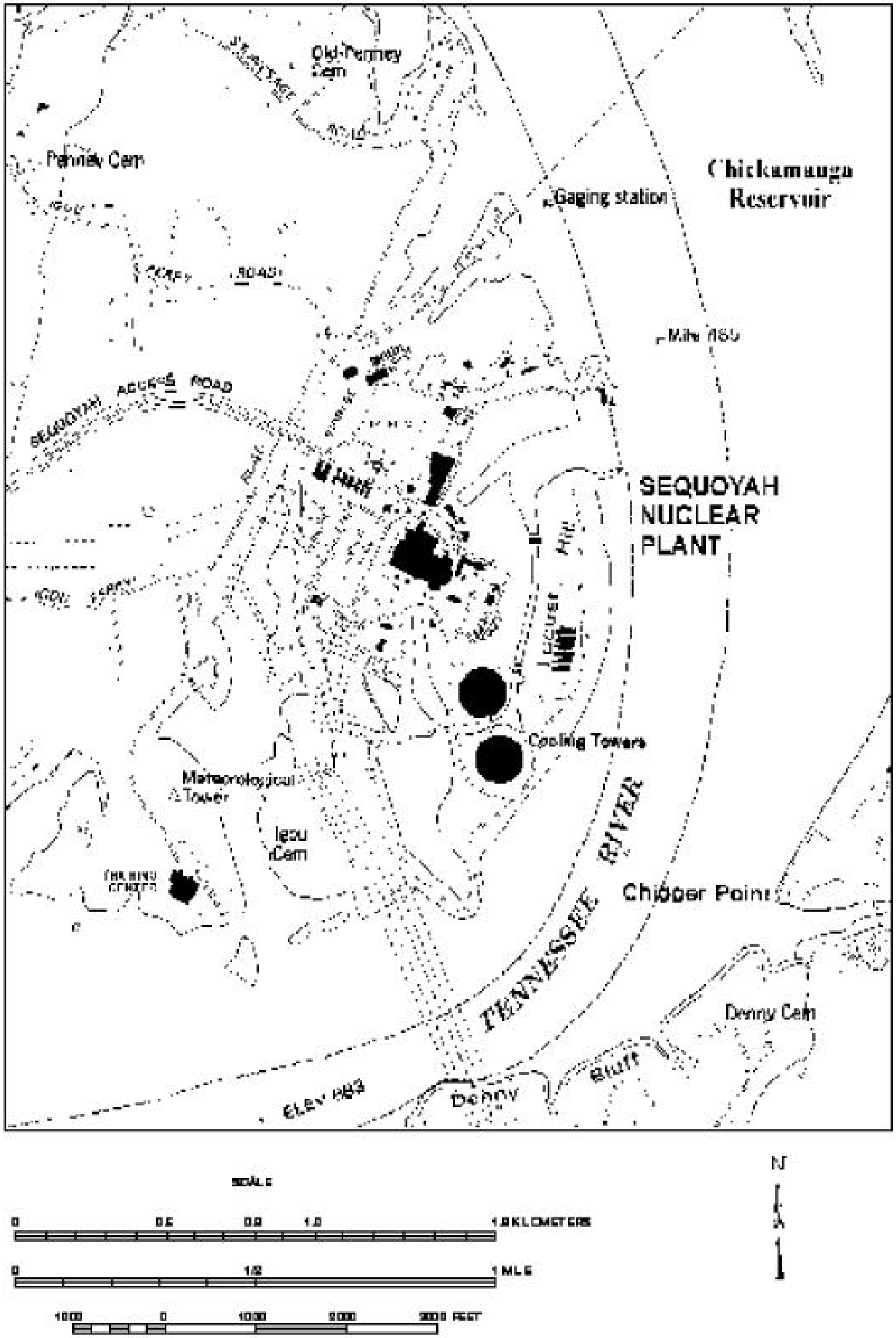


Figure 4–8 Sequoyah Nuclear Plant Site

southwest of the site that encompasses the city of Chattanooga is considered a growth area in Hamilton County. The remaining area surrounding the site is rather sparsely settled. Development consists of scattered dwellings and associated small-scale farming. The sectors east of the site and of Chickamauga Reservoir are expected to retain their rural character (TVA 1996b). Land uses in the vicinity of the Sequoyah Nuclear Plant are classified as industrial, agricultural, forest, and recreational.

Industry

There is no significant industrial development in the immediate vicinity of the Sequoyah Nuclear Plant site. Chattanooga, an industrial center, lies 12 kilometers (7.5 miles) southwest of the site. A center of diversified light industry, Cleveland, lies 23 kilometers (14 miles) east-southeast of the site (TVA 1996b).

Agriculture

Nearly 28 percent of the 225,000 hectares (556,000 acres) that constitute the land area of Hamilton and Bradley Counties, Tennessee, about 62,500 hectares (154,400 acres), is dedicated to farming. Crop land accounts for 33,500 hectares (82,800 acres) of the total agricultural area. (GISP 1998a, GISP 1998b)

Forest

The total area of forested land in Hamilton County, Tennessee, is 85,270 hectares (210,700 acres). This area is made up of approximately 19 percent loblolly and short-leaf pine (softwood) forests, 59 percent oak-hickory forests, and the remainder in oak-pine stands (DOA 1998a, DOA 1998b).

Recreation

Water-based recreation is supported by the Chickamauga Reservoir, particularly in late spring, summer, and early fall. There are three primary public recreation facilities, Harrison Bay and Booker T. Washington State Parks and the Chester Frost County Park, as well as numerous commercial marinas, group camps, cottage developments, and small formal and informal public access areas along the reservoir shoreline (TVA 1996b).

Nature Reserves

The Soddy Creek waterfowl management area is located 4.8 kilometers (3 miles) upstream from the Sequoyah Nuclear Plant site. The Hiwassee Island Refuge is located 24 kilometers (15 miles) upstream. The Hiwassee Island Refuge is the principal waterfowl unit on the Chickamauga Reservoir.

Visual Resources

The major visual elements of the plant already exist, including the cooling towers, containment structures, turbine building, and the transmission lines. Views of Sequoyah 1 and 2 from passing river traffic on the Tennessee River are partially screened by the wooded area east of the plant (TVA 1974a). The plant can be viewed from White Oak Mountain on the east side of the river. Distant glimpses of the plant site can be seen from the coves and hollows along the river and from various roads in the area, including U.S. Highway 27.

Based on the Bureau of Land Management Visual Resource Management method, the existing landscape at the Sequoyah Nuclear Plant site would be classified as Visual Resource Management Class 3 or 4. Class 3 includes areas where there has been a moderate change in the landscape and these changes may attract attention but do not dominate the view of the casual observer. Class 4 includes areas where major modifications to the character of the landscape have occurred. These changes may be both the dominant features of the view and the major focus of viewer attention (DOI 1986a).

During operation of Sequoyah 1 and 2, the vapor plume associated with the cooling towers may be visible up to 10 miles away. Cooling towers are used approximately 2 percent of the time, usually during periods of low river flow or peak summer temperatures. The plume length and frequency of occurrence with direction varies with atmospheric conditions, being most visible during cooler months and after the passage of weather fronts. Vapor plumes are visible at times from nearby residential areas, U.S. Highway 27, Tennessee State Highway 58, and County Highway 5550 (TVA 1974a).

4.2.2.2 Noise

The most common measure of environmental noise impact is the day-night average sound level. The day-night average sound level is a 24-hour sound level with a 10-dBA penalty added to sound levels between 10:00 p.m. and 7:00 a.m to account for increased annoyance due to noise during nighttime hours. The EPA has developed noise level guidelines for different land-use classifications based on day-night average sound level and equivalent sound levels. The U.S. Department of Housing and Urban Development has established noise impact guidelines for residential areas based on day-night average sound levels. Some states and localities have established noise control regulations or zoning ordinances that specify acceptable noise levels by land-use category. The State of Tennessee has not developed a noise regulation that specifies the numerical community noise levels that are acceptable.

For the purpose of this document noise impacts are assessed using a day-night average sound level of 65 dBA as the level below which noise levels would be considered acceptable for residential land uses and outdoor recreational uses. Generally the noise levels offsite are below day-night average sound level 65 dBA and are considered to be acceptable. Testing of the emergency warning siren system occurs on a regular basis and results in outdoor noise levels of about 60 dBA in areas within a radius of about 16 kilometers (10 miles) of the site. TVA typically tests siren systems on a given day of the month at noon.

4.2.2.3 Air Quality

Sequoyah 1 and 2 are located in Hamilton County in south-central Tennessee in the Chattanooga Interstate Air Quality Control Region. Ambient concentrations of criteria pollutants determined by monitoring air quality in the vicinity of Sequoyah 1 and 2 are compared with the applicable National Ambient Air Quality Standards and Tennessee state ambient air quality standards in **Table 4–13**.

The area in which Sequoyah 1 and 2 are located, the Chattanooga Interstate Air Quality Control Region, is designated by EPA as an attainment area with respect to the National Ambient Air Quality Standards for criteria pollutants (40 CFR 81). The prevention of significant deterioration Class I areas closest to Sequoyah 1 and Sequoyah 2 are the Joyce Kilmer-Slickrock National Wilderness Area and Cohutta National Wilderness Area, Georgia. For locations that are in an attainment area for criteria pollutants, Prevention of Significant Deterioration regulations limit pollutant emissions from new sources and establish allowable increments of pollutant concentrations. Class I areas include national wilderness areas, memorial parks larger than 2,020 hectares (5,000 acres), and national parks larger than 2,340 hectares (6,000 acres). The Class I areas noted above are about 60 kilometers (37 miles) distant from Sequoyah 1 and 2 (TVA 1998e).

Sources of criteria air pollutant emissions at the Sequoyah Nuclear Plant site include diesel-powered emergency generators and fire protection pumps; site, trade, and employee vehicles; auxiliary boilers; and cooling towers. Small quantities of toxic chemicals and metals are emitted from the testing and operation of the diesel-fueled equipment, resulting in offsite concentrations of less than 0.0001 percent of the threshold limit value of any of these pollutants. One tenth of the threshold limit value is often used as a guideline in identifying pollutants that may be of concern and this guideline should be evaluated in more detail. Ozone is produced at the Sequoyah

Nuclear Plant site by corona discharge (ionization of air) in the operation of transmission lines and substations, particularly at high voltages. Operation of electrical motors and generators

Table 4–13 Comparison of Baseline Sequoyah 1 and Sequoyah 2 Ambient Air Concentrations with Most Stringent Applicable Regulations and Guidelines

Criteria Pollutant	*Averaging Time*	*Most Stringent Regulation or Guideline*[a] *($\mu g/m^3$)*	*Baseline Concentration* [b] *($\mu g/m^3$)*
Carbon monoxide	8-hour 1-hour	10,000[c] 40,000[c]	1,265 1,265
Lead	Calendar quarter	1.5[c]	0.03
Nitrogen dioxide	Annual	100[c]	9.4
Ozone	8-hour (4th highest averaged over 3 years)	157[c,d]	e
Particulate matter [d]	PM_{10} Annual (3-year average) 24-hour (interim) 24-hour 99th percentile (3-year average) $PM_{2.5}$ Annual (3-year average) 24-hour (98th percentile averaged over 3-years)	 50[c] 150[c] 150[c] 15[c] 65[c]	 20.3 39 35 f f
Sulfur dioxide	Annual 24-hour 3-hour	80[c] 365[c] 1,300[c]	5.24 28.8 123
Other Regulated Pollutants			
Gaseous fluoride (as hydrogen fluoride)	30-day 7-day 24-hour 12-hour 8-hour	1.2[g] 1.6[g] 2.9[g] 3.7[g] 250[g]	h h h h h
Total suspended particulates (TSP)	24-hour	150[g]	39[i]

[a] The more stringent of the Federal and state standards is presented if both exist for the averaging time. Tennessee state and National Ambient Air Quality standards are the same for the criteria pollutants. The National Ambient Air Quality Standards (40 CFR 50), other than those for ozone, particulate matter, lead, and those based on annual averages, are not to be exceeded more than once per year. The 1-hour ozone standard is attained when the expected number of days per year with maximum hourly average concentrations above the standard is 1. The 1-hour ozone standard applies only to nonattainment areas. The 8-hour ozone standard is attained when the 3-year average of the annual fourth-highest daily maximum 8-hour average concentration is less than or equal to 157 $\mu g/m^3$. The interim 24-hour PM_{10} standard is attained when the expected number of days with a 24-hour average concentration above the standard is arithmetic mean particulate matter standard is attained when the expected annual arithmetic mean concentration is less than or equal to the standard.

[b] Based on ambient air quality monitoring data at Bradley County location for 1994–1995, except for carbon monoxide from Loudon County (1996) and lead from the Rockwood monitor in Roane County (1996). Concentrations shown are maximums for the averaging period.

[c] Federal standard.

[d] EPA recently revised the air quality standards for particulate matter and ozone. The new standards, finalized on July 18, 1997, change the ozone primary and secondary standards from a 1-hour concentration of 235 $\mu g/m^3$ (0.12 ppm) to an 8-hour concentration of 157 $\mu g/m^3$ (0.08 ppm). During a transition period while states are developing state implementation plan revisions for attaining and maintaining these standards, the 1-hour ozone standard would continue to apply in nonattainment areas (62 FR 38855). For particulate matter, the current PM_{10} (particulate matter size less than or equal to 10 micrometers) annual standard is retained and two $PM_{2.5}$ (particulate matter size less than or equal to 2.5 micrometers) standards are added. These standards are set at 15 $\mu g/m^3$ 3-year annual average arithmetic mean based on community-oriented monitors and 65 $\mu g/m^3$ 3-year average of the 98th percentile of 24-hour concentrations at population-oriented monitors. The current 24-hour PM_{10} standard is revised to be based on the 3-year average of the 99th percentile of 24-hour concentrations. The existing PM_{10} standards would continue to apply in the interim period (62 FR 38652).

[e] There is insufficient data to compare to the 8-hour standard for ozone.

[f] Compliance with the new $PM_{2.5}$ standards was not evaluate since current emissions data for $PM_{2.5}$ are not available.

[g] State standard.

[h] No local monitoring data is available for gaseous fluoride.

[i] PM_{10} value is presented and would underestimate the TSP concentration. No monitoring data available for total suspended particulates.

Sources: TN DEC 1994, TVA 1998a.

also produces ozone. TVA minimizes corona discharge by optimizing, to the extent practicable, its design and construction of transmission facilities.

An analysis of the occurrence of visible plumes has been performed for Sequoyah. Naturally occurring fog with visibility equal to or less than 0.4 kilometer (0.25 mile), occurs in the vicinity of Sequoyah about 35 days per year. Occurrences of the plume descending to the ground or causing localized surface fogging or icing are infrequent (TVA 1974a).

Compliance with the new $PM_{2.5}$ standards was not evaluated since current emissions data for $PM_{2.5}$ are not available. When the calculated concentrations from onsite sources are combined with concentrations from offsite sources, the ambient air quality standards for carbon monoxide, nitrogen oxide compounds, particulate matter, and sulfur dioxide continue to be met.

Gaseous Radioactive Emission

Sequoyah 1 and 2 have three primary sources of gaseous radioactive emissions:

Discharges from the gaseous waste management system

Discharges associated with the exhaust of noncondensable gases in the main condenser if a primary to secondary leak exists

Radioactive gaseous discharges from the building ventilation exhaust, including the reactor building, reactor auxiliary building, and the fuel handling building

The gaseous waste management system collects gaseous fission products (mainly noble gases) that accumulate in the primary coolant. A portion of the coolant is continually diverted to the coolant purification, volume, and chemical control system to remove contaminants and adjust the chemistry and volume. Noncondensable gases are stripped and sent to the gaseous waste management system, a series of gas storage tanks where the extended holdup time allows short half-life gases to decay, leaving only a small quantity of long half-life radionuclides to be released to the atmosphere. **Table 4–14** shows the annual gaseous radioactive emissions from Sequoyah 1 and Sequoyah 2.

Table 4–14 Annual Radioactive Gaseous Emissions from Sequoyah 1 or Sequoyah 2

Emission	*Quantity*
Fission gases	119.7 Ci
Tritium	24.43 Ci

Source: TVA 1998e.

Meteorology and Climatology

The regional and local meteorology and climatology of the Sequoyah Nuclear Plant site described in the TVA *Final Environmental Statement, Sequoyah Nuclear Plant Units 1 and 2* (TVA 1974a) has been updated with more recent meteorological data from Chattanooga.

Regional Climate

The Sequoyah Nuclear Plant site is in the eastern Tennessee portion of the Southern Appalachian region. The predominant air masses affecting the Sequoyah Nuclear Plant site are interchangeably continental and maritime winter and spring, predominantly maritime in the summer, and continental in the fall.

Data collected over a 30-year period (1961 to 1990) at the Chattanooga airport indicate the average annual temperature is 15.2 average daily maximum temperature in July is 31.7 average daily minimum temperature in January is -2.2

Precipitation of 0.025 centimeters (0.01 inches) or more occurs on an average of 117 days per year. The average monthly precipitation is 12.2 centimeters (4.80 inches); the maximum monthly average of 17.2 centimeters (6.76 inches) is in March.

Severe Weather

Wind storms, with wind speeds exceeding 56 kilometers per hour (35 miles per hour) and occasionally 97 kilometers per hour (60 miles per hour), occur several times each year, particularly during winter, spring, and summer. High winds also may accompany thunderstorms that occur on about 55 days per year, reaching a maximum frequency in July.

The current estimate of tornado strike probability at the Sequoyah site is 0.000044 per year (4.4 chances per 100,000 in a given year).

Local Meteorological Conditions

The terrain features of the region have some effect on the general climate. The mountain ridge and valley terrain aligned northeast-southwest over eastern Tennessee accounts for the predominant up-valley/down-valley wind flow in lower elevations of 150 to 300 meters (500 to 1,000 feet). The Cumberland Plateau terrain at elevation 460 to 550 meters (1,500 to 1,800 feet) tends to moderate many of the migratory storms that move from the west across the region.

4.2.2.4 Water Resources

Surface Water

The Sequoyah Nuclear Plant site is located at River Mile 485.0 on the Chickamauga Reservoir about 21 kilometers (13 miles) upstream of the Chickamauga Dam. Chickamauga Reservoir is TVA's sixth largest reservoir. The reservoir is 95 kilometers (59.0 miles) long on the Tennessee River and 51 kilometers (32 miles) long on the Hiwassee River, with an area of 14,300 hectares (35,356 acres), a volume of 775 million cubic meters (628,000 acre-feet). At the Sequoyah Nuclear Plant site, the Chickamauga Reservoir is about 914 meters (3,000 feet) wide, with cross-sectional depths ranging up to 15 meters (50 feet) at normal pool elevation.

During the steam cycle, heat from the Sequoyah 1 and 2 turbines is released when the steam passes through a condenser cooled with water from the Tennessee River. This water may be cooled by passing it through evaporative cooling towers. The cooling towers may be operated in open mode, helper mode, or closed mode. In open mode, the towers are not used. All cooling water is discharged first to a pond, then through diffuser pipes into the Tennessee River. In helper mode, water is cooled by the cooling towers before being discharged to the pond. From the pond, water is discharged through diffuser pipes into the Tennessee River. In closed mode, cooling is accomplished in the same manner as described for Watts Bar 1 in Section 3.2.3.1. When the cooling towers are used in closed mode, makeup water from the Tennessee River is needed to replace water losses due to evaporation, drift, and blowdown. In closed mode, most of the water is recirculated back to the condenser. Only the blowdown water is discharged to the pond in closed mode. From the pond, water is discharged through diffusers into the Tennessee River. The cooling towers have only been used for approximately 2 percent of the plant operating time (TVA 1998e) to meet thermal discharge limits. At full power, the temperature of the water flowing through each condenser is raised by approximately 17

The open cooling mode using the diffuser pipes withdraws and returns 2,123,540 l/mine (561,000 gal/min) (TVA 1974a). In the cooling tower closed cycle cooling mode, to make up for water lost through evaporation, small leaks, drift, and blowdown, approximately 249,745 l/min (65,978 gal/min) is withdrawn from the Tennessee River (TVA 1974a). When they are used, blowdown from a natural-draft cooling tower is discharged into the Tennessee River at a normal rate of 120,000 l/min (31,700 gal/min) (TVA 1974a).

The direct open cooling system uses a diffuser system that discharges water from diffuser pipes. One diffuser pipe is 4.9 meters (16 feet) in diameter and extends 107 meters (350 feet), while the other diffuser pipe is 5.2 meters (17 feet) in diameter and extends 213 meters (700 feet). These two pipes are perforated with several thousand 5-centimeter (2-inch) ports through which water is discharged into the Tennessee River for maximum thermal mixing (TVA 1974a). The diffuser located in the bed of the river at River Mile 483.65, mixes the discharge with river water to limit the temperature rise after mixing to 3
and 5 rch. The maximum Tennessee River water temperature is limited to 30.5

River flow in the vicinity of the Sequoyah site is governed by hydropower operations at the upstream Watts Bar Dam (Tennessee River Mile 529.9), and the downstream Chickamauga Dam (Tennessee River Mile 471). Peaking hydropower operation at these two hydroprojects can cause short periods of zero or reverse flow near the Sequoyah Nuclear Plant site.

Surface Water Quality

The Tennessee Department of Environment and Conservation classifies the streams and creeks of Tennessee based on water quality, stream uses, and resident aquatic biota. Classifications are defined in the State of Tennessee Water Quality Standards. The Chickamauga Reservoir is classified by the Tennessee Division of Water Pollution Control as suitable for the following uses: municipal water supply, industrial water supply, fish and aquatic life, recreation, irrigation, livestock watering and wildlife, and navigation (TVA 1996b). Monitoring data for surface water in the vicinity of Sequoyah 1 and 2 are presented in **Table 4–15.**

Surface Water Use and Rights

From its head near Knoxville to the Kentucky Dam near its mouth, the Tennessee River is a series of highly controlled multiple-use reservoirs. This chain of reservoirs provides flood control, navigation, generation of electric power, sport and commercial fishing, industrial and public water supply, waste disposal, and recreation.

There are five drinking water supply intakes from the Chickamauga Reservoir within 80 kilometers (50 miles) downstream of the Sequoyah site. They are: the Sequoyah Nuclear Plant; the E.I. DuPont de Nemours and Company (2,536); Chattanooga (405,745); South Pittsburgh (8,872); and Bridgeport (8,423). The numbers in parenthesis correspond to the projected members of the population relying on the water supply in the year 2020 (TVA 1996b).

Table 4–15 Summary of Surface Water Quality Monitoring in the Vicinity of the Sequoyah Site

Parameter	*Unit of Measure*	*Water Quality Criteria*	*Average Water Body Concentration*
Radiological			
Alpha (gross)	pCi/l	15[a]	1.9
Beta (gross)	pCi/l	50[b]	2.67
Tritium	pCi/l	20,000[a]	<300[c]
Nonradiological			
Manganese	mg/l	0.05[d]	0.000956
Nitrate (as N)	mg/l	10.0[a]	0.245
Arsenic	mg/l	0.05[e]	0.00233
Barium	mg/l	2.0[e]	<0.1
Cadmium	mg/l	0.005[e]	0.000117
Chromium	mg/l	0.1[e]	0.00333
Lead	mg/l	0.005[e]	0.00142
Mercury	mg/l	0.002[e]	0.0002
pH	pH units	6.0–9.0[e]	7.52

[a] National Primary Drinking Water Regulations (40 CFR 141).
[b] Proposed National Primary Drinking Water Regulations
[c] Below lower limit of detection of 300 pCi/l
[d] National Secondary Drinking Water Regulations (40 CFR 143)
[e] Tennessee General Water Quality Criteria for Domestic Water Supply (TN DEC, 1995).
Source: TVA 1998a, TVA 1998c, Tennessee 1998.

In Tennessee, the state's water rights are codified in the Water Quality Control Act. Water rights are similar to riparian rights in that the designated usage of a water body cannot be impaired. In order to construct intake structures for the purpose of withdrawing water from available supplies, U.S. Army Corps of Engineers and TVA permits are required.

Liquid Chemical and Radioactive Effluents

The radionuclide contaminants in the primary coolant are the source of liquid radioactive effluent in Sequoyah 1 and 2. Liquid effluent varies considerably in composition. It may include nonradioactive contaminants and chemical constituents depending on the history and collection point of the liquid. Each source of liquid effluent receives an individual degree and type of treatment before storage for reuse or discharge to the environment under the Sequoyah 1 and Sequoyah 2 NPDES Permit. To increase the efficiency of waste processing, wastes of similar characteristics are grouped together before treatment. The Sequoyah 1 or Sequoyah 2 liquid effluent to the environment during normal operation are shown in **Table 4–16**.

Table 4–16 Annual Chemical and Radioactive Liquid Effluents from Operation of Sequoyah 1 or Sequoyah 2

Materials	*Quantity*
Chemicals	294,012 kg [a]
Tritium	738.6 Ci [b]
Other Radionuclides	1.147 Ci [b]

[a] TVA 1996b.
[b] TVA 1998e.

Floodplains and Flood Risk

At the Sequoyah Nuclear Plant the 100-year floodplain for the Tennessee River would be at elevation 209.4 meters (687.0 feet) above mean sea level. The TVA Flood Risk Profile elevation on the Tennessee River would be elevation 210.0 meters (689.0 feet). The Flood Risk Profile is used to control flood damageable development for TVA projects and is based on the 500-year flood elevation (TVA 1998e). The safety-related facilities, systems, and equipment are housed in structures that provide protection from flooding for all flood conditions up to plant grade at the reactor building elevation of 215 meters (705 feet). Rainfall floods exceeding this elevation would require plant shutdown. The situation producing the maximum plant site flood level was determined to be one of two events: (1) a sequence of March storms producing maximum precipitation on the watershed above Chattanooga or (2) a sequence of March storms centered and producing maximum precipitation in the basin to the west of the Appalachian Divide and above Chattanooga. Seismic and flood events could cause dam failure surges above the plant grade elevation of 219 meters (720 feet) (TVA 1996b).

Groundwater

Groundwater at the Sequoyah Nuclear Plant site is derived principally from local precipitation. The average annual precipitation is 1.47 meters (58 inches). There is no distinct aquifer in the Conasauga Shale that underlies the Sequoyah Nuclear Plant site. The groundwater occurs in small openings, which rapidly decrease in size with depth, along fractures and bedding planes. The shales and limestones provide relatively low permeability compared to terrace deposits and, therefore, the majority of the discharge of groundwater occurs by movement along the strike of bedrock to the northeast and southwest into the Chickamauga Reservoir.

Groundwater Quality

A total of 16 groundwater monitoring wells have been installed at the Sequoyah Nuclear Plant site. Older monitoring wells at the site are primarily bedrock monitoring wells. Monthly groundwater levels are obtained at all wells except for two; one destroyed during cooling tower construction and the other installed with an automatic sampler for routine monitoring of radiological contaminants. Two of the wells were installed near the low-level radiological waste storage area in August 1981 to obtain background groundwater radiological data (TVA 1998e).

Groundwater Availability, Use, and Rights

There are 8 public groundwater supplies and 24 industrial water supplies drawn from wells within a 32-kilometer (20-mile) radius of the Sequoyah Nuclear Plant site. Two supplies are taken from groundwater springs. There is no groundwater use at the Sequoyah Nuclear Plant site.

Groundwater rights in the State of Tennessee are traditionally associated with the Reasonable Use Doctrine. Under this doctrine, landowners can withdraw groundwater to the extent that they exercise their rights reasonably in relation to the similar rights of others.

4.2.2.5 Geology and Soils

Geology

The controlling feature of the geologic structure at the site is the Kingston thrust fault that developed some 250 million years ago. The fault has been inactive for many millions of years and recurrence of movement is not expected. The fault crosses the northwestern portion of the site area; however, it was not involved directly in the foundation for any of the major plant structures.

Seismology

The Sequoyah site lies within the borders of the Southern Appalachian Seismotectonic Province, a Zone 1 (minor damage region) on the U.S. Geologic Survey Seismic Probability Map of the United States. The seismic history of the southeastern United States since 1776 indicates that there has been no seismic activity originating in the site area. Sequoyah 1 and 2 were designed based on the largest historic earthquake to occur in the Southern Appalachian Tectonic Province, the 1897 Giles County, Virginia, earthquake (Intensity: Modified Mercalli VIII and Richter magnitude of 6 to 7). The safe-shutdown earthquake for the plant has been established at a maximum horizontal acceleration of 0.18 g (g = acceleration due to gravity) and a simultaneous maximum vertical acceleration of 0.12 g (TVA 1996b). The "safe-shutdown earthquake" is defined as the earthquake that produces the maximum ground vibration for which the reactor coolant pressure boundary, the capability to shut down the reactor and maintain it in the shutdown mode, and the capability to prevent or mitigate the consequences of accidents that could result in offsite exposures comparable to the guideline exposures are designed to remain functional (10 CFR 100, Appendix A).

Soils

The Conasauga Formation provides a satisfactory and competent foundation for the plant structures. Cores from holes drilled in the plant area indicate no evidence of weathering below the upper 1.5 meters (5 feet) of the rock that would be removed under normal construction procedures. Physical testing, both static and dynamic, has shown that the unweathered rock is capable of supporting loads in excess of those that would be imposed by the plant structures. The Conasauga Formation at the site is relatively unfossiliferous and has no known areas of unique paleontological significance.

4.2.2.6 Ecological Resources

Terrestrial Resources

The Sequoyah Nuclear Plant site is located within the Ridge and Valley Physiographic Province. This province lies between the Blue Ridge Mountains and the Cumberland Plateau and is characterized by prominent, northwest-trending ridges and their adjacent valleys. The Tennessee River flows through this province, roughly paralleling the alignment of the valleys. The Sequoyah Nuclear Power Plant site is located near the center of Hamilton County, Tennessee, approximately 12 kilometers (7.5 miles) northeast of the Chattanooga city limits. The area immediately surrounding the site is primarily open agricultural lands with scattered forests.

Terrestrial Wildlife

Hamilton and Bradley Counties, Tennessee, in the vicinity of the Sequoyah Nuclear Plant site provide habitat for seven game species: white-tailed deer, gray squirrel, raccoon, wild turkey, ruffed grouse, cottontail rabbit, and bobwhite quail. The largest deer populations are located along the western border of Hamilton County (Waldens Ridge) and in the northwestern corner of Hamilton County near the junction of the Hiwassee and Tennessee Rivers. Squirrel populations occur in large stands of hardwoods, while raccoons and rabbits are most common in the wide, rolling valleys between the ridges (TVA 1974a).

The mixture of forest and open vegetative types of terrain, and the large degree of openness within the forest provide an abundance of niches favoring a diverse bird population. The diverse habitat sites surrounding the plant support varied and abundant populations of snakes, frogs, salamanders, and other reptiles (TVA 1974a).

Wetlands

Potential wetland areas are identified in the vicinity of the Sequoyah Nuclear Plant site: (1) palustrine, bottom land hardwood deciduous, temporarily flooded, and (2) fringe wetlands. They are indicated in **Figure 4–9** (TVA 1974a).

Aquatic Resources

The Chickamauga Reservoir in the vicinity of the site includes areas of varying depth, blind nonflowing embayments, tributary streams, peninsulas, inundated reservoir shallows (overbank areas), and the navigation channel or old riverbed. The area is characterized by embayments and shallow overbanks that alternate between right and left banks as the channel changes course. There are extensive shallow areas in the stretch approximately 3.2 to 6.4 kilometers (2 to 4 miles) downstream from the Sequoyah Nuclear Plant site (TVA 1974a).

There are a variety of benthic substrates in the area. They range from bedrock to fine organic leaf fragments. The substrate of greatest areal extent is composed of mixed sand, clay, and silt (TVA 1974a).

Fish Communities

Preoperational monitoring for the Sequoyah Nuclear Plant site was conducted from 1971 to 1977. Operational monitoring occurred from 1980 to 1986. Species designated important to Chickamauga Reservoir (sauger, crappie, white bass, and channel cat fish) were monitored from 1986 to 1995.

The fish community of the Chickamauga Reservoir, as in most main stream Tennessee River impoundments, is dominated by gizzard and threadfin shad. Rough fish, especially carp, drum, and smallmouth buffalo, also contribute significantly to standing crop (biomass) estimates. Among the sport fish, largemouth and spotted bass, bluegill, redear, and longear sunfish, crappie, and sauger are abundant, but smallmouth bass and walleye are rare. The Tennessee Wildlife Resources Agency reported the commercial fish harvest from Chickamauga Reservoir during 1994 to be 63,908 kilograms (140,892 pounds) of fish, primarily channel and blue catfish, buffalo, and common carp (Tennessee 1994).

Mussel and Clam Communities

Very few native mussels persist in the impounded river habitat adjacent to the Sequoyah Nuclear Plant site. Recent sampling in this part of Chickamauga Reservoir produced only a few individuals representing eight wide-ranging species. Larger numbers of native mussels occur in the Tennessee River not far downstream from Chickamauga Dam (at River Mile 471) and in an approximate 25-kilometer (15-mile) reach downstream from Watts Bar Dam (at Tennessee River Mile 529). These areas are at least 20 kilometers (13 miles) downstream and 30 kilometers (19 miles) upstream from the Sequoyah Nuclear Plant site River Mile 483). There has not been any commercial harvest of native mussels from the downstream part of Chickamauga Reservoir within the last 20–25 years. While native mussels are scarce in this part of the Tennessee River, suitable habitats support large populations of the Asiatic clam *Corbicula fluminea* and a few native snails. Also, the zebra mussel *Dreissena polymorpha* has been found in this area within the last few years. The Asiatic clam has been present in the Chickamauga Reservoir for at least 30 years (TVA 1998e).

Other Aquatic Life

There is an abundance of aquatic life in the Chickamauga Reservoir. The dominant spring and fall phytoplankton is typically a species of *Melosira*. The summer flora is dominated by two or three species of

Figure 4–9 Wetlands Map of Sequoyah Site Vicinity

green algae. Blue-green algae are represented but are not abundant. A large portion of zooplankton density is composed of rotifers. However, calenoid, copepods, and cladocerans are also plentiful.

As a rule, bottom fauna communities are not diverse and species populations are small. An exception is the Asiatic clam *Corbicula fluminea*, which achieves densities of 2,000 per square meter in limited areas. Asiatic clam densities fluctuate throughout the reservoir, but densities are much less in the lacustrine portions. The most abundant insects are the burrowing mayfly, *Hexagenia bilineata*, and midges of the family *Chironomidae*.

Aquatic Macrophytes

In the reach of the Chickamauga Reservoir above the Sequoyah site (toward the Watts Bar site), some embayments support colonies of coontail, potamogetons, and cattails. A chemical control program has been used to suppress a Eurasian watermilfoil invasion. Only few submerged or emergent macrophytes occur in the immediate area of the Sequoyah site (TVA 1974a).

Threatened and Endangered Species

The 1974 Final Environmental Statement for the Sequoyah Nuclear Plant (TVA 1974a) listed a few endangered or threatened species potentially occurring near the Sequoyah site. Based on more recent information, several terrestrial and aquatic species listed as endangered or threatened by the U.S. Fish and Wildlife Service or state agencies in Tennessee could occur in the general vicinity of the Sequoyah site (**Table 4-17**). Additional information on the status and biology of the federally listed species in Table 4-17 (except for mountain skullcap) is contained in the Biological Assessment included in the 1995 NRC Final EIS concerning the Watts Bar Nuclear Plant (NRC 1995b), which is incorporated here by reference.

Table 4–17 Listed Threatened or Endangered Species Potentially On or Near the Sequoyah Site

Common Name	*Scientific Name*	*Federal*	*State*
Plants			
Large-flowered Skullcap	*Scutellaria montana*	Endangered	Endangered
Mollusks			
Orange-footed Pearlymussel	*Plethobasus cooperianus*	Endangered	Endangered
Pink Mucket	*Lampsilis abrupta/Lampsilis orbiculata)*	Endangered	Endangered
Fish			
Blue Sucker	*Cyprogenia elongata*	a	Threatened
Snail Darter	*Percina tanasi*	Threatened	Threatened
Amphibians			
Eastern Hellbender	*Cryptobranchus a. alleganiensis*	a	NMGT[b]
Birds			
Bald Eagle	*Haliaeetus leucocephalus*	Threatened	Threatened
Osprey	*Pandion haliaetus*	a	Threatened
Peregrine Falcon	*Falco peregrinus*	Endangered	Endangered
Mammals			
Gray Bat	*Myotis grisescens*	Endangered	Endangered
Indiana Bat	*Myotis sodalis*	Endangered	Endangered

[a] Not listed.
[b] NMGT = In Need of Management
Source: NRC 1995b, TVA 1998e, Tennessee 1994, DOI 1998a.

Plants

The large-flowered skullcap (also known as the mountain skullcap) is a perennial herb in the mint family. It is restricted to three counties in southeast Tennessee and four counties in northwest Georgia. It occurs on rocky, relatively dry forested slopes and ravines and along forested streams with gravelly, fine sandy loam soils. It was first listed in 1986, when it was known from a total of 10 different locations. Since then, it has been found at many more locations, and is presently known from 36 sites with a minimum total population of 48,000 individuals. Because some of the recovery objectives for this species have been met, the U.S. Fish and Wildlife Service has recently begun a review of its status (DOI 1996, DOI 1998b).

A population of large-flowered skullcap occurs on a steep bluff across the Tennessee River from the Sequoyah site, and several other skullcap populations occur within a few kilometers of the Sequoyah site. No suitable habitat for this species occurs on the Sequoyah site (TVA 1998e).

A population of the small whorled pogonia *Isotria medeoloides*, federally listed as threatened and state listed as endangered, occurs on Walden Ridge about 24 kilometers (15 miles) southwest of the Sequoyah site. This widespread species occurs in open, dry deciduous woods with acid soul (DOI 1992). Little suitable habitat occurs on the Sequoyah site, and the species has not been found during field surveys of the site.

Terrestrial Animals

The bald eagle is a fairly common winter resident and rare summer resident on Chickamauga Reservoir. None are known to nest in the vicinity of the Sequoyah site and there is very little suitable roosting habitat on the site. Ospreys feed primarily on fish and regularly occur on Chickamauga Reservoir. None have been known to nest in the immediate vicinity of the Sequoyah site. The peregrine falcon formerly nested on the Cumberland Escarpment in Hamilton County and very recently nested on a bridge spanning the Chickamauga Dam tailwater. Suitable nest habitat does not occur in the vicinity of the Sequoyah plant. The peregrine falcon is, however, a rare migrant in the area. Peregrine falcons feed mostly on waterfowl, shorebirds, and, in urban areas, pigeons.

No caves inhabited by gray bats are known to be near the Sequoyah site; it is likely, however, that gray bats forage over adjacent portions of Chickamauga Reservoir. The Indiana bat has not been reported from Chickamauga Reservoir or elsewhere in Hamilton County. It hibernates in caves elsewhere in east Tennessee and in northeast Alabama, and periodically occurs in riparian forests along Chickamauga Reservoir. Little suitable habitat occurs on of the Sequoyah site (TVA 1998e).

Aquatic Animals

No endangered or threatened aquatic species are known or are likely to occur in the impounded part of Chickamauga Reservoir adjacent to the Sequoyah site. Present conditions in this part of the reservoir are quite unlike the flowing water, rocky bottom habitats in which nearly all Tennessee River endangered and threatened species normally occur.

Four protected aquatic species listed in Table 4-17 occur in the Tennessee River not far downstream from Chickamauga Dam, 20 kilometers (13 miles) downstream from the Sequoyah site. Of these species, only the endangered pink mucket and the threatened snail darter have been encountered in the Chickamauga Dam tailwater within the last decade. The State of Tennessee has listed the blue sucker as a threatened species and the hellbender to be In Need of Management. Both of these species have been observed only on rare occasions in the Chickamauga Dam tailwater.

Three other aquatic species, all Federally listed as endangered, were found in preimpoundment surveys of nearby portions of the Tennessee River. These species are the fine-rayed pigtoe *Fusconaia cuneolus*, tuberculedblossom pearlymussel *Epioblasma torulosa Dysnomia torulosa*, and the Cumberland monkeyface pearlymussel *Quadrula intermedia*. They all inhabit gravel riffles in medium to large rivers, and have not been found in Chickamauga Reservoir or its tailwaters for 25 years.

4.2.2.7 Archaeological and Historic Resources

No archaeological survey was conducted prior to the initiation of construction activities at the Sequoyah Nuclear Plant site. An archaeological survey of the site was conducted on June 16, 1973, after construction activity was well advanced (TVA 1974a).

No properties on the National Register of Historic Places were identified by a Tennessee Historical Commission review of the Sequoyah Nuclear Plant site (TVA 1974a).

Construction of Sequoyah 1 and Sequoyah 2 is complete and the reactors have operated since 1980 and 1982, respectively. The operational experience to date has not identified any impact on archaeological or historic resources on or near the Sequoyah Nuclear Plant site.

4.2.2.8 Socioeconomics

The Sequoyah Nuclear Power Plant is near the town of Soddy Daisy, Hamilton County, Tennessee (TVA 1998f). Its precise location is latitude 35
about 11 kilometers (7 miles) northeast of Chattanooga, Tennessee, and about 129 kilometers (80 miles) southwest of Knoxville, Tennessee. Highway access from the plant to Soddy Daisy and Chattanooga is via State Route 27. State Route 27 also links the plant to State Route 68, to the north; to Interstate Highway 40, about 73 kilometers (45 miles) north; and to State Routes 11, 127, 41, and Interstate Highway 75.

Demography

According to the U.S. Census, the population of Soddy Daisy was 8,240 in April 1990 (DOC 1998c). The estimated population in mid 1996 was 8,884, meaning a growth rate from 1990 to 1996 of almost 8 percent. Hamilton County had an estimated population of 285,536 in 1990 (DOC 1998c). It also had 79,031 families and 111,380 households in that year. **Table 4–18** shows demographic data for Soddy Daisy, Hamilton County, and the Sequoyah region of influence. The Sequoyah region of influence was defined as the area within 80 kilometers (50 miles) of the Sequoyah Nuclear Power Plant.

Table 4–18 General Demographic Characteristics of Soddy Daisy, Hamilton County, and the Sequoyah Region of Influence (1990 Census)

Demographic Measure	*Soddy Daisy*	*Hamilton County*	*Sequoyah Region of Influence*
Total population	8,240	285,536	857,880
Families	2,468	79,031	245,206
Households	3,213	111,380	325,243
Male	3,961	134,570	413,227
Female	4,279	151,026	444,654

Sources: DOC 1992, DOC 1998c.

The Sequoyah region of influence had an estimated population of 857,880 in 1990 (DOC 1992). The number of households in the region of influence was about 325,000 in 1990; the number of families, about 245,000.

Table 4–19 shows Hispanic and non-Hispanic populations residing within 80 kilometers (50 miles) of the Sequoyah site.

Table 4–19 Population Distribution by Ethnic Group in Soddy Daisy, Hamilton County, and the Sequoyah Region of Influence (1990 U.S. Census)

Ethnic Group or Subgroup (U.S. Census Definitions)	*Soddy Daisy*		*Hamilton County*		*Sequoyah Region of Influence*	
	Population	*Percentage of Total Population*	*Population*	*Percentage of Total Population*	*Population*	*Percentage of Total Population*
White not of Hispanic origin	8,176	99.22	226,222	79.23	773,795	90.20
Black not of Hispanic origin	36	0.44	54,251	19.00	71,135	8.29
American Indian, Aleut, or Eskimo not of Hispanic origin	8	0.10	762	0.27	2,688	0.31
Asian or Pacific Islander not of Hispanic origin	0	0.00	2,339	0.82	3,619	0.42
Other race not of Hispanic origin	0	0.00	97	0.03	189	0.02
White of Hispanic origin	7	0.09	1,237	0.43	3,697	0.43
Black of Hispanic origin	0	0.00	126	0.04	213	0.02
American Indian, Aleut, or Eskimo of Hispanic origin	0	0.00	10	0.00	56	0.01
Asian or Pacific Islander of Hispanic origin	13	0.16	42	0.01	66	0.01
Other race of Hispanic origin	0	0.00	450	0.16	2,422	0.28
Hispanic total	20	0.24	1,865	0.65	6,454	0.75
Total population (all ethnic groups)	8,240	100.00	285,536	100.00	857,880	100.00

Source: DOC 1992, DOC 1998c.
Note: Sum of items may not add up to population total due to rounding error.

Figure 4–10 shows the projected racial and ethnic composition of the population residing within 80 kilometers (50 miles) of the Sequoyah site. Low-income households as determined from 1990 Census data are presented on **Figure 4–11**. Low-income households are those with incomes of 80 percent or lower than the median income of the counties. As indicated in that figure, approximately 43 percent of the total households are low-income households (see Appendix G).

Income

Per capita income in Soddy Daisy was $10,709 in 1989, while median household and family income were $22,115 and $27,022, respectively (DOC 1998c). Total personal income in Hamilton County was $47 billion in 1996, up from $7.13 billion in 1995 (DOC 1998a). Per capita income in the county was $25,401 in 1996, up from $24,316 in 1995. Hamilton County was ranked fourth in the State of Tennessee in terms of per capita income in 1996. **Table 4–20** summarizes income data for Soddy Daisy and Hamilton County.

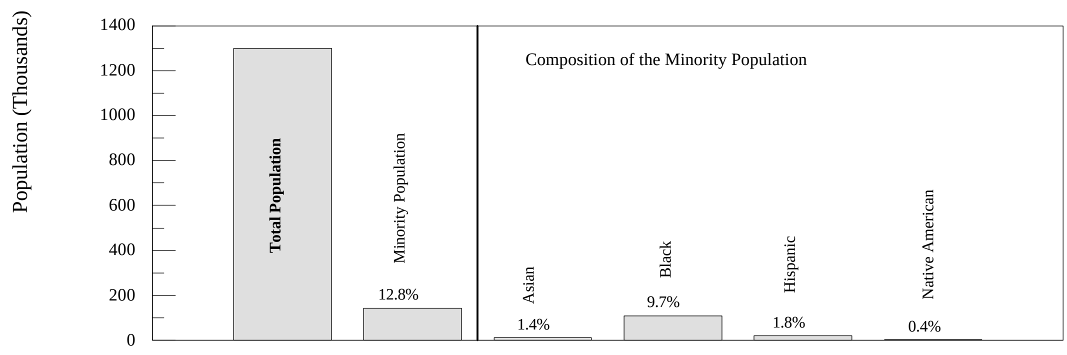


Figure 4–10 Racial and Ethnic Composition of the Minority Population Residing in Counties Within 80 Kilometers (50 Miles) of Sequoyah Projected for the Year 2025

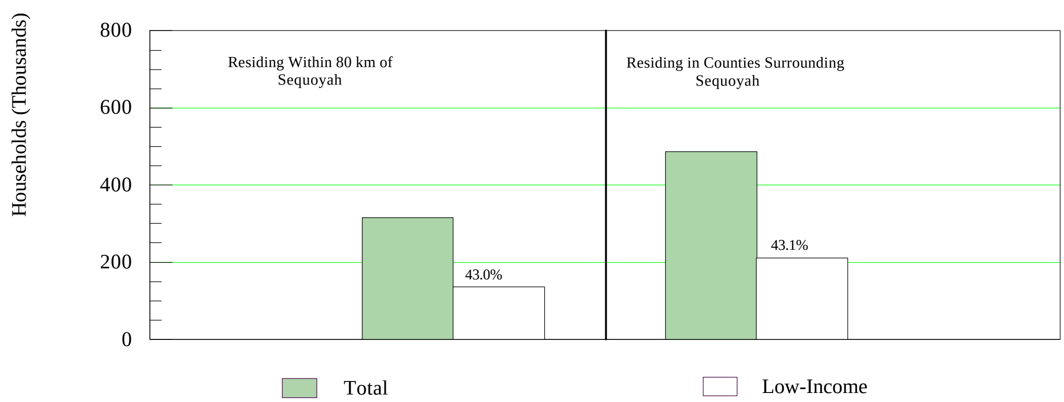


Figure 4–11 Low-Income Households Residing Within 80 Kilometers (50 Miles) of the Sequoyah Nuclear Plant (1990)

Table 4–20 Income Data Summary for Soddy Daisy and Hamilton County (1989)

Income Measure	*Soddy Daisy*	*Hamilton County*
Per capita income	$10,709	$13,619
Median household income	$22,115	$26,523
Median family income	$27,022	$32,185
Median housing value	$46,700	$61,700

Sources: DOC 1998c.

Community Services

Education, public safety, and health care were examined to determine the level of community services for the region of influence.

Education

There are 396 schools within a 80-kilometer (50-mile) radius of the Sequoyah Nuclear Plant site, with a capacity of 135,755 students. The average student-to-teacher ratio is 17:1.

Public Safety

City, county, and state law enforcement agencies provide police protection to residents of the region of influence. The average officer-to-population ratio is 1.4:1,000 persons. Fire protection services are provided by both paid and volunteer firefighters. The ratio of firefighters to population is 0.7:1,000.

Health Care

The region of influence includes 31 hospitals with a total of 3,672 beds. All of the hospitals are operating below capacity.

Local Transportation

The nearest land transportation routes are State Route 58, about 8 kilometers (5 miles) east of the site and paralleling the east bank of the Tennessee River, and U.S. Highway 27, also 8 kilometers (5 miles) from the site on the west side of the river. State Route 60 passes the northeast quadrant of the site at a distance of about 16 kilometers (10 miles). Interstate Route 75 passes the site from northeast to southwest at a distance of about 14.5 kilometers (9 miles) en route to Chattanooga. A main line of the CNO&TP Railroad (Norfolk Southern Corporation) runs adjacent to Interstate Highway 27 west of the site. The TVA railroad spur connecting the Sequoyah Nuclear Plant site is in good condition from the plant to the CNO&TP tie-in. On the site, 61 meters (200 feet) of track have been removed from the auxiliary building railroad bay. Replacement of this track and other maintenance of the onsite track would be necessary before it could be used. The Tennessee River is navigable past the site and is used as a major barge route (TVA 1996b). These transportation routes are shown in **Figure 4–12**.

The major surface roads mentioned above and the network of local roads connecting with them adequately serve the needs of the local communities and employees of TVA at the Sequoyah Nuclear Plant site.

4.2.2.9 Public and Occupational Health and Safety

Radiation Environment

Background radiation exposure to individuals in the vicinity of the Sequoyah site is expected to be the same as for the Watts Bar site. The background radiation exposure at the Sequoyah site is presented in **Table 4–21.** The annual doses to individuals from background radiation are expected to remain constant over time. Thus, any incremental change in the total dose to the population would be a function only of a change in the size of the population.

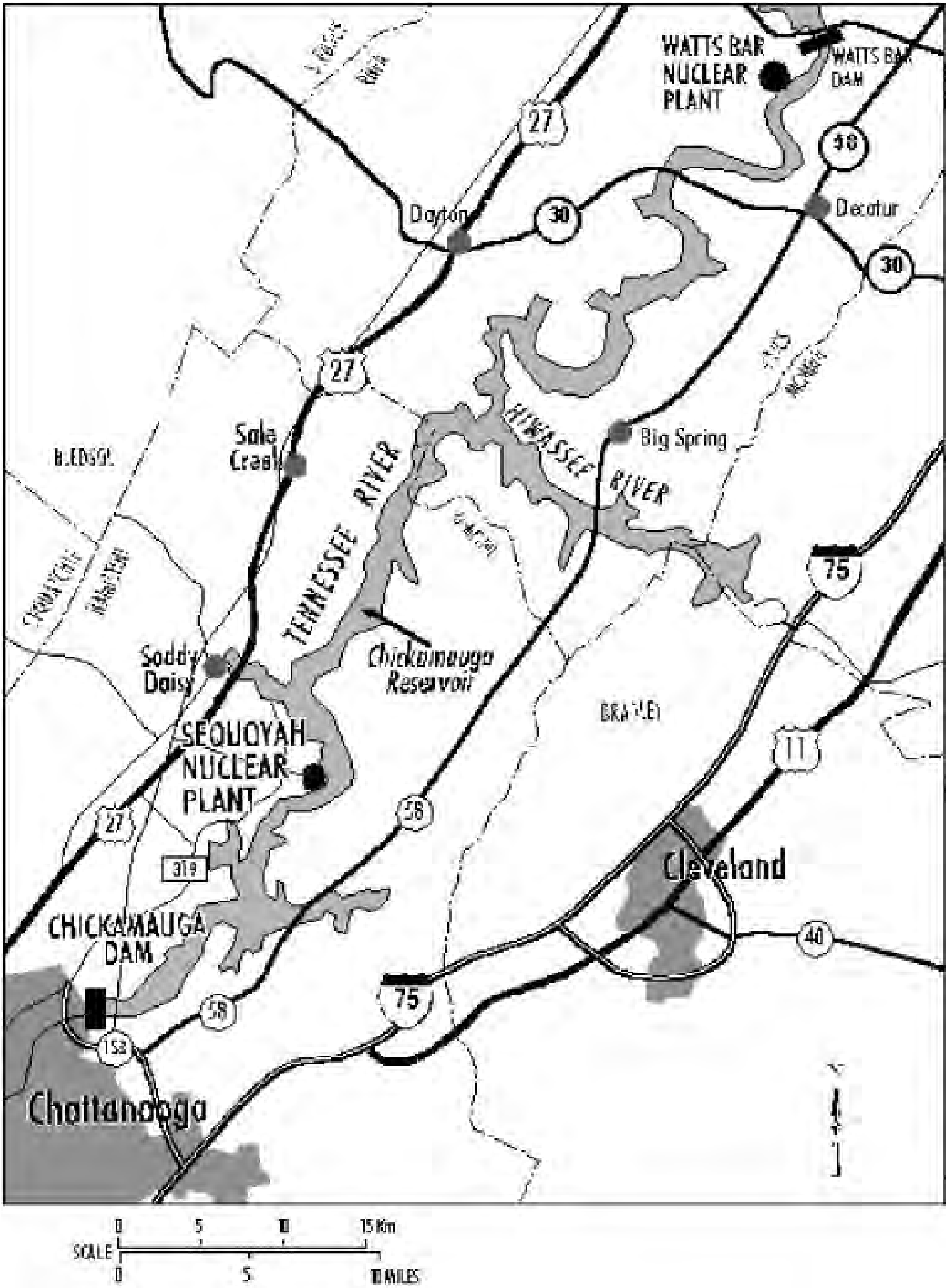


Figure 4–12 Transportation Routes in the Vicinity of the Sequoyah Nuclear Plant Site

Table 4–21 Sources of Background Radiation Exposure to Individuals in the Vicinity of the Sequoyah Site

Source	*Committed Effective Dose Equivalent (mrem/yr)*
Natural Background Radiation	
Cosmic and cosmogenic radiation	28
External terrestrial radiation	28
In the body	39
Radon in homes (inhaled)	200
Total	295
Other Background Radiation	
Release of radioactive material in natural gas, mining, ore processing, etc.	5
Diagnostic x-rays and nuclear medicine	53
Air travel	0.28
Consumer and industrial products	0.03
Total	355

Source: TVA 1998b.

Radionuclides released in effluents from Sequoyah 1 and 2 are a potential source of radiation exposure to individuals in the vicinity of Sequoyah 1 and 2 and are additive to the background radiation values listed. Calculations of radiation doses to individuals and the population surrounding the plant were performed by TVA using measurements from the various radiological monitoring points around the plant during operation in 1996 and conservative assumptions regarding individual and population exposure time. The doses are presented in **Table 4–22.**

Table 4–22 Annual Doses to the General Public During 1996 from Normal Operation at Sequoyah 1 or Sequoyah 2 (Total Effective Dose Equivalent)

	Airborne Releases		*Liquid Releases*		*Total*	
Affected Environment	*Most Stringent Standard*[a]	*Calculated Based on Actual Measurements*	*Most Stringent Standard*[a]	*Calculated Based on Actual Measurements*	*Most Stringent Standard*[b]	*Calculated Based on Actual Measurements*
Maximally exposed offsite individual (mrem)	5	0.031	3	0.022	25	0.053
Population within 80 kilometers (50 miles), (person-rem) [b]	None	0.37	None	0.79	None	1.16
Average dose to an individual within 80 kilometers (50 miles) (mrem) [c]	None	0.00039	None	0.00085	None	0.0012

[a] The standards for individuals are given in 10 CFR 50, Appendix I. The standard for maximally exposed individual 25 mrem/yr total body from all pathways is given in 40 CFR 190.
[b] Population used: 933,852
[c] The average is obtained by dividing the population dose by the 50-mile radius population.
Source: TVA 1998a.

Radiation doses to onsite workers include the same background dose received by the general public plus an additional dose from working in the facility.

Direct Radiation

Radiation fields are produced in nuclear plant environs as a result of the radioactivity contained in the reactor and its associated components. Doses from sources within the plant are largely due to nitrogen 16, a radionuclide produced from the primary coolant in the reactor core. Since the primary coolant of pressurized water reactors is contained in a heavily shielded area of the plant, dose rates from direct radiation in the vicinity of pressurized water reactors are generally less than 5 mrem/yr.

The plant operator committed to design features and operating practices that ensure that individual occupational radiation doses are within the occupational dose limits defined in 10 CFR 20, and that individual and total plant operational doses would be as low as reasonable achievable. The combined radiation doses received by the onsite worker are shown in **Table 4–23**.

Table 4–23 Annual Worker Doses from Normal Operation at Sequoyah 1 or Sequoyah 2 During 1996

Affected Environment	*Standard*[a]	*Dose*[b]
Average worker (mrem)	None	90
Maximally exposed worker (mrem)	5,000	
Total workers (person-rem)	None	132

[a] NRC regulatory limit: 10 CFR 20.
[b] TVA 1996 report based on 1,470 badged workers per unit.
Source: NRC 1997b.

Chemical Environment

Nonradioactive chemical wastes from Sequoyah 1 and 2 include boiler blowdown, water treatment wastes (sludges and high saline streams whose residues are disposed of as solid wastes and biocides), boiler metal cleaning, floor and yard drains, and stormwater runoff. Processes for defouling facility piping produce about 22,000 kg/yr (24 ton/yr) of organic residue by-products and halites (oxygenated chlorine and bromine ions) per reactor.

Operation of Sequoyah 1 and 2 takes into account the storage of process chemicals and disposal of the waste products. Adverse health impacts to the public are minimized through administrative and design controls to decrease hazardous chemical releases to the environment and to achieve compliance with permit requirements (such as air emissions and NPDES Permit requirements). The effectiveness of these controls is verified by monitoring information and inspecting compliance with mitigation measures.

Section 4.2.2.3, Table 4–13, and Section 4.2.2.4, Table 4–6, contain data on chemical concentrations in ambient air and surface water in the vicinity of Sequoyah.

Emergency Preparedness

The license issued by the NRC for the operation of Sequoyah 1 and 2 is based in part on a finding that there is reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency. This finding by NRC is based on: (1) a review of the Federal Emergency Management Agency findings, (2) determinations that state and local emergency plans are adequate with reasonable assurance that they can be implemented, and (3) the NRC assessment that the applicant's onsite emergency plans are adequate and give reasonable assurance that they can be implemented.

The plan establishes that evacuation is the most effective protective action that can be taken to cope with radiological incidents. The Sequoyah Nuclear Plant emergency plan (Annex H) provides the details of the evacuation plan. Risk Counties, identified as Bradley and Hamilton Counties, are tasked with preparing evacuation plans for citizens within the 16-kilometer (10-mile) emergency planning zone, and determining the number of people to be evacuated from the zone. Host Counties Meigs, Rhea, and Sequatchie are assigned responsibility to identify suitable shelters for evacuees. A State Emergency Operation Center would provide the focus for emergency reaction, e.g., notifications, protective action, and evacuation implementation. Fixed sirens would alert residents and transients within the 16-kilometer (10-mile) emergency planning zone with backup, if needed, by emergency vehicle sirens and loud speakers. The State Emergency Operation Center Director would involve the counties' Emergency Management Directors as required.

The Emergency Alert System and the National Oceanic and Atmospheric Administration Weather Radio would be used to provide emergency information and instructions.

The evacuation would be ordered and accomplished by designated sectors. The designated evacuation routes would be patrolled by Traffic Assistance Teams.

The American Red Cross would operate mass care shelters. Shelter Information Points would be established on each evacuation route to help direct evacuees to their assigned shelters.

Considerable planning is involved in the evacuation planning. Training, education, and practice runs are utilized to further the probability of successful evacuation in the event it is ever required.

4.2.2.10 Waste Management

As with any major industrial activity, Sequoyah 1 and 2 generate waste as a consequence of normal operation. Wastes are hazardous waste, nonhazardous solid waste, low-level radioactive waste, and sanitary liquid waste. **Table 4–24** summarizes the annual amount of waste generated at the Sequoyah Nuclear Plant site in each category.

Table 4–24 Annual Waste Generation at Sequoyah 1 and Sequoyah 2

Waste Type	*Volume or Mass*
Hazardous waste	1.196 m^3
Nonhazardous waste	1,301,966 kg
Low-level radioactive waste	382.9 m^3
Mixed waste	<1 m^3

Source: TVA 1998a.

Hazardous Waste

Hazardous wastes typically generated at Sequoyah 1 and 2 include paints, solvents, acids, oils, radiographic film and development chemicals, and degreasers. Neutralization is the only waste treatment performed onsite. Hazardous wastes are normally stored in polyethylene containment systems during accumulation. An approved storage building is used to store hazardous wastes for either 90 or 180 days, depending on the plant's hazardous waste generator status (i.e., Small Quantity or Large Quantity) at the time. Waste is transported to an offsite hazardous waste storage or disposal facility prior to exceeding the 90- or 180-day storage limit.

Low-Level Radioactive Waste

During the fission process, an inventory of radioactive fission and activation products builds up within the reactor (in the fuel and the materials of construction). A small fraction of these radioactive materials escape and contaminate the reactor coolant. The primary coolant system also receives radioactive contaminants. These contaminants are removed from the coolant by a radioactive waste treatment system. Sequoyah 1 and 2 use separate radioactive waste treatment systems for gaseous, liquid, and solid waste treatment. Residues from the gaseous and liquid waste treatment systems (filters, resins, dewatered solids) are combined and disposed of with the solid, low-level radioactive waste. Contaminated protective clothing, paper, rags, glassware, compactible and noncompactible trash, and reactor components and equipment constitute the majority of solid low-level radioactive waste at Sequoyah 1 and 2.

Before disposal, compactible trash with the exception of irradiated metals is shipped to a commercial processor where it is compacted to a lesser volume and shipped to the Barnwell, South Carolina, low-level radioactive waste disposal facility. Incinerable trash is shipped to a commercial waste incinerator in Oak Ridge, Tennessee, where the material is burned to ashes before disposal at the Barnwell disposal facility. Metal waste is either decontaminated and recycled or melted to form shielding blocks. Any radioactive waste from these processes is shipped for disposal at the Barnwell disposal facility (TVA 1998a). TVA does not send irradiated metals for volume reduction due to its excessive dose rate. This material would be accumulated until a sufficient amount is on hand to ship directly to the Barnwell disposal facility.

Mixed Waste

Mixed waste is material that is both hazardous and radioactive. No mixed waste has been generated at Sequoyah since 1990. Past sources of mixed low-level radioactive waste at TVA nuclear plants have included beta-counting fluids (e.g., zylene, toluene) for use in liquid scintillation detectors, PCBs susceptible to contact with radioactive contamination as a result of an accidental transformer spill or explosion, isopropyl alcohol used for cleaning radioactive surfaces, chelating agents, and various acids.

Waste Minimization Practices

The Sequoyah Nuclear Plant site has an active waste minimization program that consists of the following practices:

- Useful portions of construction and demolition materials are salvaged for resale.
- Segregated storage areas are maintained for each type of recoverable material.
- Scrap treated lumber is sold or placed in dumpsters for disposal by the solid waste disposal contractor at an offsite permitted landfill.
- Inert construction and demolition wastes are collected for disposal at the site permitted landfill.
- Waste paper is placed in bins or dumpsters and sold to an offsite recycle facility.
- Aluminum cans are recycled and sold.
- Nonrecoverable solid wastes are placed in dumpsters for disposal by the solid waste disposal contractor.
- Special wastes (e.g., desiccants, oily wastes, insulation) are collected and stored and then disposed of by incineration. Asbestos is sent to an approved special waste landfill for disposal.
- Used oil, fluorescent tubes, and antifreeze are collected and stored in drums or tanks and recycled.
- Medical wastes are collected and disposed of in accordance with the Medical Waste Disposal Procedure for TVA Medical Facilities.

All plant sanitary wastewater is discharged directly to the Hamilton County Public Operated Treatment Works.

Metal-cleaning wastewater (e.g., trisodium phosphate, acetic acid) is discharged into approved storage ponds for future disposal in accordance with the NPDES Permit.

Wastewater from floor and equipment drains in nonradiation areas is routed through sumps to the turbine building sump for discharge in accordance with the NPDES Permit.

Surplus chemicals are sold; lead acid batteries are recycled; refrigerant is recovered and recycled; and solvent recovery equipment is used for painting operations.

Steps to use biodegradable solvents and cleaners to replace hazardous chemicals in various cleaning operations have been incorporated to the extent practical.

4.2.2.11 Spent Fuel Management

When nuclear reactor fuel has been irradiated to the point that it no longer contributes to the operation of the reactor, the fuel assembly is termed spent nuclear fuel and is removed from the reactor core and stored in the spent fuel storage pool or basin. The Nuclear Waste Policy Act of 1982, as amended, assigned to the Secretary of Energy the responsibility for the development of a repository for the disposal of high-level radioactive waste and spent nuclear fuel. When such a repository is available, spent nuclear fuel would be transported for disposal from the nuclear power reactors to the repository. Until a repository is available, spent nuclear fuel would be stored in the reactor pools or in other acceptable, NRC-licensed storage locations. Because of the uncertainty associated with opening a repository, this EIS assumes spent fuel would be stored at the reactor facility for the duration of the proposed action (i.e., 40 years).

Storage Capacity

Storage cells have been provided in the Sequoyah 1 and 2 spent fuel storage pools to hold 2,089 fuel assemblies. A reserve capacity is required for a discharge of one complete core (193 fuel assemblies) in the event it becomes necessary to remove fuel from one of the reactor vessels. An administrative policy requires the reserve spent fuel pool capacity to discharge two complete cores (386 fuel assemblies). The remaining storage capacity is 1,703 fuel assemblies. As of January 1998, the spent fuel storage inventory of Sequoyah 1 and 2 was 1,214 assemblies, leaving a usable storage capacity of 489 fuel assemblies (TVA 1997d).

Management Practice

The normal (projected equilibrium average) refueling batch size is 80 spent fuel assemblies, with refueling frequency established at 18 months. The current capacity for storing spent nuclear fuel is adequate through the year 2001 (following Unit 1 fuel cycle Number 11). However, Sequoyah 1 and 2 are already licensed for an additional storage rack that would increase the capacity by 193 assemblies (one full core) to a total spent fuel storage pool capacity of 2,282 fuel assemblies. After Unit 2 Reload 12, scheduled for year 2003, Sequoyah 1 and 2 would no longer be able to retain a two-full-core storage reserve.

4.2.3 Bellefonte Nuclear Plant, Units 1 and 2

As discussed in Section 3.2.5.3, one of the reactor options under consideration is the irradiation of TPBARs in the Bellefonte 1 or both Bellefonte 1 and 2 after they have been completed and licensed for operation by the NRC. An assumption incorporated in this option is that the units would operate for the generation of electricity at their licensed full-power output with no reduced operability attributable to the production of tritium. However, the irradiation of TPBARs for tritium production would be considered the primary mission of the plant.

Bellefonte 1 and 2 were issued a construction permit by the Atomic Energy Commission in December 1974. By 1988, Unit 1 was 90 percent complete, and Unit 2 about 57 percent complete. On July 29, 1988, TVA notified the NRC that completion of construction of Bellefonte was being deferred. A lower-than-expected load forecast for the near future was given as the reason for deferral. On March 23, 1993, TVA notified the NRC of its plans to complete Bellefonte 1 and 2. This decision was the result of an extensive, 3-year study that concluded completion of the facility as a nuclear power plant was viable. In December 1994, the TVA Board announced that Bellefonte would not be completed as a nuclear plant without a partner. Construction was halted again and has remained stopped pending completion of a comprehensive evaluation of TVA's power needs (TVA 1997f).

Since December 1994, engineering and construction activities have been suspended. The plant systems and structures are maintained through an active layup and preservation program initiated in 1988. The program is described briefly in Section 3.2.5.3, including brief descriptions of the existing structures. Detailed descriptions of the site, buildings, structures, systems, and operations are provided in the following licensing and environmental documentation for the plant:

Atomic Energy Commission, *Final Environmental Statement Related to Construction of the Bellefonte Nuclear Plant Units 1 and 2* (AEC 1974)

Tennessee Valley Authority, *Final Environmental Impact Statement for the Bellefonte Conversion Project*, (TVA 1997f)

Tennessee Valley Authority, *Bellefonte Nuclear Plant, Final Safety Analysis Report, through Amendment 30*, Chattanooga, Tennessee, (TVA 1991)

The following sections describe the affected environment at the Bellefonte site for land resources, noise, air quality, water resources, geology and soils, ecological resources, cultural resources, and socioeconomics. In addition, the radiation and hazardous chemical environment, waste management, and spent nuclear fuel considerations are described.

4.2.3.1 Land Resources

Land Use

Located in Jackson County, Alabama, the Bellefonte site occupies approximately 607 hectares (1,500 acres) of land on a peninsula at Tennessee River Mile 392 on the west shore of Guntersville Lake about 11.3 kilometers (7 miles) east-northeast of Scottsboro, Alabama. This land has already been dedicated as the site for Bellefonte 1 and 2. No additional land is needed to complete construction of either unit or to accommodate tritium production. The location of the Bellefonte site is shown in **Figure 4–13.** The site Bellefonte is shown in **Figure 4–14.**

Greater than 90 percent of the land within the three-county area surrounding the site is characterized by forest and agricultural use or is undeveloped. The remaining land is used for residential, commercial, industrial, infrastructure, social, cultural, or governmental purposes. The nearest town, Hollywood, Alabama, is approximately 4.8 kilometers (3 miles) from the site.

Completion of the units for industrial purposes (including contracted irradiation services) would conform with the proposed urban and industrial development land use for the site and its vicinity as designated by the local governmental plans, policies, and controls.

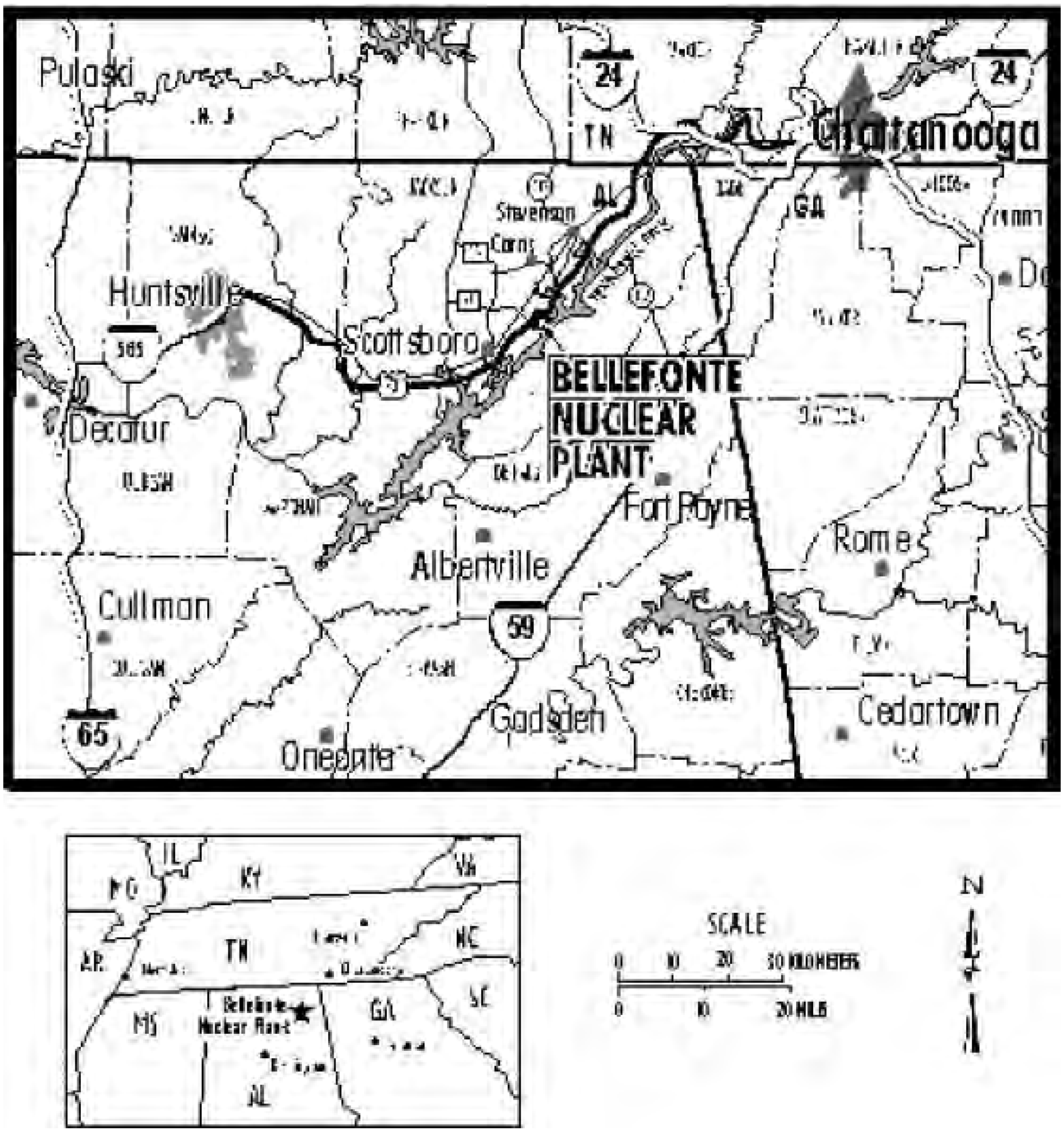


Figure 4–13 Location of Bellefonte Site

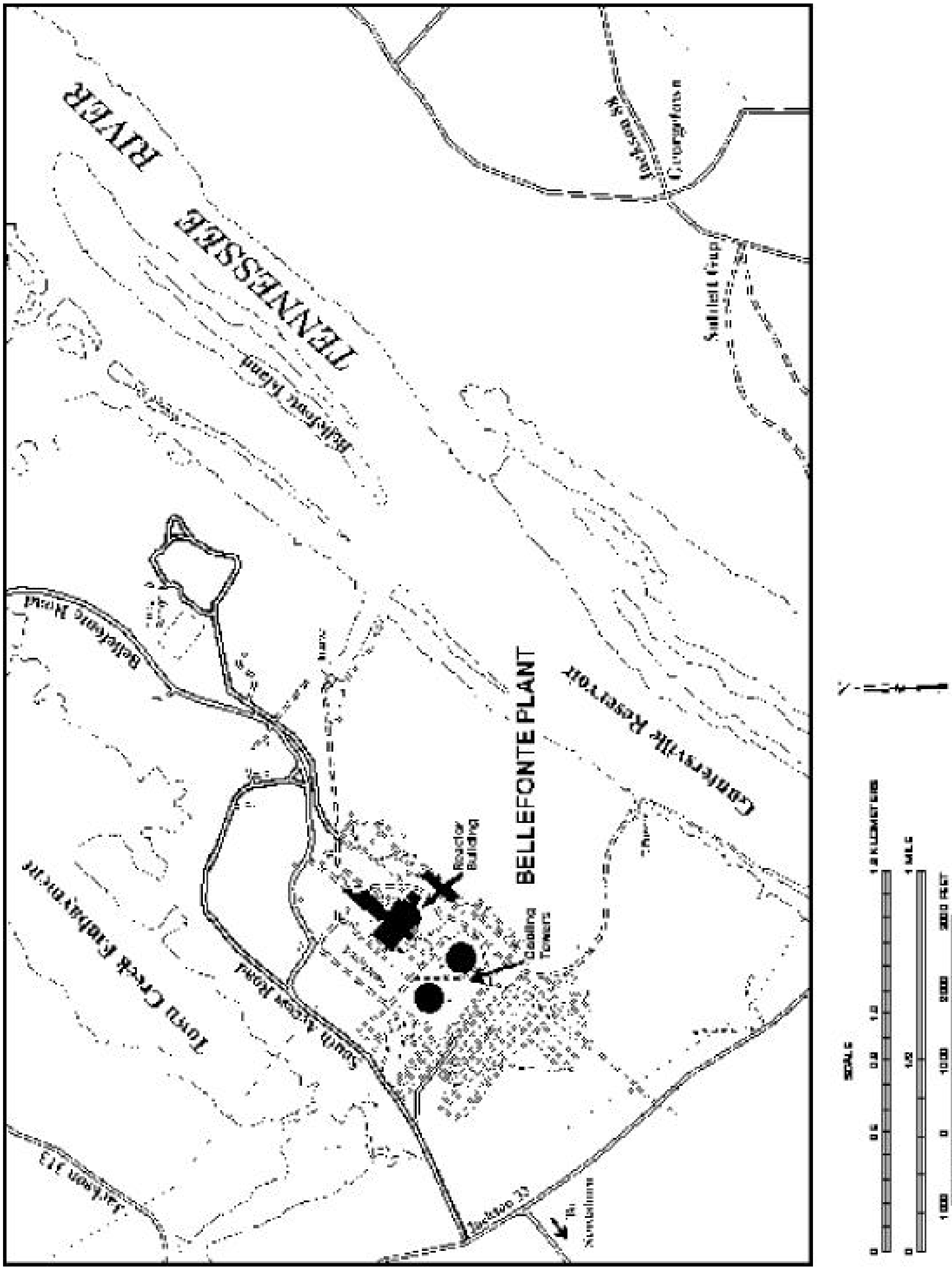


Figure 4–14 Bellefonte Nuclear Plant Site

Industry

Industrial development is largely concentrated along the Scottsboro-Stevenson-Bridgeport corridor and is mainly influenced by the availability of transportation and urban services.

Agriculture

The total area of Jackson County, Alabama, is approximately 277,000 hectares (684,500 acres), of which about 30 percent or 82,800 hectares (204,600 acres) is used for agriculture (GISP 1998c).

Forest

Sixty-three percent of the area of Jackson County, Alabama, is forested, amounting to 174,200 hectares (430,500 acres). Oak-hickory hardwood forests make up 78 percent of the forested area. The balance is in loblolly and short-leaf pine and oak-pine forests (DOA 1998c, DOA 1998d).

Recreation

Hunting, fishing, and pleasure boating are among the more popular activities in the Bellefonte site area. Guntersville Lake supports a variety of water-based recreation activities. Most of this activity occurs during the spring, summer, and early fall periods of the year.

Nature Reserves

A wild life management area includes Mud Creek and Crow Creek embayments and their shoreline lands. The Coon Gulf Habitat Protection Area on the east shore of Guntersville Reservoir is a state-managed reserve.

Visual Resources

The visual landscape of the Bellefonte Nuclear Plant site is characterized by a flat valley adjacent to a reservoir and a river. The visual landscape of the site reflects that of an industrialized facility. The viewshed includes hilly land with urban-industrial nodes surrounded by low density development scattered among agricultural uses and forest lands.

The major visual elements of the plant already exist, including the cooling towers, containment structures, turbine building, and the transmission lines. Views of the Bellefonte site from passing river traffic on the Tennessee River are partially screened by the ridge lines close to the shoreline. The plant is overlooked by a few residences on Sand Mountain on the east side of the river. Distant glimpses of the plant site can be had from the coves and hollows along the Sand Mountain rim, from State Roads 35 and 40 as they traverse Sand Mountain, and from Comber Bridge, which crosses Guntersville Lake (TVA 1997f). The plant can be seen from various locations along U.S. Highway 72 to the northwest and from residences on the north shore of Town Creek Embayment.

A visual resource inventory is composed of three factors: Visual Resource Management classification, distance zones, and sensitivity levels. Distance zones for each viewpoint are determined as foreground-middleground, background, or seldom-seen. Based on the Bureau of Land Management Visual Resource Management method, the existing landscape at the site would be classified as Visual Resource Management Class 3 or 4. Class 3 includes areas where there has been a moderate change in the landscape and these changes may attract attention, but do not dominate the view of the casual observer. Class 4 includes areas where major modifications to the character of the landscape have occurred. These changes may be dominant features of the view and the major focus of viewer attention (DOI 1986a). Due to the location of the site adjacent to the Tennessee River, the area is subject to high user volumes associated with recreational uses. Because of the proximity to urban development and recreational areas, the facilities are visible from viewpoints with low to moderate sensitivity levels (DOI 1986a).

4.2.3.2 Noise

The most common measure of environmental noise impact is the day-night average sound level. The day-night average sound level is a 24-hour sound level with a 10 dBA penalty added to sound levels between 10:00 p.m. and 7:00 a.m to account for increased annoyance due to noise during nighttime hours. EPA has developed noise level guidelines for different land-use classifications based on day-night average sound level and equivalent sound levels. The U.S. Department of Housing and Urban Development has established noise impact guidelines for residential areas based on day-night average sound levels. Some states and localities have established noise control regulations or zoning ordinances that specify acceptable noise levels by land-use category. The State of Alabama has not developed a noise regulation that specifies the numerical community noise levels that are acceptable.

For the purpose of this document, noise impacts are assessed using a day-night average sound level of 65 dBA as the level below which noise levels would be considered acceptable for residential land uses and outdoor recreational uses and an increase of 2 dBA as an indicator of "substantial" increases in noise. This approach is based on the TVA noise analysis for the Bellefonte Conversion Project (TVA 1997f).

The day-night average sound levels at locations near the site are typical of a quiet rural community. The daytime and nighttime equivalent sound level values ranged from 41 to 51 dBA. The maximum day-night average sound level, 55 dBA, falls well within the Housing and Urban Development guidelines limit. The EPA considers the typical day-night average sound level noise range for a rural location where noise sources include wind, insect activity, aircraft, and agricultural activity to be 35 to 50 dBA. The noise levels offsite, below 65 dBA, are considered to be acceptable.

4.2.3.3 Air Quality

The Bellefonte Nuclear Plant site is in the Tennessee River Valley, Alabama–Cumberland Mountains, Tennessee, Interstate Air Quality Control Region. Ambient concentrations of criteria pollutants in the vicinity of the Bellefonte Nuclear Plant that were determined by monitoring at a station on Sand Mountain are presented in **Table 4–25**. This station is about 3.8 kilometers (2.4 miles) east of the plant site. During the period, February 1, 1990, through January 31, 1991, six criteria pollutants were monitored at the station. Monitoring data for 1996 and 1997 from Scottsboro and Huntsville are used to supplement this data.

The ambient concentrations of criteria pollutants are compared with the most stringent regulation or guideline. Alabama Ambient Air Quality Standards are the same as the National Ambient Air Quality Standards for all criteria pollutants.

The area surrounding the Bellefonte site is designated by EPA as an attainment area with respect to National Ambient Air Quality Standards for criteria pollutants (40 CFR 81). The nearest Prevention of Significant Deterioration Class I areas to the Bellefonte Nuclear Plant site are the Cohutta National Wildlife Area in north-central Georgia and the Sipsey National Wildlife Area in northeastern Alabama. Both sites are more than 100 kilometers (62 miles) from the Bellefonte Nuclear Plant site.

Sources of criteria pollutant emissions found at the Bellefonte Nuclear Plant site include the occasional operation of diesel-powered emergency generators and fire protection pumps; the backup security generator; the environmental data station generator; site, trade, and employee vehicles; and auxiliary boilers. Small quantities of toxic chemicals and metals are emitted from the testing and operation of the diesel-fueled

Table 4–25 Comparison of Baseline Bellefonte 1 and 2 Ambient Air Concentrations With the Most Stringent Applicable Regulations and Guidelines

Criteria Pollutant	*Averaging Time*	*Most Stringent Regulation or Guideline[a] (μg/m^3)*	*Baseline Concentrations μg/m^3*
Carbon monoxide	8-hour 1-hour	10,000 40,000	4,140[b] 5,520[b]
Lead	Calendar quarter	1.5	0.03[c]
Nitrogen dioxide	Annual	100	24.1[b]
Ozone	8-hour (4th highest averaged over 3-years)	157[d]	e
Particulate matter	PM$_{10}$ Annual (3-year average) 24-hour (interim) 24-hour (99th percentile 3-year average) PM$_{2.5}$ Annual (3-year average) 24-hour (98th percentile averaged over 3-years)	 50[d] 150[d] 150[d] 15[f] 65[f]	 24[c] 46[c] 46[c] g g
Sulfur dioxide	Annual 24-hour 3-hour	80 365 1,300	13.1[c] 73.4[h] 210[c]

[a] The Alabama Department of Environmental Management, Air Division, has incorporated all National Primary Air Quality Standards and all National Secondary Ambient Air Quality Standards by reference in Chapter 335-3-1, General Provisions, Paragraph 335-3-1-.03. Therefore, only National Ambient Air Quality Standards are provided. The standards, other than those for ozone, particulate matter, lead, and those based on annual averages, are not to be exceeded more than once per year. The 1-hour ozone standard is attained when the expected number of days per year with maximum hourly average concentrations above the standard is
1-hour ozone standard applies only to nonattainment areas. The 8-hour ozone standard is attained when the 3-year average of the annual fourth-highest daily maximum 8-hour average concentration is less than or equal to 157 μg/m^3. The interim 24 hour PM$_{10}$ standard is attained when the expected number of days with a 24-hour average concentration above the standard is
arithmetic mean particulate matter standard is attained when the expected annual arithmetic mean concentration is less than or equal to the standard.

[b] Madison County - Huntsville. Carbon monoxide - 1997, nitrogen dioxide - 1993, ozone - 1997.

[c] Sand Mountain, 1990-1991.

[d] EPA recently revised the ambient air quality standards for particulate matter and ozone. The new standards, finalized on July 18, 1997, change the ozone primary and secondary standards from a 1-hour concentration of 235 μg/m^3 (0.12 ppm) to an 8-hour concentration of 157 μg/m^3 (0.08 ppm). During a transition period while states are developing state implementation plan revisions for attaining and maintaining these standards the 1-hour ozone standard would continue to apply in nonattainment areas (62 FR 38855). For particulate matter, the current PM$_{10}$ (particulate matter size less than or equal to 10 micrometers) annual standard is retained and two PM$_{2.5}$ (particulate matter size less than or equal to 2.5 micrometers) standards are added. These standards are set at 15 μg/m^3 3-year annual average arithmetic mean based on community-oriented monitors and 65 μg/m^3 3-year average of the 98th percentile of 24-hour concentrations at population-oriented monitors. The current 24-hour PM$_{10}$ standard is revised to be based on the 3-year average of the 99th percentile of 24-hour concentrations. The existing PM$_{10}$ standards would continue to apply in the interim period (62 FR 38652).

[e] There is insufficient data to compare to the 8-hour standard for ozone.

[f] Federal standard.

[g] Compliance with the new PM$_{2.5}$ standards was not evaluated since current emissions data for PM$_{2.5}$ are not available.

[h] Jackson County - Scottsboro. PM$_{10}$ - Scottsboro, 1996, sulfur dioxide - Jackson County, 1996.

PM = Particulate matter

Source: TVA 1998a.

equipment, resulting in contributions to offsite concentrations of less than 0.0001 percent of the threshold limit value of any of these pollutants.

The calculated concentrations of carbon monoxide, nitrogen dioxide, particulate matter, and sulfur dioxide from operation of the auxiliary steam boilers, diesel generators, lube oil system, and diesel fire pumps are two or more orders of magnitude below the ambient standards. Compliance with the new $PM_{2.5}$ standards was not evaluated since current emission data for $PM_{2.5}$ are not available. When the calculated concentrations from onsite sources are combined with concentrations from offsite sources, the ambient air quality standards for carbon monoxide, nitrogen oxide compounds, particulate matter, and sulfur dioxide continue to be met.

Gaseous Radioactive Emissions

Bellefonte 1 and 2 are not completed and not operating. Therefore, there are no gaseous radioactive emissions.

Meteorology and Climatology

The regional and local climatology and meteorology of the Bellefonte Nuclear Plant site described in the Atomic Energy Commission 1974 *Final Environmental Statement Related to Construction of Bellefonte Nuclear Plant Units 1 and 2* (AEC 1974) were reevaluated in 1997 (TVA 1997f), with consideration of additional data accumulated in the intervening years. It was determined that the records used for the 1974 Final Environmental Statement provide an adequate representation of regional climatic conditions. This information has been updated with more recent data for Huntsville and Chattanooga.

Regional Climate

The Bellefonte site is located in an area dominated by prominent valley ridge topographical features, generally aligned from northeast to southwest. Local prevailing wind patterns of the Tennessee River Valley are down-valley (north through northeast) and up-valley (south through southwest) wind directions.

Severe Weather

The site is vulnerable to severe weather: heavy general rainstorms; thunderstorms that can be accompanied by heavy downpours, strong winds, hail, lightning, or tornadoes; and snow and ice storms.

The probability of a tornado occurring at any point within a radius of 55 kilometers (34.2 miles) of the plant site is 1.15×10^{-4} (TVA 1997f) or once in 8,700 years. For straight winds, the fastest wind measured 10 meters (33 feet) above ground; is expected once in a 100-year period; is about 145 kilometers per hour (90 miles per hour) (TVA 1997f).

Local Meteorological Conditions

Data collected over a 30-year period (1961–1990) indicate that at Huntsville the annual average temperature is 15.7 (60.3 January is –1.6
daily maximum temperature in July is 31.7
approximately 145.2 centimeter (57.18 inches). Prevailing winds are from the east-southeast. The average annual wind speed is 3.6 m/s (8.0 mi/hr) (NOAA 1997b).

4.2.3.4 Water Resources

Surface Water

The Bellefonte site is located on the Tennessee River at River Mile 391.5, about 68.8 kilometers (43 miles) upstream of the Guntersville Dam on a peninsula formed between the Town Creek Embayment and the Guntersville Reservoir on the western shore of Guntersville Reservoir. The surface area of the reservoir is 275 square kilometers (106 square miles).

The average daily flow volume at the Bellefonte site is 1,100 m^3/s (38,850 ft^3/s). Seasonal averages derived from records for 1950 to 1987 are 895 m^3/s (31,600 ft^3/s) during summer and 1,400 m^3/s (49,500 ft^3/s) during winter (TVA 1997f, TVA 1998e). Hourly flows at the site may vary considerably from daily average flows, depending on turbine operations at Nickajack and Guntersville Hydro Plants. Hourly flows may be zero or may be in an upstream direction for up to six hours per day (TVA 1998e).

Surface Water Quality

Guntersville Reservoir is classified for uses of public water supply, fish and wildlife, and swimming and other whole body water-contact sports (TVA 1997f). Monitoring data from the EPA Storage and Retrieval of Parametric Data database (STORET) for 1974 to 1990 showed that dissolved oxygen concentrations routinely drop below 5 milligrams/liter during the summer months at lower depths of the lake. No concentrations less than 4 mg/l were measured. Mild dissolved oxygen stratification was found to occur occasionally in the main channel areas. Strong stratification occurred fairly frequently in the shallower overbank and embayment areas. All pH measurements were above the minimum Alabama criterion of 6.0. In areas of high biological activity, pH values above the maximum Alabama criterion of 8.5 were observed (TVA 1997f). Surface water quality–monitoring data is presented in **Table 4–26**.

Table 4–26 Summary of Surface Water Quality Monitoring in the Vicinity of the Bellefonte Site

Parameter	*Unit of Measure*	*Water Quality Criteria*	*Average Water Body Concentration*
Radiological			
Alpha (gross)	pCi/l	15[a]	3.25
Beta (gross)	pCi/l	50[b]	2.4
Tritium	pCi/l	20,000[a]	<300[c]
Nonradiological			
Fluoride	mg/l	4.0[a]	0.01
Manganese	mg/l	0.05[d]	NA
Nitrate (as N)	mg/l	10.0[a]	0.39
Arsenic	mg/l	0.05[a]	0.0002
Barium	mg/l	2.0[a]	0.05
Cadmium	mg/l	0.005[a]	0.0005
Chromium	mg/l	0.1[a]	0.003
Lead	mg/l	0.015[a]	0.006
Mercury	mg/l	0.002[a]	0.0009
pH	pH units	6.5–8.5[d]	7.4
Sulfate	mg/l	250[d]	15.3

[a] Alabama Drinking Water Standards.
[b] Proposed National Primary Drinking Water Regulations.
[c] Below Lower Limit of Detection of 300 pCi/l.
[d] National Secondary Drinking Water Regulations (40 CFR 143).
NA = Not available
Source: Alabama 1998, ADEM 1998a, ADEM 1998b, TVA 1997f.

Surface Water Use and Rights

The Bellefonte Nuclear Plant currently draws water from the Guntersville Reservoir for fire protection and some cooling needs. There are eight municipal water supplies that use water from Guntersville Reservoir downstream of the Bellefonte site at distances of 7.2 kilometers (4.5 miles) for Fort Payne to 62.6 kilometers (38.9 miles) for Guntersville. The Guntersville State Park (47.2 kilometers [29.3 miles]) downstream uses Guntersville Reservoir water for irrigation.

Surface water rights concerning the Guntersville Reservoir and the Town Creek Embayment near the Bellefonte site involve nonimpairment of designated uses. In addition, constructing intake structures for withdrawing water from available supplies requires the U.S. Army Corps of Engineers and TVA permits.

Liquid Chemical and Radioactive Effluents

The Bellefonte Nuclear Plant uses a small amount of chemicals for maintenance and layup. There is no liquid radioactive effluent at the partially completed plant.

Other effluent streams from the Bellefonte Nuclear Plant site leave through pathways, all of which are regulated by a NPDES Permit issued by the Alabama Department of Environmental Management. Three process discharge streams are routed to the Guntersville Reservoir. Nine storm water discharge streams are routed to the Town Creek Embayment and the Guntersville Reservoir. Sanitary wastewater is discharged to the Hollywood Waste Water Treatment Facility, which is operated by the city of Hollywood. A small quantity of sanitary wastewater from the simulator building, training facility, and environmental data station is treated onsite by sand filters and a septic system.

Floodplains and Flood Risk

The Bellefonte Nuclear Plant is situated on a peninsula formed between the Town Creek Embayment and the Guntersville Reservoir in Jackson County, Alabama.

The 100-year floodplain for the Guntersville Reservoir varies from elevation 183.0 meters (600.5 feet) above mean sea level at River Mile 390.4 to elevation 183.2 meters (601.1 feet) at River Mile 392.3. The TVA Flood Risk Profile elevations on the Guntersville Reservoir vary from elevation 183.4 meters (601.8 feet) at River Mile 390.4 to elevation 183.7 meters (602.7 feet) at Tennessee River Mile 392.3. For Town Creek, the 100-year floodplain is the area lying below elevation 183.7 meters (602.7 feet). The Flood Risk Profile elevation is 183.8 meters (603.1 feet). The Flood Risk Profile is used to control flood damageable development for TVA projects. At this location, the Flood Risk Profile elevations are equal to the 500-year flood elevations. The safety related facilities, systems, and equipment are housed in structures which provide protection from flooding for all flood conditions up to an elevation of 191.2 meters (627.3 feet) (TVA 1978).

Jackson County, Alabama, has adopted the 100-year flood as the basis for its floodplain regulations, and all development would be consistent with these regulations. There are no floodways published for this area.

Groundwater

The near-surface aquifer beneath the Bellefonte site occurs under unconfined conditions. Typical aquifer material is highly weathered sedimentary bedrock overlying slightly fractured bedrock. Groundwater movement through the Chickamauga underlying the site is via fractures that have been subjected to solution activity.

Groundwater Quality

Groundwater quality of the near-surface aquifer beneath the site ranges from good to fair. Sampling of groundwater for prereactor ambient condition information was initiated at the site in 1973. During the period from 1977 through 1983, monthly groundwater samples were collected from six onsite bedrock wells WT1–WT6 to establish the background radionuclide levels at the site (TVA 1997f).

Groundwater sampling has also been conducted for organics and indicator parameters associated with known or potential subsurface releases at the site. Very few constituents exceeded EPA Maximum Contaminant Levels specified in the Primary and Secondary Drinking Water Standards (TVA 1997f). Metals that appeared at levels consistently higher than the Maximum Contaminant Levels include iron, manganese, and aluminum. These may be related to the natural mineralogy of the area.

Groundwater Availability, Use, and Rights

Most of the potable water for nearby users is surface water taken from the Guntersville Reservoir near the site. There are, however, both private and public uses of groundwater in the vicinity of the site, including water supply wells for the cities of Stevenson, Scottsboro, and Hollywood, Alabama. The closest active municipal groundwater supply using the shallow (Chickamauga) aquifer is the city of Scottsboro, 11.3 kilometers (7.0 miles) from the plant site. The Bellefonte Nuclear Plant does not currently withdraw any groundwater. The aquifer is designated Class II, indicating it is currently being used for, or is a potential source of, drinking water. The city of Hollywood, 4 kilometers (2.5 miles) northwest of the site, pumps 416,000 l/day (110,000 gal/day) from two deep wells. These wells along with surface water from Guntersville Reservoir provide the water supply for the city of Hollywood and potable water for the Bellefonte Site.

Groundwater rights concerning the aquifers near the site are associated with the Reasonable Use Doctrine. Under this doctrine, landowners can withdraw water to the extent that they must exercise their rights in accordance with the similar rights of others. The location of Bellefonte on a peninsula also tends to hydraulically isolate Bellefonte from the neighborhood residential wells on the other side of Town Creek.

4.2.3.5 Geology and Soils

Geology

The Bellefonte Nuclear Plant site is located in the Southern Appalachian Tectonic Province, in a 241 kilometer (150 mile) long anticlinal valley known as the Brown-Sequatchie Valley. This valley is representative of the valley and ridge topography and structure. The valley was formed by erosion of the Sequatchie anticline. When erosion breached the arch of thick sandstone and exposed the limestone and dolomite, an axial valley developed.

The controlling feature of the geologic structure is the Sequatchie thrust fault some 4 kilometers (2.5 miles) northwest of the site. The Sequatchie fault and resultant anticline developed more than 200 million years ago. The fault has been inactive for many millions of years.

Seismology

The known seismic history of the southeastern United States since 1776 indicates the site is located in an area of low seismic risk. The maximum historic intensities affecting the site were the result of earthquakes centered at distant points. Nevertheless, Bellefonte Nuclear Plant has been designed based on the largest historic earthquake to occur in the Southern Appalachian Tectonic Province—the 1897 Giles County, Virginia, earthquake (Intensity: Modified Mercalli VIII and Richter magnitude 6 to 7). The safe-shutdown earthquake for the plant has been established at a maximum horizontal acceleration of 0.18 g (g = acceleration due to gravity) and a simultaneous maximum vertical acceleration of 0.18 g. The "safe-shutdown earthquake" is defined as the earthquake that produces the maximum ground vibration for which the reactor coolant pressure boundary, the capability to shut down the reactor and maintain it in the shutdown mode, and the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the guideline exposures are designed to remain functional (10 CFR 100, Appendix A).

Soils

Extensive evaluation was made of the soil and bedrock on the Bellefonte Nuclear Plant site. All major Seismic Category I structures important to the safe operation of Bellefonte are founded on competent bedrock. Physical testing has shown that the bedrock is capable of supporting loads in excess of those imposed by the plant structures.

The effects of amplications of ground motions through soil columns should be considered in the seismic design of structures not founded on rock. The potential for liquefaction beneath any new structure, pipeline, or conduit not founded on rock should be evaluated in areas that are not investigated as part of the original *Bellefonte Nuclear Plant Final Safety Analysis Report,* as amended (TVA 1991).

4.2.3.6 Ecological Resources

Terrestrial Resources

The Bellefonte Nuclear Plant site is located within the Ridge and Valley Physiographic Province. This province lies between the Blue Ridge Mountains and the Cumberland Plateau and is characterized by prominent, northwest trending ridges and their adjacent valleys. The Tennessee River flows through this Province, roughly paralleling the alignment of the valleys. The area surrounding the Bellefonte Site is characterized by forests that have been continuously disturbed by timbering and agricultural practices.

The forest region that constitutes the Bellefonte Nuclear Plant site is characterized by numerous tree species (rather than domination by one or only a few species) sharing the canopy. Site vegetation has been continuously disturbed by decades of timbering and agriculture. Five categories of vegetative communities are mixed hardwoods, lawns and grassy fields, scrub-shrub thickets (including fencerows), bottom land riparian hardwoods, and pine-hardwood forests. Parking lots, roads, buildings, cooling towers, and other structures associated with the partially completed nuclear facility occupy twenty percent of the site. Mixed hardwood communities, most commonly located on the ridges and knobs comprise forty percent of the site. Ten percent of the site is planted in lawns and grassy fields. Fifteen percent of the site is occupied by scrub-shrub communities occurring in areas that were previously managed as open land but which have been left undisturbed for the past 2 to 25 years. Five percent of the site is occupied by bottom land hardwood and riparian forests associated with streams and the shoreline margins of Guntersville Lake. The remainder of the site area, approximately 10 percent, is occupied by pine-hardwood forests (TVA 1997f).

Terrestrial Wildlife

Grassy fields and the more isolated lawn areas are used as nesting and foraging areas by many species of bird, such as meadowlarks, field sparrows and wild turkeys. Common mammals include eastern cottontail rabbits, woodchuck, hispid cotton rats, prairie voles, and least shrews. Common reptiles and amphibians found in these habitats include gray rat snakes, eastern garter snakes, and American toads. There is also deer hunting onsite.

Wetlands

There are many wetland areas in and around the Bellefonte Nuclear Plant site, most of them located along the 20-kilometer (12.5-mile) shoreline that borders much of the site (TVA 1997f). **Figure 4–15** indicates the location of wetlands located near the plant site. Wetland classifications are palustrine, lacustrine, and fringe wetlands. Palustrine, bottom land hardwood, deciduous, or temporarily flooded. Classification includes aquatic bed wetlands that separate the islands from the mainland and are classified as lacustrine, aquatic bed, or rooted vascular submerged permanently flooded. The fringe wetlands are characterized by the 9 hectares (22 acres) of islands along the old river channel presence of emergent and scrub-shrub plant communities and forested shoreline (TVA 1997f).

Plant species found in the fringe wetlands include:

Common cattail *(Typha latifolia)*
Giant cutgrass *(Zizaniopsis miliacae)*
Bulrush *(Scirpus americanus)*
Soft rush *(Juncus effussus)*
Button Bush *(Cephalanthus occidentalis)*
Black willow *(Salix nigra)*
River birch *(Betula nigra)*
Sycamore *(Platanus occidentalis)*
Willow oak *(Quercus phellos)*
Water oak *(Quercus nigra)*
Red maple *(Acer rubrum)*.

Aquatic bed wetlands are formed by floating mats of Eurasian milfoil *Myriophyllum heterophyllum*, American pondweed *Potamogeton pectinatus*, and spiny-leafed naiad *Najas minor*.

TVA fulfills its mandate to protect wetlands as directed by Executive Order 11990. Other wetlands have developed in areas where ponds were constructed for previous construction activities.

Aquatic Resources

The Bellefonte site, with its narrow backwater sloughs and embayments protected from the wave and current action of the main river by strip islands and bars, supports diverse aquatic flora and fauna. Beyond the strip islands and bars, the original channel of the Tennessee River also contains a diverse aquatic community which is affected by the river current.

Plankton

Assessments show phytoplankton to be quite variable among sample stations, months, and years, making the determination of spatial and temporal trends difficult. The exception is the trend for greatest phytoplankton abundance and blue-green algae dominance during parts of the year at shallow overbank habitats and at downstream sampling locations. This trend can be anticipated based on the increased hydraulic retention time during the transition from fast-flowing (lotic) to slow-flowing (lentic) conditions (TVA 1997f).

Fish Communities

Guntersville Reservoir supports an abundant and diverse fish community, including both a sport and commercial fishery. Eighty-two species of fish have been collected in TVA field investigations. Two study programs are compared: 1949 to 1984 and 1984 to 1994. Comparisons show that of 61 species were collected in both studies, only 13 species found prior to 1985 were not collected in the 1984–1994 samples. Eight new species were found after 1985. All species that are unique to either of the studies, with the exception of the introduced grass carp, are typically rare individuals.

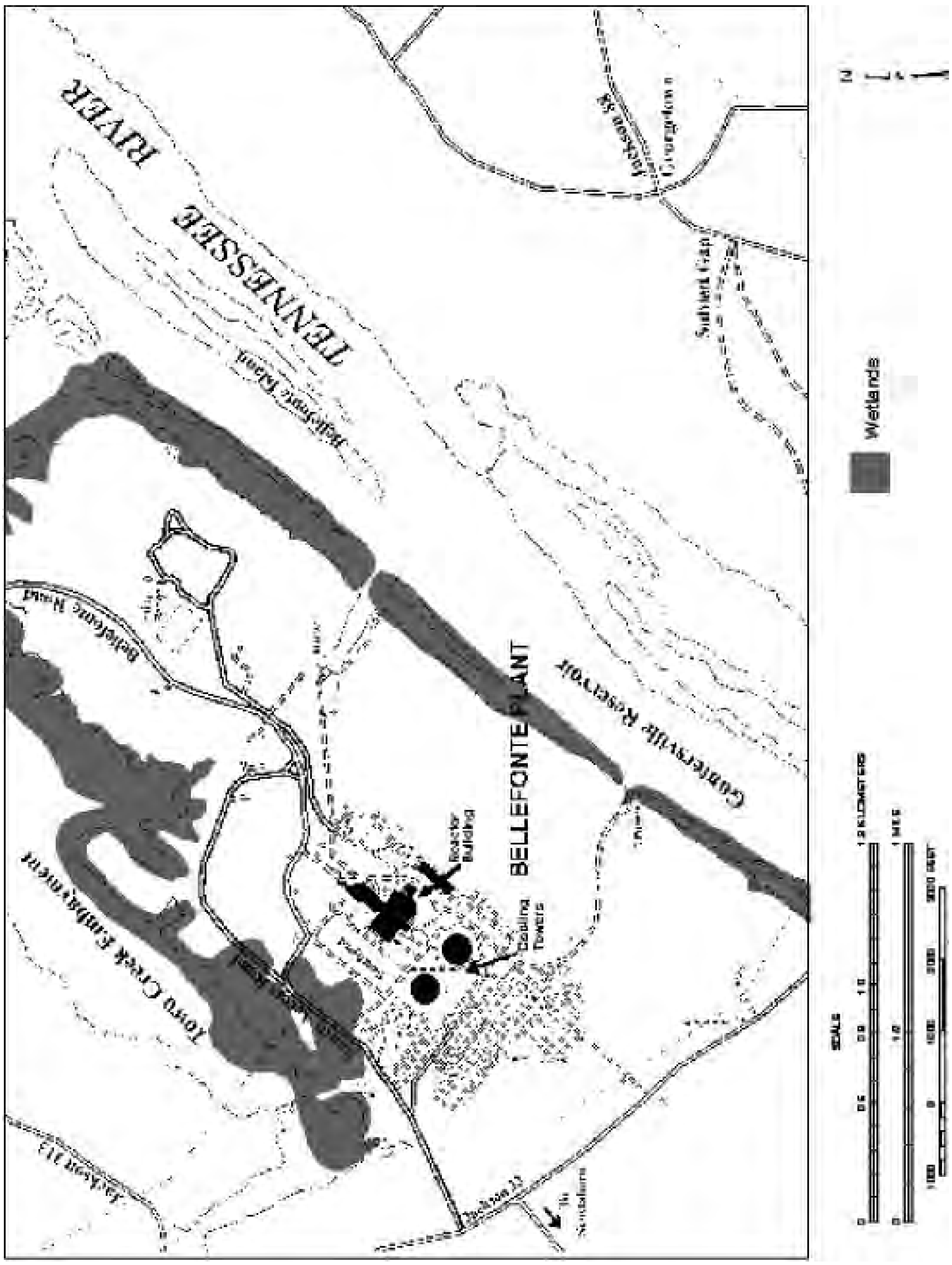


Figure 4–15 Wetlands Map of Bellefonte Nuclear Plant Vicinity

In the more recent study, the predominant game species were bluegill and redear sunfish. The predominant rough fish species were freshwater drum and yellow bullhead. Gizzard and threadfin shad were the predominant forage species.

The health of the fish community in the vicinity of Bellefonte site has been rated "fair" from 1993 to 1996 (RFAI scores ranging from 35 to 38). This assessment included sampling of the inflow region of Guntersville Reservoir (upstream from the plant site), the transition region (downstream from the plant site) and the forebay region (farfield downstream from the plant site) (TVA 1997f). Aspects that appear to be limiting the fish community quality are the low number of sucker species, the high percentage of individuals of tolerant species, numerical dominance by a single species, and the high percentage of omnivores in the community. Sport Fish Index (SFI) scores for upper Guntersville Reservoir reveal that this portion of the reservoir maintained a good sauger, channel catfish, and largemouth and spotted bass fishery during 1996. Smallmouth bass and crappie fisheries rated low (TVA 1997f).

Mussel and Clam Communities

The most permanent (long-lived) members of the benthic macroinvertebrate community are the freshwater mussels *Unionidae*. These organisms which require a fish host to complete their life cycle, were at one time a dominant and diverse part of the benthic community of the Tennessee River. Major declines in numbers and diversity of these organisms have occurred during the past 30 years. The recent investigation of August 1995 identified 14 species of mussels. The greatest abundance for one of the samples (a single transect) was at River Mile 391.1, just downstream from the Bellefonte underwater diffuser. This sample contained 65 mussels of eight species with a population of 1.3 per square meter.

The three most abundant mussels, *Megalonaias nervosa*, *Potamilusalatus*, and *Pleurobema cordatum*, made up 84 percent of the total. While some mussels species found along Bellefonte are harvested by the commercial mussel industry (e.g., *Megalonaias nervosa*), the low average density found (0.3) indicates this area does not support a valuable commercial mussel resource (TVA 1997f).

Both the Asiatic clam *Corbicula fluminea* and the zebra mussel *Dreissena polymorpha* are now known to occur in Guntersville Reservoir adjacent to the Bellefonte site. The Asiatic clam has been present in this part of the Tennessee River for at least 30 years, but the zebra mussel was first found here in 1995 (TVA 1997f).

Aquatic Macrophytes

The greatest abundance of aquatic macrophytes in the TVA system is on Guntersville Reservoir (TVA 1997f). Over the past decade, coverage of aquatic macrophytes has varied from about 8,100 hectares (20,000 acres) in 1988 (about 29 percent of the water surface area) to about 2,024 hectares (5,000 acres) in 1991. The peak coverage in 1988 occurred at the end of a record drought period (1984–1988) in the Tennessee Valley. Although several native submersed species such as southern naiad, coontail, American pondweed, small pondweed, and muskgrass colonize portions of the lake, the most abundant plants are the introduced or non-native species.

The most widespread and abundant submersed macrophyte is Eurasian watermilfoil *Myriophyllum spicatum*. This nonnative species was introduced into the TVA system in the 1950s, and established colonies were observed on Guntersville Reservoir in 1963. By the late 1960s there were several thousand acres of Eurasian watermilfoil growing in embayments and overbank areas of Guntersville Reservoir. Coverage of Eurasian watermilfoil on Guntersville Reservoir over the past decade ranged from about 1,214 hectares (3,000 acres) in 1991 to about 6,070 hectares (15,000 acres) in 1988. Abundance and coverage of Eurasian watermilfoil and other submersed macrophytes can be expected to fluctuate in response to such factors as flow and water clarity and should be most abundant in years with the low flows and clear water commonly associated with drought conditions.

Eurasian watermilfoil typically grows at water depths of a few inches up to about 3 meters (10 feet) and can form dense colonies that can interfere with small craft navigation and recreational activities, provide habitat for mosquitoes, and clog water intakes. Eurasian watermilfoil is abundant in shallow embayments near Bellefonte and along the overbank adjacent to the river channel. However, because of the riverine nature of Guntersville Reservoir in the vicinity of the site, overbank habitat is not as extensive as it is in portions of the reservoir farther downstream. Extensive colonization of Town Creek Embayment by aquatic macrophytes has little potential for clogging the facility intake structure; however, they have some potential for increasing mosquitoes at the facility.

Spinyleaf naiad *Najas minor* and hydrilla *Hydrilla verticillata* are two other introduced species of submersed aquatic macrophytes that have established on Guntersville Reservoir. Like Eurasian watermilfoil, these two species also can colonize shallow water habitats and have the potential to cause similar problems. Spinyleaf naiad was introduced into the TVA system in the 1940s. During the mid- to late 1980s, spinyleaf naiad colonized as much as 607 to 810 hectares (1,500 to 2,000 acres). These levels have declined to a few hundred acres in the 1990s. Hydrilla has the potential to be an even more problematic plant than Eurasian watermilfoil because of its ability to colonize in deeper water and because it forms a continuous plant mass through the water column. Hydrilla, which was first discovered on Guntersville Reservoir in 1982, increased to about 1,215 hectares (3,000 acres) in 1988. Although scattered plants of hydrilla are currently present throughout the mid-portion of the reservoir, visible colonies are less than 4 hectares (10 acres).

The establishment and rapid spread of hydrilla were the primary reasons for the stocking of 100,000 sterile grass carp in Guntersville Reservoir in 1990. The dramatic decline in hydrilla and spinyleaf naiad and the suppression of these species can be partially attributed to feeding by the grass carp. Like Eurasian watermilfoil, abundance of these species can be expected to fluctuate with reservoir conditions (e.g., flow and water clarity) and also can be expected to increase as populations of the grass carp decline and feeding pressure becomes less.

Because submersed aquatic macrophytes are so widespread in Guntersville Reservoir, it is not practical or desirable to attempt to eradicate them from the reservoir. Rather, as has been the case since the 1970s, aquatic macrophytes should be managed by controlling excessive populations in areas where they conflict with reservoir use, while allowing them to grow in areas that provide food and habitat for fish, waterfowl, and other aquatic organisms.

Threatened and Endangered Species

Federally listed and/or state listed threatened and endangered species occurring in the vicinity of the Bellefonte site were described in the 1974 Final Environmental Statement (TVA 1974b) and more recently in the Bellefonte Conversion Project Final EIS (TVA 1997f). At least two federally listed animals occur regularly on the Bellefonte site and several other state or federally listed species are likely to occasionally use areas of suitable habitat on or near the site (**Table 4–27**).

Plants

The snow-wreath, listed as endangered in Alabama, and smoketree and yellow honeysuckle, both listed as of special concern in Alabama, are found across the Tennessee River from the plant site. Although habitat similar to that preferred by these species exists within the Bellefonte plant site boundary, these species have not been found there during extensive field surveys (TVA 1998e).

Table 4–27 Federally and State-Listed Threatened or Endangered Species on or Near the Bellefonte Site

Common Name	*Scientific Name*	*Federal*	*State*
Plants			
Green pitcher	*Sarracenia oreophila*	a	Endangered
Snow-wreath	*Neviusia alabamensis*	a	Endangered
Smoketree	*Cotinus obovatus*	a	SPOC
Yellow Honeysuckle	*Lonicera flava*	a	SPOC
Mollusk			
Orange-footed Pearlymussel	*Plethobasus cooperianus*	Endangered	Endangered
Pink Mucket	*Lampsilis abrupta (=L. orbiculata)*	Endangered	Endangered
Anthony's Riversnail	*Athearnia anthonyi*	Endangered	Endangered
Fish			
Snail Darter	*Percina tanasi*	Threatened	Threatened
Reptiles			
Box turtle	*Terrapene carolina*	a	SPOC
Birds			
Bald Eagle	*Haliaeetus leucocephalus*	Threatened	Threatened
Osprey	*Pandion haliaetus*	a	Threatened
Cooper's Hawk	*Accipiter cooperii*	a	SPOC
Willow Flycatcher	*Empidonax traillii*	a	STUN
Warbling Vireo	*Vireo gilvus*	a	STUN
Mammals			
Gray Bat	*Myotis grisescens*	Endangered	Endangered
Indiana Bat	*Myotis sodalis*	Endangered	Endangered
Meadow Jumping Mouse	*Zapus hudsonius*	a	SPOC

[a] Not listed.
Key: SPOC = species of concern in Alabama, STUN = status undetermined in Alabama.
Source: Tennessee 1994, TVA 1997f, TVA 1998a.

Two plants federally listed as endangered occur in Jackson County. American hart's-tongue fern *Phyllitis scolopendrium var. americana* occurs in a cave mouth about 32 kilometers (20 miles) west of the site. No suitable habitat for this species occurs on the Bellefonte site and it has not been found in nearby caves or sinkholes. The green pitcher plant *Sarracenia oreophila* occurs in wet woods and streambanks on Sand Mountain. Suitable habitat is absent from the Bellefonte site and the species has not been found on or in the immediate vicinity of the site.

Terrestrial Animals

Two federally protected terrestrial animals, the bald eagle and gray bat, have been seen at the Bellefonte site. The bald eagle is a fairly common winter resident and uncommon summer resident on Guntersville Reservoir. The nearest nest sites are at the Raccoon Creek, 14 kilometers (9 miles), and Crow Creek, 16 kilometers (10 miles) embayments, upstream of the Bellefonte site. Wintering eagles on Guntersville concentrate at a few nocturnal roost sites and disperse over much of the reservoir during the day. They regularly use the wooded shoreline of the Bellefonte site along both the mainstem of the Tennessee River and the intake canal for perching and foraging. Additional information on the biology and status of bald eagles in the southeastern United States is contained in the Biological Assessment included in the 1995 NRC *Final Environmental Statement Related to the Operation of Watts Bar Nuclear Plant* (NRC 1995b).

The gray bat roosts in caves year round and forages over water on insects. At least two caves used as summer roosting sites, Blowing Wind Cave and Nitre Cave, occur within 15 kilometers (9 miles) of the Bellefonte site. The reservoir adjacent to the Bellefonte site provides suitable foraging habitat, and gray bats frequently travel 20 or more kilometers (12 or more miles) from summer roost caves to foraging sites. It is therefore likely that gray bats regularly occur along the shoreline of the Bellefonte site. Best et al. (1995) provide additional details on gray bat movements and foraging ecology at Guntersville Reservoir.

The Indiana bat roosts in hollow trees during summer months and hibernates in caves during the winter. This species typically forages in wooded areas adjacent to streams and other water courses. Because Indiana bats have been observed hibernating in caves within 15 kilometers (9 miles) of the Bellefonte site, it is likely they at least occasionally forage within forested riparian areas on the Bellefonte site during the summer.

The habitat requirements and local status of the meadow jumping mouse, osprey, Cooper's hawk, willow flycatcher, warbling vireo, and box turtle have been described by TVA (1997f).

Aquatic Species

In recent years, no aquatic species on the Federal or State of Alabama lists of endangered or threatened wildlife have been found in the Tennessee River in the vicinity of the Bellefonte site. Recent fish community assessments and mussel survey in Guntersville Reservoir near the Bellefonte site do not indicate the presence of listed or candidate endangered or threatened species (TVA 1997f). A few listed aquatic species have been found in both the upstream part of Guntersville Reservoir and in Wheeler Reservoir just downstream from Guntersville Dam.

The endangered pink mucket and the threatened snail darter occur in suitable gravel and cobble habitats in several Tennessee River reaches, including both the Nickajack and Guntersville dam tailwaters. The orange-footed pearlymussel also occurs in gravel and cobble habitats within the main stem Tennessee River. In recent years it has been found in the Guntersville Dam tailwater and not in the Nickajack tailwater. Anthony's riversnail, the only endangered snail in this group, occurs in the lower Sequatchie River and at a few locations in the Nickajack Dam tailwater about 24 kilometers (15 miles) upstream of the Bellefonte site. It has not been found in surveys near the Bellefonte site, or at any other location on Guntersville Reservoir or in the Guntersville Dam tailwater (TVA 1998a). Additional information on the biology, distribution, and recovery objectives for this species is presented in the U.S. Fish and Wildlife Service recovery plan (DOI 1997).

4.2.3.7 Archaeological and Historical Resources

An initial archaeological reconnaissance of the 607 hectares (1,500 acres) of Bellefonte was conducted in 1972 (TVA 1997f). This reconnaissance resulted in the verification and discovery of five sites, with three of the sites containing Archaic, Woodland, or Mississippian components. One of the sites was subjected to data recovery in 1973/74 as a result of mitigation of adverse impact from the proposed construction of the Bellefonte Nuclear Plant. Another of the sites consists of a Woodland component in the northeast edge of the peninsula near the confluence of Town Creek and the Tennessee River and is potentially eligible for inclusion in the National Register of Historic Places. None of the other sites are eligible for inclusion. Archival record search, an initial field check, and discussions with the Alabama Historical Commission determined that the only historical site of significance within the project locality was the original town site of Bellefonte. Bellefonte was incorporated in 1821, served as the first county seat of Jackson County, and it has been determined eligible for the National Register of Historic Places. At the time of the survey, two antebellum structures were still standing: the Daniel Martin Inn/Tavern and a one-room cabin with a more recent lean-to addition. The major street layout of Bellefonte was still discernible, as were limestone foundations of two antebellum brick structures and an associated cistern. Brick remnants of the former jail and the chimney and doorstep foundations of a cabin were also present. Since the 1972 survey, all structures associated with the original town site of Bellefonte were removed by subsequent landowners (TVA 1997f, TVA 1998e).

4.2.3.8 Socioeconomics

The social, economic, and community characteristics of the affected environment are described at three levels of increasing size: (1) the City of Scottsboro, (2) Jackson County, and (3) the region of influence, defined as the area within a 80-kilometer (50-mile) radius of the Bellefonte Nuclear Plant that includes the city of Scottsboro and Jackson County. Completion of Bellefonte 1 would have the greatest effect on the socioeconomic characteristics of Jackson County.

The Bellefonte Nuclear Plant site is near Hollywood, Jackson County, Alabama. Its exact location is latitude 34 north and longitude 85
persons about 11.3 kilometers (7 miles) from the Bellefonte Nuclear Plant, is the largest city in the county. Scottsboro is located on the banks of the Tennessee River's Guntersville Reservoir, Jackson County, Alabama. Jackson County is in the northeast corner of Alabama, adjacent to Marion County, Tennessee; DeKalb County, Alabama, to the east; Madison County, Alabama, to the west; and Marshall County, Alabama, to the south.

The affected environment section describes only those socioeconomic factors that most likely would be affected if the Bellefonte Nuclear Plant were selected for tritium production. School related issues and tax related issues are expected to be among these important socioeconomic factors.

Regional Economic Characteristics

This section presents data on the current and recent economic conditions in Scottsboro and Jackson County, including unemployment rate, workforce occupations, per capita and household income, and main businesses.

Employment

The most recent unemployment rate for Jackson County is 8.2 percent for the period January through October, 1997 (Jackson County 1998). **Table 4–28** shows the unemployment rate for the county from 1991 to 1996. As indicated in Table 4–30, the 1997 figure is considerably lower than the annual averages from 1991 through 1996. There are no comparable figures available for the City of Scottsboro.

Table 4–28 Unemployment Percentages in Jackson County (1991–1997)

1991	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*
10.0	10.2	9.6	9.1	10.0	9.5	8.2%

Source: Jackson County 1998.

In terms of occupations, manufacturing is the most important, accounting for about 31 percent of the workforce (5,064 workers) in Jackson County. This is followed by services, with about 27 percent of the workforce (4,377 workers), and by retail trade, with about 19 percent (3,151 workers). Less-important occupations include government (almost 8 percent), finance-insurance-real estate (4.7 percent), construction (3.8 percent), and wholesale trade (2.9 percent). **Table 4–29** reflects the distribution of industrial occupations in Jackson County compared with the overall figures for Alabama and the United States (as percentages of total employment only for 1996).

Table 4–29 Industrial Occupation Distribution for Jackson County, Alabama, and the United States (1996 Main Occupations as a Percentage of Total Employment Only)

Type of Occupation	*Jackson County (Estimated for 1997)*	*Alabama (1993)*	*United States (1993)*
Manufacturing	29.7	17.4	12.6
Services	15.4	24.6	30.4
Retail trade	15.7	17.1	16.9
Government	16.6	16.8	14.2
Finance-Insurance-Real Estate	3.3	4.8	7.4
Construction	6.0	6.2	5.3
Wholesale trade	2.7	4.4	4.6
Agriculture	0.9	1.1	1.2

Source: DOC 1998b.

Income

Total personal income in Jackson County increased from $876 million in 1995 to $931 in 1996 (DOC 1998b). The per capita personal income went from $17,539 in 1995 to $18,366 in 1996. In 1996, the county ranked eighteenth in Alabama in per capita income. **Table 4–30** shows the per capita and household income figures for Scottsboro and Jackson County for 1997.

Table 4–30 Per Capita and Household Income in the City of Scottsboro and Jackson County (Estimates for 1997)

Income Measure	*City of Scottsboro*	*Jackson County*
Estimated per capita income	$15,552	$13,525
Estimated average household income	N/A	$35,264
Estimated median household income	$27,856	$26,492

NA = not available.
Source: Jackson County 1998.

Businesses

The businesses of greatest economic significance in the region of influence are Akzo Nobel, CommScope, Mead Containerboard, Maples Industries, Patrick Lumber Company, Shaw Industries, U.S. Gypsum, and Wenzel Metal Spinning (Scottsboro 1998). Jackson County businesses employ a total of 16,264 workers. The average number of employees per business in the county is 10.2 (Jackson County 1998).

Population

The population of Hollywood has remained essentially flat over this decade. According to Census Bureau data, it was 916 and 914 in 1990 and 1996, respectively (DOC 1998c). The population of Scottsboro increased from 13,786 in 1990 to 14,133 in 1996 (estimated), an increase of 2.5 percent. Scottsboro ranks thirty-third in

Alabama in terms of population. The nearest metropolitan city to the Bellefonte Nuclear Plant site is Huntsville, which grew from 159,880 in 1990 to 170,424 in 1996 (estimated), an increase of 6.6 percent.

According to the 1990 U.S. Census, the total population of Jackson County was 47,796 (DOC 1998c). The estimated county population in 1997 was 50,532, and the projection for 2002 is 51,132 (Jackson County 1998). The estimated number of households in the county in 1997 was 19,315, and this number is projected to decrease to 19,177 by 2002.

The total population for the Bellefonte Nuclear Plant region of influence was estimated at 883,553 in 1990 (DOC 1992). For the same year, the number of households was estimated at 336,109. About 25 percent (220,967) of the region of influence's population was under 18 years of age; about 53 percent (468,407), 18 through 54; and about 22 percent, 55 or older.

Demographic characteristics of the region of influence and Jackson County for 1992 are shown in **Table 4–31**. For the same year, **Table 4–32** shows the ethnic breakdown by race and Hispanic origin for the population of the county, the region of influence, and the United States (for comparison).

Table 4–31 General Demographic Characteristics of the Bellefonte Site Region of Influence and Jackson County (1990 Census)

Demographic Measure	*Jackson County*	*Region of Influence*
Total population	47,796	883,553
Families	14,143	252,374
Households	18,099	336,109
Male	23,146	427,549
Female	24,650	456,004

Sources: DOC 1998c.

The racial and ethnic composition of the region of influence projected for the year 2025 is shown in **Figure 4–16**. Low-income households based on 1990 Census data are presented in **Figure 4–17**. Low-income households are those with incomes of 80 percent or less than the median income of the counties. As indicated in this figure, approximately 44 percent of total households are low-income households (see Appendix G).

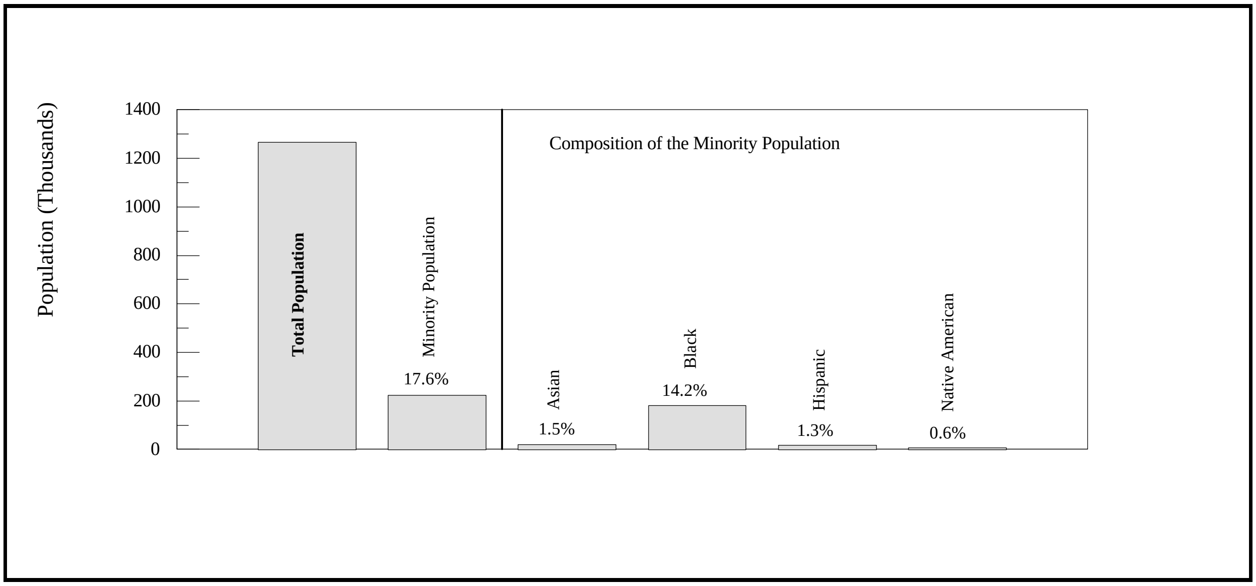


Figure 4–16 Racial and Ethnic Composition of the Minority Population Residing in Counties Within 80 Kilometers (50 Miles) of Bellefonte Projected for the Year 2025

Table 4–32 Population Distribution by Race and Hispanic Origin in Jackson County, the Bellefonte Site Region of Influence, and the United States[a]

Ethnic Group or Subgroup (U.S. Census Definitions)	United States	Jackson County		Bellefonte Site Region of Influence	
	Percentage of Total Population	*Population*	*Percentage of Total Population*	*Population*	*Percentage of Total Population*
White not of Hispanic origin	75.60	44,531	93,17	771,169	87.28
Black not of Hispanic origin	11.80	1,957	4.09	95,253	10.78
American Indian, Aleut, or Eskimo not of Hispanic origin	0.70	1,008	2.11	4,593	0.52
Asian or Pacific Islander not of Hispanic origin	2.80	89	0.19	6,243	0.71
Other race not of Hispanic origin	NA	3	0.01	90	0.01
White of Hispanic origin	4.63	165	0.35	3,955	0.45
Black of Hispanic origin	0.31	11	0.02	556	0.06
American Indian, Aleut, or Eskimo of Hispanic origin	0.07	12	0.03	33	0.00
Asian or Pacific Islander of Hispanic origin	0.12	1	0.00	142	0.02
Other race of Hispanic origin	3.83	19	0.04	1,519	0.17
Hispanic total	9.10	208	0.44	6,205	0.70
Total population (all ethnic groups)	100.00	47,796	100.00	883,553	100.00

[a]Shown as a percentage of total population for comparison purposes.
Note 1: ROI (Region of Influence) is defined as the area within a 50-mile radius of the Bellefonte site.
Note 2: Sum of items may not add up to population total due to rounding error.
Sources: DOC 1992.

Figure 4–17 Low-Income Households Residing Within 80 Kilometers (50 Miles) of Bellefonte (1990)

Housing

Temporary housing in Jackson County consists of 7 hotels and motels, about 10 trailer parks, and 13 apartment complexes. The hotels and motels are the Budget Inn, Comfort Inn, Days Inn, Goose Pond Colony Cottage Rentals, Hampton Inn, Scottish Inn Motel, and Scottsboro Hotel. The three largest trailer parks together have about 380 camper and mobile home lots, while the other 10 have about 30 each. Camper lots cover an area half the size of mobile homes and are ideal for workers who commute from nearby counties or neighboring states and drive back home on weekends. Thus, a trailer park designed for campers can accommodate twice as many tenants as one designed for mobile homes (Scottsboro 1998). An additional park adjacent to the Bellefonte plant site is planned for construction in the fall of 1998; it will feature about 125 lots, with the option for expansion to about 250. The estimated number of camper and mobile home lots in the county which was about 590 as of May 1998, is expected to increase about 84 in 1999. Trailer parks take about four months to be built. As of spring 1998, all trailer parks in the area were at or near capacity.

Currently, most apartment complexes have low vacancy rates at or near 0 percent. Vacancy rates are subject to seasonal variation and range from 0 to 12 percent (Jackson County 1998). Monthly rents range from the low $200s to the mid $300s for one-bedroom, the high $200s to the high $300s for two-bedroom, and the high $300s to the low $400s for three-bedroom apartments (Jackson County 1998). There are 12 apartment complexes in operation and one under construction in Jackson County (Scottsboro 1998). They range in size from 20 to 100 units, and include one complex for the elderly and one for low-income tenants (Jackson County 1998). The estimated number of rental apartment units is 650. There were also 36 homes for rent in Jackson County as of May 1998 (Scottsboro 1998). The home rental market is considered limited by local realtors.

In terms of permanent housing, from 1980 to 1990 a total of 621 electrical utility permits were issued to new single-family homes less than 0.5 percent increase per year (Scottsboro 1998). The number of occupied housing units in Jackson County was 18,020 in 1990, of which 13,827 (77 percent) were owner occupied and 4,193 (23 percent) were rentals (Jackson County 1998). The average number of persons per housing unit in 1990 was 2.6, is slightly higher than the average for Alabama (2.32) and the United States (2.29) (Jackson County 1998. There were 147 homes listed for sale in Jackson County as of April 21, 1998 (Scottsboro 1998). Of these, 82 were in Scottsboro. The average number of days to sell a home was 126 as of April 21, 1998.

The average home sale price in 1997 was $72,000. Property taxes, insurance costs, and utility rates are about 88 percent of the national average (Scottsboro 1998).

Community Services

General Education

A total of 152 students are enrolled in Hollywood Junior High School, part of the Jackson County School System (Jackson County 1998). The city of Scottsboro has four public elementary schools, one junior high school, and one high school. Total public school enrollment in Scottsboro is 2,967, of which 1,664 attend primary and 1,303, secondary schools (Scottsboro 1998). Scottsboro has one private elementary school (the North Alabama Christian School, a new private elementary school opened for the current academic year) and eight private preschool and kindergarten schools. The City of Scottsboro School System has 207 certified teachers, and can absorb 725 additional students next year with the construction of a new high school. The old high school is being converted into an elementary school (Scottsboro 1998). The current student-to-teacher ratio for the system is 14:1. Presented as **Table 4–33** are the student enrollment breakdown by year and the number of staff for 1997–1998 in the City of Scottsboro School System.

The system's transportation services can accommodate up to 4,080 students transported by 34 buses on a dual-route basis, or 2,040 on a single route (Armstrong 1998). Thus, the system's transportation services can accommodate an additional 1,113 students given a dual-route system.

The Scottsboro School System's budget for the current fiscal year (October 1, 1997, through September 30, 1998) is $18,368,433 (Scottsboro 1998). The system obtains revenue from the county, state, and Federal governments. For fiscal year 1997, Jackson County paid the school system $204,690 from tax revenues (Jackson County 1998). In addition, $672,657 were allocated to the school system for fiscal year 1998 by the Jackson County Commission from funds provided by TVA in lieu of taxes (Jackson County 1998). The budget per student was $5,120 for the 1995–1996 academic year.

Overall student enrollment in the Jackson County School System is 6,257, of which 713 are in elementary schools, 566 in middle schools, 1,273 in junior high schools, and 3,705 in high schools (Jackson County 1998). The Jackson County School System has 437 certified teachers and 35 administrators. The current student-to-teacher ratio for the system is 14:3. The system could absorb about 740 additional students without significant disruption. Eighteen new classrooms are being added system-wide. There are two private Christian academies in the county (one in Scottsboro, as mentioned above). The Jackson County School System has 100 school buses and, at an average of 66 students per bus, an overall transportation capacity of 6,600 on a single-route system or 13,200 on a dual-route basis. This means that the system could accommodate an additional 343 students on a single-route basis and 6,943 on a dual-route basis. The Jackson County Board of Education is considering plans to consolidate three high schools: Woodville, Skyline, and Paint Rock Valley. The proposed consolidated school would be for 432 high school students. Forty-four percent of those students are currently enrolled at Skyline, 33 percent at Woodville, and 23 percent at Paint Rock (Alabama A&M 1998).

The system's budget is $42,418,000 for the 1997–1998 academic year, of which $35,765,012 are spent directly on students (about $5,716 per student, up from $4,240 for the 1995–1996 academic year) and $6,652,988 on general student services (Armstrong 1998, Jackson County 1998). The estimated budget for next year is $43 million (Jackson County 1998). There are three revenue components to the budget: Federal, state, and county government funds. For fiscal year 1997, Jackson County's share was $374,403 (Jackson County 1998). In

Table 4–33 Scottsboro School System Breakdown by Academic Year (1991–1998)

School and Location	*Grade Levels*	*Total Enrollment (by School Year)*							*Total Faculty (1997–1998)*			*Student: Faculty Ratio (1997–1998)*
		1991–1992	*1992–1993*	*1993–1994*	*1994–1995*	*1995–1996*	*1996–1997*	*1997–1998*	*Certified Teachers*	*Support*	*Other*	
Brownwood Elementary	K–4	381	364	365	367	416	431	437	32	6	6	14
Caldwell Elementary	K–4	501	543	469	449	429	445	428	34	9	7	13
Nelson Elementary	K–4	264	239	297	297	338	355	364	27	6	4	13
Page Elementary	5–6	492	498	462	436	420	420	435	29	8	5	15
Total primary	K–6	1,638	1,644	1,593	1,549	1,603	1,651	1,664	122	29	22	14
Scottsboro Junior High School	7–8	454	461	486	480	458	451	453	29	7	7	16
Scottsboro High School	9–12	881	868	825	812	842	800	850	56	12	9	15
Total secondary	7–12	1,335	1,329	1,311	1,292	1,300	1,251	1,303	85	19	16	15
Total system	K–12	2,973	2,973	2,904	2,841	2,903	2,902	2,967	207	48	38	14

Source: Scottsboro 1998.

addition, $1,448,021 was allocated to the school system for fiscal year 1998 by the Jackson County Commission out of funds provided by the TVA in lieu of taxes (Jackson County 1998).

Public Safety

This section describes public safety specifically, fire protection and police protection, in the region of influence, including Jackson County and Scottsboro.

Fire protection in Scottsboro is provided by the City of Scottsboro Fire Department. There are 30 full-time firefighters and 14 volunteers (Scottsboro 1998). Jackson County has 490 volunteer firefighters. **Table 4–34** shows full-time and volunteer fire fighters in region of influence. There are 27 fire departments within the region of influence; 24 of these are in Jackson County, as noted above. The total number of firefighters for the region of influence (including all in Jackson County) is approximately 535.

Table 4–34 Fire Protection Services Available in the City of Scottsboro, Jackson County, and the Bellefonte Site Region of Influence (April 1998)

Level of Analysis	*Number of Stations (Fire Departments)*	*Number of Firefighters*		*Vehicles*		
		Full-Time	*Volunteer*	*Pumps and Tankers*	*Ladders*	*Rescue*
City of Scottsboro	3 (1)	30	14	4	1	1
Jackson County[a]	NA (24)	31	490	24	1	21
ROI[b]	NA (27)	31	535[c]	31	1	21

[a] Including Scottsboro Fire Department.
[b] Including Scottsboro Fire Department, all of Jackson County's Volunteer Departments, and three of DeKalb County's Fire Departments (Henager, Sylvannia, and Powell).
[c] Minimum estimate.
NA = not available.
Sources: Scottsboro 1998, Jackson County 1998.

Police Protection—Police protection in the vicinity of the Bellefonte site is provided by the City of Scottsboro Police Department, the Hollywood Police Department, and the Jackson County Sheriff's Office. The county has eight police departments (Scottsboro, Stevenson, Bridgeport, Hollywood, Woodville, Skyline, Section, and Pisgah), Scottsboro has 37 full-time officers. There are about 10 civilian dispatchers, 6 jailers, 2 clerks, and 1 maintenance employee. The Hollywood Police Department has three officers; the Sheriff's Office, 27 sworn deputies, including the Sheriff, who is based in Scottsboro (Jackson County 1998).

There are two hospitals in Jackson County. Jackson County Hospital has 170 beds and a staff of 465, including 40 physicians (Jackson County 1998). North Jackson Hospital has 40 beds and a staff of about 270, including 6 physicians.

Transportation

The nearest major interstate highway is Interstate Highway 59, approximately 47 kilometers (29 miles) southeast of the Bellefonte site. U.S. Highway 72, which connects Chattanooga, Tennessee, and Huntsville, Alabama, is 3.2 kilometers (2 miles) northwest of the site. Bellefonte Road is a two-lane road extending from the north across Town Creek Embayment to U.S. Highway 72. Site access from the south is provided by South Access Road, connecting to Jackson County Road 33. The CSX Railway main line between Chattanooga and Huntsville passes about 4.8 kilometers (3 miles) northwest of the Bellefonte site. The Tennessee River is navigable past the Bellefonte site; a minimum 2.7-meter (9-foot) channel depth is maintained for commercial or recreational vessels. The barge traffic in this portion of the Tennessee River navigation system is considered moderate (TVA 1997f). These transportation routes are shown in **Figure 4-18.**

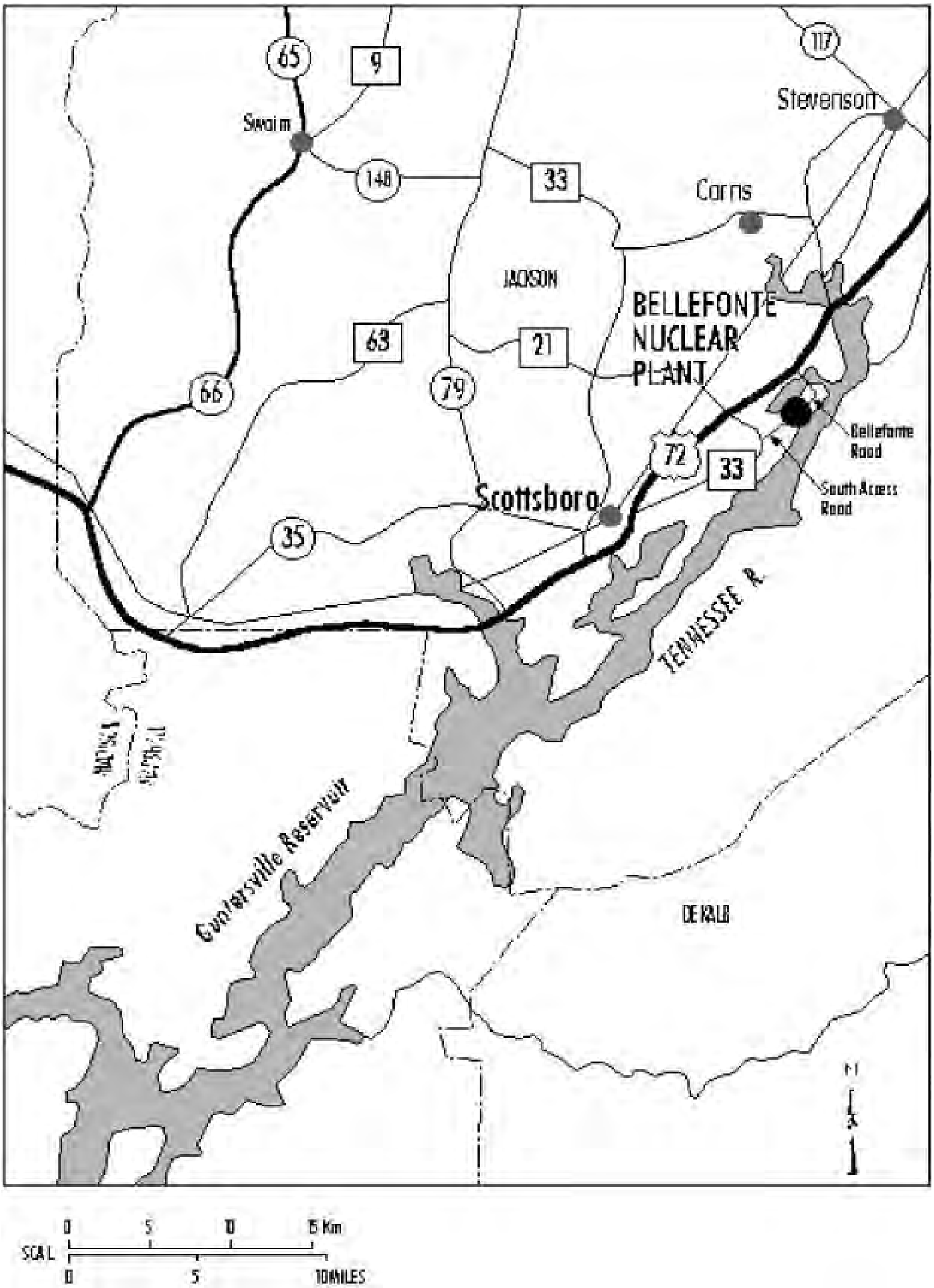
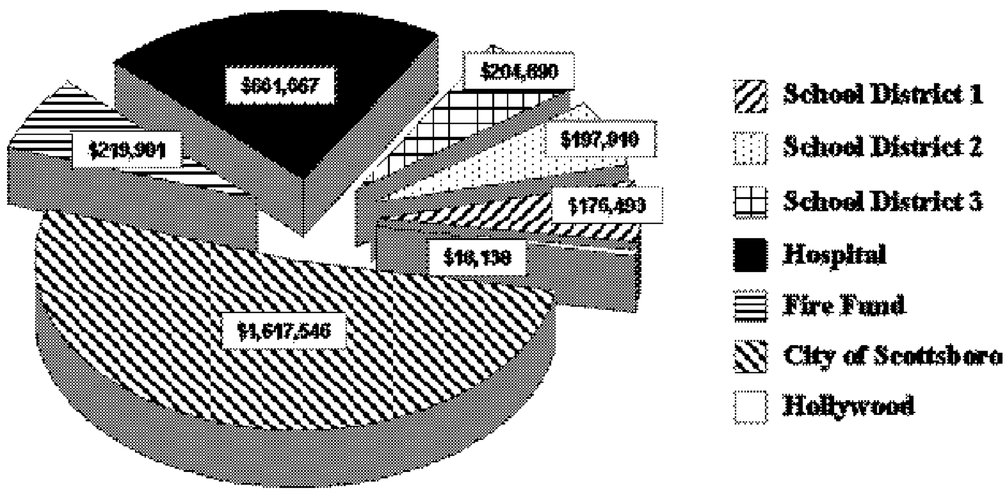


Figure 4–18 Transportation Routes in the Vicinity of the Bellefonte Nuclear Plant Site

Tax Revenues

Jackson County Tax Revenues

Jackson County collects tax revenues from real estate, sales taxes, and motor vehicle tags. The net assessed real estate value for fiscal year 1997 is $169,486,219 (Jackson County 1998). Total tax collections in fiscal year 1997 were $9,353,939, up from $8,618,488 in fiscal year 1995. **Figure 4–19** shows the total distributions by recipient for fiscal year 1997. **Table 4–35** shows Jackson County's tax and fee revenue distributions by recipient and by source for fiscal year 1997.



Source: Crawford 1998g

Figure 4–19 Jackson County Tax Revenue Distributions by Recipient FY 1997

Source: Jackson County 1998

The Jackson County Commission also receives monthly payments from the TVA of about $469,629.06, amounting to $5,635,548.72 for fiscal year 1998 (Jackson County 1998).

Tobacco Tax Revenues

The tobacco taxes in Jackson County, including county, Scottsboro, state, and Federal taxes, will probably bring in over $1 million in additional revenues (Scottsboro 1998). Scottsboro City's portion in tobacco taxes amounted to $86,538 last year. From the average $12 carton price, 30 cents goes to the city, 50 cents to the county; $1.65 to the state, $2.48 for Federal taxes, and 44 cents for sales tax (Scottsboro 1998). Those revenues are allocated to the city's general fund for operations. Jackson County's tobacco tax share amounts to approximately $300,000 (Scottsboro 1998).

Table 4–35 Jackson County Revenue Distributions by Recipient (Selected Recipients Only) and Tax and Fee Revenue Sources, Fiscal Year 1997 (October 1996 Through September 1997)

	County School Districts						
Tax or Fee Revenue Source	***District 1 (Jackson County)***	***District 2 (Jackson County)***	***District 3 (Scottsboro)***	***County Hospitals***	***Fire Fund***	***City of Scottsboro***	***Hollywood***
Real estate	$146,614	$158,878	$175,368	$548,437	$219,901	$1,302,747	$9,837
Motor vehicle ownership	$23,680	$35,918	$25,050	$113,230	$0	$185,722	$2,171
Motor vehicle sales	$0	$0	$0	$0	$0	$88,985	$3,596
Mobile home ownership [a]	$5,345	$485	$2,337	$0	$0	$2,337	$154
Motor vehicle tags	$855	$2,629	$1,935	$0	$0	$37,755	$2,380
Totals	$176,493	$197,910	$204,690	$661,667	$219,901	$1,617,546	$18,138

[a] Only when the land is not owned.
Source: Jackson County 1998.

4.2.3.9 Public and Occupational Health and Safety

Radiation Environment

Construction on Bellefonte 1 and 2 has not been completed. Therefore, no radiation has been released to the environment.

Background radiation exposure of individuals in the vicinity of the Bellefonte site is expected to be the same as for the Watts Bar site. The background radiation exposure at the Bellefonte site is presented in **Table 4–36**.

Table 4–36 Sources of Radiation Exposure to Individuals in the Vicinity of the Bellefonte Site

Source	*Committed Effective Dose Equivalent (mrem/yr)*
Natural Background Radiation	
Cosmic and cosmogenic radiation	28
External terrestrial radiation	28
In the body	39
Radon in homes (inhaled)	200
Total	295
Other Background Radiation	
Release of radioactive material in natural gas, mining, ore processing, etc.	5
Diagnostic x-rays and nuclear medicine	53
Air travel	0.28
Consumer and industrial products	0.03
Total	355

Source: TVA 1998b.

Chemical Environment

Since construction of the Bellefonte Nuclear Power Plant has not been completed, only small amounts of hazardous chemicals are used at the site for maintenance and layup (TVA 1997f).

Bellefonte is in compliance with the discharge requirements of the NPDES Permit issued by the Alabama Department of Environmental Management (TVA 1997f). Historical data (from 1974 to 1991) on storm water discharges indicate that all primary pollutants (list of major health-related contaminants) were below the Method Detection Limits, except for some metals. Two specified examples of these metals are dissolved iron and manganese (TVA 1997f). The background samples from intake water were also above the Method Detection Limits for the same metals. Section 4.2.3.3, Table 4–25, and Section 4.2.3.4, Table 4–26, contain data on quantities of concentrated chemical concentrations in ambient air and surface water in the vicinity of Bellefonte.

4.2.3.10 Waste Management

Small quantities of nonradioactive wastes are generated at the Bellefonte site. Current operations include actions necessary to maintain plant systems such as the turbines.

Ongoing maintenance activities at Bellefonte generate a small amount of solid waste. Typical solid waste is routinely put in dumpsters onsite and subsequently disposed of offsite by contractors. Asbestos and special wastes are sent to the local sanitary landfill on approval by the Alabama Department of Environmental

Management. In 1995, Bellefonte generated more than 2.8 cubic meters (100 cubic yards) of asbestos wastes, including insulation board, roofing material, tiles, gaskets, and filters. Special wastes generated by Bellefonte include activated alumina, grease, oil-contaminated rags, oil filters, sandblast grit, cement, and surplus chemicals. Bellefonte special waste disposal for 1995 included 55 drums (each containing 55 gallons) of oil-contaminated materials, grease and surplus chemicals, several hundred pounds of waste cement, and lesser amounts of other wastes.

The Bellefonte site currently qualifies as an EPA Small Quantity Generator, in accordance with 40 CFR 121.5 (i.e., the site generates more than 100 kilograms, but less than 1,000 kilograms of hazardous waste in any one calendar month per year). Hazardous wastes generated by Bellefonte include waste oil, lead wastes, nickel-cadmium batteries, acetic acid wastes, hydrazine, polyvinylchloride glue, tar, and solvents.

Some PCB wastes (e.g., lighting ballasts, small capacitors), which are regulated by the Toxic Substances Control Act (TSCA), are also generated. Hazardous wastes are shipped to the TVA Hazardous Waste Storage Facility in Muscle Shoals, Alabama, which makes arrangements for disposal at a permitted disposal facility (TVA 1997f).

4.2.3.11 Spent Fuel Management

There is no spent fuel at the Bellefonte Nuclear Plant site.

Storage Capacity

Spent fuel storage has been provided for Bellefonte 1 and 2. There are two separate spent fuel pools, one for each unit. Each pool has a storage capacity of 1,058 spent fuel assemblies.

5. ENVIRONMENTAL CONSEQUENCES

Chapter 5 describes the environmental consequences of the production of tritium in commercial light water reactors (CLWRs). It begins with a brief introduction, followed by an elaboration of the potential environmental consequences of tritium production at each site. Included for consideration are the radiological impacts of operations and potential facility accidents. There follows a description of the consequences of activities that, although related to the reactor sites, are generic in nature and can be treated separately—specifically, reactor licensing renewal, decontamination and decommissioning, and spent fuel storage. Discussion then turns to the impacts from elements of the proposed action that are not directly related to the reactor sites; the fabrication and transport of tritium-producing burnable absorber rods (TPBARs). Also presented is a sensitivity analysis focused on TPBAR design and the refueling cycle; separate evaluations of the implications of programmatic No Action and the impacts CLWR facility accidents; and a description of the cumulative impacts of the proposed actions. The chapter concludes with a look at several issues common to all sites: unavoidable, adverse environmental impacts; relationships between local, short-term uses of man's environment and the enhancement of long-term productivity; and irreversible, irretrievable commitments of resources.

5.1 INTRODUCTION

This environmental impact statement (EIS) is compliant with regulations of the Council on Environmental Quality (CEQ) the effect that the affected environment of proposed Federal actions be "interpreted comprehensively to include the natural and physical environment and the relationship of people with that environment" (40 CFR 1508.14). It focuses in part on the environmental consequences of the production of tritium in operating commercial light water reactors (CLWRs)—Watts Bar Nuclear Plant Unit 1 (Watts Bar 1) and Sequoyah Nuclear Plant Units 1 and 2 (Sequoyah 1 and 2)—from the perspective of a comparison of the incremental impacts of tritium production with operation without tritium production (the present status). Also examined are the environmental impacts of tritium production in one or both of the partially completed reactors, Bellefonte Nuclear Plant Units 1 and 2 (Bellefonte 1 and 2), as well as impacts associated with the construction activities required for the completion and full operation of those units. The assessment results presented in this chapter constitute the analytical basis for a comparison of all proposed actions with the No Action Alternative detailed in Chapter 3.

5.1.1 Methodology

Specific assumptions associated with the impact analysis common to all sites are provided in the appendixes. The environmental assessment methods used in assessing the environmental impacts for each resource and issue at each alternative reactor site are discussed in Appendix B of this EIS.

The methods for the evaluation of human health effects for: (1) normal operation of CLWR facilities, (2) CLWR facility accidents, and (3) overland transportation are presented in Appendices C, D, and E respectively. The results of these analyses are presented in this Chapter.

The discussion of public and occupational health and safety considers the radiological and chemical impacts under normal operations as well as accident scenarios. The spectrum of potential accident scenarios evaluated in this EIS include: a reactor design-basis accident, a nonreactor design-basis accident, a TPBAR handling accident, two transportation cask handling accidents, and beyond-design-basis reactor accidents involving core damage with loss of containment integrity. For operating reactors, the impacts from the accidents with tritium production are compared to operation without tritium production. The accident selection and the uncertainties are presented in Appendix D. Transportation impacts considers both routine transportation and transportation accidents. The assumptions used in these analyses are summarized below.

5.1.2 Assumptions

Conservative assumptions have been incorporated into the analysis method for this EIS to ensure that the health and safety impacts to the public and workers would not be underestimated. The following presents examples of conservative assumptions incorporated in the analysis method.

- Models used to estimate the risk of latent cancers from radiation are known to overestimate the risk for low dose rates. The actual risk may be zero.

- The effective dose from an elemental tritium gas exposure is about 10,000 times less than the effective dose from an exposure to airborne tritium oxide. Tritium released in elemental form oxidizes slowly in the environment. Experimental results estimate the long-term dose from elemental tritium releases to be approximately 1 percent of that from the oxidized form (DOE 1997b). This EIS assumes that for the accidents releasing elemental tritium directly to the environment, the analyses assumed that 1 percent of the released elemental tritium gas was converted to the oxide form at the time of release. In addition, all tritium released from the TPBARs to the reactor coolant system is converted to the oxide form at the time of release to the coolant system.

- When an accident frequency was estimated to be in a range, accident risk estimates are based on the high end of the range.

- Irrespective of the number of TPBARs irradiated in the core, the analyses assumed that two TPBARs would fail during normal operations and release all its tritium to the reactor coolant system. This assumption is very conservative based on Westinghouse experience with similar boron burnable absorber rods (WEC 1998).

- Analyses assumed that all tritium released to the reactor coolant system during normal operation would be released to the environment.

- Analyses of accidents during overland transportation assumed two failed TPBARs in each shipment.

- Analyses assumed that during the reactor design-basis accident all TPBARs are breached and their tritium contents are released to the reactor coolant system. Uncertainty exists on the actual percentage of TPBARs that would be breached during this accident.

- Analyses assumed an average tritium production of 1 gram per TPBAR per 18-month fuel cycle. This would overestimate the available tritium by about 15 percent considering an estimated average tritium production rate of about 0.84 gram per TPBAR per cycle (WEC 1997).

- Analyses assumed that during a nonreactor design-basis accident about 10 percent of the tritium that was released to the reactor coolant system during normal operation would be released to the atmosphere. However, it is expected that a very small amount (less than 1 percent) of tritium would be released in this accident.

5.2 ENVIRONMENTAL CONSEQUENCES

Environmental consequences of the No Action Alternative and tritium production are evaluated in the following sections for Watts Bar 1, Sequoyah 1 or 2, and Bellefonte 1 or 2. The evaluation of tritium production impacts considered a tritium production reactor core with a nominal 1,000 TPBARs and a core with the maximum number of 3,400 TPBARs. Both the 1,000 and 3,400 TPBAR core configurations assumed an 18-month reactor operating cycle. The impacts are evaluated for both individual and combined units at each site. In some cases the combined effects of two units at a site would be less than twice the impact of the individual units. Sensitivity analyses are performed in Section 5.2.9 to assess the changes in impacts due to TPBAR design modifications to increase tritium production per TPBAR, reducing the core reload cycle to 15.5 or 12 months, and reducing the number of TPBARs in the core to 100.

5.2.1 Watts Bar Nuclear Plant, Unit 1

5.2.1.1 Land Resources

The land resources analysis addresses land use and visual resources for the region of influence. The region of influence for land use includes land within 3.2 kilometers (2 miles) of the Watts Bar site. The region of influence for visual resources includes those lands and waters from which the site is visible (the viewshed).

LAND USE

No Action

No land use impacts are anticipated at the Watts Bar site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

No additional property would be required, and no additional land would be disturbed to prepare for tritium production at the Watts Bar site. Land use would remain unchanged from its current industrial use. The 716-hectare (1,770-acre) site contains ample area for a dry cask spent nuclear fuel storage facility, if constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

VISUAL RESOURCES

No Action

No visual impacts are anticipated at the Watts Bar site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

There would be no change in the visual character of the Watts Bar site as a result of tritium production. The major visual elements of the plant already exist, including the cooling towers and the transmission lines. As described in Section 4.2.1.1, views of the Watts Bar Nuclear Plant from passing river traffic on the Tennessee River are partially screened by the wooded area east of the plant. Distant glimpses of the plant site can be had from locations along the river and various roads in the area.

5.2.1.2 Noise

No Action

No noise impacts are anticipated at the Watts Bar site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Noise levels should not change as a result of tritium production at the Watts Bar site. No construction would occur at the Watts Bar site unless a dry cask spent nuclear fuel storage facility is constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

5.2.1.3 Air Quality

NONRADIOACTIVE GASEOUS EMISSIONS

No Action

No air quality impacts are anticipated at the Watts Bar site beyond the effects of existing and future activities that are independent of the proposed action (see Section 4.2.1.3, Table 4–1).

Tritium Production

Air quality should not change as a result of the production of tritium at the Watts Bar site. No construction-related air quality impacts would occur at Watts Bar unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

RADIOACTIVE GASEOUS EMISSIONS

No Action

Under the No Action Alternative, the radioactive gaseous emissions at Watts Bar 1 should continue at the levels described in Section 4.2.1.3, Table 4–2, assuming that no significant operational deviations would occur.

Tritium Production

Radioactive gaseous emissions from Watts Bar 1 would be expected to increase because of tritium production. During normal operation, the increase in tritium emissions would be within regulatory limits. **Table 5–1** shows the annual radioactive gaseous emissions during tritium production at Watts Bar 1 with 0, 1,000, and 3,400 TPBARs. The method and assumptions used for the calculations are provided in Appendix C, Section C.3.4. Radiological exposures of the public and workers from radioactive emissions are presented in Section 5.2.1.9. The impacts on plants and animals are described in Section 5.2.1.6.

Table 5–1 Annual Radioactive Gaseous Emissions at Watts Bar 1

	No Action (0 TPBARs)	Tritium Production [a]	
		1,000 TPBARs	3,400 TPBARs
Tritium release (Ci)	5.6	1,655.6	1,895.6
Other radioactive release (Ci)	282.5	282.5	282.5
Total release (Ci)	288.1	1,938.1	2,178.1

[a] The assumption of two failed TPBARs dominates the tritium production release with a contribution of 1,550 curies as presented in Appendix C, Table C–7.
Source: TVA 1998a.

5.2.1.4 Water Resources

SURFACE WATER

No Action

No surface water impacts are anticipated at the Watts Bar site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Impacts on surface water from nonradiological discharges at the Watts Bar site should not change as a result of tritium production. No surface water impacts would occur at the Watts Bar site unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

GROUNDWATER

No Action

No groundwater impacts are anticipated at the Watts Bar site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Impacts on groundwater at the Watts Bar site should not change as a result of tritium production. No groundwater impacts would occur at the Watts Bar site unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

RADIOACTIVE LIQUID EFFLUENT

No Action

Under the No Action Alternative, the liquid radioactive effluent at Watts Bar 1 should continue at the levels described in Section 4.2.1.4, Table 4–4, assuming that no significant operational deviations would occur.

Tritium Production

Radioactive liquid effluent from Watts Bar 1 would be expected to increase because of tritium production. During normal operation, the increase in tritium effluents would be within regulatory limits. **Table 5–2** shows the annual radioactive releases in liquid effluent during tritium production at Watts Bar 1 with 0, 1,000, and 3,400 TPBARs. The method and assumptions used for the calculations are included in Appendix C, Section C.3. Radiological exposures of the public and workers from radioactive emissions are presented in Section 5.2.1.9. The impacts on plants and animals are described in Section 5.2.1.6.

Table 5–2 Annual Radioactive Liquid Effluents at Watts Bar 1

	No Action (0 TPBARs)	*Tritium Production* [a]	
		1,000 TPBARs	*3,400 TPBARs*
Tritium release (Ci)	639	15,489	17,649
Other radioactive release (Ci)	1.32	1.32	1.32
Total release (Ci)	640.32	15,490.32	17,650.32
Tritium release concentration (pCi/l) [b]	<300	<7,270	<8,290

< = less than
[a] The assumption of two failed TPBARs dominates the tritium production release with a contribution of 13,950 curies as presented in Appendix C, Table C–7.
[b] These values are less than the 40 CFR 141 limit of 20,000 pCi/l for tritium.
Source: TVA 1998e.

5.2.1.5 Geology and Soils

No Action

No impacts on geology and soils are anticipated at the Watts Bar site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Impacts on geology and soils at the Watts Bar site should not change as a result of tritium production. No geology and soils impacts would occur at the Watts Bar site unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

5.2.1.6 Ecological Resources

No Action

No impacts on land use, air quality, or water quality are anticipated at the Watts Bar site beyond the effects of existing and future activities that are independent of the proposed action. Therefore, no impacts on ecological resources are expected under this alternative.

Tritium Production

Operation of Watts Bar 1 during tritium production would not change the terrestrial or aquatic habitat at the site. Thermal and nonradioactive chemical discharges, that could affect the ecology at the site, would remain the same. Consequently, terrestrial and aquatic plants and animals would not be affected unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impact is presented in Section 5.2.6.

Tritium production could increase radiological releases in gaseous emissions and liquid effluents, as presented in Sections 5.2.1.3 and 5.2.1.4. When tritium is inhaled or ingested by an organism, incorporation into bodily fluids is very efficient. However, long-term accumulation in the organism is limited by its rapid elimination by exhalation, excretion in body water, and its short half-life. The biological properties of tritium are discussed in Appendix C.

According to an International Atomic Energy Agency publication (IAEA 1992), a dose rate of 100 mrem/yr to the most exposed human will lead to dose rates to plants and animals of less than 0.1 rad/day. The International Atomic Energy Agency concluded that a dose rate of 0.1 rad/day or less for animals and 1 rad/day or less for plants would not affect these populations. Doses to the public and workers from potential releases at Watts Bar 1 are estimated and presented in Section 5.2.1.9. Tritium production could increase the annual dose to the maximally exposed individual of the public from 0.81 mrem/yr to approximately 1.1 mrem/yr. This cumulative exposure is well below the IAEA benchmarks. Therefore, the increase in tritium releases due to tritium production would have no effect on plants and animals at the Watts Bar site. TVA has notified the U.S. Fish and Wildlife Service of the U.S. Department of Energy's (DOE's) proposed action and will provide the States of Tennessee, Alabama, and South Carolina, and the U.S. Fish and Wildlife Service with copies of the draft and final CLWR environmental impact statement. TVA and DOE will continue to comply with the requirements of the *Endangered Species Act* and interact with the U.S. Fish and Wildlife Service, as appropriate. Since small increases in tritium releases in gaseous emissions and liquid effluents are the only operational differences for the Watts Bar Nuclear Plant (see Sections 5.2.1.3 and 5.2.1.4), no threatened and endangered species should be affected.

5.2.1.7 Archaeological and Historic Resources

No Action

No impacts on land use are anticipated at the Watts Bar site beyond the effects of existing and future activities that are independent of the proposed action. As a result, no impacts on historic and archaeological resources are expected.

Tritium Production

Since no additional land would be required for tritium production, there would be no impacts on archaeological and historic resources at the Watts Bar site unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

5.2.1.8 Socioeconomics

No Action

Under the No Action Alternative, no socioeconomic impacts are expected in the region of influence of the Watts Bar Nuclear Plant beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

As Watts Bar 1 is an operating facility, only the socioeconomic impacts associated with incremental tritium-related changes to plant operations have been considered. The primary costs of operating a CLWR for tritium production could relate to operations and maintenance, supplemental fuel procurement or fuel enrichment, the storage of additional spent fuel, replacement power, capital upgrades or replacements, and fees to the utility. Of these costs, only operations and maintenance would have the potential for material socioeconomic impacts within the region of influence. All the other expenses would relate to nonplant functions that generate corporate income, though not local income (e.g., fees from DOE) or procurements (e.g., potential spent fuel storage casks, fuel elements, TPBARs) in other parts of the country. Minor regional costs (e.g., potential maintenance of the spent fuel storage casks) would have no measurable socioeconomic impact.

Operation of Watts Bar 1 for tritium production should require less than 10 full-time equivalent workers in addition to normal plant operations staff. This addition to the normal staff of 850 would effect about a 1 percent increase in local socioeconomic factors such as income, housing requirements, and indirect employment.

The potential increase in spent fuel storage requirements due to tritium production would involve some additional costs, but the overall socioeconomic impacts would also be small. These requirements would be met via dry cask storage (see Section 5.2.6), the casks being procured from outside the region. Annual costs for additional fuel transfers, spent fuel storage cask maintenance, spent fuel cask pad expansion, and the transfer of spent fuel to shipping casks would be a maximum of $1 million.

Life extension of Watts Bar 1 as a result of tritium production (see Section 5.2.4) would have substantial regional socioeconomic benefits. A 20-year extension of normal plant operations would yield an estimated savings of $100 million per year in retained local wages, procurements, property tax revenues, and the deferral of $20 to 30 million per year (net figures in current dollars) in the costs of decontamination and decommissioning and replacement power.

Transportation impacts of tritium production would be minimal; they would be limited to commuter traffic by the personnel assigned to the site. The impact of 50 additional construction workers and associated construction vehicles, assuming the potential construction of a dry cask spent fuel storage facility, would be temporary and minor, and the traffic impact of 10 additional tritium production operations workers would not be noticeable. Additional truck traffic during tritium operations would include a total of 16 shipments of TPBARs to and from the plant per year.

5.2.1.9 Public and Occupational Health and Safety

This section describes the impacts of radiological and hazardous chemical releases resulting from normal operation and from accidents due to tritium production at Watts Bar 1. A description of the impacts of normal operation is followed by a description of the impacts of facility accidents.

5.2.1.9.1 Normal Operation

RADIOLOGICAL IMPACTS

During normal operation, there would be incremental radiological releases of tritium to the environment and also additional in-plant exposures. The resulting doses and potential health effects on the general public and workers are described below. There would be no new construction of facilities to support tritium production operations at Watts Bar 1; therefore, there would be no associated impacts on the public or workers.

The annual increase in gaseous radioactive emissions and liquid radioactive effluents from the production of tritium at Watts Bar 1 are presented in Sections 5.2.1.3 and 5.2.1.4, respectively. The radiological impacts of both gaseous and liquid radioactive releases are presented in **Table 5–3** for the maximally exposed offsite individual and the general public living within 80 kilometers (50 miles) of Watts Bar 1 in the year 2025. **Table 5–4** reflects the radiological impacts on the facility workers. A facility worker is defined as any "monitored" reactor plant employee. Doses to these workers would be kept to minimal levels through as low as is reasonably achievable (ALARA) programs. The tables include the impacts of the No Action Alternative.

Background information on the effects of radiation on the human health and safety is included in Appendix C. The method and assumptions used for calculating the impacts on the public health and safety at Watts Bar 1 are presented in Appendix C, Section C.3.

Table 5–3 Annual Radiological Impacts to the Public from Incident-Free Tritium Production Operations at Watts Bar 1

Tritium Production	*Release Media*	*Maximally Exposed Offsite Individual*		*Population Within 80 km (50 mi) for the Year 2025*	
		Dose (millirem)	*Latent Fatal Cancer Risk*	*Annual Dose (person-rem)*	*Latent Fatal Cancers*
No Action[a] (0 TPBARs)	Air	0.036	1.8×10^{-8}	0.071	0.000036
	Liquid	0.25	1.3×10^{-7}	0.48	0.00024
	Total	0.29	1.5×10^{-7}	0.55	0.00028
Incremental dose for 1,000 TPBARs	Air	0.20	1.0×10^{-7}	2.3	0.0012
	Liquid	0.024	1.2×10^{-8}	3.2	0.0016
Total dose for 1,000 TPBAR tritium production	Air	0.24	1.2×10^{-7}	2.4	0.0012
	Liquid	0.27	1.4×10^{-7}	3.7	0.0019
	Total	0.51	2.6×10^{-7}	6.1	0.0031
Incremental dose for 3,400 TPBARs	Air	0.24	1.2×10^{-7}	2.8	0.0014
	Liquid	0.027	1.4×10^{-8}	3.6	0.0018
Total dose for 3,400 TPBARs	Air	0.28	1.4×10^{-7}	2.9	0.0015
	Liquid	0.28	1.4×10^{-7}	4.1	0.0021
	Total	0.56	2.8×10^{-7}	7.0	0.0035

[a] Doses based on actual measurements during plant operation in 1997 (see Table 4–10).

Table 5–4 Annual Radiological Impacts to Workers from Incident-Free Tritium Production Operations at Watts Bar 1

Impact	*No Action*	*1,000 TPBARs*	*Total With 1,000 TPBARs*	*3,400 TPBARs*	*Total With 3,400 TPBARs*
Average worker dose (millirem)[a]	104	5.4	109	6.2	110
Latent fatal cancer risk	4.2×10^{-5}	2.2×10^{-6}	4.4×10^{-5}	3.1×10^{-6}	4.4×10^{-5}
Total worker dose (person-rem)	112	5.8	118	6.7	119
Latent fatal cancers	0.045	0.0023	0.047	0.0027	0.048

[a] Based on 1,073 badged workers in calendar year 1997.
Source: TVA 1998d, TVA 1998e.

No Action

Under the No Action Alternative, the health and safety risk of members of the public and facility workers at Watts Bar 1, assuming that the operating conditions did not change from those expected, would remain at the levels presented in Section 4.2.1.9. As shown in Tables 5–3 and 5–4:

> The annual dose to the maximally exposed offsite individual would remain at 0.29 mrem/yr, with an associated 1.5×10^{-7} risk of a latent cancer fatality per year of operation.
>
> The collective dose to the population within 80 kilometers (50 miles) of Watts Bar 1 would remain at 0.55 person-rem/yr, with an associated 0.00028 latent cancer fatality per year of operation.
>
> The collective dose to the facility workers on average would remain at 112 person-rem/yr, with an associated 0.045 latent cancer fatality per year of operation.

Tritium Production

Under the tritium production mode, the health and safety risk of the public and facility workers would increase due to the estimated releases of tritium in gaseous emissions and liquid effluent. As shown in Tables 5–3 and 5–4, for 3,400 TPBARs in the reactor core and assuming two failed TPBARs:

> The annual dose to the maximally exposed offsite individual would be 0.56 mrem/yr, with an associated 2.8×10^{-7} risk of a latent cancer fatality per year of operation. This dose is 2.2 percent of the annual total dose limit of 25 millirem set by regulations in 40 CFR 190.
>
> The collective dose to the population within 80 kilometers (50 miles) of Watts Bar 1 would be 7.0 person-rem/yr, with an associated 0.0035 latent cancer fatality per year of operation.
>
> The collective dose to the facility workers on average would be 119 person-rem/yr, with an associated 0.048 latent cancer fatality per year of operation.

It should be noted that the assumption of two failed TPBARs in the reactor core dominates the incremental increase in public and worker doses due to tritium production. Based on experience with stainless steel–clad boron burnable absorber rods, this assumption is very conservative. (WEC 1998).

HAZARDOUS CHEMICAL IMPACTS

No Action

No impacts on the public and occupational health and safety from exposure to hazardous chemicals are anticipated at Watts Bar beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Tritium production would introduce no additional operations at the plant that would require the use of hazardous chemicals.

5.2.1.9.2 Facility Accidents

RADIOLOGICAL IMPACTS

The accident set selected for evaluation of impacts of the No Action Alternative and tritium production are described in Section 5.1 and discussed in detail in Appendix D, Section D.1. The consequences of the reactor and nonreactor design-basis accidents for the No Action Alternative at the Watts Bar Nuclear Plant (0 TPBAR) and for maximum tritium production (3,400 TPBARs) were estimated using the NRC-based licensing approach presented in the *Watts Bar Nuclear Plant Final Safety Analysis Report* (TVA 1995c), the receptors being an individual at the reactor site exclusion area boundary and an individual at the reactor site low-population zone. The margin of safety for site dose criteria associated with the same accidents and the same receptors are presented in **Table 5–5.** Data presented for the No Action Alternative were extracted directly from the *Watts Bar Nuclear Plant Final Safety Analysis Report*. As indicated in Table 5–5 the irradiation of TPBARs at the Watts Bar Nuclear Plant would result in a very small increase in design-basis accident consequences and thus a reduction in the consequence margin. The accident consequences would be dominated by the effects of the nuclide releases inherent to the No Action Alternative.

Table 5–5 Design-Basis Accident Consequence Margin to Site Dose Criteria at Watts Bar 1

Accident	Tritium Production	Dose Description[a]	Site Dose Criteria (rem)[b]	Individual at Area Exclusion Boundary		Individual at Low Population Zone	
				Dose (rem)	Margin (%)[c]	Dose (rem)	Margin (%)[c]
Reactor design-basis accident	0 TPBARs (No Action)[d]	Thyroid inhalation dose	300	34.1	88.6	11.0	96.3
		Beta + gamma whole body dose	25	3.5	86.1	3.4	86.2
	3,400 TPBARs	Thyroid inhalation dose	300	34.1	88.6	11.0	96.3
		Beta + gamma whole body dose	25	3.5	86.1	3.4	86.2
Nonreactor design-basis accident	0 TPBARs (No Action)[d]	Thyroid inhalation dose	300	0.018	99.99	0.042	99.99
		Beta + gamma whole body dose	25	0.13	99.5	0.031	99.9
	3,400 TPBARs	Thyroid inhalation dose	300	0.056	99.98	0.051	99.98
		Beta + gamma whole body dose	25	0.13	99.5	0.032	99.9

[a] Dose is the total dose from the reactor plus the contribution from the TPBARs.
[b] 10 CFR 100.11.
[c] Margin below the site dose criteria.
[d] TVA 1995c.

Table 5–6 presents risks of the postulated set of accidents to the maximally exposed offsite individual, an average individual in the public within an 80-kilometer (50-mile) radius of the reactor site, and a noninvolved worker 640 meters (0.4 mile) from the release point. Accident consequences for the same receptors are summarized in **Table 5–7**. The assessment of dose and the associated cancer risk to the noninvolved worker is not applicable for beyond-design-basis accidents. A site emergency would have been declared early in the beyond-design-basis accident sequence, all nonessential site personnel would have evacuated the site in accordance with site emergency procedures before any radiological release to the environment, and, in accordance with emergency action guidelines, the public within 16.1 kilometers (10 miles) of the plant would have been evacuated.

Table 5–6 Annual Accident Risks at Watts Bar 1

Accident	*Tritium Production*	*Maximally Exposed Offsite Individual*[a]	*Average Individual in Population to 80 km (50 mi)*[a]	*Noninvolved Worker*[a]
Design-Basis Accidents				
Reactor design-basis accident[b]	1,000 TPBARs	1.4×10^{-10}	1.1×10^{-12}	1.9×10^{-12}
	3,400 TPBARs	4.8×10^{-10}	3.8×10^{-12}	6.4×10^{-12}
Nonreactor design-basis accident[b]	1,000 TPBARs	5.5×10^{-7}	6.5×10^{-9}	6.8×10^{-9}
	3,400 TPBARs	6.0×10^{-7}	7.5×10^{-9}	8.0×10^{-9}
Sum of design-basis accident risks	1,000 TPBARs	5.5×10^{-7}	6.5×10^{-9}	6.8×10^{-9}
	3,400 TPBARs	6.0×10^{-7}	7.5×10^{-9}	8.0×10^{-9}
Handling Accidents				
TPBAR handling accident	1,000 TPBARs	8.5×10^{-10}	1.0×10^{-11}	1.1×10^{-11}
	3,400 TPBARs	2.9×10^{-9}	3.5×10^{-11}	3.7×10^{-11}
Truck cask handling accident	1,000 TPBARs	1.9×10^{-13}	2.3×10^{-15}	2.3×10^{-15}
	3,400 TPBARs	5.8×10^{-13}	6.9×10^{-15}	7.0×10^{-15}
Rail cask handling accident	1,000 TPBARs	9.7×10^{-14}	1.2×10^{-15}	1.2×10^{-15}
	3,400 TPBARs	1.9×10^{-13}	2.3×10^{-15}	2.3×10^{-15}
Sum of handling accident risks	1,000 TPBARs	8.5×10^{-10}	1.0×10^{-11}	1.1×10^{-11}
	3,400 TPBARs	2.9×10^{-9}	3.5×10^{-11}	3.7×10^{-11}
Beyond-Design-Basis Accidents (Severe Reactor Accidents)				
Reactor core damage accident with early containment failure	0 TPBARs (No Action)	6.7×10^{-9}	8.8×10^{-11}	N/A
	3,400 TPBARs	6.7×10^{-9}	8.8×10^{-11}	N/A
Reactor core damage accident with containment bypass	0 TPBARs (No Action)	2.2×10^{-8}	1.2×10^{-9}	N/A
	3,400 TPBARs	2.2×10^{-8}	1.2×10^{-9}	N/A
Reactor core damage accident with late containment failure	0 TPBARs (No Action)	2.4×10^{-9}	1.1×10^{-10}	N/A
	3,400 TPBARs	2.5×10^{-9}	1.2×10^{-10}	N/A
Sum of severe reactor accident risks	0 TPBARs (No Action)	3.1×10^{-8}	1.4×10^{-9}	N/A
	3,400 TPBARs	3.1×10^{-8}	1.4×10^{-9}	N/A

N/A = Not applicable

[a] Increased likelihood of cancer fatality per year

[b] Design-basis accident risks only reflect the incremental increase in accident risk due to the production of tritium in TPBARs.

Table 5–7 Annual Accident Consequences at Watts Bar 1

Accident	*Accident Frequency (per year)*	*Tritium Production*	*Maximally Exposed Offsite Individual*		*Average Individual in Population to 80 km (50 mi)*		*Noninvolved Worker*	
			Dose (rem)	*Cancer Fatality* [a]	*Dose (rem)*	*Cancer Fatality* [a]	*Dose (rem)*	*Cancer Fatality* [a]
Design-Basis Accidents								
Reactor design-basis accident [b]	0.0002	1,000 TPBARs	0.0014	7.0×10^{-7}	0.000011	5.5×10^{-9}	0.000024	9.6×10^{-9}
		3,400 TPBARs	0.0047	2.4×10^{-6}	0.000038	1.9×10^{-8}	0.000081	3.2×10^{-8}
Nonreactor design-basis accident [b]	0.01	1,000 TPBARs	0.11	0.000055	0.0013	6.5×10^{-7}	0.0017	6.8×10^{-7}
		3,400 TPBARs	0.12	0.000060	0.0015	7.5×10^{-7}	0.0020	8.0×10^{-7}
Handling Accidents								
TPBAR handling accident	0.0017/ 0.0058[c]	All TPBAR Configurations	0.0010	5.0×10^{-7}	0.000012	6.0×10^{-9}	0.000016	6.4×10^{-9}
Truck cask handling accident	5.3×10^{-7}/ 1.6×10^{-6} [c]	All TPBAR configurations	0.00071	3.6×10^{-7}	8.5×10^{-6}	4.3×10^{-9}	0.000011	4.4×10^{-9}
Rail cask handling accident	2.7×10^{-7}/ 6.0×10^{-7} [c]	All TPBAR configurations	0.00071	3.6×10^{-7}	8.5×10^{-6}	4.3×10^{-9}	0.000011	4.4×10^{-9}
Beyond-Design-Basis Accidents (Severe Reactor Accidents)								
Reactor core damage with early containment failure	6.8×10^{-7}	0 TPBARs (No Action)	19.7	0.0099	0.25	0.00013	N/A	N/A
		3,400 TPBARs	19.8	0.0099	0.25	0.00013	N/A	N/A
Reactor core damage with containment bypass	6.9×10^{-6}	0 TPBARs (No Action)	6.4	0.0032	0.35	0.00018	N/A	N/A
		3,400 TPBARs	6.4	0.0032	0.35	0.00018	N/A	N/A
Reactor core damage with late containment failure	9.1×10^{-6}	0 TPBARs (No Action)	0.51	0.00026	0.024	0.000012	N/A	N/A
		3,400 TPBARs	0.53	0.00027	0.025	0.000013	N/A	N/A

N/A = Not applicable
[a] Increased likelihood of cancer fatality.
[b] Design-basis accident consequences only reflect the incremental increase in accident consequences due to the production of tritium in TPBARs.
[c] Frequency for 1,000 TPBARs/frequency for 3,400 TPBARs.

Presented in Tables 5–6 and 5–7 are calculations of the risks and consequences of the No Action Alternative (0 TPBAR) and the tritium production (3,400 TPBARs) for severe reactor accidents. The tritium release is governed by the nature of the core melt accident scenarios analyzed; the accident risks and consequences by actions taken in accordance with the Environmental Protection Agency (EPA) Plant Protective Action Guidelines (e.g., evacuation of the public, interdiction of the food and water supply, condemnation of farmland and public property) in response to the postulated core melt accident with containment failure or containment bypass.

The severity of the reactor accident dominates the consequences, is the basis for implementation of protective actions, and is independent of the number of TPBARs. Accident risk is the product of the accident probability (i.e, accident frequency) times the accident consequences. In this EIS, risk is expressed as the increased likelihood of cancer fatality per year for an individual (i.e., the maximally exposed offsite individual, an average individual in the population within 80 kilometers [50 miles] of the reactor site, or a noninvolved worker). Table 5–6 indicates that the risks associated with tritium production are low. The highest risk to each individual—the maximally exposed offsite individual, one fatality every 1.7 million years (6.0×10^{-7} per year); an average member of the public, one fatality every 130 million years (7.5×10^{-9} per year); the exposed population, one fatality every 714 years (0.0014 per year); and a noninvolved worker, one fatality every 130 million years (8.0×10^{-9} per year)—is from the nonreactor design-basis accident.

The nonreactor design-basis accident has the highest consequence of the design-basis and handling accidents because the postulated accident scenario entails an acute release of tritium, in oxide form, directly to the environment without any mitigation. While the reactor design-basis accident scenario has a much larger release, the reactor containment and other safety systems mitigate the accident consequences by limiting the tritium available for release to the environment. During the handling accidents, up to 24 TPBARs would fail, but they would release only a small fraction of their tritium content (less than one percent). The low accident frequency is reflected in the accident risks presented in Table 5–6. Review of Table 5–7 indicates that there would be a very small increase of severe reactor accident consequences due to the irradiation of TPBARs at the Watts Bar Nuclear Plant. The accident consequences are dominated by the effects of the radionuclide releases inherent to the No Action Alternative. The secondary impacts of severe reactor accidents are discussed in Section 5.2.13.

HAZARDOUS CHEMICALS IMPACTS

No Action

No impacts on public and occupational health and safety from exposure to hazardous chemicals are anticipated at the Watts Bar site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Tritium production would introduce no additional operations at the plant that would require the use of hazardous chemicals.

5.2.1.10 Environmental Justice

As discussed in Appendix G, Executive Order 12898 directs Federal agencies to address disproportionately high and adverse health or environmental effects of alternatives on minority and low-income populations. The Executive Order does not alter prevailing statutory interpretations under the National Environmental Policy Act (NEPA) or existing case law. Regulations prepared by the Council on Environmental Quality remain the foundation for the preparation of environmental documentation in compliance with NEPA (40 CFR Parts 1500 through 1508).

No Action

Under the No Action Alternative, there would be no impacts on the general population, and thus, no disproportionately high and adverse consequences for minority and low-income populations beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Analyses of incident-free operations and accidents show the risk of latent cancer fatalities among the public residing within 80 kilometers (50 miles) of the reactor site to be much less than 1. Because tritium production would not have high and adverse consequences for the population at large, no minority or low-income populations would be expected to experience disproportionately high and adverse consequences.

5.2.1.11 Waste Management

No Action

Under the No Action Alternative, waste generation at Watts Bar 1 should continue at the levels described in Section 4.2.1.10. Provisions for the management of these wastes would continue unchanged.

Tritium Production

No additional hazardous waste, nonhazardous solid waste, or sanitary liquid waste should be generated at Watts Bar 1 as a result of tritium production. Management of these wastes would continue as described in Section 4.2.1.10. However, it is expected that an additional 0.43 m^3/yr (15 ft^3/yr) of low-level radioactive waste would be generated as a result of tritium production (WEC 1998). It would consist of the approximately 140 base plates and other irradiated hardware remaining after the TPBARs were separated from their assemblies to be placed in the 17 × 17 array consolidation baskets at the reactor site.

Similar to the quantities of low-level radioactive waste generated as a result of activities independent of this action, the additional low-level radioactive waste generated as a result of tritium production (with the exception of the base plates and associated hardware) would be shipped to a commercial processor where it would be compacted to a lesser volume and shipped to the Barnwell, South Carolina, low-level radioactive waste disposal facility. The base plates and associated hardware would be accumulated until a sufficient amount was on hand to ship directly to Barnwell for disposal. The additional low-level radioactive waste of 0.43 cubic meter (15 cubic feet) represents approximately 0.1 percent of the total low-level radioactive waste currently generated at the site.

For purposes of completeness, this EIS also analyzes the management of the additional volume of low-level radioactive waste (0.43 cubic meter [15 cubic feet]) generated as a result of tritium production at DOE-owned facilities at the Savannah River Site. Under this scenario, the additional low-level radioactive wastes could be transported to the Low-Level Radioactive Waste Disposal Facility at the Savannah River Site, near Aiken, South Carolina. The facility consists of a series of vaults in E-Area that have been operational since September 1994. The operating capacity of each vault is 30,500 cubic meters of low-level radioactive waste (DOE 1998c). Therefore, the addition of low-level radioactive waste from the proposed action at Watts Bar for a 40-year period would be approximately 0.06 percent of the capacity of a single vault.

5.2.1.12 Spent Fuel Management

Production of tritium at Watts Bar 1 would not increase the generation of spent nuclear fuel if less than approximately 2,000 TPBARs were irradiated in a fuel cycle. For the irradiation of the maximum number of 3,400 TPBARs, up to a maximum of 140 spent nuclear fuel assemblies could be generated. This represents up to 60 additional spent nuclear fuel assemblies over the normal refueling batch of 80 assemblies. For the purposes of this EIS, it is assumed that the additional spent nuclear fuel would be stored onsite for the duration of the proposed action. If needed, an independent spent nuclear fuel storage installation (ISFSI) would be constructed at the site. Environmental impacts of the construction and operation of a generic ISFSI are presented in Section 5.2.6.

5.2.2 Sequoyah Nuclear Plant, Units 1 and 2

5.2.2.1 Land Resources

The land resources analysis addresses land use and visual resources for the region of influence. The region of influence for land use includes land within 3.2 kilometers (2 miles) of the site. The region of influence for visual resources includes those lands and waters from which the Sequoyah Nuclear Plant is visible (the viewshed).

LAND USE

No Action

No land use impacts are anticipated at the Sequoyah site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

No additional property would be required and no additional land would be disturbed to prepare for tritium production at the Sequoyah site. Land use would remain unchanged from its current industrial use. The 212-hectare (525-acre) site contains ample area for a dry cask spent nuclear fuel storage facility, if constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

VISUAL RESOURCES

No Action

No visual impacts are anticipated at the Sequoyah site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

There would be no change in the visual character of the Sequoyah site as a result of tritium production. The major visual elements of the plant already exist, including the cooling towers and the transmission lines. As described in Section 4.2.2.1, views of the Sequoyah Nuclear Plant from passing river traffic on the Tennessee River are partially screened by the wooded area east of the plant (TVA 1974a).

5.2.2.2 Noise

No Action

No noise impacts are anticipated at the Sequoyah site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Noise levels should not change as a result of tritium production at the Sequoyah site. No construction would occur at the Sequoyah site, unless a dry cask spent nuclear fuel storage facility is constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

5.2.2.3 Air Quality

NONRADIOACTIVE GASEOUS EMISSIONS

No Action

No air quality impacts are anticipated at the Sequoyah site beyond the effects of existing and future activities that are independent of the proposed action (see Section 4.2.2.3, Table 4–13).

Tritium Production

Air quality should not change as a result of the production of tritium at Sequoyah. No construction-related air quality impacts would occur at the Sequoyah site unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

RADIOACTIVE GASEOUS EMISSIONS

No Action

Under the No Action Alternative, the radioactive gaseous emissions at Sequoyah 1 or Sequoyah 2 should continue at the levels described in Section 4.2.2.3, Table 4–14, assuming that no significant operational deviations would occur.

Tritium Production

Radioactive gaseous emissions from Sequoyah 1 or Sequoyah 2 would be expected to increase because of tritium production. During normal operation, the increase in tritium emissions would be within regulatory limits. **Table 5–8** shows the annual radioactive gaseous emissions during tritium production at Sequoyah 1 or Sequoyah 2 with 0, 1,000, and 3,400 TPBARs. The method and assumptions used for the calculations are included in Appendix C, Section C.3.4. Radiological exposures of the public and workers from radioactive emissions are presented in Section 5.2.2.9. The impacts on plants and animals are described in Section 5.2.2.6.

Table 5–8 Annual Radioactive Gaseous Emissions at Sequoyah 1 or Sequoyah 2

	No Action (0 TPBARs)	*Tritium Production [a]*	
		1,000 TPBARs	*3,400 TPBARs*
Tritium release (Ci)	24.43	1,674.43	1,914.43
Other radioactive release (Ci)	119.7	119.7	119.7
Total release (Ci)	144.13	1,794.13	2,034.13

[a] The assumption of two failed TPBARs dominates the tritium production release with a contribution of 1,550 curies as presented in Appendix C, Table C–7.

Source: TVA 1998a.

5.2.2.4 Water Resources

SURFACE WATER

No Action

No surface water impacts are anticipated at the Sequoyah site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Impacts on surface water from nonradiological discharges at the Sequoyah site should not change as a result of tritium production. No surface water impacts would occur at the Sequoyah site unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

GROUNDWATER

No Action

No groundwater impacts are anticipated at Sequoyah beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Impacts on groundwater at Sequoyah 1 or Sequoyah 2 should not change as a result of tritium production. No groundwater impacts would occur at Sequoyah 1 or Sequoyah 2 unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

RADIOACTIVE LIQUID EFFLUENT

No Action

Under the No Action Alternative, the liquid radioactive effluent at Sequoyah 1 or Sequoyah 2 should continue at the levels described in Section 4.2.2.4, Table 4–16, assuming that no significant operational deviations would occur.

Tritium Production

Radioactive liquid effluents from Sequoyah 1 or Sequoyah 2 would be expected to increase because of tritium production. During normal operation, the increase in tritium effluents would be within regulatory limits. **Table 5–9** shows the increase in tritium release in liquid effluent during tritium production at Sequoyah 1 or Sequoyah 2 with 0, 1,000, and 3,400 TPBARs. The method and assumptions used for the calculations are included in Appendix C, Section C.3. Radiological exposures of the public and workers from radioactive emissions are presented in Section 5.2.2.9. The impacts on plants and animals are described in Section 5.2.2.6.

Table 5–9 Annual Radioactive Liquid Effluent at Sequoyah 1 or Sequoyah 2

	No Action (0 TPBARs)	*Tritium Production*[a]	
		1,000 TPBARs	*3,400 TPBARs*
Tritium release (Ci)	738.6	15,588.6	17,748.6
Other radioactive release (Ci)	1.147	1.147	1.147
Total release (Ci)	739.74	15,589.747	17,749.747
Tritium release concentration (pCi/l)[b]	<300	<6,330	<7,210

< = less than
[a] The assumption of two failed TPBARs dominates the tritium production release with a contribution of 13,950 curies as presented in Appendix C, Table C–7.
[b] These values are less than the 40 CFR 141 limit of 20,000 pCi/l for tritium.
Source: TVA 1998e.

5.2.2.5 Geology and Soils

No Action

No impacts on geology and soils are anticipated at the Sequoyah site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Impacts on geology and soils at the Sequoyah site should not change as a result of tritium production. No geology and soils impacts would occur at the Sequoyah site unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

5.2.2.6 Ecological Resources

No Action

No impacts on land use, air quality, or water quality are anticipated at the Sequoyah site beyond the effects of existing and future activities that are independent of the proposed action. Therefore, no impacts on ecological resources are expected under this alternative.

Tritium Production

Operation of Sequoyah 1 or Sequoyah 2 in a tritium production mode would not involve any physical changes to the terrestrial or aquatic habitat at the site. Thermal and nonradioactive chemical discharges that could affect the ecology at the site would remain the same. Consequently, terrestrial and aquatic plants and animals would not be affected unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

Tritium production could increase the release of tritium in gaseous emissions and liquid effluents, as presented in Sections 5.2.2.3 and 5.2.2.4. When tritium is inhaled or ingested by an organism, incorporation into bodily fluids is very efficient. However, long-term accumulation in the organism is limited by its rapid elimination by exhalation, excretion in body water, and its short half-life. The biological properties of tritium are discussed in Appendix C.

According to an International Atomic Energy Agency publication (IAEA 1992), a dose rate of 100 mrem/yr to the most exposed human will lead to dose rates to plants and animals of less than 0.1 rad/day. The International Atomic Energy Agency concluded that a dose rate of 0.1 rad/day or less for animals and 1 rad/day or less for plants would not affect these populations. Doses to the public and workers from potential releases at Sequoyah 1 have been estimated and are presented in Section 5.2.2.9. Tritium production could increase the annual dose to the maximally exposed individual of the public from 2.9 mrem/yr to approximately 3.2 mrem/yr. This cumulative exposure is below the International Atomic Energy Agency benchmarks. Therefore, the increase in tritium releases due to tritium production would have no effect on plants and animals at the Sequoyah site. TVA has notified the U.S. Fish and Wildlife Service of DOE's proposed action and will provide the States of Tennessee, Alabama, and South Carolina and the U.S. Fish and Wildlife Service with copies of the draft and final CLWR environmental impact statement. TVA and DOE will continue to comply with the requirements of the *Endangered Species Act* and interact with the U.S. Fish and Wildlife Service as appropriate. Since small increases in tritium releases in gaseous emissions and liquid effluents would be the only operational differences for the Sequoyah Nuclear Plant (see Sections 5.2.2.3 and 5.2.2.4), no threatened and endangered species should be affected.

5.2.2.7 Archaeological and Historic Resources

No Action

No impacts on land use are anticipated at the Sequoyah site beyond the effects of existing and future activities that are independent of the proposed action. As a result, no impacts on historic and archaeological resources are expected.

Tritium Production

Since no additional land would be required for tritium production, there would be no impacts on archaeological and historic resources at the Sequoyah site unless a dry cask spent nuclear fuel storage facility were constructed. A description of a generic dry cask spent nuclear fuel storage facility and its impacts is presented in Section 5.2.6.

5.2.2.8 Socioeconomics

No Action

Under the No Action Alternative, no adverse socioeconomic impacts are expected in the region of influence of the Sequoyah Nuclear Plant beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

As Sequoyah 1 and Sequoyah 2 are operating facilities, only the socioeconomic impacts associated with incremental tritium-related changes to plant operations have been considered. The primary costs to operate a CLWR for tritium production could relate to operations and maintenance, supplemental fuel procurement or fuel enrichment, the storage of additional spent fuel, replacement power, capital upgrades or replacements, and fees to the utility. Of these costs, only operations and maintenance would have the potential for material socioeconomic impacts within the region of influence. All the other expenses would relate to nonplant functions that generate corporate income, though not local income (e.g., fees from DOE) or procurements (e.g., potential spent fuel storage casks, fuel elements, TPBARs) in other parts of the country. Small regional costs (e.g., potential maintenance of the spent fuel storage casks) would have no measurable socioeconomic impact.

Operation of Sequoyah 1 or Sequoyah 2 for tritium production should require less than 10 full-time equivalent workers per unit in addition to normal plant operations staff. This addition to a normal staff of 850 would effect about a 1 percent increase in local socioeconomic factors such as income, housing requirements, and indirect employment.

The potential increase in spent fuel storage requirements resulting from tritium production would involve some additional costs, but the overall socioeconomic impacts would be small. These requirements would be met via dry cask storage (see Section 5.2.6), the casks being procured from outside the region. Annual costs for activities such as additional fuel transfers, spent fuel storage cask maintenance, spent fuel cask pad expansion, and the transfer of spent fuel to shipping casks would be a maximum of $1 million.

Life extension of Sequoyah 1 and 2 as a result of tritium production (see Section 5.2.4) would have substantial regional socioeconomic benefits. A 20-year extension of normal plant operations would yield an estimated savings of $100 million per year in retained local wages, procurements, property tax revenues, and the deferral of $20 to 30 million per year (net figures in current dollars) in decontamination and decommissioning costs and the cost of replacement power.

Transportation impacts associated with tritium production would be minimal; they would be limited to commuter traffic by the personnel assigned to the site. The impact of 50 additional construction workers and associated construction vehicles, assuming potential construction of the dry cask spent fuel storage facility, would be temporary and minor. The traffic impact from 10 to 20 additional tritium production operations workers commuting to and from the plant would not be noticeable. Additional truck traffic during tritium operations would include a total of 16 shipments of TPBARs to and from the plant per year.

5.2.2.9 Public and Occupational Health and Safety

This section describes the impacts of radiological and hazardous chemical releases resulting from either normal operation or accidents due to tritium production at Sequoyah 1 or Sequoyah 2. A description of impacts of normal operation is followed by a description of impacts from facility accidents.

5.2.2.9.1 Normal Operations

RADIOLOGICAL IMPACTS

During normal operation, there would be incremental radiological releases of tritium to the environment and also additional in-plant exposures. The resulting dose and potential health effects on the general public and workers are described below. There would be no new construction of facilities to support tritium production operations at the Sequoyah Nuclear Plant site; therefore, there are no associated impacts on the public or workers.

The annual increase in gaseous radioactive emissions and liquid radioactive effluents from the production of tritium at Sequoyah 1 or Sequoyah 2 are presented in Sections 5.2.2.3 and 5.2.2.4, respectively. The radiological impacts of both gaseous and liquid radioactive releases are presented in **Table 5–10** for the maximally exposed offsite individual and the general public living within 80 kilometers (50 miles) of Sequoyah 1 or Sequoyah 2 in the year 2025. **Table 5–11** reflects the radiological impacts on the facility workers. A facility worker is defined as any “monitored” reactor plant employee. Doses to these workers

Table 5–10 Annual Radiological Impacts to the Public from Incident-Free Tritium Production Operations at Sequoyah 1 or Sequoyah 2

Tritium Production	Release Media	Maximally Exposed Offsite Individual		Population Within 80 km (50 mi) for the Year 2025	
		Dose (millirem)	Latent Fatal Cancer Risk	Annual Dose (person-rem)	Latent Fatal Cancers
No Action [a] (0 TPBARs)	Air	0.031	1.6×10^{-8}	0.49	0.00025
	Liquid	0.022	1.1×10^{-8}	1.1	0.00055
	Total	0.053	2.7×10^{-8}	1.6	0.00080
Incremental dose for 1,000 TPBARs	Air	0.25	1.3×10^{-7}	2.5	0.0013
	Liquid	0.026	1.3×10^{-8}	6.9	0.0035
Total dose for 1,000 TPBARs	Air	0.28	1.4×10^{-7}	3.0	0.0015
	Liquid	0.048	2.4×10^{-8}	8.0	0.0040
	Total	0.33	1.7×10^{-7}	11.0	0.0055
Incremental dose for 3,400 TPBARs	Air	0.29	1.5×10^{-7}	3.0	0.0015
	Liquid	0.030	1.5×10^{-8}	7.5	0.0038
Total dose for 3,400 TPBARs	Air	0.32	1.6×10^{-7}	3.5	0.0018
	Liquid	0.052	2.6×10^{-8}	8.6	0.0043
	Total	0.37	1.9×10^{-7}	12.1	0.0061

[a] Doses based on actual measurements during plant operation in 1997 (see Table 4–22).

Table 5–11 Annual Radiological Impacts to Workers from Incident-Free Tritium Production Operations at Sequoyah 1 or Sequoyah 2

Impact	No Action	1,000 TPBARs	Total With 1,000 TPBARs	3,400 TPBARs	Total With 3,400 TPBARs
Average worker dose (millirem)[a]	90	3.9	94	4.6	95
Latent fatal cancer risk	3.6×10^{-5}	1.6×10^{-6}	3.8×10^{-5}	1.8×10^{-6}	3.8×10^{-5}
Total worker dose (person-rem)	132	5.8	138	6.7	139
Latent fatal cancers	0.053	0.0023	0.055	0.0027	0.056

[a] Based on 1,470 badged workers per unit for a total of 2,940 badged workers for the site.
Source: NRC 1997b, TVA 1998d.

would be kept to minimal levels through ALARA programs. The tables include the impacts of the No Action Alternative.

Background information on the effects of radiation on the human health and safety is included in Appendix C. The method and assumptions used in calculating the impacts on the public health and safety at Sequoyah 1 or Sequoyah 2 are presented in Appendix C, Section C.3.

No Action

Under the No Action Alternative the health and safety risk of members of the public and facility workers at Sequoyah 1 or Sequoyah 2, assuming that the operating conditions did not change from those expected, would remain at the levels presented in Section 4.2.2.9. As shown in Tables 5–10 and 5–11:

The annual dose to the maximally exposed offsite individual would remain at 0.053 mrem/yr, with an associated 2.7×10^{-8} risk of a latent cancer fatality per year of operation.

The collective dose to the population within 50 miles of Sequoyah 1 or Sequoyah 2 would remain at 1.6 person-rem/yr, with an associated 0.00080 latent cancer fatality per year of operation.

The collective dose to the facility workers would remain at 132 person-rem/yr, with an associated 0.053 latent cancer fatality per year of operation.

Tritium Production

In the tritium production mode, the health and safety risk of the public and facility workers would increase due to the estimated releases of tritium in gaseous emissions and liquid effluents. As shown in Tables 5–10 and 5–11 for 3,400 TPBARs in the reactor core and assuming two failed TPBARs:

The annual dose to the maximally exposed offsite individual would be 0.37 mrem/yr, with an associated 1.9×10^{-7} risk of a latent cancer fatality per year of operation. This dose is 1.5 percent of the annual total dose limit of 25 millirem set by regulations in 40 CFR 190.

The collective dose to the population within 50 miles of Sequoyah 1 or Sequoyah 2, would be 12.1 person-rem/yr, with an associated 0.0061 latent cancer fatality per year of operation.

The collective dose to the facility workers would be 139 person-rem/yr, with an associated 0.056 latent cancer fatality per year of operation.

It should be noted that the assumption of two failed TPBARs in the reactor core dominates the incremental increase in worker dose due to tritium production. Based on experience with stainless steel–clad boron burnable absorber rods, this assumption is very conservative (WEC 1998).

HAZARDOUS CHEMICAL IMPACTS

No Action

No impacts on the public and occupational health and safety from exposure to hazardous chemicals are anticipated at Sequoyah beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Tritium production would introduce no additional operations at the plant that would require the use of hazardous chemicals.

5.2.2.9.2 Facility Accidents

RADIOLOGICAL IMPACTS

The accident set selected for evaluation of impacts of the No Action Alternative and tritium production are described in Section 5.1 and discussed in detail in Appendix D, Section D.1. The consequences of the reactor and nonreactor design-basis accidents for the No Action Alternative at the Sequoyah Nuclear Plant (0 TPBAR) and for maximum tritium production (3,400 TPBARs) were estimated using the NRC-based deterministic approach presented in the *Sequoyah Nuclear Plant Final Safety Analysis Report* (TVA 1996b) the receptor being an individual at the reactor site exclusion area boundary and an individual at the reactor site low-population zone. The margin of safety for site dose criteria associated with the same accidents and the same receptors are presented in **Table 5–12.** Data presented for the No Action Alternative were extracted directly from the *Sequoyah Nuclear Plant Final Safety Analysis Report*. As indicated in Table 5–12 the irradiation of TPBARs at the Sequoyah Nuclear Plant would result in a very small increase in design-basis accident consequences and thus a reduction in the consequence margin. The accident consequences would be dominated by the effects of the nuclide releases inherent to the No Action Alternative.

Table 5–12 Design-Basis Accident Consequence Margin to Site Dose Criteria at Sequoyah 1 or Sequoyah 2

Accident	*Tritium Production*	*Dose Description* [a]	*Site Dose Criteria (rem)* [b]	*Individual at Area Exclusion Boundary*		*Individual at Low Population Zone*	
				Dose (rem)	*Margin (%)* [c]	*Dose (rem)*	*Margin (%)* [c]
Reactor design-basis accident	0 TPBARs (No Action)[d]	Thyroid inhalation dose	300	145	51.6	27	91.0
		Beta + gamma whole body dose	25	12.2	51.1	2.9	88.4
	3,400 TPBARs	Thyroid inhalation dose	300	145	51.6	27	91.0
		Beta + gamma whole body dose	25	12.2	51.1	2.9	88.4
Nonreactor design-basis accident	0 TPBARs (No Action)[d]	Thyroid inhalation dose	300	0.000013	100	1.1 × 10	100
		Beta + gamma whole body dose	25	0.0017	99.99	0.00014	99.999
	3,400 TPBARs	Thyroid inhalation dose	300	0.10	99.97	0.012	99.996
		Beta + gamma whole body dose	25	0.0078	99.97	0.00087	99.997

a Dose is the total dose from the reactor plus the contribution from the TPBARs.
b 10 CFR 100.11.
c Margin below the site dose criteria.
d TVA 1996b.

Table 5–13 presents risks of the postulated set of accidents to the maximally exposed offsite individual, an average individual in the public within an 80-kilometer (50-mile) radius of the reactor site, and a noninvolved worker at the site boundary 556 meters (0.35 mile) from the release point. Accident consequences for the same receptors are summarized in **Table 5–14**. The assessment of dose and the associated cancer risk to the noninvolved worker is not applicable for beyond-design-basis accidents. A site emergency would have been declared early in the beyond-design-basis accident sequence, all nonessential site personnel would have evacuated the site in accordance with site emergency procedures before any radiological release to the environment, and in accordance with emergency action guidelines, the public within 16.1 kilometers (10 miles) of the plant would have been evacuated.

Presented in Tables 5–13 and 5–14 are calculations of the risks and consequences of the No Action Alternative (0 TPBAR) and the tritium production (3,400 TPBARs) for severe reactor accidents. The tritium release is governed by the nature of the core melt accident scenarios analyzed; the accident risks and consequences, by actions taken in accordance with the EPA Protective Action Guidelines (e.g., evacuation of the public, interdiction of the food and water supply, condemnation of farmland and public property) in response to the postulated core melt accident with containment failure or containment bypass.

The severity of the reactor accident dominates the consequences, is the basis for implementation of protective actions, and is independent of the number of TPBARs. Accident risk is the product of the accident probability

Table 5–13 Annual Accident Risks at Sequoyah 1 or Sequoyah 2

Accident	*Tritium Production*	*Maximally Exposed Offsite Individual* [a]	*Average Individual in Population to 80 km (50 mi)* [a]	*Noninvolved Worker* [a]
Design-Basis Accidents				
Reactor design-basis accident [b]	1,000 TPBARs	1.9×10^{-10}	2.2×10^{-12}	6.4×10^{-13}
	3,400 TPBARs	6.6×10^{-10}	7.6×10^{-12}	2.2×10^{-12}
Nonreactor design-basis accident [b]	1,000 TPBARs	1.3×10^{-7}	1.0×10^{-8}	2.1×10^{-9}
	3,400 TPBARs	1.5×10^{-7}	1.2×10^{-8}	2.5×10^{-9}
Sum of design-basis accident risks	1,000 TPBARs	1.3×10^{-7}	1.0×10^{-8}	2.1×10^{-9}
	3,400 TPBARs	1.5×10^{-7}	1.2×10^{-8}	2.5×10^{-9}
Handling Accidents				
TPBAR handling accident	1,000 TPBARs	2.0×10^{-10}	1.6×10^{-11}	3.4×10^{-12}
	3,400 TPBARs	7.0×10^{-10}	5.5×10^{-11}	1.2×10^{-11}
Truck cask handling accident	1,000 TPBARs	4.5×10^{-14}	3.4×10^{-15}	7.4×10^{-16}
	3,400 TPBARs	1.4×10^{-13}	1.0×10^{-14}	2.2×10^{-15}
Rail cask handling accident	1,000 TPBARs	2.3×10^{-14}	1.8×10^{-15}	3.8×10^{-16}
	3,400 TPBARs	4.5×10^{-14}	3.4×10^{-15}	7.4×10^{-16}
Sum of handling risks	1,000 TPBARs	2.0×10^{-10}	1.2×10^{-11}	3.4×10^{-12}
	3,400 TPBARs	7.0×10^{-9}	4.2×10^{-11}	1.2×10^{-11}
Beyond-Design-Basis Accidents (Severe Reactor Accidents)				
Reactor core damage accident with early containment failure	0 TPBARs (No Action)	1.7×10^{-8}	1.6×10^{-10}	N/A
	3,400 TPBARs	1.7×10^{-8}	1.6×10^{-10}	N/A
Reactor core damage accident with containment bypass	0 TPBARs (No Action)	2.1×10^{-8}	1.4×10^{-9}	N/A
	3,400 TPBARs	2.1×10^{-8}	1.5×10^{-9}	N/A
Reactor core damage accident with late containment failure	0 TPBARs (No Action)	3.9×10^{-9}	2.4×10^{-10}	N/A
	3,400 TPBARs	4.0×10^{-9}	2.5×10^{-10}	N/A
Sum of severe reactor accident risks	0 TPBARs (No Action)	4.2×10^{-8}	1.4×10^{-9}	N/A
	3,400 TPBARs	4.2×10^{-9}	1.5×10^{-9}	N/A

N/A = Not applicable
[a] Increased likelihood of cancer fatality per year.
[b] Design-basis accident risks only reflect the incremental increase in accident risk due to the production of tritium in TPBARs.

Table 5–14 Annual Accident Consequences at Sequoyah 1 or Sequoyah 2

Accident	Accident Frequency (per year)	Tritium Production	Maximally Exposed Offsite Individual		Average Individual in Population to 80 km (50 mi)		Noninvolved Worker	
			Dose (rem)	Cancer Fatality [a]	Dose (rem)	Cancer Fatality [a]	Dose (rem)	Cancer Fatality [a]
Design-Basis Accidents								
Reactor design-basis accident [b]	0.0002	1,000 TPBARs	0.0019	9.5×10^{-7}	0.000022	1.1×10^{-8}	8.1×10^{-6}	3.2×10^{-9}
		3,400 TPBARs	0.0065	3.3×10^{-6}	0.000075	3.8×10^{-8}	0.000028	1.1×10^{-8}
Nonreactor design-basis accident [b]	0.01	1,000 TPBARs	0.026	0.000013	0.0020	1.0×10^{-6}	0.00053	2.1×10^{-7}
		3,400 TPBARs	0.030	0.000015	0.0023	1.2×10^{-6}	0.00062	2.5×10^{-7}
Handling Accidents								
TPBAR handling accident	0.0017/ 0.0058[c]	All TPBAR Configurations	0.00024	1.2×10^{-7}	0.000019	9.5×10^{-9}	5.0×10^{-6}	2.0×10^{-9}
Truck cask handling accident	5.3×10^{-7}/ 1.6×10^{-6} [c]	All TPBAR Configurations	0.00017	8.5×10^{-8}	0.000013	6.5×10^{-9}	3.6×10^{-6}	1.4×10^{-9}
Rail cask handling accident	2.7×10^{-7}/ 6.0×10^{-7} [c]	All TPBAR Configurations	0.00017	8.5×10^{-8}	0.000013	6.5×10^{-9}	3.6×10^{-6}	1.4×10^{-9}
Beyond-Design-Basis Accidents (Severe Reactor Accidents)								
Reactor core damage with early containment failure	6.8×10^{-7}	0 TPBARs (No Action)	25.0 [d]	0.025 [d]	0.48	0.00024	N/A	N/A
		3,400 TPBARs	25.1 [d]	0.025 [d]	0.48	0.00024	N/A	N/A
Reactor core damage with containment bypass	4.0×10^{-6}	0 TPBARs (No Action)	10.4	0.0052	0.72	0.00036	N/A	N/A
		3,400 TPBARs	10.4	0.0052	0.73	0.00037	N/A	N/A
Reactor core damage with late containment failure	9.2×10^{-6}	0 TPBARs (No Action)	0.84	0.00042	0.051	0.000026	N/A	N/A
		3,400 TPBARs	0.87	0.00044	0.053	0.000027	N/A	N/A

N/A = Not applicable

[a] Increased likelihood of cancer fatality.

[b] Design-basis accident consequences only reflect the incremental increase in accident consequences due to the production of tritium in TPBARs.

[c] Frequency for 1,000 TPBARs/frequency for 3,400 TBPARs.

[d] Dose > 20 rem. Cancer fatality risk doubled.

(i.e, accident frequency) times the accident consequences. In this EIS, risk is expressed as the increased likelihood of cancer fatality per year for an individual (i.e., the maximally exposed offsite individual, an average individual in the population within 80 kilometers [50 miles] of the reactor site, or a noninvolved worker). Table 5–13 indicates that the risks associated with tritium production are low. The highest risk to each individual—the maximally exposed offsite individual, one fatality every 6.7 million years (1.5×10^{-7} per year); an average member of the public, one fatality every 83 million years (1.2×10^{-8} per year); the exposed population, one fatality every 333 years (0.0030 per year); and a noninvolved worker, one fatality every 400 million years (2.5×10^{-9} per year)—is from the nonreactor design-basis accident.

The nonreactor design-basis accident has the highest consequence of the design-basis and handling accidents because the postulated accident scenario entails an acute release of tritium, in oxide form, directly to the environment without any mitigation. While the reactor design-basis accident scenario has a much larger release, the reactor containment and other safety systems mitigate the accident consequences by limiting the tritium available for release to the environment. During the handling accidents, up to 24 TPBARs would fail, but they would release only a small fraction of their tritium content (less than one percent). The low accident frequency is reflected in the accident risks presented in Table 5–13. Review of Table 5–14 indicates that there would be a very small increase of severe reactor accident consequences due to the irradiation of TPBARs at the Sequoyah Nuclear Plant. The accident consequences are dominated by the effects of the radionuclide releases inherent to the No Action Alternative. The secondary impacts of severe reactor accidents are presented in Section 5.2.13.

HAZARDOUS CHEMICAL IMPACTS

No Action

No impacts on public and occupational health and safety from exposure to hazardous chemicals are anticipated at the Sequoyah site beyond the effects existing and future activities that are independent of the proposed action.

Tritium Production

Tritium production would introduce no additional operations at the plant that would require the use of hazardous chemicals.

5.2.2.10 Environmental Justice

As discussed in Appendix G, Executive Order 12898 directs Federal agencies to address disproportionately high and adverse health or environmental effects of alternatives on minority and low-income populations. The Executive Order does not alter prevailing statutory interpretations under NEPA or existing case law. Regulations prepared by the Council on Environmental Quality remain the foundation for the preparation of environmental documentation in compliance with NEPA (40 CFR Parts 1500 through 1508). As discussed previously, the alternatives would have no adverse or beneficial environmental effects on the general population. Nor would they have any effects on any particular group within the general population, including minority and low-income populations.

No Action

Under the No Action Alternative, there would be no impacts on the general population, and thus no disproportionately high and adverse consequences for minority and low-income populations beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Analyses of incident-free operations and accidents show the risk of latent cancer fatalities among the public residing within 80 kilometers (50 miles) of the reactor site to be much less than 1. Because tritium production would not have high and adverse consequences for the population at large, no minority or low-income populations would be expected to experience disproportionately high and adverse consequences.

5.2.2.11 Waste Management

No Action

Under the No Action Alternative, waste generation at Sequoyah 1 or Sequoyah 2 should continue at the levels described in Section 4.2.2.10. Provisions for the management of these wastes would continue unchanged.

Tritium Production

No additional hazardous waste, nonhazardous solid waste, or sanitary liquid waste should be generated at Sequoyah 1 or Sequoyah 2 as a result of tritium production. Management of these wastes would continue as described in Section 4.2.2.10. However, it is expected that an additional 0.43 m^3/yr (15 ft^3/yr) of low-level radioactive waste would be generated as a result of tritium production (WEC 1998). It would consist of the approximately 140 base plates and other irradiated hardware remaining after the TPBARs were separated from their assemblies to be placed in the 17 × 17 array consolidation baskets at the reactor site.

Similar to the quantities of low-level radioactive waste generated as a result of activities independent of this action, the additional low-level radioactive waste generated as a result of tritium production (with the exception of the base plates and associated hardware) would be shipped to a commercial processor where it would be compacted to a lesser volume and shipped to the Barnwell, South Carolina, low-level radioactive waste disposal facility. The base plates and associated hardware would be accumulated until a sufficient amount was on hand to ship directly to Barnwell for disposal. The additional low-level radioactive waste of 0.43 cubic meter (15 cubic feet) represents less than 0.1 percent of the total low-level radioactive waste generated currently at Sequoyah 1 or Sequoyah 2.

For purposes of completeness, this EIS also analyzes the management of the additional volume of low-level radioactive waste (0.43 cubic meter [15 cubic feet]) generated as a result of tritium production at DOE-owned facilities at the Savannah River Site. Under this scenario, the additional low-level radioactive waste could be transported to the Low-Level Radioactive Waste Disposal Facility at the Savannah River Site, near Aiken, South Carolina. The facility consists of a series of vaults in E-Area that have been operational since September 1994. The operating capacity of each vault is 30,500 cubic meters of low-level radioactive waste (DOE 1998c). Therefore, the addition of low-level radioactive waste from the proposed action at Sequoyah 1 or Sequoyah 2 for a 40-year period would be approximately 0.06 percent of the capacity of a single vault.

5.2.2.12 Spent Fuel Management

Production of tritium at Sequoyah 1 or 2 would not increase the generation of spent nuclear fuel if less than approximately 2,000 TPBARs were irradiated in a fuel cycle. For the irradiation of the maximum number of 3,400 TPBARs, up to a maximum of 140 spent nuclear fuel assemblies could be generated. This represents up to 60 additional spent nuclear fuel assemblies over the normal refueling batch of 80 assemblies. For the purposes of this EIS it is assumed that the additional spent nuclear fuel would be stored onsite for the duration of the proposed action. If needed, an ISFSI would be constructed at the site. Environmental impacts of the construction and operation of a generic ISFSI are presented in Section 5.2.6.

5.2.3 Bellefonte Nuclear Plant, Units 1 and 2

5.2.3.1 Land Resources

The land resources analysis addresses land use and visual resources for the region of influence. The region of influence for land use includes land within 3.2 kilometers (2 miles) of the site. The region of influence for visual resources includes those lands from which the Bellefonte Nuclear Plant is visible (the viewshed). Land use impacts of tritium production are compared with the existing land use patterns. Visual resource impacts are associated with changes in the existing landscape character that could result from tritium production.

LAND USE

No Action

No land use impacts are anticipated at the Bellefonte site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

The land use analysis considers the magnitude and extent of potential impacts on current land use patterns and densities that are attributable to the alternative. The amount of land disturbed during construction and used during operation is identified, as are the potential changes in land use, and conflicts with land use policies, plans, and controls.

Construction

The 607-hectare (1,500-acre) site contains ample existing construction laydown areas that are conveniently located near large warehouse storage buildings and yard storage areas. Land disturbance would be limited to that required for new support buildings. Completing construction of Bellefonte 1 alone or both Bellefonte 1 and Bellefonte 2 would require land already disturbed during previous construction at the site. There would be no impacts on undisturbed grassland and forest land. Completing construction should not impact the ability to continue hay production on areas of the site. The total land disturbed is discussed in Section 4.2.3.1. Land use would remain unchanged from its current industrial and agricultural uses.

An electric power distribution system exists to adequately support the power demands of plant equipment, construction shops, and employee facilities. No additional land area would be required for furnishing utilities to the site. Utility distribution systems are in place and occupy sufficient land area to accommodate any required additions or enhancements.

Based on the evaluation of land use impacts for the Bellefonte Conversion Project, for completion of Bellefonte 1 or both units, there would be a small increase in the amount of land used for residential development and mobile homes to accommodate construction workers. The overall impact, however, should be very small (TVA 1997f).

Operation

Operation of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 would require no additional undisturbed land on the site other than described for construction.

Based on the evaluation of the land use impacts for the Bellefonte Conversion Project (TVA 1997f) and the projected operations employment at Bellefonte 1 or both units, the anticipated population increase in Jackson

County from operation of the Bellefonte Nuclear Plant would result in increased demand for new housing units, as discussed in Section 5.2.3.8. According to the latest estimates of population by the U.S. Bureau of the Census, Jackson County has averaged an increase of about 466 persons per year since the 1990 Census of Population was taken. The population increase resulting from completion and operation of the Bellefonte Nuclear Plant would noticeably exceed normal growth. Therefore, an increased demand for housing would increase the amount of land needed for residential development, but would not be an important impact in the context of the county land base.

VISUAL RESOURCES

The visual resources analysis addresses the magnitude and extent of potential changes in the visual environment that could result from tritium production. Visual resources impact assessments are conducted using the Bureau of Land Management Visual Resource Management method (DOI 1986a). The existing landscape at a site is assigned a classification ranging from 1 to 4. The existing landscape at the Bellefonte site would be Class 3 or 4. Class 3 includes areas in which there have been moderate changes in the landscape that could attract attention but do not dominate the view of the casual observer. Class 4 includes areas in which major modifications to the character of the landscape have occurred. These changes may be dominant features of the view and the major focus of viewer attention (DOI 1986b).

Class designations are derived from an inventory of the scenic quality, sensitivity levels, and distance zones of a particular area. The elements of scenic quality are landform, vegetation, water, color, adjacent scenery, scarcity, and cultural modification. Scenic value is determined by the variety and harmonious composition of the elements of scenic quality. Sensitivity levels are determined by user volumes and user attention. Distance zones concern the relative visibility from travel routes or observation points. They include the following categories: foreground–middleground less than 4.8 to 8 kilometers (less than 3 to 5 miles) away; background, 4.8 to 24 kilometers (3 to 15 miles); and seldom seen, 24 kilometers (15 miles) to infinity and areas blocked or screened from view. The analysis objectives are identification of the degree of contrast between the proposed action and the existing landscape, the location and sensitivity levels of viewpoints accessible to the public, and the visibility of the proposed action from the viewpoints. The distance from a viewpoint to the affected area, as well as atmospheric conditions, is also taken into consideration because distance and haze can diminish the degree of contrast and visibility (DOI 1986a, DOI 1986b, DOE 1996c).

No Action

No visual impacts are anticipated at the Bellefonte site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Construction

Little physical change would be required to the parts of the Bellefonte Nuclear Plant that are visible to the public. The major visual elements of the plant, the two hyperbolic cooling towers and the transmission lines, already exist. As discussed in Section 4.2.3.1, views of Bellefonte from passing river traffic on the Tennessee River are partially screened by the ridge lines close to the shoreline. The plant is overlooked by a few residences on Sand Mountain on the east side of the river. Distant glimpses of the plant site can be had from the coves and hollows along the Sand Mountain rim, from State Roads 35 and 40 as they traverse Sand Mountain, and from Comer Bridge, which crosses Guntersville Reservoir (TVA 1997f). The plant also can be seen from various locations along U.S. Highway 72 to the northwest and from residences on the north shore of Town Creek Embayment. Completion of construction would result in little or no visual change from offsite viewpoints.

Operation

During operation, additional visual impacts would result from the vapor plume associated with the 145-meter (477-foot) cooling towers; one would be operating with Bellefonte 1, and two would be operating with the combination of Bellefonte 1 and Bellefonte 2. The plume would be visible up to 16 kilometers (10 miles) away. The plume would vary with atmospheric conditions, being most visible during cooler months and after the passage of weather fronts. Plumes would be less visible during summer months when hazy conditions persist and morning fog is more common. Since the reactor site represents an existing condition that would be classified Visual Resource Management Class 4, contrasts created by minor changes at the plant site and the cooling tower plume are considered to be moderate to none; that is, there would be no visual impact when there was no plume (TVA 1974b, TVA 1997f). Vapor plumes would have an aesthetic impact on the towns of Pisgah, Hollywood, and Scottsboro, as well as on traffic along U.S. Highway 72 (TVA 1974b).

5.2.3.2 Noise

Sound results from the compression and expansion of air or some other medium when an impulse is transmitted through it. Sound requires a source of energy and a medium for transmitting the sound wave. The propagation of sound is affected by various factors, including meteorology, topography, and barriers. Noise is undesirable sound that interferes or interacts negatively with the human or natural environment. Noise may disrupt normal activities (e.g., hearing, sleep), damage hearing, or diminish the quality of the environment (i.e., cause annoyance).

Sound-level measurements used to evaluate effects of nonimpulsive sound on humans are compensated for an A-weighting scale that accounts for the hearing response characteristics (i.e., frequency) of the human ear. Sound levels are expressed in decibels (dB) or, in the case of A-weighted measurements, decibels A-weighted (dBA). The most common measure of environmental noise impact is the day-night average sound level, a 24-hour, A-weighted equivalent sound level with a 10-dBA penalty added to sound levels between 10:00 p.m. and 7:00 a.m to account for increased annoyance due to noise during nighttime hours. EPA has developed noise-level guidelines for different land use classifications that are based on the day-night average and equivalent sound levels. The U.S. Department of Housing and Urban Development has established noise impact guidelines for residential areas that are based on day-night average sound level. Some states and localities have established noise control regulations or zoning ordinances that specify acceptable noise levels by land use category. The State of Alabama has not developed a noise regulation that specifies numerical community noise levels that are acceptable.

For the purpose of this document, noise impacts are assessed using a day-night average sound level of 65 dBA as the level above which noise impacts would be considered “significant impacts” and an increase of 2 dBA as an indicator of “substantial” increases in noise. This approach is based on the TVA noise analysis for the Bellefonte Conversion Project (TVA 1997f). Short-term noises above a level of about 75 dBA, such as steam releases, could have a startle effect on humans and wildlife (TVA 1997f).

The noise analysis conducted by TVA for the conversion project considered the nearest fence line receptor as representative of a future residential land use or other use, the nearest existing residential area (across Town Creek), the nearest ecologically sensitive area (a heron rookery near the confluence of Town Creek and the Tennessee River), and a location on the high bluffs on Sand Mountain across the Tennessee River from the site. Measured sound levels near the boundaries of the site range from a day-night average sound level of 50 dBA to 55 dBA. For the purpose of the analysis, a background day-night average sound level of 50 dBA was used. This level is typical of a low-density residential or rural location (TVA 1997f).

No Action

No noise impacts are anticipated at the Bellefonte site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Construction

The location of the Bellefonte facilities relative to the Bellefonte site boundary and sensitive receptors was examined to evaluate the potential for onsite and offsite noise impacts. Noise sources during construction would include materials-handling equipment (e.g., cranes and forklifts), employee vehicles, and truck traffic. Traffic noise associated with construction of these facilities would occur both onsite and along offsite local and regional transportation routes used to bring construction materials and workers to the site.

The Bellefonte Conversion Project noise analysis was based on a composite of construction noise. This composite included excavation and structure erection activities, with all activities occurring during daylight hours between 7 a.m. and 5 p.m. Noise impacts from these construction activities would depend on the equipment used, the noise levels from individual equipment items, the number of sources, the duration and frequency of operation, the time of day, and other factors. Most of the activities associated with completion of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 would be indoors. Activities occurring outdoors would not be expected to produce the high levels of noise that were analyzed for the Bellefonte Conversion Project. The analysis indicated that the daytime equivalent sound levels would not increase at the two more distant sensitive receptors evaluated, the heron rookery and Sand Mountain. At the fence line receptor and the nearest residential area, the daytime equivalent sound levels would increase less than 1 dBA. Regular sounding of the shift change whistle would be heard at the fence line receptor and at the nearest residence.

Table 5–15 presents a range of noise levels for the major construction equipment expected to be used during construction activities for Bellefonte 1 or both Bellefonte 1 and Bellefonte 2. In addition, a variety of other noise-producing equipment would be used: pumps, generators, compressors, pneumatic wrenches, vibrators, saws, hand compactors, concrete mixers, concrete pumps, pavers, and compactors. These items are typically somewhat quieter than the items shown in the table.

Table 5–15 General Construction Equipment Noise Levels

Activity	*Item*	*Maximum Noise Level (dBA) at 15 meters (50 feet)*
Earthmoving:	Front-end loaders	82–86
	Backhoes	81–84
	Tractors	82–86
	Scrapers, graders	86–91
	Trucks	81–87
	Dozers	81–90
Materials handling:	Concrete trucks	81–87
	Cranes (movable)	80–85
	Cranes (derrick)	82–86
	Fork-lift trucks	82–86
	Delivery trucks	81–87
Impact equipment:	Jack hammers, rock drills	83–99
	Pile drivers	81–86

Source: BBN 1977, TVA 1998a.

Noise from traffic associated with construction of these facilities should result in less than 1 dB increase in day-night average sound level from traffic along U.S. Highway 72 near the Bellefonte Nuclear Plant entrance. This noise level should not result in any increased annoyance of the public. Peak-hour construction traffic noise at the beginning and end of the workday would result in about a 2 dB increase in traffic noise levels (1-hour equivalent sound level) along U.S. Highway 72 from about 65 dBA at 30 meters (100 feet) to about 67 dBA.

Traffic noise levels along the access road, which has been fairly quiet since construction of Bellefonte was deferred, would increase to about a day-night average sound level of 55 dBA during construction. Much of the traffic during the construction period would be at the beginning and end of the work day. Peak-hour traffic noise would increase by about 12 dB along the access road. Traffic noise during the peak hours should be noticeable at the nearby residences.

Operation

The location of Bellefonte 1 and 2 relative to the site boundary and sensitive receptors was examined to evaluate the potential for onsite and offsite noise impacts. Noise sources during operation would include cooling towers, heating–ventilation–air conditioning systems, vents, motors, pumps, transformers, switchyard equipment, generators, material-handling equipment, audible paging systems, sirens, employee vehicles, and truck traffic. Traffic noise associated with operation of these facilities would occur onsite and along offsite local and regional transportation routes used to bring materials and workers to the site. Operational noise sources would be primarily in the center of the site near the switchyard, turbine building, and cooling towers. Modeling of routine onsite noise sources associated with the operation of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 indicates that day-night average sound levels would increase to about 51 dBA at the site boundary receptor and at the nearest residence receptor. Day-night average sound levels at the other two receptors considered, the heron rookery and Sand Mountain, would not change from the 50 dBA background level. The routine noise should have no impact (less than 2 dBA) in the nearby residential areas. Other noise sources such as the infrequent actuation of the modulating atmospheric dump valves would result in higher noise levels at the site boundary and could disturb wildlife on the site. Noise from traffic associated with the operation of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 should result in an increase of less than 4 dBA in the day-night average sound level along U.S. Highway 72, and could be noticeable at nearby residences. Peak-hour operations traffic noise at shift changes would result in an increase in traffic noise levels along U.S. Highway 72 from about 65 dBA at 30 meters (100 feet) to about 67 dBA.

Traffic noise levels along the access road would increase to about a day-night average sound level of 57 dBA during operation. Peak-hour traffic would result in an increase in traffic noise levels along the access road from about 51 dBA at 30 meters (100 feet) to about 58 dBA. This increase in noise levels could be noticeable at nearby residences.

Regular testing of the emergency warning siren system would result in outdoor noise levels of about 60 dB (C-weighted) in areas within a radius of about 16 kilometers (10 miles) of the site. At other nuclear plants, TVA typically tests siren systems on a given day of the month at noon (TVA 1998a).

Noise exposure for workers is regulated under Occupational Safety and Health Administration regulations (29 CFR 1910.95). Where the 8-hour noise exposure guidelines would be exceeded, appropriate administrative and engineering controls would be implemented to control noise exposure, and a hearing protection program would be implemented.

5.2.3.3 Air Quality

NONRADIOACTIVE GASEOUS EMISSIONS

Air pollution refers to any substance in the air that could harm human or animal populations, vegetation, or structures, or that unreasonably interferes with the comfortable enjoyment of life and property. For the purpose of this document, only outdoor air pollutants are addressed. These may be in the form of solid particles, liquid droplets, gases, or any combination of these forms. Generally, they can be categorized as primary pollutants (those emitted directly from identifiable sources) and secondary pollutants (those produced in the air by interaction between two or more primary pollutants or by reaction with normal atmospheric constituents that may be influenced by sunlight). Air pollutants are transported, dispersed, or concentrated by meteorological and topographical conditions. Air quality is affected by air pollutant emission characteristics, meteorology, and topography.

Ambient air quality in a given location can be described in terms of a comparison of the concentrations of various pollutants in the atmosphere against the corresponding standards. Ambient air quality standards have been established by Federal and state agencies to ensure an adequate margin of safety for the protection of the public health and welfare from adverse effects of pollutants in the ambient air. Pollutant concentrations higher than the corresponding standards are considered unhealthy. Concentrations below the corresponding standards are considered acceptable.

The pollutants of concern are primarily those for which Federal and state ambient air quality standards have been established, including criteria air pollutants, hazardous air pollutants, and other toxic air compounds. The criteria pollutants are those listed in 40 CFR 50, *National Primary and Secondary Ambient Air Quality Standards*. The hazardous air pollutants and other toxic compounds are those listed in Title III of the 1990 Clean Air Act, as amended; those regulated by the National Emissions Standards for Hazardous Air Pollutants; and those that have been proposed or adopted for regulation by the state or are listed in state guidelines. Also of concern are air pollutant emissions that may contribute to the depletion of stratospheric ozone or to global warming.

An assessment of the impacts on air quality is based on a comparison of air pollutant concentrations with applicable Federal and state ambient air quality standards and concentration limits. The more stringent of either the EPA or state standards serve as the assessment criteria. The primary air pollutant emissions resulting from completing the construction of Bellefonte 1 and the operation of Bellefonte 1 or both units would consist largely of sulfur dioxide, nitrogen oxide compounds, particulate matter, and carbon monoxide. The ambient standards for these pollutants are presented in Table 5–19. Compliance with the new standards for particulate matter with an aerodynamic diameter less than or equal to 2.5 micrometers ($PM_{2.5}$) was not evaluated because the currently available emission factors are for particulate matter with an aerodynamic diameter less than or equal to 10 micrometers (PM_{10}).

No Action

No air quality impacts are anticipated at the Bellefonte site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Construction

Potential air quality impacts of construction activities required to complete Bellefonte 1 or both units were evaluated. Since most of the activities such as earth moving, excavation, and erection of major structures have been completed, the air pollution sources associated with unit completion would be similar to those associated with ongoing maintenance of the facilities and sources associated with completion of interior work and a few structures (e.g., piping systems). These include diesel generators, auxiliary boilers, employee vehicles, and trucks moving materials and wastes. Emissions from the currently operating generators and boilers are discussed in Section 4.2.3.3.

Air pollutant concentrations during construction should be similar to those for maintenance of the existing facilities, as discussed in Section 4.2.3.3, except for increased vehicular traffic; additional emissions from materials-handling equipment such as trucks, cranes, and forklifts; welding fumes; and emissions of cleaning solvents. Estimated emissions from these sources are presented in **Table 5–16.**

Table 5–16 Annual Nonradioactive Gaseous Emissions from Bellefonte 1 or Bellefonte 1 and Bellefonte 2 During Construction

Pollutant	*Emissions (kg/yr)*			
			Vehicles	
	Bellefonte 1 Equipment	*Bellefonte 1 and Bellefonte 2 Equipment*	*Bellefonte 1*	*Bellefonte 1 and Bellefonte 2*
Carbon monoxide	20,800	24,700	57,800	87,300
Nitrogen dioxide	54,400	64,700	16,400	24,800
Particulate matter	4,220	5,000	57,300	86,700
Sulfur dioxide	6,110	7,160	0	0
Formaldehyde	6.34	6.34	0	0
Arsenic	0.0658	0.0658	0	0
Beryllium	0.0392	0.0392	0	0
Cadmium	0.172	0.172	0	0
Chromium	1.05	1.05	0	0
Lead	0.14	0.14	0	0
Manganese	0.219	0.219	0	0
Mercury	0.047	0.047	0	0
Nickel	2.66	2.66	0	0

Source: TVA 1995c, TVA 1998a.

The total amount of these emissions would be small and would result in minimal offsite impacts, as shown in **Table 5–17.** As described in Appendix B, the short-term version of the ISC3 model, ISCST3, was used to calculate concentrations with averaging times of 1 to 24 hours, calendar quarter concentrations, and annual average concentrations. Construction equipment and other associated emissions for each alternative were evaluated as a volume source using the ISC3 model. Although there would be finite increases in air pollutant concentrations from construction activities, they would not exceed the ambient air quality standards.

Concentrations of toxic air pollutants from the combustion of diesel fuel in the auxiliary boilers, diesel generators, and construction equipment were also evaluated. There are no Alabama state standards that specify acceptable ambient concentrations of toxic air pollutants. During the permitting process, Alabama compares 1-hour concentrations of toxic air pollutants to 1/40 of the applicable threshold limit value for a

Table 5–17 Annual Air Pollutant Concentrations from Bellefonte 1 and Bellefonte 2 During Construction

Pollutant	*Averaging Period*	*Most Stringent Standard or Guidelines[a] ($\mu g/m^3$)*	*Construction's Contribution ($\mu g/m^3$)*	*Total Concentration[c] ($\mu g/m^3$)*	*Percent of Standard or Guideline*
Carbon monoxide	8-hour 1-hour	10,000 40,000	211 846	4,350 6,370	44 16
Lead	Calendar Quarter 1-hour	1.5 3.75	0.00007 0.00275	0.0301 0.00275	2.0 0.22
Nitrogen dioxide	Annual	100	69.1	93.2	93
Ozone	8-hour (3-year average of annual 4th highest)	157	N/A	b	b
Particulate matter	PM_{10} Annual 24-hour	 50 150	 5.29 24.2	 29.3 70.2	 59 47
Sulfur dioxide	Annual 24-hour 3-hour	80 365 1,300	7.04 31.1 79.7	20.0 105 290	25 29 22
Formaldehyde	1-hour	9.25	0.126	0.126	1.4
Arsenic	1-hour	0.25	0.00130	0.00130	0.52
Beryllium	1-hour	0.05	0.000773	0.000773	1.5
Cadmium	1-hour	0.05	0.0034	0.0034	6.8
Chromium	1-hour	12.5	0.0207	0.0207	0.17
Manganese	1-hour	5.0	0.00432	0.00432	0.086
Mercury	1-hour	0.625	0.000928	0.000928	0.15
Nickel	1-hour	1.25	0.0526	0.0526	2.1

[a] The more stringent of the Federal and state standards are presented for the averaging time. For toxic air pollutants, a value of 1/40 of the applicable threshold limit value (TLV) is used for comparison.
[b] There is insufficient monitoring data to assess based on the new ozone standard.
[c] Sum of the maximum ambient monitored concentration and the construction contribution.

Note: The National Ambient Air Quality Standards (40 CFR 50), other than those for particulate matter and those based on annual averages, are not to be exceeded more than once per year. The 1-hour ozone standard applies only to nonattainment areas. The 8-hour ozone standard is attained when the 3-year average of the annual fourth-highest daily maximum 8-hour average concentration is less than or equal to 157 $\mu g/m^3$. The 24-hour particulate matter standard is attained when the expected number of days with a 24-hour average concentration above the standards is
is attained when the expected annual arithmetic mean concentration is less than or equal to the standard. EPA recently revised the ambient air quality standards for particulate matter. The new standards were finalized on July 18, 1997. The current PM_{10} annual standard is retained and two $PM_{2.5}$ (particulate matter less than or equal to 2.5 micrometers) standards are added. These standards are set at 15 $\mu g/m^3$ 3-year annual average arithmetic mean based on community-oriented monitors and 65 $\mu g/m^3$ 3-year average of the 98th percentile of 24-hour concentrations at population-oriented monitors. The current 24-hour PM_{10} standard is revised to be based on the 99th percentile of 24-hour concentrations. The existing PM_{10} standards would continue to apply in the interim period (62 FR 38652).

N/A = Not applicable.

Source: ADEM 1972, TVA 1998a, TVA 1995b, ADEM 1995.

pollutant to assess whether the pollutant is of concern and should be evaluated in more detail. Offsite concentrations of all toxic pollutants evaluated for construction at Bellefonte would be below 1 percent of the applicable threshold limit value.

Operation

Operational impacts would result from emissions from four diesel generators, four diesel fuel–fired fire pumps, a security power diesel generator, two auxiliary boilers fueled with No. 2 fuel oil (0.05 percent sulfur), two cooling towers, two turbogenerator lube oil systems, and two fixed-roof tanks for storing No. 2 fuel oil (TVA 1997d). Emissions from these sources based on recent operating experience at TVA's Sequoyah Nuclear Plant are summarized in **Table 5–18.** In addition to these sources, there would be emissions from employee vehicles and trucks moving materials and wastes.

Table 5–18 Nonradioactive Gaseous Emissions from Bellefonte 1 and Bellefonte 2 During Operations

Pollutant	Emissions (kg/yr)	
	Stationary Sources[a]	Vehicles
Carbon monoxide	23,714	48,100
Nitrogen dioxide	90,707	13,700
Particulate matter	12,611	47,800
Sulfur dioxide	8,869	0
Volatile organic compound	2,105	6,230
Benzene	16.9	0
Toluene	6.13	0
Xylenes	4.21	0
1,3-Butadiene	0.00696	0
Formaldehyde	62.9	0
Acetaldehyde	0.679	0
Acrolein	0.186	0
Arsenic	0.632	0
Beryllium	0.376	0
Cadmium	1.66	0
Chromium	10.1	0
Lead	1.34	0
Manganese	2.11	0
Mercury	0.451	0
Nickel	25.6	0

[a] Stationary sources include diesel generators, diesel fuel-fired fire pumps, security power diesel generator, auxiliary boilers, lube oil system, fuel oil storage, and cooling towers.
Source: TVA 1997d, TVA 1998a

Maximum air pollutant concentrations resulting from the stationary sources (diesel generators, diesel fuel-fired fire pumps, security power diesel generators, and auxiliary boilers) are summarized in **Table 5–19**. There would be finite increases in air pollutant concentrations from operational activities, but even in combination with air pollutant concentrations from offsite sources (see Section 4.2.3.3), they would continue to meet the ambient air quality standards for carbon monoxide, nitrogen dioxide, PM_{10}, and sulfur dioxide. Concentrations of toxic air pollutants from the combustion of diesel fuel in the auxiliary boilers and diesel generators also were evaluated. There are no Alabama state standards that specify acceptable ambient concentrations of toxic air

Table 5–19 Annual Air Pollutant Concentrations from Bellefonte 1 and Bellefonte 2 During Operations

Air Pollutant	*Averaging Period*	*Most Stringent Standard or Guidelines[a] (μg/m³)*	*Operation's Contribution (μg/m³)*	*Total Concentration (μg/m³)*	*Percent of Standard or Guideline*
Carbon monoxide	8-hour 1-hour	10,000 40,000	404.0 662.0	4,540 6,180	45 15
Lead	Calendar Quarter 1-hour	1.5 1.25	0.000132 0.00541	0.0301 0.00541	2 0.43
Nitrogen dioxide	Annual	100	1.19	25.3	25
Ozone	8-hour (3-year average of annual 4th highest)	157	N/A	b	b
Particulate matter	PM_{10} Annual 24-hour	 50 150	 0.169 18.6	 24.2 64.6	 48 43
Sulfur dioxide	Annual 24-hour 3-hour	80 365 1,300	0.198 15.6 64.6	13.2 89 275	16 24 21
Benzene	1-hour	24	0.618	0.618	2.6
Toluene	1-hour	4,700	0.226	0.226	0.0048
Xylenes	1-hour	10,850	0.15	0.15	0.0014
1,3-Butadiene	1-hour	110	0.00148	0.00148	0.0013
Formaldehyde	1-hour	9.25	0.35	0.35	3.8
Acetaldehyde	1-hour	1,125	0.0479	0.0479	0.0043
Acrolein	1-hour	5.75	0.0094	0.0094	0.16
Arsenic	1-hour	0.25	0.00256	0.00256	1.0
Beryllium	1-hour	0.05	0.00152	0.00152	3.0
Cadmium	1-hour	0.05	0.00668	0.00668	13
Chromium	1-hour	12.5	0.0407	0.0407	0.33
Manganese	1-hour	5.0	0.00851	0.00851	0.17
Mercury	1-hour	0.625	0.00183	0.00183	0.29
Nickel	1-hour	2.5	0.104	0.104	4.2

[a] The more stringent of the Federal and State standards is presented for the averaging time. For toxic air pollutants, a value of 1/40 of the applicable threshold limit value (TLV) is used for comparison.

[b] There is insufficient monitoring data to assess based on the new ozone standard.

Note: The National Ambient Air Quality Standards (40 CFR 50), other than those for particulate matter and those based on annual averages, are not to be exceeded more than once per year. The 1-hour ozone standard applies only to nonattainment areas. The 8-hour ozone standard is attained when the 3-year average of the annual fourth-highest daily maximum 8-hour average concentration is less than or equal to 157 μg/m³. The 24-hour particulate matter standard is attained when the expected number of days with a 24-hour average concentration above the standards is
is attained when the expected annual arithmetic mean concentration is less than or equal to the standard. EPA recently revised the ambient air quality standards for particulate matter. The new standards were finalized on July 18, 1997. The current PM_{10} annual standard is retained and two $PM_{2.5}$ (particulate matter less than or equal to 2.5 micrometers) standards are added. These standards are set at 15 μg/m³ 3-year annual average arithmetic mean based on community-oriented monitors and 65 μg/m³ 3-year average of the 98th percentile of 24-hour concentrations at population-oriented monitors. The current 24-hour PM_{10} standard is revised to be based on the 99th percentile of 24-hour concentrations. The existing PM_{10} standards would continue to apply in the interim period (62 FR 38652).

N/A = Not applicable.

Source: TVA 1997d, TVA 1998a.

pollutants. During the permitting process, Alabama compares the concentrations of toxic air pollutants to 1/40 of the applicable threshold limit value for a pollutant to assess whether the pollutant is of concern and should be evaluated in more detail. The offsite concentrations of all the toxic pollutants evaluated for operations at Bellefonte would be below 15 percent of the applicable 1/40 of the threshold limit value. Emissions and resulting concentrations of air pollutants from the operation of Bellefonte 1 individually would be similar to those from operation of the combined units, since the testing and maintenance of the stationary sources would not vary.

The potential air pollutant emissions from the auxiliary boilers would exceed the emission level for applicability of the Prevention of Significant Deterioration permitting requirements, although the actual emissions from these sources would be well under these levels. The auxiliary boilers are currently permitted by the Alabama Department of Environmental Management. The department has stated that the boilers are not subject to the Prevention of Significant Deterioration regulations, and thus has not issued a Prevention of Significant Deterioration Permit. The diesel generators are operating under a "synthetic minor" permit by the Alabama Department of Environmental Management, owing to their continued operation at less than 50 percent of the 91 metric ton/yr (100-ton/yr) emission threshold. Under the new operating permit program, permits could be required for other sources such as chlorine, ammonia, and hydrazine storage tanks; lubricating oil system vapor extraction vents; paint and welding shops; and oil storage tanks. Emissions from employee vehicles and trucks carrying materials and wastes would result in some emissions, as shown in Table 5–18.

The combustion of fossil fuels associated with this alternative would result in emission of carbon dioxide, one of the atmospheric gases believed to influence global climate. Annual carbon dioxide emissions from this alternative would represent less than 0.0006 percent of the 1995 annual U.S. emissions of carbon dioxide from fossil fuel combustion and industrial processes (EPA 1997b). Operation of Bellefonte in lieu of fossil fuel–fired generation would significantly reduce future TVA carbon dioxide emissions.

The possible effects of natural-draft cooling tower operation would include inadvertent localized atmospheric modifications, such as the creation of plumes; cloud formation; changes in local rain, drizzle, fog, icing, and snowfall patterns; and the fallout of salts from cooling tower drift. Cooling tower drift is the dispersion and deposition of wet or dry aerosols emitted from cooling towers. Plans for normal operation of the Bellefonte cooling towers were based on the discharge of heated air carrying 62,800 l/min (16,600 gal/min) water as vapor and 170 l/min (45 gal/min) of water as drift from each of the towers (AEC 1974). Most of the drift that fell to the ground would do so within 300 meters (1,000 feet) of the towers. The remainder of the drift and residue would disperse and eventually be removed from the air and deposited on the ground by precipitation. Studies of natural-draft cooling towers in England indicate maximum rates of salt deposition on the order of 10^{-3} g/m^2-hr, and a similar rate would be expected at Bellefonte. The major anions in the drift at Bellefonte would be sulphate and carbonate (AEC 1974).

Modeling of the occurrence of visible plumes was performed for the Bellefonte Environmental Statement (AEC 1974). Incidents of the plume's descending to the ground or causing localized surface fogging should be rare. However, the plume would frequently cause surface fog on Sand Mountain Plateau, about 2.4 to 4.0 kilometers (1.5 to 2.5 miles) southeast from the site at an elevation 122 meters (400 feet) higher than the tops of the cooling towers. Fogging along roads in this area is predicted to occur about 80 hours per year. The plume modeling is expected to overpredict the occurrence of fog however, since the model does not account for the tendency of the plume to follow the terrain. For this reason, ground-level fog from operation of the cooling towers would likely occur only 1 to 2 days per year; icing in the Sand Mountain Plateau area would occur less frequently (AEC 1974).

Ozone is produced from corona discharge (ionization of the air) in the operation of transmission lines and substations, particularly at the higher voltages. TVA gives careful attention to the design and construction of its transmission facilities to minimize corona discharges (TVA 1974b). All but 20 miles of the transmission lines serving the Bellefonte Nuclear Plant site are currently energized, and no change in corona discharge from them is anticipated.

RADIOACTIVE GASEOUS EMISSIONS

No Action

Under the No Action Alternative, construction of Bellefonte 1 and Bellefonte 2 would not be completed. As described in Section 4.2.3.3, there would be no radioactive gaseous emissions at the Bellefonte site.

Tritium Production

Operation of the Bellefonte units as nuclear reactor facilities would result in radioactive gaseous emissions. These would include operational emissions typical of nuclear reactor facilities, as well as an expected increase in tritium emissions due to tritium production. **Table 5–20** shows the anticipated radioactive gaseous emissions at Bellefonte 1 from operations with 0, 1,000, and 3,400 TPBARs. The values presented for 0 TPBARs are based on the operational experience of Watts Bar 1. The calculation method and assumptions are described in Appendix C. Radiological exposures of the public and workers are presented in Section 5.2.3.9.

Table 5–20 Annual Radioactive Gaseous Emissions from Tritium Production at Bellefonte 1

	No Action (0 TPBARs)	*Tritium Production* [a]	
		1,000 TPBARs	*3,400 TPBARs*
Tritium release (Ci)	5.6	1,655.6	1,895.6
Other radioactive release (Ci)	282.5	282.5	282.5
Total release (Ci)	288.1	1,938.1	2,178.1

[a] The assumption of two failed TPBARs dominates the tritium production release with a contribution of 1,550 curies as presented in Appendix C, Table C-7.
Note: For Bellefonte 1 and Bellefonte 2 operation the emission values would be twice the values given.
Source: Based on Watts Bar 1 operation (see Table 5-1).

5.2.3.4 Water Resources

The availability and quality of water resources (surface water and groundwater) and facility-related effect on those resources that affect other users, are important factors in evaluating the acceptability of these facilities. The presence of floodplains is another important consideration. Legislation passed to protect water resources includes the Clean Water Act, especially Section 402, *National Pollution Discharge Elimination Systems*, and 307(b), *Pretreatment Standards*, and the Safe Drinking Water Act. DOE regulation 10 CFR 1022, *Compliance with Floodplains/Wetlands Environmental Review Requirements*, implements Executive Orders 11988 and 11990 and requires evaluation of the potential effects of an action on floodplains and wetlands.

The issues related to water resources include: (1) whether there is sufficient water available for both the proposed use and local domestic consumption, (2) whether water quality would be degraded or further degraded, (3) whether the proposed use challenges legislative or regulatory compliance, and (4) whether the proposed action is threatened by flooding.

The State of Alabama implements the requirements of the Clean Water Act and Safe Drinking Water Act and National Pollutant Discharge Elimination System (NPDES) regulations through its Department of Environmental

Management's Water Quality Program. Bellefonte operations are covered under the Alabama Department of Environmental Management NPDES Permit, as described in Section 4.2.3.4.

SURFACE WATER

No Action

No surface water impacts are anticipated at the Bellefonte site beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Analysis of impacts to surface water is presented separately for construction and operations activities.

Construction

Water uses during construction would include water for employee use, demineralized water, and raw water for cleaning, systems testing, and cooling. A peak use of 3,330,000 l/day (872,000 gal/day) of water would be required during startup, when plant flushing and cleanup are performed (TVA 1998e). Approximately 379,000 l/day (100,000 gal/day) of this peak usage would be potable water. Peak usage could occur over a period of several weeks. A peak use of 280,000 l/day (74,000 gal/day) would be required for completion of Unit 2. Potable water would continue to be obtained from the Hollywood water supply system (see Table 5–21). The quantities of water (raw and potable) obtained from the Guntersville Reservoir would have little effect on the availability of water for other uses.

Since construction completion would involve little or no new land disturbance or excavation, there would be little or no impact to surface water quality resulting from soil erosion of disturbed land or siltation of surface drainage channels. Storm water runoff would continue to be collected and treated, if necessary, before discharge. An NPDES Permit was issued for the Bellefonte Nuclear Plant that covers existing site outfalls and storm water monitoring during construction of the nuclear facility.

Sanitary wastewater would be treated at the Hollywood Waste Water Treatment Facility. This facility is a publicly owned treatment works designed to ensure compliance with the effluent limitations of the state. The City of Hollywood has agreed to add additional treatment facilities as needed to handle the sanitary wastewater from the Bellefonte Nuclear Plant. A small quantity of sanitary wastewater from the simulator building, training facility, and environmental data station is treated onsite by sand filters and a septic system.

Operation

All water for operation of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 would be drawn from the Guntersville Reservoir, except for potable water, which is obtained from the Hollywood water supply system. Potable water requirements should average 95,000 l/day (25,000 gal/day) with two units operating (TVA 1998a). Average river flow rates at the Bellefonte Nuclear Plant are 65.9 million l/min (17.4 million gal/min); the 7-day, 10-year minimum flow, 21.9 million l/min (5.78 million gal/min). Operation of Bellefonte 1 and 2 should require 376 million l/day (99.4 million gal/day) for normal full operation. This represents about 0.4 percent of the average river flow and about 1.2 percent of the 7-day, 10-year minimum. In addition, about 24 million l/yr (6 million gal/yr) of water would be used for firefighter training and the testing and maintenance of fire protection systems. Other major water uses served by the Guntersville Reservoir include the 30 million l/day (7.8 million gal/day) of potable water demand of several municipalities in Alabama and Tennessee; the 6.1 billion l/day (1.6 billion gal/day) for the Widows Creek Fossil Plant; and various smaller, industrial uses. The water supply from

Guntersville Reservoir appears to be adequate to meet the foreseeable requirements for the area (TVA 1997d, TVA 1997f).

Discharges from the Bellefonte Nuclear Plant include storm and process water outfalls, covered by the existing NPDES Permit, which would be treated and monitored before release. Water quality–based limitations include the following:

- Use classification of the upper stretch of Tennessee River Basin as a public water supply and for swimming, fishing, and wildlife protection.

- Select water quality criteria (e.g., temperature, dissolved oxygen, and toxics) for public water supply–designated segments.

- Secondary treatment, or the equivalent, of all industrial, sanitary, and combined discharges for biologically degradable waste. Parameters of interest are biochemical/biological oxygen demand, total suspended solids, and acidity (pH) (TVA 1997f).

Process water discharges would be mostly from cooling tower blowdown (about 247 million l/day [65.2 million gal/day]) and sump collection ponds (2.46 million l/day [0.65 million gal/day]) with both units operating. These discharges would be to the main river channel (Guntersville Reservoir). In addition to these discharges, approximately 2,720,000 l/day (718,000 gal/day) of water would be used for intake strainer and screen backwash (TVA 1997e).

Sanitary wastewater would be treated at the Hollywood Waste Water Treatment Facility, a publicly owned treatment works designed to ensure compliance with the effluent limitations of the State of Alabama. The City of Hollywood has agreed to add additional treatment facilities, as needed, to handle the wastewater from the Bellefonte Nuclear Plant. Discharges to the treatment facility would not include industrial wastes. The outfall from the Hollywood Waste Water Treatment Facility is covered under the NPDES Permit held by the City of Hollywood.

Discharges from the plant would be monitored to comply with the Bellefonte NPDES Permit limitations. Limitations of the existing NPDES Permit issued by the Alabama Department of Environmental Management are summarized in Section 4.2.3.4. **Table 5–21** presents changes to surface water resources attributable to the alternatives involving the Bellefonte Nuclear Plant. Water required from the Guntersville Reservoir would be a small fraction of the river flow, and most of it would be returned to the reservoir after use.

Chemical discharges to the Guntersville Reservoir from various systems at the Bellefonte Nuclear Plant are summarized in **Tables 5–22** and **5–23**. The blowdown diffuser is designed to mix the blowdown with nine equal parts of reservoir water. The average and maximum expected chemical concentrations in the reservoir after mixing have been calculated on this basis. Sources of chemical discharges would include cooling tower blowdown, cooling tower makeup and essential raw water systems, the water filtration plant, steam system makeup water demineralizers, alternative treatment of wastes from makeup and condensate demineralizers, component-cooling systems, the reactor coolant system, auxiliary steam generator blowdown, and yard drainage systems and various sumps (TVA 1974b). Even under adverse conditions, chemical discharges would be small. The change in maximum concentrations in the reservoir after mixing had occurred would represent a small increase over the observed maximum background concentrations. Actual discharges and concentrations in the reservoir should meet the limitations of the NPDES Permit and Alabama Department of Environmental Management drinking water standards.

Table 5–21 Potential Changes to Water Resources from Bellefonte 1 or Bellefonte 1 and Bellefonte 2

Affected Resource Indicator	*No Action*	*Tritium Production Bellefonte 1*	*Tritium Production Bellefonte 1 and Bellefonte 2*
Construction			
Water availability and use:			
Raw water source	Guntersville Reservoir	Guntersville Reservoir	Guntersville Reservoir
Site water use requirement (million l/yr)	None	1,260[a]	1,390[a]
Percent of river flow	None	0.0036	0.004
Water quality:			
Discharge to surface water (million l/yr)	None[b]	3,100[c]	3,430[c]
Discharge of sanitary waste to local treatment plant (million l/yr)	N/A	155[c]	155[c]
Operation			
Water availability and use:			
Water source	Guntersville Reservoir	Guntersville Reservoir	Guntersville Reservoir
Site raw water use requirement (million l/yr)	N/A[d]	68,700[e]	137,000
Percent of river flow	N/A	0.2	0.39
Potable water use requirement (million l/yr)	2.76	27.6	34.5
Water quality:			
Discharge to surface water (million l/yr)	None[b]	46,000[e]	91,100
Discharge of sanitary waste to local treatment plant (million l/yr)	2.76	27.6	34.5
Floodplain:			
Actions in 500-year floodplains	None	Intake	Intake

N/A = not applicable
[a] Potable and raw water usage.
[b] Except stormwater runoff and a small quantity discharged from the simulator training facility sand filters.
[c] Discharges from construction activities and from runoff are discharged to the diffuser or to other discharge points.
[d] Current raw water use from Guntersville Reservoir is limited to fire protection and cooling water needs.
[e] Estimated assuming one cooling tower operation.
Source: TVA 1997f, TVA 1997d.

A portion of the circulated cooling water would be discharged to prevent the buildup of dissolved salts and minerals in the cooling system (blowdown), resulting in the discharge of heated water to the Guntersville Reservoir. The NPDES Permit for Bellefonte (ADEM 1992) limits in-stream temperatures to less than or equal to 30 mbient upstream temperatures typically exceed this limit an average of 8.5 days per year, in July and August, primarily as a result of natural heating of the lake. Monitoring data for 1975 to 1991 indicate that the ambient upstream temperature ranged from 1.7

The combined discharges to the Guntersville Reservoir would be through the submerged diffuser to provide dilution with the stream flow. The temperature of the discharge would vary with the ambient wet-bulb temperature. Alabama water quality standards limit the maximum temperature rise (difference between upstream and downstream temperature) to no more than 2.8 temperature rise would occur when the river was cold and the discharge warm (TVA 1997f).

Results of temperature analyses for various discharges using the Cornell Mixing Zone Expert System (CORMIX) indicate that the maximum water temperature 3 meters (10 feet) downstream from the diffuser

Table 5–22 Summary of "Added" Inorganic Chemical Discharges to Guntersville Reservoir from Operation of Bellefonte 1 and Bellefonte 2[a]

Chemical	Maximum Daily Discharge of Chemical (kg)	Maximum Daily[b] Contribution to Cooling Tower Blowdown (mg/l)	Observed Chemical Concentrations in Reservoir Water at Tennessee River Mile 385.9 (mg/l)		Concentration During Period of Added Chemical Discharge			
					Blowdown (mg/l) [c]		Reservoir After Mixing[d] (mg/l)	
			Average	Maximum	Average	Maximum	Average	Maximum
Sulfates	1,446	47.9	17.7	23.0	83.3	93.9	24.3	30.1
Sodium	693.1	23.0	7.7	12.4	38.4	47.8	10.8	15.9
Chlorides[e]	225	7.4	14.8	22.0	37.0	51.4	17.0	24.9
Ammonia[f]	0.3	0.009	0.026	0.09	0.061	0.189	0.031	0.10
Total dissolved solids	2,450	81.1	95.0	140.0	271.1	361.1	112.6	162.1

[a] Assumes all maximum daily waste streams are retained in a holding tank and discharged within a 4-hour period each day. The makeup demineralizer spent regenerate and condensate demineralizer spent regenerate would be retained in separate tanks. However, when discharged to blowdown, the tanks could be emptied simultaneously. This would constitute the maximum discharge during a specific 4-hour period.
[b] Based on maximum daily contributions in blowdown stream for a 2-unit plant with a 74 ft^3/s continuous blowdown rate.
[c] Based on concentrations occurring only when the cooling tower blowdown is being released.
[d] Downstream of the mixing zone. Assumes jet mixing diffuser would be provided to mix nine volumes reservoir water with one volume of blowdown.
[e] Computation is for chlorides.
[f] Ammonia and hydrazine added to the auxiliary steam system for pH control and dissolved oxygen control, respectively. Hydrazine assumed to decompose to ammonia.

Source: TVA 1974b.

Table 5–23 Summary of Observed Trace Metal Concentrations and Expected Maximum Trace Metal Concentrations in the Discharge Stream and at the Edge of the Jet Mixing Zone from Operation of Bellefonte 1 and Bellefonte 2

Parameter (Dissolved)	*Number of Times Observed in Nine Samples*	*Statistics for Observed Values[a] (µg/l)*			*Maximum Expected Trace Metal Concentrations Closed-Cycle Cooling Operation[b] (µg/l)*	
		Minimum	*Maximum*	*Mean*	*In Blowdown*	*Reservoir after Mixing[c]*
Zinc	5	6	23	12	46	25.3
Boron	9	7	45	24	90	49.5
Iron	9	4	52	21	104	57.2
Manganese	3	0.6	1.9	1.4	3.8	2.1
Copper	9	2	9	4	18	9.9
Barium	9	11	36	24	72	39.6
Strontium	9	20	118	54	236	129.8
Aluminum	6	16	53	28	106	58.3
Chromium	3	3	13	6	26	14.3
Lead	2	11	14	12.5	28	15.4
Molybdenum	1	12	12	12	24	13.2

[a] From *Trace Metals in Waters of the United States: A Five Year Summary of Trace Metals in Rivers and Lakes of the United States, October 1, 1962 through September 30, 1967*, U.S. Department of the Interior, FWPCA, Division of Pollution Surveillance, Cincinnati, OH. Weekly samples were composited for 3-month periods twice a year during the period. Data collected at Widows Creek Fossil Plant at Tennessee River Mile 408.

[b] Assumes maximum observed concentrations occur.

[c] Downstream of the mixing zone. Assumes jet diffuser would be designed to mix nine volumes of river water with one volume of blowdown.

Source: TVA 1974b.

would be 32.6 0.7 2,440-MWe nuclear option). At 800 meters (2,620 feet) downstream the predicted maximum temperature was 32.3 occur in January and February; it has been computed at 1.8 C (3.2 kilometers (10 miles) downstream (TVA 1997f, TVA 1998a). The one-unit option would result in lower temperatures downstream due to the lower discharge rate.

An earlier analysis for two-unit operation indicated that the maximum discharge temperature at the diffusers would vary from 28.5 C (83.3 mixing ratio of 9 to 1, the maximum in-stream temperature at the edge of the mixing zone would vary from 16.8 C (62.2 C (90 the one-unit option would be lower due to the lower discharge flow rate. The maximum predicted discharge temperature rise (downstream temperature minus upstream temperature) would be 1.6 (TVA 1982). Holdup of the blowdown could be necessary on occasion when the ambient temperature in the summer is neared or exceeded the maximum temperature standards. A temperature variance to the NPDES Permit has been requested from the Alabama Department of Environmental Management. Although there would be a finite increase in reservoir water temperature due to the discharge from Bellefonte operation, both the increase in temperature and the maximum temperature would be limited such that impacts on aquatic species would meet the limitations of the NPDES Permit.

The Widows Creek Fossil Plant is about 24 kilometers (15 miles) upstream of the Bellefonte site. It discharges approximately 68 m^3/s (2,400 ft^3/s) of water heated to 10 Assuming that full mixing occurred before the water reached the Bellefonte site, the temperature increase would be 0.8 Temperature measurements at Guntersville Dam and Nickajack Dam indicate that the water at the downstream dam is about 0.7 on the average. A portion of this temperature increase could be due to the Widows Creek plant, and another portion, to solar heating. The Bellefonte plant by comparison would increase the average water temperature flowing past the plant by about 0.05 thermal effect assignable to Bellefonte would likely be small (AEC 1974).

Since storm water runoff would continue to be collected and treated, if necessary, before discharge, little or no impact on surface water would result from soil erosion or the siltation of surface drainage channels.

RADIOACTIVE LIQUID EFFLUENT

No Action

Under the No Action Alternative, construction of Bellefonte 1 and Bellefonte 2 would not be completed. As discussed in Section 4.2.3.4, there would be no radioactive liquid effluent at the Bellefonte site.

Tritium Production

Surface Water

Operation of the Bellefonte units as nuclear reactor facilities should produce the liquid radioactive effluents typical of such operation as well as those attributable exclusively to tritium production. **Table 5–24** shows the expected radioactive liquid effluents from operation of Bellefonte 1 with 0, 1,000, and 3,400 TPBARs. The values presented for 0 TPBARs are based on the operational experience at Watts Bar 1. The calculation method and assumptions are described in Appendix C, Section C.3. Radiological exposures of the public and workers are presented in Section 5.2.3.9.

Table 5–24 Annual Radioactive Liquid Effluents from Tritium Production at Bellefonte 1

	No Action (0 TPBARs)	Tritium Production [a]	
		1,000 TPBARs	3,400 TPBARs
Tritium release (Ci)	639	15,489	17,649
Other radioactive release (Ci)	1.32	1.32	1.32
Total release (Ci)	640.32	15,490.32	17,650.32
Tritium release concentration (pCi/l)[b]	<300	<7,270	<8,290

[a] The assumption of two failed TPBARs dominates the tritium production release with a contribution of 13,950 curies as presented in Appendix C, Table C-7.
[b] These values are significantly less than the 40 CFR 141 limit of 20,000 pCi/L for tritium.
Note: For Bellefonte 1 and Bellefonte 2 operation the effluent values would be twice the values given.
Source: Based on Watts Bar 1 operation (see Table 5-2).

Flooding

The Bellefonte facilities have been sited to provide a reasonable level of protection from flooding. The requirements of Executive Order 11988, *Floodplain Management,* would be fulfilled. To the extent practicable, required actions would be conducted outside the limits of the 100-year floodplain unless there are no practicable alternatives. If possible, moreover, "critical action" facilities (i.e., those facilities whose inoperability would compel the curtailment or shutdown of power generation) would be located outside the 500-year floodplain or protected to the 500-year-flood elevation. All safety-related structures, systems, and components have been designed to remain functional in the worst potential flood from any cause (TVA 1997f).

The maximum plant site flood level from any cause would be elevation 190.4 meters (624.8 feet). Coincident wind waves would raise the reservoir to a maximum elevation of 191.3 meters (627.7 feet). The safety-related facilities, systems, and equipment in the reactor building have been protected against the maximum flood level and the maximum wind- or wave-induced level. The intake pumping station has been designed for the static and dynamic forces resulting from such an event, and is protected from runup by a wall built around the top deck (TVA 1991).

The situation conducive to the maximum plant site flood level has been determined to be a sequence of March storms producing maximum precipitation on the watershed above Chattanooga. The flood crest would be augmented by failure of earth embankments at the Fort Loudoun-Tellico, Watts Bar, Chickamauga, and Nickajack Dams upstream (TVA 1991). While some support facilities and utilities (e.g., the railroad, water and sewer pipelines) would be below the 500-year-flood level, they too have been constructed to protect them from flood damage.

Groundwater

Construction activities related to the completion of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 should have no effect on groundwater availability. There are no planned withdrawals of groundwater. The potential for groundwater contamination from fuels, oils, solvents, or other chemicals used in the operation and maintenance of equipment and other activities during construction would be minimized by careful handling and proper disposal of potential contaminants. TVA's Spill Prevention, Control, and Countermeasures Plan provides a method for mitigating releases of contamination into the groundwater at the site. Should a release occur, remediation methods would be employed to prevent impacts on water supplies (TVA 1997f).

Groundwater availability would not be affected by operation of the Bellefonte units. There are no planned withdrawals of groundwater. Any impacts on groundwater quality during operations would most likely be associated with the storage and handling of fuel oil and the storage, handling, and disposal of wastes generated. The disposal of wastes is discussed in Section 5.2.3.11. No impacts on groundwater are expected. TVA's Spill Prevention, Control, and Countermeasures Plan provides a method for mitigating groundwater releases at the site. Should a release occur, remediation methods would be employed to prevent impacts on water supplies (TVA 1997f).

5.2.3.5 Geology and Soils

No Action

No impacts on geology and soils are anticipated at Bellefonte beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Construction

The limited construction activities required to complete the Bellefonte units should have no effect on geology and soils.

Soil Amplification and Ground Deformation. Liquefaction of soils at Bellefonte due to earthquake ground motion is believed to be very unlikely. The effects of amplification of ground motions through soil columns should be considered in the seismic design of structures not founded on rock.

Seismic Hazard Assessments. Bellefonte is in a Seismic Hazard Zone 2, or a zone of low seismic hazard. The use of existing building codes should adequately address the earthquake hazard to ordinary buildings at Bellefonte. Additional considerations might be needed for special structures that house hazardous processes or sensitive equipment. Underground or aboveground piping that transports hazardous substances could also require nonroutine design to address seismic hazards at the site.

Bedrock. No problems should be created within the consolidated bedrock (Chickamauga Formation) beneath the main plant area footprint by activities such as excavation or dewatering. All of the unweathered rock at the site is capable of supporting intended loads.

Overburden. Soils beneath the footprint areas are variable in depth (0 to 7 meters [0 to 23 feet]) and are expected to consist primarily of stiff silty clays and clayey silts. Structural design would be based upon in-situ soil investigations at the proposed foundation location and appropriate safety factors for proposed foundations of new facilities on soil.

Operation

No impacts on geologic stability are expected to occur. All structures would be designed and constructed according to sound engineering practices, no materials would be injected underground, and groundwater would not be required for tritium production. The normal operation of the Bellefonte units would have no effect on soils and prime farmland at the site.

5.2.3.6 Ecological Resources

No Action

No impacts on land use, air quality, or water quality are anticipated at the Bellefonte site beyond the effects of existing and future activities that are independent of the proposed action. Therefore, no impacts on ecological resources are expected under this alternative.

Tritium Production

The evaluation of impacts on ecological resources was based on a review of previous studies for the Bellefonte Nuclear Plant and analysis of any changes associated with tritium production that might be relevant to previously disclosed impacts. Where relevant, these impacts were identified.

Construction

Evaluation of the ecological impacts of construction activities at the Bellefonte site encompassed terrestrial resources, aquatic resources, wetlands, and threatened and endangered species.

<u>Terrestrial Resources</u>

Construction activities required to complete Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 would include the installation of additional equipment, the construction of new support buildings, and minor activities associated with making the intake water structure operational (TVA 1998a) (see description in Section 3.2.5.3). Most major facilities at Bellefonte have already been completed (TVA 1993). The existing area of the site that was cleared during initial construction should be adequate for the construction of the new support buildings and for the remaining construction-related activities. Therefore, no additional land would be cleared, and there would be no impacts from disturbance or destruction of vegetation or wildlife habitat in currently undisturbed areas of the site. The transient emissions of gaseous and particulate air pollutants from construction operations would have little or no adverse effect on the terrestrial ecological resources (TVA 1974b). During construction, no radioactive materials would be handled. Thus, there should be no radiological impacts on terrestrial resources. Although there would be increased activity at the site and increases in sound levels from construction activities and from traffic along the access road, these changes should have little effect on wildlife on the site (TVA 1974b).

<u>Aquatic Resources</u>

Impacts to aquatic resources from increased surface runoff and sediment loading should be temporary and limited. Land disturbance would be limited to that required for the new support buildings, and there would be no physical disturbance of the Guntersville Reservoir shoreline or adjacent riparian habitat in the vicinity of the Bellefonte site. Standard erosion control and sedimentation mitigation techniques would be used as appropriate in any construction areas. Runoff from construction activities would be collected and processed before release to surface waters (TVA 1974b). Monitoring investigations from 1974 to 1979 during the major construction activities at Bellefonte indicated that these activities did not adversely impact the Guntersville Reservoir or Town Creek Embayment (TVA 1980). Therefore, the activities required to complete Bellefonte 1 and 2 would have no runoff or sedimentation impacts.

<u>Wetlands</u>

Construction activities to complete Bellefonte should disturb no additional wetlands beyond those disturbed during initial construction of the Bellefonte Nuclear Plant. The activity required to make the intake structure operational would be a desilting of the existing pumps. This would not disturb any wetlands. As discussed previously for aquatic resources, activities required to complete Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 would have no runoff or sedimentation impacts.

Threatened and Endangered Species

Construction activities at the Bellefonte site would not adversely affect any federally or state-listed threatened or endangered species. There should be no impacts on threatened or endangered aquatic species or plants from construction activities, because the additional land disturbance would be small and no federally or state-listed aquatic or plant species have been identified at the site.

The gray bat and Indiana bat, both federally listed as endangered, are known to forage along the Guntersville Reservoir shoreline. Indiana bats also roost in heavily wooded areas on the hillsides and bluff areas along the Tennessee River. The bald eagle, federally listed as threatened, has been seen along the wooded shoreline on the east side of the Bellefonte site and along the intake canal during the winter. Activities associated with completion of Bellefonte 1 and 2 would not reduce foraging areas and roosting sites for the gray bat, Indiana bat, or the bald eagle (TVA 1993, TVA 1997f).

TVA has notified the U.S. Fish and Wildlife Service of DOE's proposed action and will provide the States of Tennessee, Alabama, and South Carolina and the U.S. Fish and Wildlife Service with copies of the draft and final CLWR environmental impact statement. TVA and DOE will continue to comply with the requirements of the Endangered Species Act and interact with the U.S. Fish and Wildlife Service, as appropriate.

Operation

Evaluation of the ecological impacts of the operation of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 encompassed terrestrial resources, aquatic resources, wetlands, and threatened and endangered species. Specific sources of operational impacts would include emissions of air pollutants to the atmosphere, effluent releases to surface waters, increases in human activity, and increased noise levels.

Terrestrial Resources

Wildlife on the Bellefonte site would be exposed to increased noise levels from operational sources and from traffic during peak traffic hours. Short-term noises above a level of about 75 dBA could startle wildlife (TVA 1997f). Noises from site activities above this level would not likely be experienced by wildlife in the undeveloped areas of the site. The increased operational noise levels should cause little or no disturbance of wildlife on the site and thus should affect no changes in local wildlife populations. Testing of the emergency sirens could elicit a startle response in nearby wildlife, but these infrequent tests should cause no changes in wildlife populations in these areas.

Emissions of gaseous and particulate air pollutants from combustion sources would result in small increases in air pollutant concentrations (see Section 5.2.3.3). However, the resulting concentrations of criteria and hazardous and toxic pollutants in the vicinity of the site should continue to meet the ambient standards and guidelines and to have no adverse effect on terrestrial resources.

Surface deposition or root uptake of concentrated salts could cause stress on vegetation. Effects on vegetation would vary with the plant species and the salts being deposited. Most of the drift that fell to the ground would do so within 300 meters (1,000 feet) of the towers (AEC 1974). The remainder would disperse and eventually be removed from the air and deposited on the ground by precipitation. The estimated salt deposition rate for the cooling towers is 10^{-3} gal/m^2-hr. The analysis of cooling tower drift for Bellefonte indicates that gross impacts on terrestrial biota as a result of salt deposition from the cooling towers would be unlikely, but that sensitive species could be adversely affected (AEC 1974).

Changes in incoming radiation (due to shadows from the cooling tower plume) and moisture could effect biota in the vicinity of the cooling towers. However, these changes would likely be indistinguishable from natural variations. Impacts should not be adverse—they might not even be measurable—but over the lifetime of the station, subtle effects could appear (AEC 1974). There should be no operations-related changes in bird mortalities from collision with the cooling towers.

Operation of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 for tritium production would release radioactive gaseous emissions and radioactive liquid effluents to the Guntersville Reservoir as discussed in Sections 5.2.3.3 and 5.2.3.4. When tritium is inhaled or ingested by an organism, incorporation into bodily fluids is very efficient. However, long-term accumulation in the organism is limited by its rapid elimination by exhalation, excretion in body water, and its short half-life. The biological properties of tritium are discussed in Appendix C.

Doses to the public and workers have been estimated and are presented in Tables 5–27 and 5–28. Various studies on exposure of vegetation, wildlife, and aquatic species indicate that radiological effects on the human species is a reasonable indicator of the effects on other organisms. In the Bellefonte Final Environmental Statement (TVA 1974b), maximum radiological doses to terrestrial vertebrates (excluding doses from tritium production) from liquid effluent releases under normal operating conditions were estimated at 160 mrad/yr. Particularly instructive in this connection is the International Atomic Energy Agency's 100-mrad/day benchmark of a chronic dose rate that appears unlikely to cause observable changes in terrestrial animal populations (IAEA 1992). It has been concluded that, since the exposure estimates are small relative to that benchmark, and the incremental doses due to tritium production (see the analysis for the public and workers in Section 5.2.3.9) would be small, the impact of radiological releases on terrestrial species would be minor.

<u>Aquatic Resources</u>

Possible major environmental impacts on the aquatic ecosystem of Guntersville Reservoir due to the operation of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 include fish losses at the cooling water intake screens; almost total loss of entrained, unscreened organisms; and thermal and chemical discharges.

Fish Impingement—Since the water velocity in the intake channel would be low, fish would enter the channel in the normal course of their activities. The recessed embayment location of the intake would be conducive to fish congregation. If congregated fish swam until they were fatigued, they could eventually be impinged on the traveling screens. Since the overbank area has a high density of young-of-the-year fish, impingement should be high for this age group (AEC 1974).

Entrainment—Because of closed-cycle cooling, it can be assumed that a large proportion of the free-floating organisms that pass through the vertical traveling intake screens would be destroyed. These would include phyto- and zooplankton, fish eggs and larvae (ichthyoplankton), and small fish. An evaluation of plankton population densities and stream flow data indicates that there would be no discernible effect on the plankton populations in Guntersville Reservoir. This is due largely to the small volume of water (less than 1 percent of the Tennessee River flow) that would be used by Bellefonte 1 or both units relative to the volume in the river (TVA 1991). Similarly, no adverse effect on fish populations in the reservoir would be expected from fish egg and larvae mortalities, since the withdrawal requirements for the closed-cycle cooling system is small relative to the volume of the river (TVA 1974b).

Entrainment effects on aquatic macrophytes would mean the probable destruction of submerged floating plants and plant fragments. However, these losses would not constitute a significant reduction in the aquatic macroflora (TVA 1991).

Thermal Effects—Fish are normally attracted to the outfalls of power plants, especially when the ambient river temperatures are lower than the preferred temperature of a given species. In some cases, fish captured in the discharge region for a power plant are in poorer condition than those from unheated regions. Although the condition of some fish could be adversely affected, there should be no major effect on the abundance of fish species in Guntersville Reservoir (AEC 1974).

The impact from thermal effects on the population of plankton in the Guntersville Reservoir should be small, given the limited diffuser mixing zone, which would limit the time of plankton entrainment in the plume, and the 10-fold dilution that would occur in the mixing zone. Some localized changes of backwater plankton assemblages (e.g., upstream and downstream of Jones Creek [Tennessee River Mile 388]) could result from plume dispersion along the left shore, beginning within 1.6 kilometer (1 mile) of the diffuser. Because of the small amounts of heat involved, these changes should be small (TVA 1991).

A major benthic community has been identified along the near shore (right side) overbank area extending downstream of the Bellefonte Nuclear Plant site (see Section 4.2.3.6). The impact of the thermal plume to the macrobenthos should be small. The benthos in the main channel is very limited in diversity, being composed primarily of the Asiatic clam, *Corbicula fluminea*. No thermal impacts would be expected on mainstream benthic populations. The impact of the thermal plume on emersed, floating-leaved, and submerged aquatic macrophyte species should be limited due to the small temperature change predicted. Some localized enhancement of macrophyte growth could occur along portions of the mainstream left bank and the adjacent shallow overbank area.

During startup and shutdown operations, blowdown discharges would continue. Therefore, changes in the mixed temperature at the edge of the diffuser mixing zone would not be rapid and would be expected to occur primarily from routine changes in plant operation. These changes would be smaller than the maximum changes of -0.4 C (-0.7 Therefore, impacts of the rate of temperature change (e.g. fish kills due to cold shock) should be small (AEC 1974, TVA 1991).

Chemical Effects—Analyses of chemical releases to surface waters from operations indicate that releases should comply with NPDES Permit limitations, and thus that the potential impacts of these releases should be minor (TVA 1993). The potential impacts on aquatic organisms from the use of biocides, such as chlorine, in the treatment of cooling tower makeup water and raw cooling water systems, and the use of tolytriazole and potassium hydroxide for pH and corrosion control in the cooling system, also should be minor, as the release of these compounds to surface waters is controlled by provisions of the NPDES Permit. Runoff would be treated before release to receiving surface water bodies in accordance with applicable NPDES Permit requirements (TVA 1993).

Radiological Effects—When tritium is ingested by an aquatic organism, incorporation into bodily fluids is very efficient. However, long-term accumulation in the organism is limited by its elimination in body water and its short half-life. The biological properties of tritium are discussed in Appendix C.

TVA has estimated maximum annual doses to aquatic organisms from liquid effluent releases at 8.5 millirads for plants, 3.5 millirads for suspended invertebrates, 120 millirads for benthic invertebrates, and 0.4 millirad for fish (TVA 1974b). Instructive in this connection is the benchmark dose of 1 rad/day (1,000 mrad/day) established by the National Council on Radiation Protection and Measurements and International Atomic Energy Agency as a level that appears unlikely to cause observable changes in aquatic populations (NCRP 1991, IAEA 1992). It has been concluded that, since the exposure estimates are small relative to that benchmark, and the incremental doses due to tritium production (see the analysis for the public and workers in Section 5.2.3.9) would be small, the impact of radiological releases on aquatic species would be small, as defined by 10 CFR 51 (see Glossary term "qualitative environmental impacts").

Wetlands

As discussed previously for aquatic resources, wetlands would not likely be impacted from runoff or sedimentation during tritium production.

Threatened and Endangered Species

Operational impacts on threatened or endangered species could occur through the release of thermal, chemical, or radioactive discharges to the atmosphere or river. These releases could affect listed species in the vicinity of the site and in the reservoir downstream of the site, either directly or indirectly, through the food chain. Listed species occurring on or in the immediate vicinity of the Bellefonte site could also be affected by the increased human presence during plant operations.

Impacts on threatened or endangered plants from operational activities would be unlikely, as no federally or state-listed plant species occur on or in the immediate vicinity of the Bellefonte site. The periodic presence of plant workers at the intake canal could cause foraging eagles to move from this area; however, this disruption would be temporary and unlikely to negatively affect eagles. There should be no other operational impacts on wooded areas used by eagles, gray bats, or Indiana bats.

Potential thermal and chemical effects on aquatic biota are described above. No aquatic listed species occur in the immediate vicinity of the Bellefonte site, and no thermal or chemical impacts to the Guntersville Dam tailwater would be expected. Thermal and chemical effects on potential prey of bald eagles and gray bats should be small and localized. Thus, thermal or chemical effects on listed threatened or endangered species would be unlikely.

As discussed previously for terrestrial and aquatic species, the impact of radiological releases should not adversely affect the listed threatened and endangered species.

TVA has notified the U.S. Fish and Wildlife Service of DOE's proposed action and will provide the States of Tennessee, Alabama, and South Carolina, and the U.S. Fish and Wildlife Service with copies of the draft and final CLWR environmental impact statement. TVA and DOE will continue to comply with the requirements of the Endangered Species Act and interact with the U.S. Fish and Wildlife Service as appropriate.

Environmental Monitoring

Before and during the construction of Bellefonte 1 and 2, TVA conducted an extensive environmental monitoring program. It has continued environmental monitoring for various parameters during the period of construction deferment, especially as required to comply with various permits (e.g. NPDES Permit). TVA has also committed to an extensive environmental monitoring program to be conducted during operations, the aim being to confirm that operation of the plant does not have a significant adverse impact on the environment, including threatened and endangered species (TVA 1993).

5.2.3.7 Archaeological and Historic Resources

No Action

No impacts on land use are anticipated at the Bellefonte site beyond the effects of existing and future activities that are independent of the proposed action. As a result, no impacts on archaeological or historic resources are expected.

Tritium Production

Analysis of impacts on archaeological and historic resources is presented separately for construction and operations activities.

Construction

There are no known archaeological sites within the previously disturbed areas of the Bellefonte site. Historic resources would be unaffected, as all structures associated with the original Bellefonte town site have been removed since 1974, when it was determined that the site was eligible for placement on the National Register of Historic Places. The town site was not on TVA property, and the buildings were removed by non-TVA land owners. Before construction of the existing facilities at Bellefonte, the Alabama State Historic Preservation Office approved the design and indicated that no mitigation would be required (TVA 1997f).

Operation

No impacts to historic or archaeological resources would occur from tritium production activities at the Bellefonte site.

5.2.3.8 Socioeconomics

The socioeconomic impacts resulting from the completion and operation of the Bellefonte units are presented for Unit 1 and then for both units combined. Completion and operation of Bellefonte 2 without Bellefonte 1 is not considered a Reasonable Alternative (see Section 3.2.4).

5.2.3.8.1 Bellefonte 1

No Action

The No Action Alternative requires the continuation of the deferred status of Bellefonte 1. Therefore, no socioeconomic impacts are expected. Approximately 80 employees maintain the partially completed plant in its layup condition.

Tritium Production

Estimates of the staffing requirements needed to complete and operate Bellefonte 1 as a nuclear power plant for the production of tritium are presented as **Table 5–25**. About 12,800 person-years will be needed through the 5-year construction phase and 800 for plant operations. (The estimate of 12,800 takes into account the tendency to variation in employment throughout the construction period, especially in years 1 and 5, and thus does not reflect the total construction employment figure given in the table.) A comparison of peak staffing levels by year for the No Action Alternative and for the completion of Bellefonte 1 is provided as **Figure 5–1**.

Income estimates for construction and operations staff are based on a fully burdened labor cost of $91,000 per person-year, which is 30 percent higher than the estimated cost to complete and operate the facility as a nonnuclear plant. The high compensation reflects the requirements levels for many categories of nuclear construction and operations and provides increased revenues to the local economy.

Another potentially important socioeconomic benefit is the direct and indirect income associated with the procurement of equipment and supplies for completion of the plant. Millions of dollars would be added to the local economy during the construction and operations periods.

Table 5–25 Staffing for Completion and Operation of Bellefonte 1

Construction Year	*Staffing (Peak)*
1	1,500
2	2,700
3	4,100
4	4,500
5	2,600
6	800+ (operations begin)
7	800
8	800
9	800
10 to 40+	800

Sources: TVA 1998a, TVA 1997e.

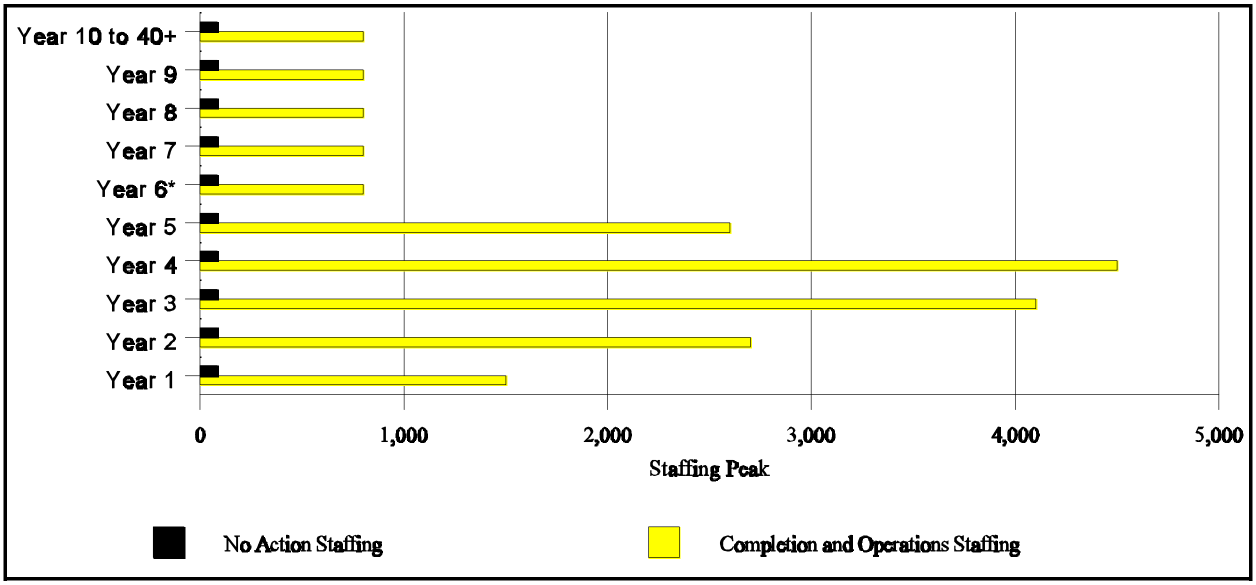


Figure 5–1 Staffing for Completion and Operation of Bellefonte 1, Compared to No Action from First Year of Construction

Source: TVA 1998a, TVA 1997e.
* Operations begin.

The largest impacts would be experienced in the Scottsboro-Hollywood area of Jackson County. A larger region of influence, which encompasses the commuting area, would have a lesser effect. The reasons for the concentration of socioeconomic impacts within Jackson County and Scottsboro-Hollywood are several: first, Scottsboro-Hollywood (population approximately 15,000) is the only densely populated area within Jackson County; second, due to the sparseness of the plant environs, local spending, and indirect income generation from that spending, would be concentrated in the Scottsboro-Hollywood area; third, procurement of goods and services by the plant and TVA outside Jackson County would be modest. Major impacts, such as those relating to schools and taxes, would be felt within the county but not within the region of influence outside the county.

Population and Housing

The completion of Bellefonte 1 would result in a temporary increase in population and income in the region of influence as a direct and indirect result of increased employment at the site. An estimated 33 percent of the construction workers and 50 percent of the operations workers would be expected to move into the area. This is consistent with the values in the *Final Environmental Impact Statement for the Bellefonte Conversion Project* (TVA 1997f).

Most construction workers prefer not to buy permanent housing. Their housing needs would include rental homes and apartments, mobile homes, and camper-trailers. Operations workers generally purchase permanent single-family housing. Up to 70 percent of all incoming construction workers and 90 percent of all operations workers would be expected to bring their families. That number could be appreciably lower than 70 percent, depending on the availability of rentals and the availability of trailer parks for camper-trailers. Residents of camper-trailers rarely bring their families. Currently, trailer parks near the Bellefonte site are close to capacity. A trailer park with an estimated capacity of 250 campers/trailers is planned for operation near the site in the fall of 1998. Additional trailer parks could be built in 3 to 4 months if construction activity at the plant increased rapidly. DOE is estimating maximum housing and, more importantly, school system impacts, on the expectation that up to 70 percent of construction workers moving into the area would bring their families.

About 75 percent of the construction workers and 90 percent of the operations workers would be expected to live in Jackson County. About 70 percent could be expected to live in the Scottsboro-Hollywood area, assuming housing were available. About 20 percent would likely be along Routes 79 and Route 72 in the valley between Guntersville and Bridgeport, with the remainder, scattered throughout the county.

The influx of construction and plant operations personnel, plus families, would increase the population of Jackson County by about 3,800, or more than 7 percent. This influx within a period of 4 years is about 70 percent greater in the seven years from 1990 through 1997. Within the Scottsboro-Hollywood area, the estimated peak of about 2,700 workers and family members would represent an 11 percent increase. Adding indirect employees and their families, the population influx into the Scottsboro-Hollywood area could be 15 to 20 percent at the peak. Peak population growth in Jackson County, including indirect employees and their families, would probably be no more than about 10 percent. Population impacts outside Jackson County would be negligible.

Completion of Bellefonte would likely produce a similar influx of renters and, to a lesser extent, home-buyers. The demand for housing would substantially exceed the number of available rental units and homes for sale in Jackson County. It would probably be met, for the most part, by the opening of new trailer parks near the plant and the expansion of existing parks elsewhere in the county. Permanent residents, including plant operators, would tend to favor single-family housing.

Employment and Income

Peak employment during construction has been estimated at 4,500. Average employment for construction workers during the construction phase would be about 2,400 per year. Operations workers would average 800 per year over the operational life of the plant. Indirect employment (e.g., food, retail, banking) could reach an average at least equal to the number of operations workers. During the construction phase indirect employment would be considerably higher. The effect of this change in employment at the county level (estimated workforce: 25,000) and Scottsboro-Hollywood (estimated workforce: 7,500) would be high. Unemployment in 1997 averaged 8.2 percent. This could decline by very roughly half over the first few years of construction and then likely stabilize at least two points below the average. The unemployment rate would not drop by as much as the employment requirements would suggest. As the construction project escalated and the labor market tightened, the labor pool would expand from the influx of inmigrating workers.

Total person-years of employment during construction, including operations staff, have been estimated at about 12,800 over the 5-year construction phase. This level of employment should generate about $1.15 billion in direct labor income (i.e., wages and benefits). A large fraction of the locally generated income would be spent locally, indirect economic impacts would be expected. By means of an income multiplier of 1.7, total regional income during the period has been estimated at $2.0 billion. This multiplier compares to the roughly 1.8 to 2.5 multipliers TVA used to estimate the impact of conversion of Bellefonte to a nonnuclear plant (TVA 1997f).

Regional income during the period of plant operation has been estimated at a minimum of $130 million per year. This estimate was developed using a multiplier of 1.8. The higher multiplier reflects the longer-term, more level injection of income into the region during operations than during construction.

Public Finance and Schools

Construction and operation of Bellefonte 1 as a nuclear unit would generate about $5.5 million per year in tax-equivalent payments (payments in-lieu-of-taxes) for Alabama. Tax revenues to the region of influence and Jackson County and, in part, to the Scottsboro-Hollywood area, are derived from real estate taxes, motor vehicle taxes, and motor vehicle and mobile home sales taxes. Income and sales taxes are collected at the state level. Jackson County collected approximately $9.4 million (roughly $200 per capita) in taxes in 1997.

Completion of the plant would affect the school systems of Jackson County and Scottsboro City. The county school system has approximately 6,500 students; the city system, approximately 3,000. Roughly two-thirds of the students (about 6,300) are in the Scottsboro-Hollywood area and the Guntersville-to-Bridgeport corridor, the major impact areas within the county and the region of influence. School facilities within the Scottsboro-Hollywood area and the Guntersville-Bridgeport corridor have the capacity to accommodate about 7,850 students. The peak influx of schoolchildren associated with inmigrating workers in the fourth year of construction would be an estimated 1,150 for the whole of Jackson County and 900–1,000 within the Scottsboro-Hollywood area and the Guntersville-Bridgeport corridor. DOE believes these estimates to be conservative. As discussed in the section on housing, more construction workers than expected could chose to live without their families in camper-trailers rather than with their families in apartments, mobile homes, or single-family homes. As a result, the increase in the number of new schoolchildren in the county would be lower than expected. The number of schoolchildren from the families of inmigrating workers would decline equally rapidly to about 325 from the sixth year onward.

The Scottsboro school transportation system operates 26 buses on a dual-route system and 8 on a single-route system. The system can currently accommodate about 4,080 students on a dual-route basis. Even an exclusively dual-route system would not accommodate the influx of students from families of inmigrating direct and indirect workers. The system capacity would be exceeded during the fourth year of construction. This shortfall could be addressed with several new buses and drivers.

One or two additional buses would be needed to accommodate all the students from families of inmigrating direct and indirect workers. The costs of redistricting would likely be greater than those of acquiring new buses and drivers. Overall, the Jackson County school transportation system would incur a greater impact than the Scottsboro system.

The combined Jackson County and Scottsboro Boards of Education receive about 40 percent of TVA's payment in-lieu-of-taxes. Completion of Bellefonte 1 would increase TVA's payment to about $5.5 million. Assuming that the 40 percent share were maintained, this would translate into a payment to the Jackson County and Scottsboro boards of about $2.2 million. Over the long term, a payment of $2.2 million would be around $1 million more than the increase in school costs attributable to students whose families directly support the operation of Bellefonte.

In the short term, however, construction of Bellefonte would impose costs averaging almost twice Jackson County's likely long-term receipts from the TVA payment. The TVA payment would not reach the $5.5 million level until plant operations had begun. Educational costs in the city school system would increase by an estimated $3.3 million per year, on average, for the four busiest years of the construction phase. This estimate includes the cost of hiring 45 additional teachers and the product of 638 students per year at an outlay of $5,120 per student (the 1995–1996 average). Instructional costs in the county system should increase by more than $1.6 million over the same period. This figure reflects the product of an average of 273 students per year and an outlay of $5,716 per student (the 1997–1998 average), and the cost of hiring 60 additional teachers and additional instructional support staff. Peak year costs would be about 25 percent higher than 4-year average costs. Assuming 3-percent-per-year increases in costs per student from the 1995–1996 average for the city and the 1997–1998 average for the county, average annual cost increases for the 4-year period beginning with the 1999 school year would be in the range of $3.7 million for Scottsboro and $1.7 million for Jackson County. These amounts approach 25 percent and 3 percent, respectively, of the existing Scottsboro and Jackson County school budgets. Costs for the first 2 years would be well below the 4-year average, however, and would allow a gradual phase-in of revenues and expenses to meet the added student population. The graphs in **Figures 5–2** and **5–3** reflect the projected budget requirements for the first 4 years of construction versus the No Action Alternative for the Scottsboro and Jackson County School Boards. To meet its expenses, the Scottsboro Board of Education could request additional funding from the state government.

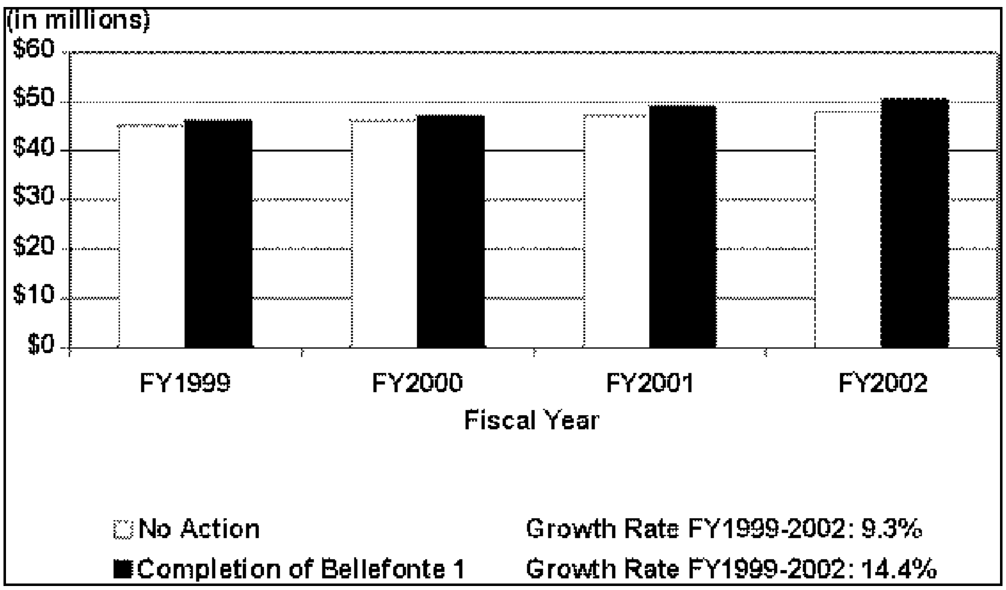


Figure 5–2 Scottsboro School Board Projected Budget, Completion of Bellefonte 1 Versus No Action Alternative (FY 1999-2002)

Source: Scottsboro 1998.

Additional tax revenues would also be generated by the increased economic activity involving the plant and plant workers. Such revenues (e.g., property taxes, income taxes, real estate transfer fees, sales taxes, motor vehicle taxes) are collected by or on behalf of the state government and then distributed to the jurisdictions.

The effect of an influx of families on other areas of public finance (e.g., fire, police, ambulance, hospitals) should be minimal. Additional and new equipment would be required for the police and fire departments, but these items could probably be accommodated within the overall expanding budgets arising from additional tax revenues and payments in-lieu-of-taxes.

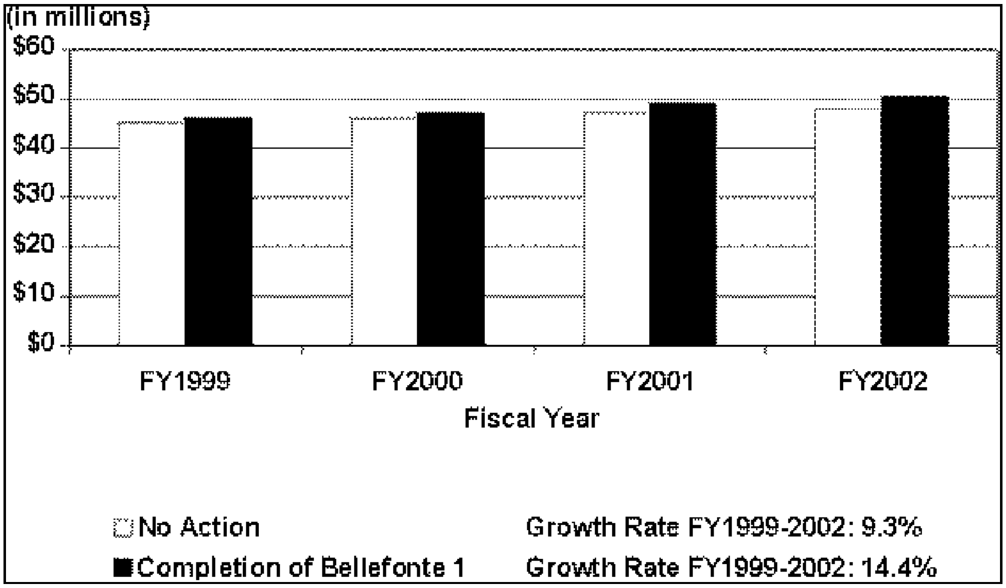


Figure 5–3 Jackson County School Board Projected Budget, Completion of Bellefonte 1 Versus No Action Alternative (FY 1999-2002)

Source: Scottsboro 1998.

Local Transportation

Traffic generated by construction activities associated with the completion of Bellefonte 1 could strain the capacity of the local road network. Traffic impacts during construction would be temporary and similar to the impacts described for the Bellefonte conversion project (TVA 1997f). During peak construction periods, U.S. Highway 72 could experience a 46 percent increase in traffic volume during morning and evening rush hours to the north, and a 48 percent increase in traffic volume to the south. Access roads to the Bellefonte site could experience more than an 80 percent increase in traffic volumes during these hours.

Increased traffic volume during plant operations, attributable both to the commuting of 800 additional plant employees and to truck transport requirements, would decrease the available capacity of site access roads during morning and evening rush hours. The impacts would be lower than those experienced during peak construction. During plant operations, U.S. Highway 72 could experience a 13 percent increase in traffic volume during morning and evening rush hours to the north, and a 14 percent increase in traffic volume to the south. Access roads to the Bellefonte site could experience a 43 to 59 percent increase in traffic volumes during these hours. Additional truck traffic during plant operations would include a total of 16 shipments of TPBARs to and from the plant per year.

Possible measures that could be used to mitigate traffic volume impacts are physical improvements to the local road or road network to increase capacity, including construction of additional vehicle lanes throughout road segments, construction of passing lanes in certain locations, or realignment to eliminate some of the no-passing zones. Employee programs that provide flexible hours could also reduce road travel during peak hours, and restrictions for trucks traveling during the peak hour could be made. Also, establishing employee programs and incentives for ride sharing could be encouraged and bus and/or vanpool programs could be initiated.

5.2.3.8.2 Bellefonte 1 and 2

No Action

The No Action Alternative requires continuation of the deferred status of Bellefonte 1 and 2. Therefore, no socioeconomic impacts are expected. Approximately 80 employees maintain the partially completed plant in its lay-up condition.

Tritium Production

Estimates of the staffing requirements needed to complete and operate Bellefonte 1 and 2 as nuclear power plant are presented as **Table 5–26**. About 15,600 person-years will be needed through the 6-year construction phase and 1,000 for plant operations. In terms of construction workers, completion of Bellefonte 1 and 2 is estimated to require about 10 percent more labor hours than for completion of Unit 1 alone, because all the common facilities were completed as part of Unit 1. Peak employment is about the same in either case, the additional Bellefonte 2–related employment occurring mainly in the fifth and sixth years of the construction program. A comparison of the peak staffing levels by year for the No Action Alternative and for the completion of Bellefonte 1 and Bellefonte 2 is provided in **Figure 5–4**.

Table 5–26 Staffing For Completion And Operation of Bellefonte 1 and Bellefonte 2

Construction Year	*Staffing (Peak)*
1	1,400
2	3,000
3	4,000
4	4,500
5	3,900 (Unit 1 operates)
6	2,000 (Unit 2 operates)
7	1,000
8	1,000
9	1,000
10 to 40+	1,000

Source: TVA 1998a.

Income estimates for construction and operations staff are based on a fully burdened labor cost of $91,000 per person-year, which is 30 percent higher than the estimated cost to complete and operate the facility as a nonnuclear plant. The high compensation reflects the requirements levels for many categories of nuclear construction and operations and provide increased revenues to the local economy.

Another potentially important socioeconomic benefit is the direct and indirect income associated with the procurement of equipment and supplies for completion of the plant. Millions of dollars would continue to be added to the local economy during the construction and operations period.

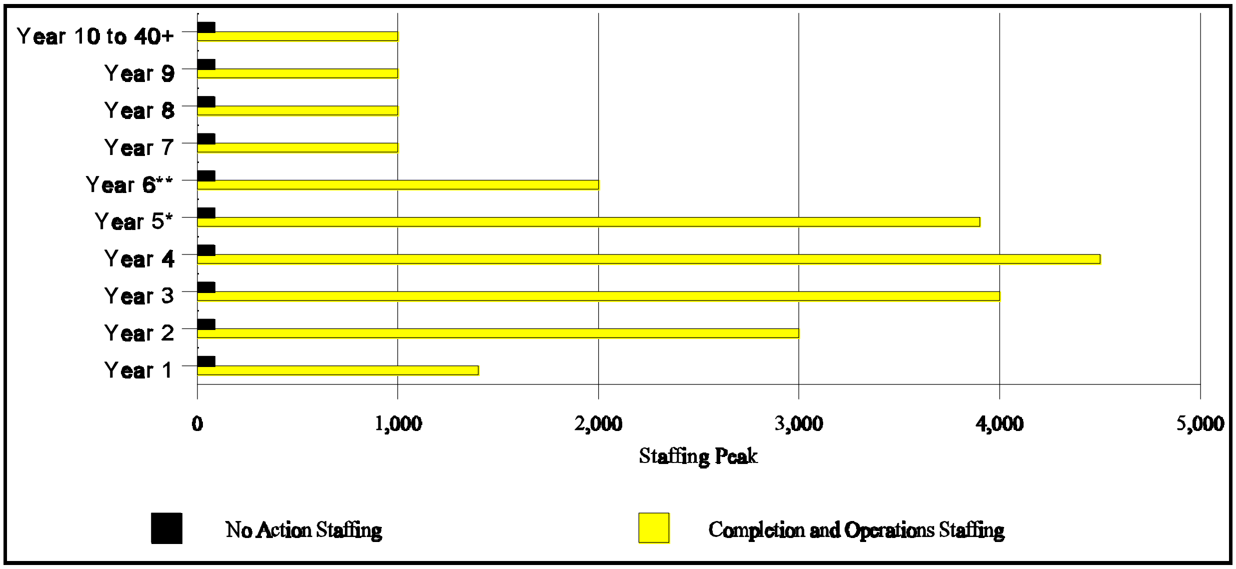


Figure 5–4 Staffing for Completion and Operation of Bellefonte 1 and 2, Compared to No Action from First Year of Construction

Sources: TVA 1998a, TVA 1997e.
* Operations at unit 1 begin.
** Operations at unit 2 begin.

The largest impacts would be experienced in the Scottsboro-Hollywood area of Jackson County. A larger region of influence, which encompasses the commuting area, would have a lesser effect. The reasons for the concentration of socioeconomic impacts within Jackson County and Scottsboro-Hollywood are several: first, Scottsboro-Hollywood (population approximately 15,000) is the only densely populated area within Jackson County; second, due to the sparseness of the plant environs, local spending, and indirect income generation from that spending, would be concentrated in the Scottsboro-Hollywood area; third, procurement of goods and services by the plant and TVA outside Jackson County would be modest. Major impacts, such as those relating to schools and taxes, would be felt within the county but not within the region of influence outside the county.

Population and Housing

The completion of Bellefonte 1 and Bellefonte 2 would result in a temporary increase in population and income in the region of influence as a direct and indirect result of increased employment at the site. An estimated 33 percent of the construction workers and 50 percent of the operations workers would be expected to move into the area. This is consistent with the values in the *Final Environmental Impact Statement for the Bellefonte Conversion Project* (TVA 1997f).

Most construction workers prefer not to buy permanent housing. Their housing needs would include rental homes and apartments, mobile homes, and camper-trailers. Operations workers generally purchase permanent single-family housing. Up to 70 percent of all incoming construction workers and 90 percent of all operations workers would be expected to bring their families. That number could be appreciably lower than 70 percent, depending on the availability of rentals and the availability of trailer parks for camper-trailers. Residents of camper-trailers rarely bring their families. Currently, trailer parks near the Bellefonte site are close to capacity. A trailer park with an estimated capacity of 250 campers/trailers is planned for operation near the site in the fall of 1998. Additional trailer parks could be built in 3 to 4 months if construction activity at the plant increased rapidly.

DOE is estimating maximum housing and, more importantly, school system impacts, on the expectation that up to 70 percent of construction workers moving into the area would bring their families.

About 75 percent of the construction workers and 90 percent of the operations workers who moved would be expected to live in Jackson County. About 70 percent could be expected to live in the Scottsboro-Hollywood area, assuming housing were available. About 20 percent would likely to be along Route 79 and Route 72 in the valley between Guntersville and Bridgeport with the remainder, scattered throughout the county.

The influx of construction and plant operations personnel, plus families, would increase the population of Jackson County by about 4,100, or more than 8 percent. This influx within a period of 4 years is almost 95 percent greater in the seven years from 1990 through 1997. Within the Scottsboro-Hollywood area, the estimated peak population influx of about 2,900 workers and family members would represent a 12 percent increase. Adding indirect employees and their families, the population influx into the Scottsboro-Hollywood area could approach 20 percent at the peak. Peak population growth in Jackson County, including indirect employees and their families, would probably be no more than about 12 percent. Population impacts outside Jackson County would be small.

Completion of Bellefonte would likely produce an influx of renters and, to a lesser extent, home-buyers. The demand for housing would substantially exceed the number of available rental units and homes for sale in Jackson County. It would probably be met, for the most part, by the opening of new trailer parks near the plant and the expansion of existing parks elsewhere in the county. Permanent residents, including plant operators, would tend to favor single-family housing.

Employment and Income

Peak employment during construction has been estimated at 4,500. Average employment during the middle 4 years of the construction phase would be about 3,300 per year. Operations workers would average 1,000 per year over the operational life of the plant. Indirect employment (e.g., food, retail, banking) could reach an average at least equal to the number of operations workers. During the construction phase indirect employment would be considerably higher. The effect of this change in employment in Jackson County (estimated workforce: 25,000) and Scottsboro-Hollywood (estimated workforce: 7,500) would be high. Unemployment in 1997 averaged 8.2 percent. This would be expected to decline to perhaps 3 percent over the first few years of construction and then stabilize at least two points below the average. The unemployment rate would not drop by as much as the employment requirements would suggest. As the construction project escalated and the labor market tightened, the labor pool would expand from the influx of inmigrating workers.

Total person-years of employment during construction, including operations staff, have been estimated at about 15,600 over the 6-year construction phase. This level of employment should generate about $1.4 billion in direct labor income (i.e., wages and benefits). A large fraction of the locally generated income would be spent locally, indirect economic impacts would be expected. By means of an income multiplier of 1.7, total regional income during the period has been estimated at $2.4 billion. This multiplier compares to the roughly 1.8 to 2.5 multipliers TVA used to estimated the impact of conversion of the Bellefonte Nuclear Plant to a nonnuclear plant (TVA 1997e).

Regional income during the period of plant operation has been estimated at a minimum of $160 million per year. This estimate was developed using a multiplier of 1.8. The higher multiplier reflects the longer-term, more level injection of income into the region during operations than during construction.

Public Finance and Schools

Construction and operation of Bellefonte 1 and 2 as a nuclear plant would generate more than $8 million per year in tax-equivalent payments (payments in-lieu-of-taxes) for Alabama. Tax revenues to the region of influence and Jackson County and, in part, to the Scottsboro-Hollywood area are derived from real estate taxes, motor vehicle taxes, and motor vehicle and mobile home sales taxes. Income and sales taxes are collected at the state level. Jackson County collected approximately $9.4 million (roughly $200 per capita) in taxes in 1997.

Completion of the plant would affect the school systems of Jackson County and Scottsboro City. The Jackson County school system has approximately 6,500 students; the city system, approximately 3,000. Roughly two-thirds of the students (about 6,300) are in the Scottsboro-Hollywood area and the Guntersville-to-Bridgeport corridor, the major impact areas within the county and the region of influence. School facilities within the Scottsboro-Hollywood area and Guntersville-Bridgeport corridor have the capacity to accommodate about 7,850 students. The peak influx of schoolchildren associated with inmigrating workers in the fourth year of construction would be just over 1,200 for the whole of Jackson County and probably about 1,000–1,100 within the Scottsboro-Hollywood area and the Guntersville-Bridgeport corridor. DOE believes these estimates to be conservative. As discussed in the section on housing, more construction workers than expected could chose to live without their families in camper-trailers rather than with their families in apartments, mobile homes, or single-family homes. As a result, the increase in the number of new schoolchildren in the county would be lower than expected. The number of schoolchildren from the families of inmigrating workers would decline equally rapidly to about 400 from the sixth year onward.

The Scottsboro school transportation system operates 26 buses on a dual-route system and 8 on a single-route system. The system can currently accommodate about 4,080 students on a dual-route basis. Even an exclusively dual-route system would not accommodate the influx of students from families of inmigrating direct and indirect workers. The system capacity would be exceeded during the fourth year of construction. This shortfall could be addressed with several new buses and drivers.

Several additional buses would be needed to accommodate all the students from families of inmigrating direct and indirect workers. The costs of redistricting would likely be greater than those of acquiring new buses and drivers. Overall, the Jackson County school transportation system would incur a greater impact than the Scottsboro system.

The combined Jackson County and Scottsboro Boards of Education receive about 40 percent of TVA's payment in-lieu-of-taxes. Completion of Bellefonte 1 and 2 would increase TVA's payment to about $8 million. Assuming that the 40 percent share were maintained, this would translate into a payment to the Jackson County and Scottsboro boards of about $3.2 million. Over the long term, a payment of $3.2 million would be around $1 million more than the increase in school costs attributable to students whose families directly support the operation of Bellefonte.

In the short term, however, construction of Bellefonte would impose costs averaging almost twice Jackson County's likely long-term receipts from the TVA payment. The TVA payment would not reach the $8 million level until plant operations had begun. Educational costs in the city school system would increase by an estimated $3.7 million per year, on average, for the four busiest years of the construction phase. This estimate includes the cost of hiring 50 additional teachers and the product of 732 students at an outlay of $5,716 per student (the 1997–1998 average). Instructional costs in the county system should increase by more than $1.8 million over the same period. This figure reflects the product of an average of 305 students per year and an outlay of $5,716 per student (the 1997–1998 average), and the cost of hiring 65 additional teachers and instructional support staff. Peak year costs would be about 16 percent higher than 4-year average costs. Assuming 3-percent-per-year increases in costs per student from the 1995–1996 average for the city and the 1997–1998 average for the county, average annual cost increases for the 4-year period starting with the 1999 school year would be in the range of $4.2 million for Scottsboro and $1.9 million for Jackson County. These amounts exceed 30 percent and 5 percent, respectively of the existing Scottsboro and Jackson County school budgets. Costs for the first 2 years would be well below the 4-year average, however, and would allow a gradual phase-in of revenues and expenses to meet the added student population. The graphs in **Figures 5–5** and **5–6** reflect the projected budget requirements for the first 4 years of construction versus the No Action Alternative for the Scottsboro and Jackson County School Boards. These growth rates are similar to those for the case in which only Unit 1 is completed, as the differential impacts of completing Unit 2 become greater in the fifth year of construction. To meet its expenses, the Scottsboro Board of Education could request additional funding from the state government.

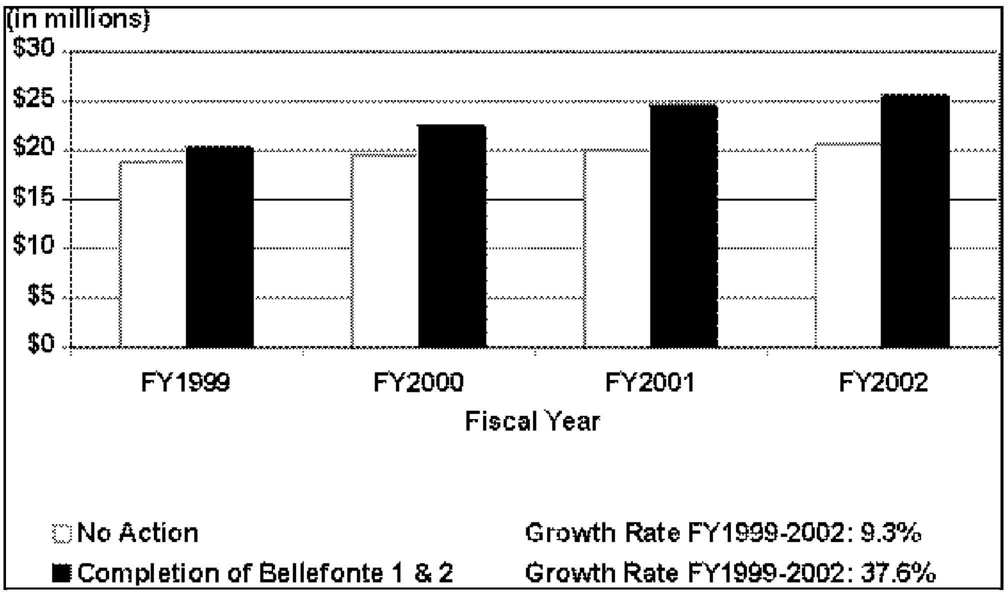


Figure 5–5 Scottsboro School Board Projected Budget, Completion of Bellefonte 1 and 2 versus No Action Alternative (FY 1999-2002)

Source: Scottsboro 1998.

Additional tax revenues would also be generated by the increased economic activity involving the plant and plant workers. Such revenues (e.g., property taxes, income taxes, real estate transfer fees, sales taxes, motor vehicle taxes) are collected by or on behalf of the state government and then distributed to the jurisdictions.
The effect of an influx of families on other areas of public finance (e.g., fire, police, ambulance, hospitals) should be minimal. Additional and new equipment would be required for the police and fire departments, but these items could probably be accommodated within the overall expanding budgets arising from additional tax revenues and payments in-lieu-of-taxes.

Local Transportation

Traffic generated by construction activities associated with the completion of Bellefonte 1 and Bellefonte 2 could strain the capacity of the local road network. Traffic impacts during construction would be temporary and similar to the impacts described for the Bellefonte conversion project (TVA 1997f). During peak construction periods, U.S. Highway 72 could experience a 46 percent increase in traffic volume during morning and evening rush hours to the north, and a 48 percent increase in traffic volume to the south. Access roads to the Bellefonte site could experience more than an 80 percent increase in traffic volumes during these hours.

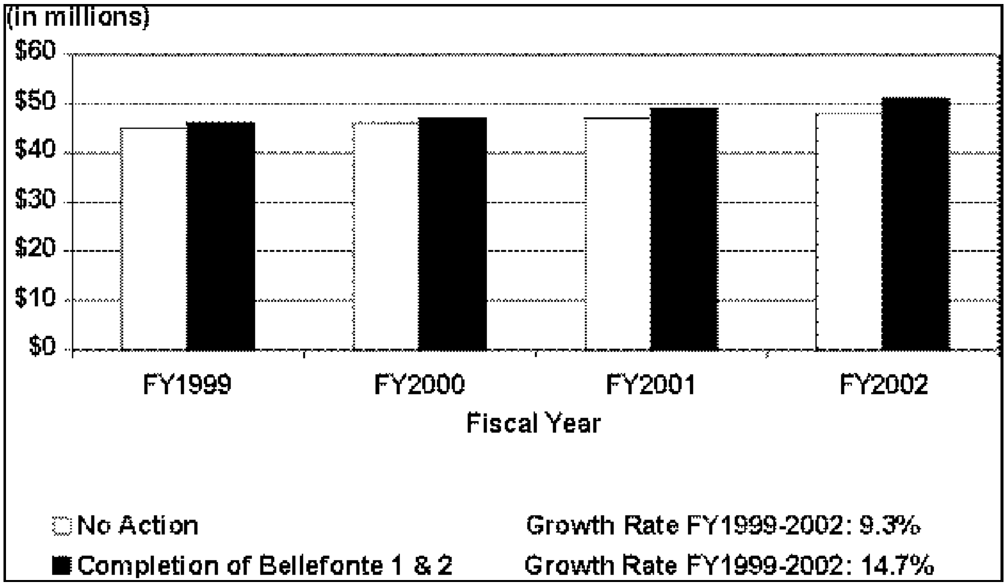


Figure 5–6 Jackson County School Board Projected Budget, Completion of Bellefonte 1 and 2 versus No Action Alternative (FY 1999-2002)

Source: Scottsboro 1998.

Increased traffic volume during plant operations, attributable both to the commuting of 1,000 additional plant employees and to truck transport requirements, would decrease the available capacity of site access roads during morning and evening rush hours. The impacts would be lower than those experienced during peak construction. During plant operations, U.S. Highway 72 could experience a 16 percent increase in traffic volume during morning and evening rush hours to the north, and a 17 percent increase in traffic volume to the south. Access roads to the Bellefonte site could experience a 48 to 64 percent increase in traffic volumes during these hours. Additional truck traffic during plant operations would include a total of 16 shipments of TPBARs to and from the plant per year.

Possible measures that could be used to mitigate traffic volume impacts are physical improvements to the local road or road network to increase capacity, including construction of additional vehicle lanes throughout road segments, construction of passing lanes in certain locations, or realignment to eliminate some of the no-passing zones. employee programs that provide flexible hours could also reduce road travel during peak hours, and restrictions for trucks traveling during the peak hour could be made. also, establishing employee programs and incentives for ride sharing could be encouraged and bus and/or vanpool programs could be initiated.

5.2.3.9 Public and Occupational Health and Safety

This section describes the impacts of radiological and hazardous chemical releases resulting from the construction activities required to complete the units, and the normal operation or accidents due to tritium production at Bellefonte 1 or both Bellefonte 1 and Bellefonte 2. A description of the impacts of normal operations is followed by a description of the impacts of facility accidents.

5.2.3.9.1 Normal Operation

RADIOLOGICAL IMPACTS

The annual gaseous radioactive emissions and liquid radioactive effluents from the production of tritium at Bellefonte 1 are presented in Sections 5.2.3.3 and 5.2.3.4, respectively. Presented in **Table 5–27** are the

Table 5–27 Annual Radiological Impacts from Incident-Free Tritium Production Operations at Bellefonte 1

Tritium Production	Release Media	Maximally Exposed Offsite Individual		Population Within 80 km (50 mi) for the Year 2025	
		Dose (millirem)	Latent Fatal Cancer Risk	Dose (person rem)	Latent Fatal Cancers
No Action (not operating)	Air	0	0	0	0
	Liquid	0	0	0	0
	Total	0	0	0	0
0 TPBARs [a] (operation without tritium production)	Air	0.25	1.3×10^{-7}	0.27	0.00014
	Liquid	0.012	6.0×10^{-9}	1.1	0.00055
	Total	0.26	1.4×10^{-7}	1.4	0.00069
Incremental dose for 1,000 TPBARs	Air	0.032	1.6×10^{-8}	2.1	0.0011
	Liquid	0.021	1.1×10^{-8}	2.3	0.0012
Total dose for 1,000 TPBARs [b]	Air	0.28	1.4×10^{-7}	2.4	0.0012
	Liquid	0.033	1.7×10^{-8}	3.4	0.0017
	Total	0.31	1.6×10^{-7}	5.8	0.0029
Incremental dose for 3,400 TPBARs	Air	0.037	1.9×10^{-8}	2.5	0.0013
	Liquid	0.023	1.2×10^{-8}	2.6	0.0013
Total dose for 3,400 TPBARs[b]	Air	0.29	1.5×10^{-7}	2.8	0.0014
	Liquid	0.035	1.8×10^{-8}	3.7	0.0019
	Total	0.32	1.6×10^{-7}	6.5	0.0033

[a] AEC 1974.

[b] The total values are a summation of incremental impacts attributable to tritium production and estimated Bellefonte 1 operational impacts.

Note: The impact from Bellefonte 1 and Bellefonte 2 operation would be twice that for Bellefonte 1.

radiological impacts of both gaseous and liquid radioactive releases on the maximally exposed offsite individual and on the general public living within 80 kilometers (50 miles) of Bellefonte 1 in the year 2025. **Table 5–28** provides the radiological impacts on the facility workers. A facility worker is defined as any "monitored" reactor plant employee. Doses to these workers would be kept to minimal levels through ALARA programs. The tables include the impacts of the No Action Alternative and, for comparison purposes, the estimated radiological impacts of operation of the Bellefonte units without tritium production (0 TPBARs). These values are based on the Bellefonte Final Environmental Statement (AEC 1974). Based on actual experience at Watts Bar 1 and Sequoyah 1 and 2 (see Tables 5–3 and 5–10), the actual values are expected to be lower.

Background information on the effects of radiation to human health and safety is included in Appendix C. The calculation method and assumptions are presented in Appendix C, Section C.3.

No Action

Under the No Action Alternative, the health and safety risk of members of the public and facility workers at Bellefonte 1 would remain at the level associated with the natural background radiation.

Table 5–28 Annual Radiological Impacts to Workers from Incident-Free Tritium Production Operations at Bellefonte 1

Impact	*No Action[a]*	*0 TPBARs[b]*	*1,000 TPBARs*	*Total With 1,000 TPBARs[c]*	*3,400 TPBARs*	*Total With 3,400 TPBARs[c]*
Average worker dose (millirem)[d]	0	104	5.4	109	6.2	110
Latent fatal cancer risk	0	4.2×10^{-5}	2.2×10^{-6}	4.4×10^{-5}	2.5×10^{-6}	4.4×10^{-5}
Total worker dose (person-rem)	0	112	5.8	118	6.7	119
Latent fatal cancers	0	0.045	0.0023	0.047	0.0027	0.048

[a] These no action values represent the absence of impacts associated with the non-operational status of Bellefonte.
[b] 0 TPBAR entry is included for consistency with the Watts Bar and Sequoyah Nuclear Plant analyses.
[c] These values are a summation of incremental impacts and estimated single Bellefonte unit operational (baseline) impacts. "Baseline" impacts are defined as those impacts which result from normal plant (design specification) operation (i.e., operations without tritium production activities).
[d] Based on 1,073 badged workers.
Note: The impact from Bellefonte 1 and Bellefonte 2 is twice that for Bellefonte 1.
Sources: TVA 1998d, TVA 1998e.

Tritium Production

Construction

During construction, no radioactive materials would be handled. Therefore, there would be no radiological impacts on the worker and the general population.

Operation

During tritium production, the health and safety risk of the public and facility workers would increase as a function of Bellefonte's normal operation as a nuclear reactor facility and the estimated releases of tritium in gaseous emissions and liquid effluents. As shown in Tables 5–27 and 5–28, for 3,400 TPBARs in the reactor core and assuming two failed TPBARs:

> The annual dose to the maximally exposed offsite individual would be 0.32 mrem/yr, with an associated 1.6×10^{-7} latent cancer fatality per year of operation. This dose is 1.3 percent of the annual total dose limit of 25 millirem set by regulations in 40 CFR 190.
>
> The collective dose to the population within 50 miles of Bellefonte 1 would be 6.5 person-rem/yr, with an associated 0.0033 latent cancer fatality per year of operation.
>
> The collective dose to the facility workers would be 119 person-rem/yr, with an associated 0.048 latent cancer fatality per year of operation. It should be noted that the assumption of two failed TPBARs in the reactor core dominates the incremental increase in worker dose due to tritium production.

Based on experience with stainless steel–clad boron burnable absorber rods, this assumption is very conservative (WEC 1998).

HAZARDOUS CHEMICAL IMPACTS

No Action

Under the No Action Alternative, no additional impacts on public and occupational health and safety from exposure to hazardous chemicals are anticipated at Bellefonte beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Analysis of impacts on public and occupational health and safety from exposure to hazardous chemicals is presented separately for construction and operations activities.

Construction

Construction activities at the Bellefonte Nuclear Plant could release a number of hazardous chemicals to the atmosphere, as discussed in Section 5.2.3.3 and presented in Table 5–16. The estimated annual and daily airborne concentrations of these chemicals at the location of the maximally exposed offsite individual during construction of both Bellefonte 1 and Bellefonte 2 are presented in **Table 5–29.** Airborne concentrations were estimated using the method described in Section 5.2.3.3 and Appendix C, Section C.4. Table 5–29 also presents the EPA inhalation cancer unit risk factor values for the carcinogenic chemicals (i.e., formaldehyde, arsenic, beryllium, cadmium, chromium, and nickel) and the Reference Concentration (RfC) values for the noncarcinogenic chemicals (i.e., beryllium, manganese, and mercury). Application of the estimated airborne concentrations to the chemical-specific inhalation cancer unit risk factor and RfC values, as described in Section C.4, enables estimation of the potential adverse health effects for the maximally exposed offsite individual. For the noncarcinogens, these estimates are chemical-specific Hazard Quotient values; for the carcinogens, probabilities of excess latent cancer incidence. Both types of estimates are also presented in Table 5–29.

For the noncarcinogenic chemicals, the chemical-specific Hazard Quotient values are summed to generate a Hazard Index value. Hazard Index values lower than 1 suggest that the offsite receptor would not likely experience adverse noncancer health effects as a result of the exposure. The Hazard Index value for the noncarcinogenic chemicals presented in Table 5–29 is 0.03.

The highest probability estimate for excess latent cancer incidence presented in Table 5–29 (2×10^{-7} for chromium) is lower than the 1 in 1 million established by EPA as the lower bound of concern. This value suggests that exposure to chromium released from construction activity would result in 2 in 10 million additional chances of cancer incidence for the maximally exposed offsite individual. This estimate is actually higher than would be expected, because all of the released chromium was conservatively assumed to be in the form of chromium VI, which is carcinogenic. Actual releases of chromium would also include some amount of chromium III, which is not carcinogenic.

Operation

During normal operation, the Bellefonte Nuclear Plant could release a number of toxic chemicals to the atmosphere. These chemicals, discussed in Section 5.2.3.3 (Table 5–18), include carcinogenic (i.e., benzene, acetaldehyde, formaldehyde, arsenic, cadmium, chromium VI, and nickel) and noncarcinogenic (i.e., toluene, acetaldehyde, acrolein, manganese, and mercury) substances. The annual and daily airborne concentrations of these chemicals were estimated at the location of the maximally exposed offsite individual using the method described in Section 5.2.3.3 and Appendix C, Section C.4. The concentrations from the operation of both Bellefonte 1 and Bellefonte 2 are presented in **Table 5–30**. The table presents the EPA's inhalation cancer

Table 5–29 Cancer and Noncancer Adverse Health Impacts from Exposure to Hazardous Chemicals at Bellefonte 1 and Bellefonte 2 During Construction

Chemical	*Estimated Annual Airborne Concentration[a] ($\mu g/m^3$)*	*Estimated Daily Airborne Concentration[a] ($\mu g/m^3$)*	*Reference Concentration (RfC)[b] ($\mu g/m^3$)*	*Cancer Inhalation Unit Risk Factor[c] (cancers/($\mu g/m^3$))*	*Hazard Quotient (HQ)[d]*	*MEI Cancer Incidence Probability[e]*
Formaldehyde	8.5×10^{-5}	0.031	N/A	0.000013	N/A	1×10^{-9}
Arsenic	9×10^{-7}	0.0003	N/A	0.0043	N/A	4×10^{-9}
Beryllium	5×10^{-7}	0.0002	0.02	0.0024	0.01	1×10^{-9}
Cadmium	2.3×10^{-6}	0.00083	N/A	0.0018	N/A	4×10^{-9}
Chromium	1.4×10^{-5}	0.005	N/A	0.012	N/A	2×10^{-7}
Manganese	2.9×10^{-6}	0.001	0.05	N/A	0.02	N/A
Mercury	6×10^{-7}	0.0002	0.3	N/A	0.0007	N/A
Nickel	3.6×10^{-5}	0.013	N/A	0.00048	N/A	2×10^{-8}

[a] Reference Concentration (RfC) values are estimates, with uncertainty spanning perhaps an order of magnitude, of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime. Values are developed by the U.S. Environmental Protection Agency, as reported in EPA 1997a and 1998.
[b] Cancer Inhalation Unit Risk Factors are estimates of the cancer potency of carcinogens by the inhalation route of exposure. Values are developed by the U.S. Environmental Protection Agency, as reported in EPA 1997a and 1998.
[c] Estimates of annual and daily airborne concentrations developed by Industrial Source Complex (ISC3) air dispersion model. See Appendix C, Section C.4 for additional information.
[d] Hazard Quotient (HQ) estimates are developed by dividing the estimated daily airborne concentration by the RfC. HQ estimates are chemical-specific measures of potential noncancer health effects. The Hazard Index (HI) is the sum of the HQ values. HI values of less than one suggest low concern for noncancer effects as a result of the exposure, whereas, HI values of greater than one suggest a potential for noncancer effects.
[e] Offsite population maximally exposed individual (MEI) cancer incidence probability is estimated by multiplying the estimated annual airborne concentration by the cancer inhalation unit risk factor. See Appendix C, Section C.4 for additional information.
N/A = not applicable

unit risk factor values for the carcinogens and the RfC values for the noncarcinogens. Also presented are the chemical-specific Hazard Quotient estimates for noncarcinogens and the probability estimates for excess latent cancer incidence for carcinogens.

The sum of all of the Hazard Quotient estimates is called the Hazard Index. Hazard Index values lower than 1 suggest that the offsite receptor would not likely experience adverse noncancer health effects as a result of the exposure. The Hazard Index value for the noncarcinogenic chemicals presented in Table 5–30 is 0.1, considerably lower than 1.

The only probability of excess latent cancer incidence greater than 1 in 1 million (the lower EPA bound for concern) is the probability attributed to chromium VI: 3 in 1 million (3×10^{-6}). However, all the chromium was conservatively assumed to be in the form of chromium VI, which is carcinogenic. Actual releases of chromium would also include some amount of chromium III, which is not carcinogenic.

The health risk estimates presented in Table 5–30 assume that the airborne pathway would be the exposure route of most importance because aqueous waste streams would be treated before release to potable water sources. Health risks were not estimated for facility workers because their exposures to hazardous chemicals would likely be kept within the occupational safety limits established by Occupational Safety and Health Administration and the American Conference of Governmental Industrial Hygienists, Inc., through the use of personal protective equipment and engineering controls.

Table 5–30 Cancer and Noncancer Adverse Health Impacts from Exposure to Hazardous Chemicals at Bellefonte 1 and Bellefonte 2 During Normal Operation

Chemical	*Estimated Annual Airborne Concentration[a] (μg/m³)*	*Estimated Daily Airborne Concentration[a] (μg/m³)*	*Reference Concentration[b] (RfC) (μg/m³)*	*Cancer Inhalation Unit Risk Factor[c] (cancers/(μg/m³))*	*Hazard Quotient (HQ)[d]*	*MEI Cancer Incidence Probability[e]*
Benzene	0.0002	0.15	N/A	8.3×10^{-6}	N/A	2×10^{-9}
Toluene	0.00008	0.06	400	N/A	0.0002	N/A
Formaldehyde	0.0015	0.085	N/A	0.000013	N/A	2×10^{-8}
Acetaldehyde	9×10^{-6}	0.012	9	2.2×10^{-6}	0.0013	2×10^{-11}
Acrolein	2.5×10^{-6}	0.002	0.02	N/A	0.1	N/A
Arsenic	0.000015	0.00062	N/A	0.0043	N/A	6×10^{-8}
Cadmium	0.000039	0.0016	N/A	0.0018	N/A	7×10^{-8}
Chromium VI	0.00024	0.0098	N/A	0.012	N/A	3×10^{-6}
Manganese	0.00005	0.002	0.05	N/A	0.04	N/A
Mercury	0.000011	0.00044	0.3	N/A	0.001	N/A
Nickel	0.0006	0.025	N/A	0.00048	N/A	3×10^{-7}

[a] Estimates of annual and daily airborne concentrations developed by Industrial Source Complex (ISC3) air dispersion model. See Appendix C, Section C.4 for additional information. Note that 24-hour maximum daily concentrations were used to calculate Hazard Quotient values in order to be conservative.
[b] Reference Concentration (RfC) values are estimates, with uncertainty spanning perhaps an order of magnitude, of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime. Values are developed by the U.S. Environmental Protection Agency, as reported in EPA 1997a.
[c] Cancer Inhalation Unit Risk Factors are estimates of the cancer potency of carcinogens by the inhalation route of exposure. Values are developed by the U.S. Environmental Protection Agency, as reported in EPA 1997a.
[d] Hazard Quotient (HQ) estimates are developed by dividing the estimated daily airborne concentration by the RfC. HQ estimates are chemical-specific measures of potential noncancer health effects. The Hazard Index (HI) is the sum of the HQ values. HI values of less than one suggest low concern for noncancer effects as a result of the exposure, whereas, HI values of greater than one suggest a potential for noncancer effects.
[e] Offsite population maximally exposed individual (MEI) cancer incidence probability is estimated by multiplying the estimated annual airborne concentration by the cancer inhalation unit risk factor. See Appendix C, Section C.4 for additional information.
N/A = not applicable

ENERGIZING TRANSMISSION LINES FROM BELLEFONTE 1 AND BELLEFONTE 2

No Action

Under the No Action Alterative, construction of Bellefonte 1 and Bellefonte 2 would not be completed. The transmission lines from the plant switchyard would not be energized to transmit power, and thus no impacts would be expected.

Tritium Production

The operation of Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 as commercial light water reactors would require the activation of the electric power transmission lines that have already been installed. The Bellefonte Final Environmental Statement (AEC 1974) addressed the environmental impacts of transmission lines. Issues associated with their activation include ozone from corona effects, compatibility with communications equipment, and electromagnetic field effects.

Ozone can be produced from corona discharges (ionization of the air) in the operation of transmission lines and substations, particularly at the higher voltages. It can be harmful if breathed in sufficient concentrations over prolonged periods. However, it is not considered to be injurious to vegetation, animals, and humans unless concentrations exceed 0.05 part per million. According to the Bellefonte Final Environmental Statement, any levels of ozone that could reasonably be expected to be generated by Bellefonte's transmission lines would be environmentally inconsequential.

High-voltage power lines operating close to telephone and signaling equipment can produce undesirable effects on the communication circuit through inductive coupling. However, it is TVA's normal practice to send transmission line vicinity maps to railroad and telephone companies having tracks or communication lines in the general area of proposed power lines for the purpose of making inductive coordination studies. If corrective action is indicated, the problem is jointly studied and any required changes mutually resolved (AEC 1974).

During the past two decades, the potential role of electromagnetic fields (EMFs) in causing or promoting cancer or other adverse health effects has been the subject of scientific investigation and public concern. If Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 were selected for production of tritium, electric power lines to the plant would be activated. Like all such lines, the power lines to Bellefonte would act as a source of weak, extremely low frequency electrical and magnetic fields. While research in EMF health effects is continuing, there is no conclusive scientific evidence of a "significant" link between cancer and power line fields. In 1995, the American Physical Society (APS 1995) concluded that: "While it is impossible to prove that no deleterious health effects occur form exposure to any environmental factor, it is necessary to demonstrate a consistent, significant, and casual relationship before one can conclude that such effects do occur. From this standpoint, the conjectures relating cancer to power line fields have not been scientifically substantiated." In response to a Congressional request to review the literature concerning potential EMF health effects, the National Academy of Sciences (NAS 1996) observed: "Based on a comprehensive evaluation of published studies relating to the effects of power-frequency electric and magnetic fields on cells, tissues, and organisms (including humans), the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard." While the TVA recognizes that continuing research may establish a credible link between adverse health effects and exposure to power line fields, it has concluded that no mitigation of potential EMF health effects would be implemented at the Bellefonte site until such a link was conclusively established through scientific investigation.

5.2.3.9.2 Facility Accidents

RADIOLOGICAL IMPACTS

The accident set selected for evaluation of impacts of the No Action Alternative and tritium production are described in Section 5.1 and discussed in detail in Appendix D, Section D.1. The consequences of the reactor and nonreactor design-basis accidents at Bellefonte 1 for the no tritium production (0 TPBARs) and for maximum tritium production (3,400 TPBARs) were estimated using the NRC-based deterministic approach presented in the *Bellefonte Nuclear Plant Final Safety Analysis Report* (TVA 1991), the receptors being an individual at the reactor site exclusion area boundary and an individual located at the reactor site low- population zone. The margin of safety for site dose criteria associated with the same accidents and the same receptors are presented in **Table 5–31.** Data presented for no tritium production case were extracted directly from the *Bellefonte Nuclear Plant Final Safety Analysis Report*. As indicated in **Table 5–32,** the irradiation of TPBARs at Bellefonte 1 would result in a very small increase in design-basis accident consequences and thus a reduction in the consequence margin. The accident consequences would be dominated by the effects of the same nuclide releases inherent to operation without tritium production. If constructed, Bellefonte 2 accident consequences would be the same as those for Bellefonte 1.

Table 5–32 presents risks of the postulated set of accidents with mean (50 percent) meteorological conditions to the maximally exposed offsite individual, an average individual in the public within an 80-kilometer (50-mile) radius of the reactor site, and a noninvolved worker 640 meters (0.4 mile) from the release point. Accident consequences to the same receptors are summarized in **Table 5–33**. The assessment of dose and the

Table 5–31 Design-Basis Accident Consequence Margin to Site Dose Criteria at Bellefonte 1

Accident	Tritium Production	Dose Description [a]	Site Dose Criteria (rem) [b]	Individual at Area Exclusion Boundary		Individual at Low Population Zone	
				Dose (rem)	Margin (%) [c]	Dose (rem)	Margin (%) [c]
Reactor design-basis accident	0 TPBARs [d]	Thyroid inhalation dose	300	5.8	98.1	2.7	99.1
		Beta + gamma whole body dose	25	0.031	99.9	0.18	99.3
	3,400 TPBARs	Thyroid inhalation dose	300	5.9	98.0	2.7	99.1
		Beta + gamma whole body dose	25	0.032	99.9	0.18	99.3
Nonreactor design-basis accident	0 TPBARs [d]	Thyroid inhalation dose	300	0.0067	99.998	0.0019	99.999
		Beta + gamma whole body dose	25	0.71	97.2	0.14	99.4
	3,400 TPBARs	Thyroid inhalation dose	300	0.13	99.96	0.027	99.991
		Beta + gamma whole body dose	25	0.72	97.1	0.14	99.4

[a] Dose is the total dose from the reactor plus the contribution from the TPBARs.
[b] 10 CFR 100.11.
[c] Margin below the site dose criteria.
[d] TVA 1991.

associated cancer risk to the noninvolved worker is not applicable for beyond-design-basis accidents. A site emergency would have been declared early in the accident sequence, all nonessential site personnel would have evacuated the site in accordance with site emergency procedures before any radiological release to the environment, and in accordance with emergency action guidelines, the public within 16.1 kilometers (10 miles) of the plant would have been evacuated.

Presented in Tables 5–32 and 5–33 are the risks and consequences without tritium production (0 TPBAR) and with maximum tritium production (3,400 TPBARs) for severe reactor accidents. The tritium release is governed by the nature of the core melt accident scenarios analyzed, and the accident risks and consequences by actions taken in accordance with the EPA Protective Action Guidelines (e.g., evacuation of the public, interdiction of the food and water supply, condemnation of farmland and public property) in response to the postulated core melt accident with containment failure or containment bypass.

The severity of the reactor accident dominates the consequences, is the basis for implementation of protective actions, and is independent of the number of TPBARs. Accident risk is the product of the accident probability (i.e, accident frequency) times the accident consequences. In this EIS, risk is expressed as the increased likelihood of cancer fatality per year for an individual (i.e., the maximally exposed offsite individual, an average individual in the population within 80 kilometers [50 miles] of the reactor site, or a noninvolved worker). Table 5–33 indicates that the risks associated with tritium production are low. The highest risk to each individual—the maximally exposed offsite individual, one fatality every 2.7 million years (3.7×10^{-7} per year); an average member of the public, one fatality every 244 million years (4.1×10^{-9} per year); the exposed population, one fatality every 909 years (0.001 per year); and a noninvolved worker, one fatality every 42 billion years (2.4×10^{-11} per year)—is from the nonreactor design-basis accident.

There is a very small increase in design-basis and beyond-design-basis reactor accident consequences due to the irradiation of TPBARs at Bellefonte 1. The consequences are dominated by the effects of radionuclides releases inherent to the operation without tritium production. As described in Appendix D, Section D.1.1.10,

Table 5–32 Annual Accident Risks at Bellefonte 1

Accident	*Tritium Production Core*	*Maximally Exposed Offsite Individual* [a]	*Average Individual in Population to 80 km (50 mi)* [a]	*Noninvolved Worker* [a]
Design-Basis Accidents				
Reactor design-basis accident	0 TPBARs [b]	3.3×10^{-9} [c]	1.4×10^{-12} [c]	[d]
	1,000 TPBARs	3.3×10^{-9}	1.5×10^{-12}	2.4×10^{-15} [e]
	3,400 TPBARs	3.3×10^{-9}	1.9×10^{-12}	8.0×10^{-15} [e]
Nonreactor design-basis accident	0 TPBARs [b]	3.5×10^{-7} [c]	3.8×10^{-11} [c]	[d]
	1,000 TPBARs	3.6×10^{-7}	3.6×10^{-9}	2.0×10^{-11} [e]
	3,400 TPBARs	3.7×10^{-7}	4.1×10^{-9}	2.4×10^{-11} [e]
Sum of design-basis accident risks	0 TPBARs [b]	3.5×10^{-7}	3.8×10^{-11}	[d]
	1,000 TPBARs	3.6×10^{-7}	3.6×10^{-9}	2.0×10^{-11}
	3,400 TPBARs	3.7×10^{-7}	4.1×10^{-9}	2.4×10^{-11}
Handling Accidents				
TPBAR handling accident	Nominal 1,000 TPBARs	2.0×10^{-11}	5.8×10^{-12}	3.2×10^{-14}
	3,400 TPBARs	7.0×10^{-11}	2.0×10^{-11}	1.1×10^{-13}
Truck cask handling accident	1,000 TPBARs	4.5×10^{-15}	1.3×10^{-15}	7.4×10^{-18}
	3,400 TPBARs	1.4×10^{-14}	3.8×10^{-15}	2.2×10^{-17}
Rail cask handling accident	1,000 TPBARs	2.3×10^{-15}	6.5×10^{-16}	3.8×10^{-18}
	3,400 TPBARs	4.5×10^{-15}	1.3×10^{-15}	7.2×10^{-18}
Sum of handling accident risks	1,000 TPBARs	2.0×10^{-11}	5.8×10^{-12}	3.2×10^{-14}
	3,400 TPBARs	7.0×10^{-11}	2.0×10^{-11}	1.1×10^{-13}
Beyond Design-Basis Accidents (Severe Reactor Accidents)				
Reactor core damage accident with early containment failure	0 TPBARs [c]	1.1×10^{-9}	1.1×10^{-11}	N/A
	3,400 TPBARs	1.1×10^{-9}	1.1×10^{-11}	N/A
Reactor core damage accident with containment bypass	0 TPBARs [c]	3.1×10^{-8}	9.1×10^{-11}	N/A
	3,400 TPBARs	3.1×10^{-8}	9.1×10^{-11}	N/A
Reactor core damage accident with late containment failure	0 TPBARs [b]	6.3×10^{-10}	2.6×10^{-11}	N/A
	3,400 TPBARs	6.3×10^{-10}	2.8×10^{-11}	N/A
Sum of severe reactor accident risks	0 TPBARs [b]	3.3×10^{-8}	1.3×10^{-10}	N/A
	3,400 TPBARs	3.3×10^{-8}	1.3×10^{-10}	N/A

N/A = not applicable

[a] Increased likelihood of cancer fatality per year.

[b] The No Action Alternative at Bellefonte 1 implies the reactor is not brought into commercial service. The No Action radiological dose is 0.

[c] Derived from AEC 1974.

[d] Dose to noninvolved worker was not estimated in AEC 1974.

[e] Design-basis accident risks only reflect the incremental increase in accident risk due to the production of tritium in TPBARs.

Table 5–33 Annual Accident Consequences at Bellefonte 1

Accident	Accident Frequency (per year)	Tritium Production	Maximally Exposed Offsite Individual		Average Individual Population to 80 km (50 mi)		Noninvolved Worker	
			Dose (rem)	Cancer Fatality [a]	Dose (rem)	Cancer Fatality [a]	Dose (rem)	Cancer Fatality [a]
Design-Basis Accidents								
Reactor design-basis accident	0.0002	0 TPBARs [b]	0.033 [c]	0.000017	0.000014 [d]	6.8×10^{-9}	e	e
		1,000 TPBARs	0.033	0.000017	0.000015	7.6×10^{-9}	2.9×10^{-8} [f]	1.2×10^{-11}
		3,400 TPBARs	0.033	0.000017	0.000019	9.5×10^{-9}	1.0×10^{-7} [f]	4.0×10^{-11}
Nonreactor design-basis accident	0.01	0 TPBARs [b]	0.070 [c]	0.000035	7.5×10^{-6} [d]	3.8×10^{-9}	e	e
		1,000 TPBARs	0.073	0.000037	0.00072	3.6×10^{-7}	5.1×10^{-6} [f]	2.0×10^{-9}
		3,400 TPBARs	0.073	0.000037	0.00083	4.1×10^{-7}	5.9×10^{-6} [f]	2.4×10^{-9}
Handling Accidents								
TPBAR handling accident	0.0017/ 0.0058 [g]	All TPBAR configurations	0.000024	1.2×10^{-8}	6.7×10^{-6}	3.4×10^{-9}	4.8×10^{-8}	1.9×10^{-11}
Truck cask handling accident	5.3×10^{-7}/ 1.6×10^{-6} [g]	All TPBAR configurations	0.000017	8.5×10^{-9}	4.8×10^{-6}	2.4×10^{-9}	3.4×10^{-8}	1.4×10^{-11}
Rail cask handling accident	2.7×10^{-7}/ 6.0×10^{-7} [g]	All TPBAR configurations	0.000017	8.5×10^{-9}	4.8×10^{-6}	2.4×10^{-9}	3.4×10^{-8}	1.4×10^{-11}
Beyond Design-Basis Accidents (Severe Reactor Accidents)								
Reactor core damage with early containment failure	9.0×10^{-7}	0 TPBARs [b]	2.3	0.0012	0.023	0.000012	N/A	N/A
		3,400 TPBARs	2.4	0.0012	0.024	0.000012	N/A	N/A
Reactor core damage with containment bypass	9.1×10^{-7}	0 TPBARs [b]	34 [h]	0.034 [h]	0.20	0.00010	N/A	N/A
		3,400 TPBARs	34 [h]	0.034 [h]	0.20	0.00010	N/A	N/A
Reactor core damage with late containment failure	3.3×10^{-6}	0 TPBARs [b]	0.37	0.00019	0.016	8.0×10^{-6}	N/A	N/A
		3,400 TPBARs	0.38	0.00019	0.017	8.5×10^{-6}	N/A	N/A

N/A = not applicable

a Increased likelihood of cancer fatality.

b The No Action Alternative at Bellefonte 1 implies the reactor is not brought into commercial service. The No Action radiological dose is 0.

c AEC 1974.

d Derived from AEC 1974, estimate adjusted for differences in population data.

e Dose to noninvolved worker was not estimated in AEC 1974.

f Consequences only reflect the incremental increase in accident consequences due to the production of tritium in TPBARs.

g Frequency for 1,000 TPBARs/frequency for 3,400 TPBARs.

h Dose >20 rem. Cancer fatality risk is doubled.

surrogate data were used for the accident sequences and plant responses in the Bellefonte 1 beyond-design-basis accident analysis. Sensitivity analyses indicated that the analysis results are driven by the assumed release fractions and release timing sequences (see Appendix D, Table D–13). As indicated by the results provided in Table 5–33, the accidents involving reactor core damage with containment bypass that have the shortest warning time had resulted in the highest dose to a maximally exposed offsite individual. This is because, after such accidents the offsite individual would not have sufficient time to evacuate and would be exposed to the radionuclide releases at the site boundary. For the other core damage accidents, the individual would have sufficient time to evacuate before radionuclide releases would occur. It should be noted that Bellefonte 1 beyond-design-basis accident analysis estimates do not have the same level of applicability as those for the Watts Bar and Sequoyah Nuclear Plants. TVA will perform a plant-specific severe accident analysis for Bellefonte prior to its operation.

The secondary impacts of severe reactor accidents are discussed in Section 5.2.13.

HAZARDOUS CHEMICAL IMPACTS

No Action

No additional impacts to public and occupational health and safety from exposure to hazardous chemicals are anticipated at Bellefonte 1 beyond the effects of existing and future activities that are independent of the proposed action, tritium production.

Tritium Production

The impacts of using, handling, and storing hazardous chemicals at Bellefonte 1 were assessed. The chemical inventory for Bellefonte 1 was reviewed to identify potential accident scenarios. Details of the review and accident analysis are presented in Appendix D, Section D.2.

Two hazardous chemical accident scenarios were postulated for this EIS: an accidental, uncontrolled release of ammonium hydroxide from a 15,142-liter (4,000-gallon) tank in the basement of the turbine building; and an accidental, uncontrolled release of hydrazine from a 1,987-liter (525-gallon) tank in the same area. For both scenarios, it was postulated that the total tank inventory is released to form a pool on the floor. The size of the pool is limited by a dike around the chemical storage tanks. Vapor is generated from pool evaporation and fills the immediate area, leaks from the building, and is dispersed downwind.

The potential health impacts of accidental releases of hazardous chemicals were assessed by comparing estimated airborne concentrations of the chemicals to Emergency Response Planning Guidelines (ERPGs) developed by the American Industrial Hygiene Association. The ERPG values are not regulatory exposure guidelines and do not incorporate the safety factors normally included in healthy worker exposure guidelines. ERPG–1 values are concentrations below which nearly all individuals could be exposed for up to one hour and experience only mild, transient, and reversible adverse health impacts. ERPG–2 values are indicative of irreversible or serious health effects or impairment of an individual’s ability to take protective action. ERPG-3 values are indicative of potentially life-threatening health effects.

On release of ammonium hydroxide from the storage tank, ammonia would volatilize and be dispersed. The ERPG values for ammonia were used to evaluate the potential health impacts of an ammonium hydroxide release. The ERPGs for ammonia and hydrazine are presented in **Table 5–34**.

Table 5–34 ERPG Values for Hydrazine and Ammonia

Chemicals	*ERPG-1 (ppm)*	*ERPG-2 (ppm)*	*ERPG-3 (ppm)*
Hydrazine [a]	0.03	8	80
Ammonia [b]	25	200	1000

ppm = concentration in parts per million

[a] Gephart, et al. 1994. Hydrazine ERPGs were removed by AIHA for further study in 1996 and have not been reinserted as of July 1998.
[b] Craig, et al. 1995

The potential health impacts of the accidental release of ammonium hydroxide and hydrazine were assessed for two types of receptors: (1) noninvolved workers, or workers assumed to be located 640 meters (2,100 feet) from the point of release; and (2) maximally exposed offsite individual or member of the public located offsite at the site boundary 914 meters (3,000 feet) from the point of release.

Facility workers (i.e., those individuals in the building at the time of the accident) were assumed to be killed by the release. The analysis took no credit for mitigative actions (e.g., area atmosphere monitoring, area evacuation alarms, emergency operating procedures) or accident precursors (e.g., leak before break) to reduce the accident consequences to the facility worker.

The computer code selected for estimation of airborne concentrations is the Computer Aided Management of Emergency Operations/Areal Locations of Hazardous Atmospheres (CAMEO/ALOHA), developed by the National Safety Council, EPA, and the National Oceanic and Atmospheric Administration (NSC 1990).

The model results are presented for atmospheric Stability Classes D and F, with wind speeds of 5.3 m/s (17.4 ft/s) and 1.5 m/s (4.9 ft/s), respectively. Atmospheric Stability Class D is considered to be representative of "average" weather conditions; Stability Class F is considered to be representative of "worst-case" weather conditions. These weather conditions were selected because they are recommended by EPA in its *Technical Guidance for Hazards Analysis* (EPA 1987).

The potential health impacts of the accidental releases were assessed by comparing the modeled ambient concentrations of ammonia and hydrazine at each of the receptor locations to the ERPGs. **Table 5–35** presents a summary of the impacts data.

Table 5–35 Summary of Impacts Data for Release Scenarios at Bellefonte 1

Impacts		*Hydrazine (Stability Class D)*	*Hydrazine (Stability Class F)*	*Ammonia (Stability Class D)*	*Ammonia (Stability Class F)*
Maximum distance (m) to concentrations of	ERPG-1 ERPG-2 ERPG-3	>2,000 179 44	>2,000 500 200	464 150 65	2,250 825 425
Noninvolved worker (640 m)	Parts per million (ppm) Level of concern Potential health effects	0.8 ERPG-1 Mild, transient	6 ERPG-1 Mild, transient	14 ERPG-1 Mild, transient	318 ERPG-2 Serious
Maximally exposed offsite individual (914 m)	Parts per million (ppm) Level of concern Potential health effects	0.4 ERPG-1 Mild, transient	3.2 ERPG-1 Mild, transient	7.7 ERPG-1 None (<ERPG-1)	169 ERPG-1 Mild, transient

Impacts to Noninvolved Workers

The concentrations of ammonia at 640 meters (3,000 feet) would range from 14 to 318 parts per million (ppm), depending on the assumed meteorological conditions. The maximum estimated airborne concentration at that point under Stability Class F conditions would exceed the ERPG–2 value of 200 ppm for ammonia, which suggests that noninvolved workers could experience irreversible or serious, but not life-threatening, adverse health effects if the exposures were not mitigated.

For the hydrazine release scenarios, the concentrations at 640 meters (3,000 feet) range from 0.8 to 6.0 ppm, depending on the assumed meteorological conditions. As a result, the maximum estimated airborne concentration at that point would exceed the ERPG–1 value of 0.03 ppm for hydrazine, which suggests the potential for only mild, transient, and reversible adverse health impacts on noninvolved workers.

Impacts to Maximally Exposed Offsite Individual

For the ammonium hydroxide release scenarios, the maximally exposed offsite individual could be exposed to an ammonia concentration of 7.7 ppm under Stability Class D conditions (see Table 5–35), which is below the ERPG–1 value for ammonia of 25 ppm. Exposures to concentrations below the ERPG–1 value should not produce any adverse health effects for the maximally exposed offsite individual. Under Stability Class F conditions, the maximally exposed offsite individual could be exposed to an ammonia concentration of about 169 ppm (see Table 5–35), which is below the ERPG–2 value for ammonia of 200 ppm. Exposure of the maximally exposed offsite individual to concentrations higher than the ERPG–1 value but lower than the ERPG–2 value could produce only mild, transient, and reversible adverse health effects.

For the hydrazine release scenarios, the maximally exposed offsite individual exposure concentrations would range from 0.4 to 3.2 ppm (see Table 5–35; both stability classes). These concentrations exceed the ERPG–1 value for hydrazine of 0.03 ppm, but are less than the ERPG–2 value of 8 ppm. This suggests that the maximally exposed offsite individual could experience only mild, transient, and reversible adverse health effects as a result of the exposure.

The results of this analysis should be considered only as screening-level estimations. TVA would conduct analyses compliant with the requirements of 40 CFR 68 before operation of Bellefonte 1.

5.2.3.10 Environmental Justice

As discussed in Appendix G, Executive Order 12898 directs Federal agencies to address disproportionately high and adverse health or environmental effects of alternatives on minority and low-income populations. The Executive Order does not alter prevailing statutory interpretations under NEPA or existing case law. Regulations prepared by the Council on Environmental Quality remain the foundation for the preparation of environmental documentation in compliance with NEPA (40 CFR Parts 1500 through 1508).

No Action

There would be no impacts on the general population, and thus, no disproportionately high and adverse consequences for minority and low-income populations beyond the effects of existing and future activities that are independent of the proposed action.

Tritium Production

Analyses of incident-free operations and accidents have shown estimates of the risk of latent cancer fatalities to the public residing within 80 kilometers (50 miles) of the reactor site to be much lower than 1. Because tritium production would not have significant adverse consequences for the population at large, no minority or low-income populations should experience disproportionately high adverse consequences.

5.2.3.11 Waste Management

No Action

No additional wastes should be generated at the Bellefonte Nuclear Plant Site beyond the wastes generated as a result of activities independent of the proposed action. These wastes and provisions for its management are described in Section 4.2.3.10. Solid nonhazardous waste is disposed of offsite by contract at a permitted facility. The small quantity of hazardous waste is temporarily stored onsite until it is shipped to the TVA Hazardous Waste Storage Facility in Muscle Shoals, which makes arrangements for disposal at a permitted disposal facility offsite.

Tritium Production

Should a Bellefonte 1 or Bellefonte 1 and 2 be completed for the purpose of producing tritium, some waste would be generated during the construction. During operation, the waste that would be generated would be typical to that of an operating reactor plant like Watts Bar 1, or Sequoyah 1, or Sequoyah 2, except for the additional waste due to tritium production.

Construction

No radioactive waste should be generated during construction activities. Hazardous waste generated during construction would likely be due to maintenance activities. This waste could include materials such as waste oils containing solvent residuals or high in selected trace metal content, waste paint and paint thinners, solvents, and degreasers. The estimated amounts of solid and liquid wastes that would be generated over the entire construction period for one or both units are presented in **Table 5–36.**

Table 5–36 Total Amounts of Wastes Generated During Construction to Complete Bellefonte 1 or Bellefonte 1 and Bellefonte 2

Waste Category	*Quantity*	
	Bellefonte 1	*Bellefonte 1 and Bellefonte 2*
Hazardous		
Solids (metric tons)	6.3	9.7
Liquids (metric tons)	56.7	87.3
Nonhazardous solids		
Concrete (m^3)	392	603
Steel (metric tons)	208	296
Other (m^3)	21,000	70,000
Nonhazardous liquids		
Sanitary (m^3)	309,000	475,000
Flushing (m^3)	6,000	49,100
Other (m^3)	65	100

Source: TVA 1995b.

It is expected that the monthly hazardous wastes generated would be more than 100 kilograms (220 pounds) but less than 1,000 kilograms (2,205 pounds), thus qualifying the site as an EPA Small Quantity Generator, which is the current status of the plant. Hazardous wastes would be stored onsite temporarily, pending shipment to the TVA Hazardous Waste Disposal Facility at Muscle Shoals, Alabama. Nonhazardous solid waste from construction activities would be routinely placed in dumpsters onsite and subsequently disposed of offsite by contractors.

Operation

Waste would be generated at Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 as a consequence of normal operation as a nuclear power plant. Judging from the operating experience at Sequoyah and Watts Bar, the waste to be generated under the proposed action would fall into four broad categories: hazardous waste, nonhazardous solid waste, low-level radioactive waste, and sanitary liquid waste. **Table 5–37** summarizes the expected annual amounts of waste that would be generated at Bellefonte 1 or both Bellefonte 1 and Bellefonte 2. The low-level radioactive waste would include an additional 0.43 m^3/yr (15 ft^3/yr) (WEC 1998)

Table 5–37 Annual Waste Generation at Bellefonte 1

Waste Type	*Volume or Mass*
Hazardous waste	1.025 m^3
Nonhazardous solid waste	853,438 kg
Low-level radioactive waste	40 m^3
Mixed low-level radioactive waste	<1 m^3

Note: For Bellefonte 1 and Bellefonte 2 operations the waste values would be twice the values given.
Source: Based on Watts Bar 1 Operation.

generated as a result of tritium production. It would consist of the approximately 140 base plates and other irradiated hardware remaining after the TPBARs were separated from their assemblies to be placed in the 17 × 17 array consolidation baskets at the reactor site.

Hazardous Waste

Hazardous waste typical of nuclear plant operation would include paints, solvents, acids, oils, radiographic film and development chemicals, and degreasers. Neutralization would be the only waste treatment performed onsite. Hazardous waste would be normally stored in polyethylene containment systems during accumulation. An approved storage building would be used to store hazardous waste for either 90 or 180 days, depending on the plant's hazardous waste generation status (i.e., Small Quantity or Large Quantity Generator) at the time. The waste would be transported to an offsite hazardous waste storage or disposal facility before it exceeded the 90- or 180-day storage limit.

Low-Level Radioactive Waste

One category of low-level radioactive waste would be the solidified and dewatered product of gaseous and liquid waste treatment systems, along with filters and resins. Another would be contaminated protective clothing, paper, rags, glassware, compactible and noncompactible trash, and nonirradiated reactor components. A third category would be the irradiated hardware of the TPBAR assemblies that would have been separated from the TPBARs before the TPBARs were placed in consolidation containers for eventual shipment. Low-level radioactive waste would be shipped to the Barnwell, South Carolina, low-level radioactive waste disposal facility.

For purposes of completeness, this EIS also addresses the management of the irradiated TPBAR hardware portion of the low-level radioactive waste at DOE-owned facilities—specifically, the Low-level Radioactive Waste Disposal Facility at the Savannah River Site, near Aiken, South Carolina. That facility consists of a series of vaults in E–Area that have been operational since September 1994. The operating capacity of each vault is 30,500 cubic meters (1,077,100 cubic feet) of low-level radioactive waste (DOE 1998c). Therefore, the addition of low-level radioactive waste from the proposed action at Bellefonte 1 or both Bellefonte 1 and Bellefonte 2 for a 40-year period would be approximately 0.06 percent of the capacity of a single vault. The total production of low-level radioactive waste, approximately 41 cubic meters (1,448 cubic feet), represents 0.1 percent of the capacity of a single vault.

Mixed Waste

Typical sources of mixed low-level radioactive waste would be: beta-counting fluids (e.g., zylene, toluene) used in liquid scintillation detectors; polychlorinated biphenyls (PCBs) susceptible to contact with radioactive contamination through an accidental spill or explosion in a transformer; isopropyl alcohol used for cleaning radioactive surfaces; chelating agents; and various acids. The amount of mixed low-level radioactive waste generated should be less than 1 cubic meter (35 cubic feet), judging from experience with Watts Bar 1 operation.

Bellefonte 1 or Bellefonte 2 would have an active waste minimization program similar to the existing programs described for Watts Bar and Sequoyah in Sections 4.2.1.10 and 4.2.2.10, respectively.

5.2.3.12 Spent Fuel Management

Production of tritium at Bellefonte 1 or 2 with less than 2,000 TPBARs in the reactor core would generate approximately 72 spent nuclear fuel assemblies per fuel cycle. This is the expected normal refueling batch without tritium production. The spent fuel assemblies would be stored in the plant's spent nuclear fuel pools which have been completed. For the irradiation of the maximum number of 3,400 TPBARs, up to a maximum of 141 spent nuclear fuel assemblies could be generated. This represents up to 69 additional spent nuclear fuel assemblies over the normal refueling batch. For the purposes of this EIS it is assumed that this additional spent nuclear fuel would be stored onsite for the duration of the proposed action. If needed, an ISFSI would be constructed at the site. Environmental impacts of the construction and operation of this generic ISFSI are presented in Section 5.2.6.

5.2.4 Licensing Renewal

Watts Bar 1, Sequoyah 1 and Sequoyah 2 are currently operating plants. Their operating licenses would expire before the end of the tritium production program which is assumed to last until the year 2043. Therefore, these units would need to undergo licensing renewal before the end of the program. The environmental impacts associated with the licensing renewal activities for these units are discussed in this section.

5.2.4.1 Background

The decision whether to seek license renewal rests with the licensees. Each licensee must determine whether they are likely to satisfy NRC requirements and evaluate the costs of the venture. As early as 20 years before the expiration of its current license, an applicant may apply to extend its license for up to 20 years. It is estimated that it would take a licensee between 3 and 5 years to prepare an application and that the NRC staff would require between 3 and 5 years to complete the review and the hearing process. The license renewal application would be subject to public hearings, using a formal, adjudicatory process.

License renewal requirements for power reactors are based on two key principles: (1) the regulatory process, continued into the extended period of operation, is adequate to ensure that the licensing basis of all currently operating plants provides an acceptable level of safety; and (2) each plant's licensing basis is required to be maintained during the renewal term. In other words, the foundation of license renewal rests on the determination that currently operating plants continue to maintain adequate levels of safety and, over the plant's life, this level has been enhanced through maintenance of the licensing bases, with appropriate adjustments to address new information from industry operating experience. Additionally, NRC activities provide ongoing assurance that the licensing bases would continue to provide an acceptable level of safety.

The environmental and technical requirements for the renewal of power reactor operating licenses are contained in NRC's regulations, 10 CFR Parts 51 and 54, respectively. The environmental protection regulations in 10 CFR 51 were revised on December 18, 1996, to facilitate the environmental review for license renewal. Part 54 was revised in May 1995 to simplify and clarify the license renewal scope and process.

The license renewal environmental review requirements in 10 CFR 51 are based on a conclusion of a detailed generic environmental impact study (NRC 1996a) that certain environmental issues can be resolved generically, rather than separately in each plant-specific licensing application. This approach reduces the number of issues that need to be evaluated in detail for each plant site, and improves the efficiency of the licensing process for both the licensee and the NRC.

The changes to the licensing requirements in 10 CFR 54 stress managing the effects of aging rather than managing aging mechanisms, and more explicitly address the role of existing licensee programs and the maintenance rule provisions as means to demonstrate the adequacy of programs to manage the effects of aging for the renewal term. Under this regulatory requirement, licensees are required to identify all systems, structures, and components within the scope of the renewal application. The systems, structures, and components within the scope are (1) all safety-related systems, structures, and components; (2) all systems, structures, and components whose failure could affect safety-related functions; and (3) systems, structures, and components relied on to demonstrate compliance with the NRC's regulations for fire protection, environmental qualification, pressurized thermal shock, anticipated transients without scram, and station blackout. A screening review is required of all systems, structures, and components within the scope of the rule to identify “passive” and “long-lived” structures and components, for which the applicant must demonstrate that the effects of aging would be managed in such a way that the intended function or functions of those structures and components would be maintained for the period of extended operation. Active equipment is considered to be adequately monitored under the current regulatory process where the detrimental aging effects that may occur are more readily detectable and would be identified and corrected by routine surveillances and performance indicators. For some structures and components within the scope of the evaluation, no additional action may be required where the applicant can demonstrate that the existing programs provide adequate aging management throughout the period of extended operation. However, if additional aging management activities are warranted for a structure or component within the scope of the rule, applicants would have the flexibility to determine appropriate actions. These activities could include, for example, new monitoring programs, new inspections, or revised design criteria. Another requirement for license renewal is the identification and updating of time-limited aging analyses, which are those design analyses for systems, structures, and components based on the current operating license term.

In 1996, the NRC developed a draft regulatory guide for the format and content of a license renewal application that proposes to endorse an implementation guideline prepared by the Nuclear Energy Institute as an acceptable method of implementing the license renewal rule. The NRC plans to maintain the regulatory guide in draft form and use it along with the working draft of the standard review plan for license renewal to review plant-specific and owners group reports. An update of the working draft standard review plan has been made publicly available in September 1997. NRC staff would use the experience gained from the review of plant-specific and owners groups reports to incorporate improvements into the working draft standard review plan and clarify regulatory guidance before soliciting formal public comment and approval of those documents. The NRC has developed a draft inspection guidance for license renewal. Consistent with the development of the standard review plan and regulatory guide, the inspection guidance would be prepared in final form after the staff completes the review of several license renewal applications.

5.2.4.2 Environmental Effect of Renewing the Operating License of a Nuclear Power Plant

The NRC staff has assessed the environmental impacts associated with granting a renewed operating license for a nuclear power plant to a licensee who holds either an operating license or construction permit as of June 30, 1995, and documented the results in a report titled, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants,* NUREG–1437 (NRC 1996a). The NRC amended the environmental protection regulations in 10 CFR 51 to streamline the process of environmental review for license renewal by drawing on the experience of the operating nuclear power reactors and to generically assess many of the environmental impacts. The amendment eliminated consideration of the need for generating capacity and of utility economics from the environmental reviews.

The NRC decided to undertake a generic assessment of the environmental impacts associated with the renewal of a nuclear power plant operating license because:

- License renewal would involve nuclear power plants where the environmental impacts of operation are well understood as a result of data evaluated from operating experience to date;
- Activities associated with license renewal are expected to be within this range of operating experience, thus environmental impacts can be reasonably predicted;
- Changes in the environment around nuclear power plants are gradual and predictable with respect to characteristics important to environmental impact analyses.

In general, there are 92 discrete NEPA issues associated with license renewal requiring responses in an environmental assessment. Of the 92 issues, 68 were found to have impacts of small significance on all plants and that no mitigation beyond that already employed at the plants is needed. Those issues are adequately addressed in the NRC's generic EIS, and no further assessment of these issues would be required in a plant specific review. Twenty-four issues were determined to require further analysis and possible new information. The qualitative impacts on these issues were determined to be "small," "moderate," or "large," depending on the specific plant. **Table 5–38** summarizes the issues and the NRC's findings in the generic EIS. These issues need to be addressed by the licensees as part of the plant life extension license renewal application.

Table 5–38 Summary of Findings on NEPA Issues for License Renewal of Nuclear Power Plants

Issue	***Findings***
Surface Water Quality, Hydrology, and Use (for all plants)	
Water use conflicts (plants with cooling ponds or cooling towers using make-up water from a small river with low flow).	SMALL OR MODERATE. The issue has been a concern at nuclear power plants with cooling ponds and at plants with cooling towers. Impacts on in stream and riparian communities near these plants could be of moderate significance in some situations. See § 51.53(c)(3)(ii)(A).
Aquatic Ecology	
Entrainment of fish and shellfish in early life stages.	SMALL, MODERATE, OR LARGE. The impacts of entrainment are small at many plants but may be moderate or even large at a few plants with once-through and cooling-pond cooling systems. Further, ongoing efforts in the vicinity of these plants to restore fish populations may increase the numbers of fish susceptible to intake effects during the license renewal period, such that entrainment studies conducted in support of the original license may no longer be valid. See § 51.53(c)(3)(ii)(B).
Impingement of fish and shellfish	SMALL, MODERATE, OR LARGE. The impacts of impingement are small at many plants but may be moderate or even large at a few plants with once-through and cooling-pond cooling systems. See § 51.53(c)(3)(ii)(B).
Heat shock	SMALL, MODERATE, OR LARGE. Because of continuing concerns about heat shock and the possible need to modify thermal discharges in response to changing environmental conditions, the impacts may be of moderate or large significance at some plants with once-through and cooling-pond systems. See § 51.53(c)(3)(ii)(B).
Groundwater Use and Quality	
Ground-water use conflicts (potable and service water, and dewatering; plants that use >100 gpm).	SMALL, MODERATE, OR LARGE. Plants that use more than 100 gpm may cause ground-water use conflicts with nearby ground-water users. See § 51.53(c)(3)(ii)(C).
Ground-water use conflicts (plants using cooling towers withdrawing make-up water from a small river).	SMALL, MODERATE, OR LARGE. Water use conflicts may result from surface water withdrawals from small water bodies during low flow conditions which may affect aquifer recharge, especially if other ground-water or upstream surface water users come on line before the time of license renewal. See § 51.53(c)(3)(ii)(A).

Issue	Findings
Ground-water use conflicts (Ranney wells).	SMALL, MODERATE, OR LARGE. Ranney wells can result in potential ground-water depression beyond the site boundary. Impacts of large ground-water withdrawal for cooling tower makeup at nuclear power plants using Ranney wells must be evaluated at the time of application for license renewal. See § 51.53(c)(3)(ii)(C).
Ground-water quality degradation (cooling ponds at inland sites).	SMALL, MODERATE, OR LARGE. Sites with closed-cycle cooling ponds may degrade ground-water quality. For plants located inland, the quality of the groundwater in the vicinity of the ponds must be shown to be adequate to allow continuation of current uses. See § 51.53(c)(3)(ii)(D).
Terrestrial Resources	
Refurbishment impacts	SMALL, MODERATE, OR LARGE. Refurbishment impacts are insignificant if no loss of important plant and animal habitat occurs. However, it cannot be known whether important plant and animal communities may be affected until the specific proposal is presented with the license renewal application. See § 51.53(c)(3)(ii)(E).
Threatened or Endangered Species (for all plants)	
Threatened or endangered species.	SMALL, MODERATE, OR LARGE. Generally, plant refurbishment and continued operation are not expected to adversely affect threatened or endangered species. However, consultation with appropriate agencies would be needed at the time of license renewal to determine whether threatened or endangered species are present and whether they would be adversely affected. See § 51.53(c)(3)(ii)(E).
Air Quality	
Air quality during refurbishment (non-attainment and maintenance areas).	SMALL, MODERATE, OR LARGE. Air quality impacts from plant refurbishment associated with license renewal are expected to be small. However, vehicle exhaust emissions could be cause for concern at locations in or near nonattainment or maintenance areas. The significance of the potential impact cannot be determined without considering the compliance status of each site and the numbers of workers expected to be employed during the outage. See § 51.53(c)(3)(ii)(F).
Human Health	
Microbiological organisms (public health)(plants using lakes or canals, or cooling towers or cooling ponds that discharge to a small river).	SMALL, MODERATE, OR LARGE. These organisms are not expected to be a problem at most operating plants except possibly at plants using cooling ponds, lakes, or canals that discharge to small rivers. Without site-specific data, it is not possible to predict the effects generically. See § 51.53(c)(3)(ii)(G).
Electromagnetic fields, acute effects (electric shock).	SMALL, MODERATE, OR LARGE. Electrical shock resulting from direct access to energized conductors or from induced charges in metallic structures have not been found to be a problem at most operating plants and generally are not expected to be a problem during the license renewal term. However, site-specific review is required to determine the significance of the electric shock potential at the site. See § 51.53(c)(3)(ii)(H).
Electromagnetic fields, chronic effects	UNCERTAIN. Biological and physical studies of 60-Hz electromagnetic fields have not found consistent evidence linking harmful effects with field exposures. However, research is continuing in this area and a consensus scientific view has not been reached. If in the future, the Commission finds that, contrary to current indications, a consensus has been reached by appropriate Federal health agencies that there are adverse health effects from electromagnetic fields, the Commission will require applicants to submit plant specific review of these health effects as part of their license renewal applications. Until such time, applicants for license renewal are not required to submit information on this issue.
Socioeconomic	
Housing impacts	SMALL, MODERATE, OR LARGE. Housing impacts are expected to be of small significance at plants located in a medium or high population area and not in an area where growth control measures that limit housing development are in effect. Moderate or large housing impacts of the workforce associated with refurbishment may be associated with plants located in sparsely populated areas or in areas with growth control measures that limit housing development. See § 51.53(c)(3)(ii)(I).
Public services: public utilities	SMALL OR MODERATE. An increased problem with water shortages at some sites may lead to impacts of moderate significance on public water supply availability. See § 51.53(c)(3)(ii)(I).
Public services, education (refurbishment)	SMALL, MODERATE, OR LARGE. Most sites would experience impacts of small significance but larger impacts are possible depending on site- and project-specific factors. See § 51.53(c)(3)(ii)(I).

Issue	***Findings***
Offsite land use (refurbishment)	SMALL OR MODERATE. Impacts may be of moderate significance at plants in low population areas. See § 51.53(c)(3)(ii)(I).
Offsite land use (license renewal term)	SMALL, MODERATE, OR LARGE. Significant changes in land use may be associated with population and tax revenue changes resulting from license renewal. See § 51.53(c)(3)(ii)(I).
Public services, Transportation	SMALL, MODERATE, OR LARGE. Transportation impacts are generally expected to be of small significance. However, the increase in traffic associated with the additional workers and the local road and traffic control conditions may lead to impacts of moderate or large significance at some sites. See § 51.53(c)(3)(ii)(J).
Historic and archaeological resources.	SMALL, MODERATE, OR LARGE. Generally, plant refurbishment and continued operation are expected to have no more than small adverse impacts on historic and archaeological resources. However, the National Historic Preservation Act requires the Federal agency to consult with the State Historic Preservation Officer to determine whether there are properties present that require protection. See § 51.53(c)(3)(ii)(K).
Postulated Accidents	
Severe accidents	SMALL. The probability weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to groundwater, and societal and economic impacts from severe accidents are small for all plants. However, alternatives to mitigate severe accidents must be considered for all plants that have not considered such alternatives. See § 51.53(c)(3)(ii)(L).
Uranium Fuel Cycle and Waste Management	
Transportation	Table S-4 of Part 51 (CFR 51.52 (c)) contains an assessment of impact parameters to be used in evaluating transportation effects in each case. See CFR 51.53(c)(3)(ii)(M).
Environmental Justice	
Environmental Justice	This issue was not addressed in the generic EIS. The need for and content of an environmental justice will be addressed in plant-specific review.

Consistent with 10 CFR 51, Subpart A, Appendix B, the following definition of environmental impacts was used:

Small Environmental effects are not detectable or are so minor that they would neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the NRC has concluded that those impacts that do not exceed permissible levels in the NRC's regulations are considered small as the term is used in this table.

Moderate Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

Large Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

Source: 10 CFR 51.

5.2.5 Decontamination and Decommissioning

Construction of Bellefonte 1 or Bellefonte 2 has not been completed. Neither of the units are operational. For the purposes of this EIS the future operation of these units depends on whether or not they would be used for tritium production. Consequently, the environmental impacts associated with the production of tritium at Bellefonte will include impacts resulting from construction activities, operation of the units to produce tritium, and the decontamination and decommissioning of these reactors at the end of their useful life. The following provides a summary of the impacts that can be expected from the decontamination and decommissioning of the Bellefonte units.

5.2.5.1 Background

Since no commercial light water reactors of a size (i.e., ~ 1,000 MWe) comparable to the Bellefonte units have been decommissioned, data for decontamination and decommissioning are limited. In 1988, the Nuclear Regulatory Commission issued a *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities* NUREG-0586 (NRC 1988). The NUREG provides generic assessments and projections of the environmental consequences of decontamination and decommissioning for various nuclear facilities. Projections associated with impacts from commercial pressurized water reactors have been used to characterize the environmental impacts.

Another aspect of decontamination and decommissioning of commercial reactors that would continue to influence the nature and extent of environmental impacts is the continuing evolution in the NRC and EPA regulations that govern decontamination and decommissioning activities. An example of this evolution is the *Final Rule on Radiological Criteria for License Termination*, which was issued by the NRC in July 1997. The final rule provides specific radiological criteria for the decommissioning of NRC-licensed facilities. The criteria clarify, for example, that a site would be considered acceptable for unrestricted use if decontaminated to a level of 25 mrem/yr. Comparable regulatory guidance on other aspects of decontamination and decommissioning are in various stages of creation/issuance.

5.2.5.2 Decontamination and Decommissioning Options

The decontamination and decommissioning of a CLWR can be accomplished via one of the following three options:

- *Entomb*—Complete isolation of radioactivity from environment by means of massive concrete and metal barriers until radioactivity has decayed to levels which permit unrestricted release of the facility. This decay may take up to several hundreds of thousands of years.

- *Safstor*—Process of placing and maintaining a nuclear facility in a condition that allows the nuclear facility to be safely stored (to allow radioactive decay) and subsequently decontaminated (i.e., deferred decontamination) to levels that permit the property to be released for unrestricted use.

- *Decon*—Process of immediately removing and disposing of all radioactivity in excess of levels that would permit the release of the facility for unrestricted use.

It would be assumed that the decontamination and decommissioning of the CLWR used for tritium production would select the Decon option. The advantages inherent in Decon are prompt termination of NRC license shortly after cessation of operation, elimination of a radioactive site, return of site for unrestricted use, reactor operating staff is available to support site characterization and subsequent decontamination and decommissioning activities, and long-term surveillance and maintenance is not required.

5.2.5.3 Decommissioning Activities

The decontamination and decommissioning of a pressurized water reactor would typically be completed in a period of 8 to 12 years after facility shutdown. It is anticipated that the initial 2 to 3 years would focus on planning and scheduling of the decontamination and decommissioning program and the required coordination activities with local, state and regulatory agencies. The decontamination and decommissioning program would be implemented in a series of steps, but the process can be summarized as follows:

Removal/dismantlement of the major components of the primary system—This would involve the removal of the reactor vessel, vessel internals, steam generators, pressurizer and other major components. The "removal" phase may be completed in one of two ways: (1) removal of the intact component (e.g., with all reactor vessel internals intact) shipped to the final disposal site; or (2) segmentation of the major component and/or its internals with the segments shipped to the final disposal site.

Decontamination of primary system piping—The primary system and other large-bore contaminated piping systems would be decontaminated in place, subsequently removed and disposed of in accordance with appropriate regulations.

Decontamination of primary containment and facility structures—The primary containment surfaces and structures would be decontaminated in place, using scabbling, scarifying and similar technologies. The waste materials would be packaged and disposed of in accordance with appropriate regulations.

Spent fuel and Greater-Than-Class-C waste shipments—It has been assumed that a final high-level waste repository would be operational to receive spent fuel and Greater-Than-Class-C waste in a timely manner that does not prolong or delay decontamination and decommissioning activities.

Disposal of low-level radioactive waste—Low-level radioactive waste would be processed in accordance with established procedures.

5.2.5.4 Decontamination and Decommissioning Impacts

The impacts to be anticipated via decontamination and decommissioning activities would vary as a result of operating history, facility maintenance, and related factors. The NRC's *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities,* NUREG-0586 (NRC 1988) provides estimates of impacts that would be used in the discussion below. (The NUREG estimates have recently been characterized as bounding by a commercial reactor [i.e., 619 MWe pressurized water reactor] that submitted its Post Shutdown Decommissioning Activity Report in August 1997.)

Radiation Exposure

NUREG–0586 evaluates the radiation dose to plant workers and the public resulting from decontamination and decommissioning activities for a generic pressurized water reactor (1,175 MWe) over a 4-year period as follows:

Occupational exposure due to decontamination		1,114.5 person-rem
Occupational exposure due to decontamination truck shipments		100.2 person-rem
Total for workers	=	*1,215 person-rem*
Public exposure due to decontamination		Negligible
Public exposure due to decontamination truck shipments		20.6 person-rem
Total for public	=	*21 person-rem*

These doses are considerably lower than the typical worker doses accumulated during reactor operation, maintenance, and refueling operations.

In addition to the doses calculated above, the NUREG summarized the results of exposure calculations to a maximally exposed individual from accidental airborne release during decommissioning. These analyses indicated that the radiation doses were "quite low."

Waste Disposal

Decontamination and decommissioning of a pressurized water reactor would result in the creation of low-level radioactive waste that would require transportation to and burial within a licensed site for disposal. NUREG–0586 estimates that approximately 18,340 cubic meters (647,677 cubic feet) of low-level radioactive waste would be generated.

In addition, the disposal of highly activated components (e.g., reactor, reactor internals) could require disposal in a deep geologic repository. NUREG–0586 estimates that approximately 11 cubic meters of highly activated waste would require disposal in this manner.

Socioeconomics

Completion of Bellefonte 1 and 2 would generate impacts associated with the eventual decontamination and decommissioning of the plant. Currently, decontamination and decommissioning of a two-unit nuclear station to green-field status using the immediate dismantlement approach (commonly called Decon) is estimated to cost between $600 and $700 million. Offsite disposal of low-level radioactive waste would be responsible for at least half the cost. Low-level radioactive waste disposal costs have escalated at double-digit rates for many years and cannot be forecast with confidence. Currently, onsite costs for labor and materials can be rounded to $200–250 million, excluding the potential for onsite long-term spent fuel storage. It is also impossible to predict what these costs would be 40 years in the future. It is reasonable to expect that decontamination and decommissioning 40 years in the future would not require the kind of dry cask spent fuel storage facility that is necessary for existing reactors with limited onsite spent fuel storage pools.

Assuming that decontamination and decommissioning 40 years in the future will take 5 years and that onsite spending at that time would have a net present value of $200–250 million, the effect of decontamination and decommissioning would be to continue local spending at the level of $30–40 million per year. Operations spending would be at roughly $90 million per year, which includes local procurements. Costs at the upper end of any range would be incurred the last few years of operation as planning for retirement took place. The net socioeconomic effect of decontamination and decommissioning is to extend the local receipt of income by perhaps 6 years at roughly 30 percent of the operational level. This is beneficial, since it smooths the transition from operational to postoperational status.

Other Environmental Impacts

NUREG–0586 (NRC 1988) characterizes as "minor" other environmental impacts that result from decommissioning activities when compared to the impacts which result from normal operation of the reactor. These impacts include:

- Water use during decontamination and decommissioning activities is estimated to be 18,000 m^3 (635,670 ft^3), which is far less than water use and evaporation during operation—i.e., approximately 27 million m^3/yr (953 million ft^3/yr).

- Numbers of workers onsite would typically not exceed the number of workers during initial construction or operation.

- Disturbance of ground cover would be limited to the restoration of contaminated sites.

5.2.6 Spent Fuel Storage

The environmental impacts from the storage of additional spent fuel due to the production of tritium presented in this section assumes that 3,400 TPBARs would be irradiated in a reactor core over an 18-month reactor operating cycle. Westinghouse has estimated (WEC 1998) that no additional spent nuclear fuel would be generated if approximately 2,000 TPBARs or less were irradiated in each operating cycle.

As discussed in Appendix A, the production of tritium in any of the alternative reactor units considered in this EIS would generate additional spent fuel. For the purposes of this EIS, it is assumed that the additional spent fuel generated from the tritium production over the duration of the program would be accommodated at the site at a dry cask ISFSI. This section presents the environmental impact of the construction and operation of, and postulated accidents associated with, a generic dry cask ISFSI should it become necessary. This generic ISFSI would be designed to store the number of additional spent nuclear fuel assemblies required for 40-year tritium production at the reactor site.

Number of ISFSI Casks for 40-Year Tritium Production

The number of ISFSI dry casks required to store the additional nuclear fuel needed for tritium production was calculated using fuel usage information for each nuclear power plant and current NRC-licensed ISFSI dry cask designs applicable to pressurized water reactor spent nuclear fuel (VECTRA 1995, PSNA 1991). **Table 5–39** presents the data used for each nuclear plant and the resulting calculated number of ISFSI dry casks required to accommodate the spent nuclear fuel increment from 40 years of tritium production.

The number of dry storage casks calculated to accommodate tritium production delineated in Table 5–39 above is based on the 24 pressurized water reactor spent nuclear fuel assembly capacity of four of the ISFSI cask designs in the United States (VECTRA 1995, PSNA 1991, NRC 1987, NRC 1989). The number of dry storage casks would be used in this report to quantify the specific environmental impact for each of the three nuclear power plants.

Table 5–39 Data for Number of ISFSI Cask Determination for Each Nuclear Power Plant

Data Parameter	*Watts Bar*	*Sequoyah* [a]	*Bellefonte* [a]
Operating cycle length	18 months	18 months	18 months
Fresh fuel assemblies per cycle—no tritium	80	80	72
Fresh fuel assemblies per cycle—maximum tritium production (3,400 TPBARs)	136	140	141
Increase in fresh fuel assemblies per cycle due to tritium production	56	60	69
Number of operating cycles in 40 years (rounded)	27	27	27
Number of additional fuel assemblies for 40-year tritium production	1512	1620	1863
Integer number of ISFSI dry casks needed to store additional tritium production fuel assemblies	63	68	78

[a] Per reactor.

A number of ISFSI dry storage designs have been licensed by the NRC and are in operation in the United States (NRC 1996d). These designs include the Modular Vault Dry Store, metal casks, and concrete casks. The majority of operating ISFSIs have chosen to use concrete casks (NRC 1996d). Concrete casks consist of either a vertical or horizontal concrete structure housing a metal basket that confines the spent nuclear fuel. The Modular Vault Dry Store is a large reinforced concrete building that has been judged by the utility industry to be economically noncompetitive with metal and concrete casks, especially for the number and type of spent nuclear fuel assemblies being evaluated in this report. Therefore, for the determination of the maximum environmental impact of any economically viable and currently licensed ISFSI, only concrete dry storage casks would be considered for this environmental impact analysis.

Currently, the two concrete pressurized water reactor spent nuclear fuel dry cask designs licensed in the United States are the VSC–24 (PSNA 1991) and the NUHOMS–24P (VECTRA 1995). The VSC–24 shape is that of a vertical concrete cylinder whereas the NUHOMS–24P shape is a rectangular concrete block. Both designs store the same 24 pressurized water reactor spent nuclear fuel assemblies. However, the NUHOMS–24P requires a greater quantity of concrete and steel and occupies a larger footprint for the same number of stored fuel assemblies as compared to the VSC–24. Therefore, the environmental impact of using the NUHOMS–24P concrete dry storage ISFSI design would be determined since it should bound all other currently licensed dry storage cask designs.

The environmental impact of dry cask storage of the excess pressurized water reactor spent nuclear fuel required for tritium production is presented in the following three sections entitled: construction, operation, and accidents. Supporting information for this environmental impact evaluation was obtained from the Calvert Cliffs NUHOMS–24P ISFSI (BGE 1989a, BGE 1989b) and the Oconee NUHOMS–24P ISFSI (Duke 1988) as well as the standardized NUHOMS ISFSI report (VECTRA 1995).

Construction Impacts

The construction of a concrete dry cask ISFSI uses conventional equipment for land leveling and grading, rebar and concrete forms installation, and pouring of concrete for base slabs and the NUHOMS–24P horizontal storage module. The horizontal storage module consists of a rectangular, reinforced concrete block 5.79 meters (19 feet) long, 2.76 meters (9.7 feet) wide, and 4.6 meters (15 feet) high. The module has a hollow internal cavity to accommodate a stainless steel cylindrical cask that contains the spent nuclear fuel (VECTRA 1995). The stainless steel cask that is placed inside the horizontal storage module is fabricated offsite.

Construction of the spent nuclear fuel ISFSI would use a small amount of local water resources. Concrete would be delivered premixed in trucks while water for drinking, cleaning, and fugitive dust control would be brought onto the construction site by trucks. Portable toilets that would be used on the construction site would also require no local water.

No construction would be located within the limits of the 100-year flood plain which would be consistent with the requirements of Executive Order 11988, *Floodplain Management*. Because these facilities would be considered as “critical actions,” they would be located above the 500-year flood elevation.

Land use during construction of the ISFSI is dependent on the specific site characteristics. More land is disturbed than the actual footprint of the ISFSI due to associated security and personnel exclusion fence boundaries. At Calvert Cliffs, a wooded site that is located approximately 700 meters (2,300 feet) from the nuclear power plant was selected for the ISFSI. Preparation of this site affected approximately 24,281 square meters (6 acres) of land for the ISFSI footprint of 13,982 square meters (3.5 acres) (BGE 1989a). The Calvert Cliffs installation was designed to contain 120 spent nuclear fuel casks (also called horizontal storage modules for the NUHOMS–24P design). For this EIS, it is conservatively assumed that the same ratio (e.g., 1.71) of affected land to actual ISFSI footprint land is applicable. **Table 5–40** delineates the land use for each specific nuclear power plant's tritium excess spent nuclear fuel ISFSI.

Table 5–40 Environmental Impact of ISFSI Construction

No.	*Environmental Parameter*	*Bellefonte*	*Sequoyah*	*Watts Bar*
1	External appearance	78 HSM Rectangular cubes (5.79 × 2.96 meters) (19 × 9.7 feet) Constructed on 3 concrete cask foundation pads approximately: (31.4 × 11.58 meters) (106.7 × 38 feet)	68 HSM Rectangular cubes (5.79 × 2.96 meters) (19 × 9.7 feet) Constructed on 3 concrete cask foundation pads approximately: (38.43 × 11.58 meters) (126.1 × 38 feet)	63 HSM Rectangular cubes (5.79 × 2.96 meters) (19 × 9.7 feet) Constructed on 3 concrete cask foundation pads approximately: (35.47 × 11.58 meters) (116.4 × 38 feet)
Site Preparation and Facility Construction				

No.	Environmental Parameter	Bellefonte	Sequoyah	Watts Bar
2	Health and safety (Only construction work performed subsequent to the loading of any HSM with spent fuel may result in worker exposures from direct and skyshine radiation in the vicinity of the loaded HSM.)	Total dose during Construction: 58.5 person-rem	Total dose during Construction: 51.00 person-rem	Total dose during Construction: 47.25 person-rem
3	Electrical distribution	Existing electrical services would be used.	Existing electrical services would be used.	Existing electrical services would be used.
4	Construction water use	Small	Small	Small
Site Preparation and Facility Construction Continued				
5	Effects on land use	Footprint: 13,700 m^2 (3.4 acre) Disturbed: 23,600 m^2 (5.8 acre)	Footprint: 12920 m^2 (3.2 acre) Disturbed: 22,093 m^2 (5.5 acre)	Footprint: 12503 m^2 (3.1 acre) Disturbed: 21,380 m^2 (5.3 acre)
6	Effects on water bodies use	Small	Small	Small
7	Impact on workers	50 workers	50 workers	50 workers
8	Impact of construction generation of fugitive dust	Small	Small	Small
9	Impact on ecology	Small	Small	Small
10	Construction noise	Small	Small	Small
Transmission Facilities Construction Resources Committed				
11	Water	Small	Small	Small
12	Air	None	None	None
13	Biota	Limited to the land used	Limited to the land used	Limited to the land used
14	Materials (approx.)	Concrete: 12,128 metric tons (13,369 tons) Steel: 1,378 metric tons (1,519 tons)	Concrete: 10,533 metric tons (11,611 tons) Steel: 1198 metric tons (1,321 tons)	Concrete: 9,653 metric tons (10,618 tons) Steel: 1,096 metric tons (1,208 tons)
Construction Impact Control				
15	Construction traffic control	Use of existing public roadways is recommended.	Use of existing public roadways is recommended.	Use of existing public roadways is recommended.
16	Dust and particulate emission control	During construction paved road would be used.	During construction paved road would be used.	During construction paved road would be used.
17	Noise control	Small/No provision required	Small/No provision required	Small/No provision required
18	Chemical waste management	A chemical control program would be prepared. Liquid waste would be stored in a tank.	A chemical control program would be prepared. Liquid waste would be stored in a tank.	A chemical control program would be prepared. Liquid waste would be stored in a tank.

No.	Environmental Parameter	Bellefonte	Sequoyah	Watts Bar
19	Solid waste management	Construction scrap would be collected in designated area for recycling or removal.	Construction scrap would be collected in designated area for recycling or removal.	Construction scrap would be collected in designated area for recycling or removal.
20	Site clearing	Site would be paved. By providing drainage, erosion would be controlled.	Site would be paved. By providing drainage, erosion would be controlled.	Site would be paved. By providing drainage, erosion would be controlled.
21	Excavation and Soil deposition	Construction site would be stabilized.	Construction site would be stabilized.	Construction site would be stabilized.

Consistent with 10 CFR 51, Subpart A, Appendix B, the following definition of environmental impacts was used:
Small Environmental effects are not detectable or are so minor that they would neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the NRC has concluded that those impacts that do not exceed permissible levels in the NRC's regulations are considered small as the term is used in this table.
Note: These environmental parameters were taken directly from an earlier approved NRC EA for similar ISFSI design. This EIS states that if built, all NEPA requirements for the ISFSI will be addressed.

A peak workforce of 50 people is projected for the construction of this ISFSI (BGE 1989a). The use of local contractors and the rather small number of personnel are not expected to have any impact on housing, transportation, and educational facilities. Construction fugitive dust should be small. The small construction area should not have any impact on local flora and fauna. The effects of construction noise should be limited for the construction workers by OSHA regulations, for the public by distance to the nearest public residence, and for the local fauna by the small area involved with easy access and egress. No electric power transmission lines would have to be erected because access to existing transmission lines to the nuclear power plant would provide the electric power requirements.

The ISFSI construction would not require the commitment of any water or air resources. The principal materials used in the construction of this ISFSI are steel and concrete. The steel and concrete quantities are delineated previously in Table 5–38. During construction, workers building casks could be exposed to radiation emitted from adjacent casks that have already been completed and loaded with spent nuclear fuel. The dose rates to the construction workers from these casks should average 0.5 mrem/hr (BGE 1989a), and an estimated 1,500 person-hours would be required to complete the construction of one cask or horizontal storage module. The construction dose to workers, as delineated in Table 5–39, conservatively assumes that each cask would be immediately loaded with spent nuclear fuel after it was completed.

Construction traffic would be accommodated by existing nuclear power plant site roadways. Any dust or particulate fugitive emissions caused by earth moving and grading would be controlled by wetting, seeding, and the use of gravel to minimize soil erosion and runoff. Standard equipment and vehicle noise control devices, limiting construction hours, and minimal use of explosives along with adherence to all applicable OSHA requirements would minimize noise impact during construction. Any liquid or solid wastes generated during construction would be collected at the construction site and removed from the site for suitable recycling or disposal offsite in accordance with applicable EPA regulations. None of the wastes would be radioactive.

Operation Impacts

Spent nuclear fuel decay heat is removed by natural air convection in the NUHOMS horizontal storage module dry cask system. Each HSM cask is designed and licensed to safely remove up to 24 kilowatts of decay heat from pressurized water reactor spent nuclear fuel (VECTRA 1995). Conservative calculations have shown that, for 24 kilowatts of decay heat, air entering the cask at a temperature of 21
temperature of 72 cay heat expected for the ISFSI casks would be in the range of 7 to 12 kilowatts with a concomitantly smaller air temperature rise (PN 1993).

The environmental impact of the discharge of this amount of heat can be compared to the heat (336 kilowatts) emitted to the atmosphere by an automobile with a 150–brake horsepower engine (Bosch 1976). The heat released by an average automobile is the equivalent of 14 to 48 ISFSI casks at their design maximum heat load. The decay heat released to the atmosphere from the tritium spent nuclear fuel ISFSI is equivalent to the heat released to the atmosphere from two to six average cars.

The operating ISFSI does not release any radioactive material because the spent nuclear fuel is in a sealed confinement boundary metal cask. The external surface of the cask is decontaminated inside the spent fuel pool building to remove any radioactive contamination from the spent fuel pool water. The horizontal storage module concrete cask is never exposed to any radioactive material and, therefore, can not release any radioactive contamination to the environment.

The ISFSI is a source of direct and skyshine scattered radiation which has penetrated the thick concrete shielding of the cask. The ISFSI direct and scattered radiation is composed of greater than 90 percent gamma radiation and less than 10 percent neutron radiation (BGE 1989b, VECTRA 1995, Duke 1988). The combined direct and scattered dose rate is a function of distance from the ISFSI, the number and configuration of casks in the horizontal storage module, and the presence of any radiation absorbing natural structures or intervening topographical features such as earth berms. NRC regulations (10 CFR 72.106) require that a minimum distance of 100 meters (328 feet) be maintained as a controlled area around the ISFSI. The direct-scattered total dose rate to an individual at 100 meters was calculated to be in the range of 0.01 to 0.1 mrem/hr (BGE 1989b, Duke 1988). The determination of the dose to an offsite individual depends on site-specific factors (e.g., distance and direction of the nearest offsite residence, fuel conditions, contribution of offsite dose from reactor plant effluents). Based on site-specific environmental assessments of operating ISFSIs (e.g., Surry, H.B. Robinson, Calvert Cliffs), the annual dose to the nearest "real" individual would be a small fraction of the 25-mrem/yr criterion in 10 CFR 72.67 and 40 CFR 190. This dose was calculated to be 0.00006 mrem/yr at Surry (VEPCO 1985), 0.4 mrem/yr at H.B. Robinson (CPL 1986), and less than 2 mrem/yr at Calvert Cliffs (BGE 1989b). When combined with the dose commitment from other reactor operations, the total dose commitment would be well within the regulatory limits. **Table 5–41** presents an estimated range of dose rates and annual doses assuming that onsite workers are 100 meters (328 feet) from the ISFSI and that the nearest public residence is 1,000 meters (3,280 feet) from the installation. The radiation dose effect of the number of casks at each specific ISFSI should be minor because of the small magnitude of the doses.

Table 5–41 Environmental Impact of ISFSI Operation

No.	***Environmental Parameter***	***Bellefonte***	***Sequoyah***	***Watts Bar***
1	Effects of operation of heat dissipation system	Equivalent to heat emitted into atmosphere by 2–6 average size cars.	Equivalent to heat emitted into atmosphere by 2–6 average size cars.	Equivalent to heat emitted into atmosphere by 2–6 average size cars.
2	Facility water use	Transfer cask decontamination water consumption of less than 35 m^3 (1,236 ft^3).	Transfer cask decontamination water consumption of less than 28.9 m^3 (1,020 ft^3).	Transfer cask decontamination water consumption of less than 26.8 m^3 (946 ft^3).

No.	Environmental Parameter	Bellefonte	Sequoyah	Watts Bar
3	Radiological impact from routine operation	Worker Exposure: As the result of daily inspection of casks, during a 40-year life cycle, workers would be exposed to 74.4 person-rem. Public Exposure: The regulatory limit for public exposure is 25 mrem/yr. Doses received by a member of public living in the vicinity of the ISFSI would be well below the regulatory requirements.	Worker Exposure: As the result of daily inspection of casks, during a 40-year life cycle, workers would be exposed to 64.3 person-rem. Public Exposure: The regulatory limit for public exposure is 25 mrem/yr. Doses received by a member of public living in the vicinity of the ISFSI would be well below the regulatory requirements.	Worker Exposure: As the result of daily inspection of casks, during a 40-year life cycle, workers would be exposed to 58.8 person-rem. Public Exposure: The regulatory limit for public exposure is 25 mrem/yr. Doses received by a member of public living in the vicinity of the ISFSI would be well below the regulatory requirements.
3	Radwaste and source terms	Cask loading and decontamination operation generates less than 4.42 m^3 (156 ft^3) of low-level radioactive waste.	Cask loading and decontamination operation generates less than 3.85 m^3 (136 ft^3) of low-level radioactive waste.	Cask loading and decontamination operation generates less than 3.57 m^3 (126 ft^3) of low-level radioactive waste.
4	Effects of chemical and biocide discharges	Small	Small	Small
5	Effect of sanitary waste discharges	Small	Small	Small
6	Effects of maintenance of the electrical distribution system	Small	Small	Small
7	Noise impact	Small	Small	Small
8	Climatological impact	Small (less than 0.1% of the nuclear power plant's heat emission to the atmosphere).	Small (less than 0.1% of the nuclear power plant's heat emission to the atmosphere).	Small (less than 0.1% of the nuclear power plant's heat emission to the atmosphere).
9	Impact on Wildlife	Small	Small	Small
10	Impact of runoff from operation	The HSM surface is not contaminated. No contaminated runoff is expected.	The HSM surface is not contaminated. No contaminated runoff is expected.	The HSM surface is not contaminated. No contaminated runoff is expected.
11	Vehicle emissions during construction and operation	Small	Small	Small
12	Socioeconomics	Small	Small	Small

Consistent with 10 CFR 51, Subpart A, Appendix B, the following definition of environmental impacts was used.

Small Environmental effects are not detectable or are so minor that they would neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the NRC has concluded that those impacts that do not exceed permissible levels in the NRC's regulations are considered small as the term is used in this table.

Note: These environmental parameters were taken directly from an earlier approved NRC EA for similar ISFSI design. This EIS states that if built, all NEPA requirements for the ISFSI will be addressed.

The storage cask-loading operation includes moving the spent fuel into the confinement cask, removing the transport cask out of the pool, draining water from the cask, vacuuming and backfilling the cask, welding the cover plate, decontaminating the cask surface, moving the cask to the ISFSI site, and installing the cask into the concrete horizontal storage module. These operations will result in a total dose to all the involved workers conservatively estimated to be in the range of 1.05 to 1.45 person-rem for each ISFSI cask that has been loaded and installed at the ISFSI site (Duke 1988, BGE 1989b). Table 5–41 presents a range of onsite worker doses associated with cask-loading operations for the three nuclear power plants being considered for tritium production. These doses assume that casks are loaded with the same frequency and quantity of spent nuclear fuel as the fuel cycle predictions given in Table 5–39.

Operation of the ISFSI would generate no chemical, biocide, or sanitary wastes. The loading process for each cask would generate less than 0.43 cubic meter (15 cubic feet) of low-level radioactive liquid waste and less than 0.057 cubic meters (2 cubic feet) of low-level solid waste per cask. This amount of low-level radioactive solid and liquid waste is presented in Table 5–41 for each nuclear power plant.

The ISFSI operation would generate minimal noise. The only measurable noise levels would be generated by the truck transporting each cask from the spent fuel pool building to the site (two times for every 18-month fuel cycle). Additional light traffic noise would be generated by personnel transportation for daily ISFSI inspection and periodic health physics or security personnel visits. The noise level should be within the range of noise typically generated by nuclear power plant activities.

The heat emitted by the fully loaded, largest projected tritium spent nuclear fuel ISFSI, even at the maximum design-licensed decay heat level for each cask of 24 kilowatts would be less than 2 megawatts (i.e., 78 casks × 24 kilowatts = 1,872 kilowatts or 1.87 megawatts). This amount of heat of less than 2 megawatts added to the atmosphere is less than 0.1 percent of the heat released to the environment from any of the proposed nuclear power plants: on the order of 2,400 megawatts for each operating nuclear reactor. The actual decay heat from spent nuclear fuel in the ISFSI should be lower than 1.87 megawatts and would decay with time due to the natural decay of fission products in the spent nuclear fuel. In addition, the incremental loading of the ISFSI over a 40-year period would not generate the full ISFSI heat until 40 years after the initial operation. The heat emitted from the ISFSI would have no effect on the environment or climate because of its small magnitude.

The small amount of land expected to be disturbed would have no impact on local flora and fauna. Runoff from rain would have no radioactive contamination and would not require monitoring or holdup capability. ISFSI operational vehicle emissions would be a small fraction of the vehicle emissions generated by the operation of the adjacent nuclear power plant. The operation would not involve an irreversible or irretrievable commitment of resources.

Decommissioning and dismantling of the ISFSI should occur sometime after the availability of a Federal permanent spent nuclear fuel storage facility. The materials used in the ISFSI (i.e., concrete, steel, and lead) would be identical to materials at the adjoining nuclear power plant. Decontamination and decommissioning methods for the nuclear power plant would be applied to the site, and would represent a small fraction of the quantity and radioactive contamination level of components within the nuclear plant. Some decontamination of an inner layer of the concrete shielding and the metal confinement cask would be required. A minimal incremental environmental impact is expected from the decontamination and decommissioning of the ISFSI assuming that it occurs simultaneously with the decontamination and decommissioning of the nuclear power plant.

The potential increase in spent fuel storage requirements due to tritium production would create additional costs, but would not appreciably increase socioeconomic impacts. The spent fuel dry storage casks would be procured from outside the region. The costs incurred at the site for additional fuel transfers, spent fuel storage cask maintenance, spent fuel cask pad expansion, transfer of spent fuel to shipping casks, etc. and related storage activities should be no more than $1 million per year. These costs are not material in a regional socioeconomic context.

Environmental Effects of Postulated Accidents

The most severe environmental impact of all postulated accidents analyzed for the ISFSI is the nonmechanistic release of the gaseous gap content from all 24 pressurized water reactor spent nuclear fuel assemblies in a storage cask (VECTRA 1995). This accident conservatively assumes that 30 percent of all fission product gases present in all the spent nuclear fuel within one cask would be released to the environment. This scenario is extremely conservative because the ISFSI is designed to maintain its confinement capability under all postulated accidents. In addition, ISFSI casks encapsulate intact fuel. Failed fuel must be enclosed in a second sealed container within the cask to ensure the required two levels of confinement for ISFSI design. The radiological consequences of this accident are calculated using the bounding spent nuclear fuel radioisotope fission product inventory and conservative site-specific atmospheric dispersion factors. The regulatory limit for this accident is a 5,000-millirem whole-body or individual organ dose (10 CFR 72.106). The numerical value of the calculated dose for this accident is a function of the specific stored spent nuclear fuel bounding fission product inventory, site-specific atmospheric dispersion factors, and the site-specific distance from the ISFSI to the nearest public boundary. A generic and conservative calculation for the NUHOMS–24P design resulted in a 300-meter (984-foot) whole-body dose of 53 millirem (VECTRA 1995). Similarly, generic conservative calculations for this accident with the VSC–24 ISFSI design (PSNA 1991) resulted a whole-body dose of 88 millirem at 200 meters (656 feet), 18 millirem at 500 meters (1,640 feet), and 5.7 millirem) at 1,000 meters (3,280 feet). All of these results are well within the regulatory limit. The impact of these calculated doses can be compared with the natural radiation dose received by each human being in the United States of about 300 millirem annually (DOE 1996a). Thus, even at an unrealistically close distance of 200 meters, the public dose to this extremely conservative, nonmechanistic accident represents about 29 percent of the average annual dose due to natural sources. At a more realistic distance of 1,000 meters (3,281 feet), the dose from this accident represents only 2 percent of the average annual natural dose to the public. The generic conservative radiological consequences of this accident are presented in **Table 5–42** along with the regulatory limit and average U.S. public natural annual dose.

All other postulated ISFSI accidents would either have no radiological impacts on the public or would deliver a dose smaller than that calculated for the 100 percent fuel failure coincident with a cask leakage.

Table 5–42 Environmental Impact of Accidents at ISFSI

Normal Operation and Operational Occurrences			
	Postulated Accident	***Accident Evaluation Requirements***	***Consequences***
Anticipated Accident			
1	An inadvertent cask movement causing lateral impact of the fuel basket against the inside of the storage cask.	This event should be evaluated to ensure that no release of radioactive materials in the ISFSI would result.	This event does not result in release of radioactive materials.
2	Extreme ambient temperatures	This event should be evaluated to ensure that no release of radioactive materials in the ISFSI would result.	This event does not result in release of radioactive materials.
3	Partial blockage of air passages	This event should be evaluated to ensure that no release of radioactive materials in the ISFSI would result.	This event does not result in release of radioactive materials.
4	The postulated release of surface contamination from baskets	This event could result in the release of radioactive materials from the ISFSI. An analysis should be done to demonstrate that the proposed contamination limits would not result in radiological concern at a distance of 100 meters from the ISFSI. The analysis should also determine the allowable surface contamination limits.	This accident would result in dose of less than 10 millirem to a person at 100 meters away.

Normal Operation and Operational Occurrences			
	Postulated Accident	***Accident Evaluation Requirements***	***Consequences***
Maximum Credible Accident			
1	Fires	The ISFSI Safety Analysis Report should evaluate the consequences of this hypothetical accident to demonstrate that the storage cask system provides a substantial safety margin for the protection of public, facility personnel, and the environment.	Designed to withstand the accident with no consequence.
2	Structural collapse	The presence of any structure which its collapse may result in any accident should be acknowledged. The ISFSI Safety Analysis Report should evaluate the consequences of this hypothetical accident to demonstrate that the storage cask system provides a substantial safety margin for the protection of public, facility personnel, and the environment.	Designed to withstand the accident with no consequence.
3	The postulated tipping over of a storage cask	The ISFSI Safety Analysis Report should evaluate the consequences of this hypothetical accident to demonstrate that the storage cask system provides a substantial safety margin for the protection of public, facility personnel, and the environment.	Designed to withstand the accident with no consequence.
4	Blockage of the storage cask air inlet vents	The ISFSI Safety Analysis Report should evaluate the consequences of this hypothetical accident to demonstrate that the storage cask system provides a substantial safety margin for the protection of public, facility personnel, and the environment.	Designed to withstand the accident with no consequence.
Beyond-Design-Basis Accident			
5	Dry shielded canister leakage	Sites should identify the radiological consequences of this accident and ensure that it is below the regulatory limit at the ISFSI facility fence.	88 millirem at 200 meters (656 feet) 18 millirem at 500 meters (1,640 feet), 5.7 millirem at 1,000 meters (3,280 feet).
Transportation Accidents Involving Radioactivity			
1	Transportation accidents	Sites should: – confirm that transportation of the storage system would take place within the existing site boundary. – describe on-site transportation aspects and procedures (i.e., towing and transfer method, distance traveled). – ensure that no transportation accident (i.e., drop of a loaded cask) could lead to release of radioactive materials.	Designed to withstand the accident with no consequence.
Other Accidents			
1	Tornadoes	This accidents should be evaluated consistent with the plant's FSAR requirements.	Consistent with the ISFSI's design criteria in the Safety Analysis Report.
2	Floods	This accidents should be evaluated consistent with the plant's FSAR requirements.	Consistent with the ISFSI's design criteria in the Safety Analysis Report.

Normal Operation and Operational Occurrences			
	Postulated Accident	**Accident Evaluation Requirements**	**Consequences**
3	Earthquakes	This accidents should be evaluated consistent with the plant's FSAR requirements.	Consistent with the ISFSI's design criteria in the Safety Analysis Report.
4	Volcanoes	This accidents should be evaluated consistent with the plant's FSAR requirements.	Consistent with the ISFSI's design criteria in the Safety Analysis Report.
5	Nearby explosions	This accidents should be evaluated consistent with the plant's FSAR requirements.	Consistent with the ISFSI's design criteria in the Safety Analysis Report.
6	Lightning strikes	This accidents should be evaluated consistent with the plant's FSAR requirements.	Consistent with the ISFSI's design criteria in the Safety Analysis Report.
7	The collapse of structures around the ISFSI	Sites should determine any probability of a failure of a surrounding structure which could effect integrity of the ISFSI.	Consistent with the ISFSI's design criteria in the Safety Analysis Report.
8	Fire protection	Sites should ensure that no combustible material are stored within the ISFSI or its boundaries.	Consistent with the ISFSI's design criteria in the Safety Analysis Report.
9	Explosion protection	Sites should ensure that no explosive materials and no credible internal explosion is possible.	Consistent with the ISFSI's design criteria in the Safety Analysis Report.

5.2.7 Fabrication of TPBARs

Commercial facilities would fabricate and assemble the TPBARs. Potential fabrication and/or assembly sites include: General Electric, Wilmington, North Carolina; Framatome - Cogema Fuels, Lynchburg Virginia; BWX Technologies, Inc., Lynchburg, Virginia; Siemens Power Corporation, Richland, Washington; and Westinghouse Electric, Columbia, South Carolina. Each of the facilities has a 10 CFR 70 license issued by the NRC. The successful fabrication bidder will determine whether its NRC license will require an amendment. In the event a license amendment is required, the NRC will prepare the appropriate environmental documentation. In addition, if this DOE fabrication procurement is subject to 10 CFR 1021, DOE will consider the environmental impacts during the fabrication procurement process. Since the fabricator of the TPBARs is still to be determined, the qualitative assessment presented in this EIS presents the reasonably foreseeable impacts of fabrication. This EIS provides a brief description of the fabrication process and a qualitative discussion of the potential, non-site-specific environmental consequences. It also provides estimates of the material resources required by the tritium production program.

The TPBARs consist of multiple layers of materials designed to produce, capture, and store tritium until the TPBARs can be removed from the reactor and processed, under controlled conditions, to remove the tritium. The outer and inner layers of the TPBAR provide structural integrity and the cylindrical form for the TPBAR. These layers are made of stainless steel and zircaloy as cladding material for the burnable absorber rods. Additional layers of material would include aluminum and zirconium. The zirconium provides a collection point for the tritium produced, while the aluminum provides an effective barrier to prevent outleakage of the tritium and in leakage of hydrogen from the reactor coolant and moderator (water). Finally, a lithium aluminate pellet contains the lithium necessary for tritium production (Additional information regarding TPBAR configuration is provided in Appendix A.)

The enriched lithium aluminate is produced through the chemical reaction of lithium carbonate and aluminum oxide. In the TPBAR fabrication facility, these two materials would be blended, spray dried (to limit the amount of water trapped in the product) and calcined to form the lithium aluminate. The lithium aluminate is combined with a dry binder, pressed into its final ceramic annular shape, and sintered. These annular pellets are then assembled with the remaining rod components including the zirconium getter and the rod cladding. Final rod assembly includes additional drying, backfilling of the rods with helium, and welding end caps onto the rods. During fabrication some machining of the rods is necessary to ensure the rod dimensions meet production tolerances. The TPBARs are attached to a base plate to create a TPBAR assembly, which is inserted into a fuel assembly at which point they are ready for transport to the CLWR.

No filtration of the off-gases (principally carbon dioxide) produced by this reaction would be necessary. Wastes generated from the TPBAR production would consist of sanitary wastes, process wastes, and chemical wastes. Wastes would primarily be generated from TPBAR fabrication laboratory analysis, pellet grinding, and stainless steel tube working. Usable scrap material generated during the machining operations would be recycled for later use in the TPBAR production process. (DOE 1992)

The quantities of material required for TPBAR production are presented in **Table 5–43**. These numbers are based on the production of 4,000 TPBARs per year (6,000 TPBARs, or 250 TPBAR assemblies, produced for refueling outages for reactors on an 18-month operating cycle). Each TPBAR assembly weighs less than 27 kilograms (60 pounds) of which less than 400 grams (0.8 pound) is lithium (WEC 1997). The amounts of source material for the production of lithium aluminate are derived from the amount of lithium required for each TPBAR. Materials used for the fabrication of the TPBARs (i.e., lithium) have been mined and processed and are part of the Department's inventory of material resources. Therefore, no environmental consequences of any significance are expected from activities other than the fabrication and assembly of the TPBARs.

Table 5–43 Materials Required for TPBAR Production

Material	*Annual Requirement (kg)*	*Program Requirement (metric tons)* [a, b]
Lithium	61	2.4
Lithium carbonate	325	13
Aluminum oxide	450	18
Other materials [c]	4000	160

[a] Based on 40-year program duration
[b] 1 metric ton = 1,000 kg (2,200 lb)
[c] Includes aluminum, zircalloy, stainless steel, and nickel

The TPBARs are inserted into fresh fuel assemblies in place of burnable absorber rods or an empty thimble tube. The replacement of the burnable absorber rods with TPBARs for tritium production requires that additional fuel assemblies be used in the CLWR fuel cycle. The addition of lithium into the core design increases the amount of uranium^{235} that must be in the core to produce the design power level throughout the 18-month fuel cycle. The number of fresh assemblies required for each 18-month refueling cycle depends on the number of TPBARs inserted for irradiation in the reactor core. Up to approximately 2,000 TPBARs additional fresh fuel assemblies are required. As the number of TPBARs increases the additional fresh fuel assemblies increase. For the maximum number of 3,400 TPBARs considered in this EIS, approximately 60 fresh fuel assemblies would be required in addition to the approximately 80 fresh fuel assemblies normally used in an 18-month refueling cycle nontritium production mode. Therefore, the additional number of fresh fuel assemblies that would be required at Watts Bar or Sequoyah for a 40-year program duration would be approximately 1,620 fresh fuel assemblies.

At Bellefonte, all fresh fuel required is attributed to tritium production, therefore approximately 3,870 fresh fuel assemblies would be required.

Tritium production would require fuel assemblies with higher enrichments of $uranium^{235}$ than the assemblies used in a commercial power reactor. The increased enrichment is required to compensate for the increased "loss" of neutrons from the power production capability of the reactor core. These two factors, increased number of fuel assemblies and increased $uranium^{235}$ enrichment, result in an increased use of $uranium^{235}$ in a tritium production reactor compared to the same reactor operated solely for power production. **Table 5–44** provides a summary of the amounts of $uranium^{235}$ required for commercial operation and tritium production operation of three reactors. These figures are based on the initial core load of fresh fuel and 26 refueling outages over the 40-year life of the program. An average $uranium^{235}$ enrichment of 4.95 percent has been assumed for the fuel assemblies used for tritium production (WEC 1997).

Table 5–44 Additional Fuel Requirements

Requirements	*Tritium Production Core Configuration*	*Watts Bar 1 Sequoyah 1 or 2*	*Bellefonte 1*
Fresh fuel assemblies	3,400 TPBARs	1,620	3,870
	less than 2,000 TPBARs	0	2,080
$Uranium^{235}$ (MT)	3,400 TPBARs	32.1	76.7
	less than 2,000 TPBARs	0	41.1

MT = metric ton = 1,000 kg (2,200 lb)

The enriched uranium to be used for the nuclear fuel assemblies would likely be provided by DOE from surplus highly enriched uranium by downblending it with other uranium materials to commercially usable low enriched uranium. It has already been decided that 33 to 40 metric tons (36 to 44 tons) would be transferred to TVA for use in its reactors over the period between 2001 and 2006 (DOE 1998b). Additional low-enriched uranium could be provided for use in the tritium program. Therefore, environmental impacts resulting from the potential increase in the use of uranium would be minimal.

5.2.8 Transportation of TPBARs

Transportation impacts may be divided into two parts: the impacts of incident free or routine transportation and the impacts of transportation accidents. Incident-free transportation and transportation accident impacts are divided into two parts: nonradiological impacts and radiological impacts. Incident free transportation includes radiological impacts on the public and the crew from the radiation field that surrounds the package. Nonradiological impacts of incident free transportation include vehicular emissions. Nonradiological impacts of potential transportation accidents are traffic accident fatalities. Only in the worst conceivable conditions, which are of low probability, could a transportation cask of the type used to transport radioactive material be so damaged that there could be a release of radioactivity to the environment.

The impacts of accidents are expressed in terms of probabilistic risk, which is a probability of an accident multiplied by the consequences of that accident, and summed over all reasonably conceivable accidents. The units for radiological accidents are additional latent cancer fatalities, and for nonradiological accidents are additional immediate fatalities. The impacts of incident-free effects are expressed in additional latent cancer fatalities.

The first step in the ground transportation analysis was to determine the incident free and accident risk factors, on a per shipment basis, for transportation of the various materials. Calculation of risk factors was accomplished by using the HIGHWAY (ORNL 1993a) and INTERLINE (ORNL 1993b) computer codes to choose representative routes in accordance with the DOT regulations. These codes provide population estimates so that

RADTRAN (SNL 1993), and TICLD (SNL 1993) codes could be used to determine the radiological risk factors. This analysis is discussed in Appendix E.

Four transportation segments were evaluated in this EIS: (1) Shipment of fabricated TPBARs to an assembly facility; (2) Shipment of TPBAR assemblies to each of the CLWRs; (3) Shipment of irradiated TPBARs to a Tritium Extraction Facility (assumed for purposes of evaluation to be at SRS); and (4) Shipment of irradiated hardware to a waste disposal site. **Table 5–45** shows the estimated impacts of transportation for the 40-year duration of the program.

The impacts from transportation segments (1) and (2) are limited to toxic vehicle exhaust emissions and traffic fatalities since the fabricated TPBARs contain no radioactive elements. Combinations of fabrication and assembly sites were evaluated, including Richland, Washington; Lynchburg, Virginia (Framatome-Cogema Fuels or B&W Technologies, Inc.); and Columbia, South Carolina (Westinghouse Electric Corporation). The maximum possible impacts are included in Table 5–45. The choice of facilities would be made by DOE using normal commercial procurement practices.

Transportation segment (3) involves shipment of irradiated TPBARs from the CLWRs to the Tritium Extraction Facility at DOE's Savannah River Site in South Carolina. This EIS has evaluated the shipment of TPBARs by three distinct methods: (1) truck casks on trucks, (2) truck casks on trains, and (3) rail casks on trains.

Transportation segment (4) involves shipment of irradiated hardware from the CLWRs to either DOE's Savannah River Site in South Carolina or Barnwell for disposal as low-level radioactive waste. Irradiated hardware includes base plates and thimble plugs removed from the TPBARs at the CLWR site. The number of thimble plugs and base plates cannot be determined until the detailed plans for irradiation are completed.

Table 5–45 Risks of Transporting the Hazardous Materials

Reactor Site (No. of TPBARs)	*TPBAR Transportation Mode*	*Routine*				*Accidental*
		Radiological		*Nonradiological*		
		Crew	*Public*	*Emission*	*Traffic*	*Radiological*
Watts Bar (3,400 TPBARs/cycle)	Truck cask via truck	0.0033	0.021	0.0032	0.031	4.0×10^{-6}
	Truck cask via rail	0.0016	0.008	0.0023	0.029	5.7×10^{-6}
	Rail cask via rail	0.0016	0.008	0.0023	0.029	1.6×10^{-6}
Sequoyah (3,400 TPBARs/cycle)	Truck cask via truck	0.0030	0.019	0.0035	0.029	4.9×10^{-6}
	Truck cask via rail	0.0014	0.007	0.0024	0.028	5.2×10^{-6}
	Rail cask via rail	0.0014	0.007	0.0024	0.028	1.4×10^{-6}
Bellefonte (3,400 TPBARs/cycle)	Truck cask via truck	0.0026	0.018	0.0034	0.030	4.2×10^{-6}
	Truck cask via rail	0.0010	0.005	0.0024	0.028	5.7×10^{-6}
	Rail cask via rail	0.0010	0.005	0.0024	0.028	1.6×10^{-6}
Watts Bar (1,000 TPBARs/cycle)	Truck cask via truck	0.0010	0.007	0.0010	0.009	1.5×10^{-6}
	Truck cask via rail	0.0005	0.002	0.0007	0.009	1.9×10^{-6}
	Rail cask via rail	0.0005	0.002	0.0007	0.009	5.2×10^{-7}
Sequoyah (1,000 TPBARs/cycle)	Truck cask via truck	0.0009	0.006	0.0011	0.009	1.9×10^{-6}
	Truck cask via rail	0.0004	0.002	0.0007	0.008	1.7×10^{-6}
	Rail cask via tail	0.0004	0.002	0.0007	0.008	4.8×10^{-7}
Bellefonte (1,000 TPBARs/cycle)	Truck cask via truck	0.0008	0.006	0.0010	0.009	1.6×10^{-6}
	Truck cask via rail	0.0003	0.001	0.0007	0.009	1.9×10^{-6}
	Rail cask via rail	0.0003	0.001	0.0007	0.009	5.3×10^{-7}

Notes: 1. Maximum impacts are assumed for fabrication, assembly and waste transportation, and are included in these totals.

2. All risks are expressed in latent cancer fatalities during the implementation of the policy, except for the Accident-Traffic column, which is the number of fatalities.

The next step is to use the risk factors and the number of shipments to estimate the risk for transportation segments. The exact number of shipments cannot be determined unless the precise numbers of TPBARs to be handled are known. The transportation analysis provided information to bound the impacts at each site in **Figure 5–7**. The transportation analysis looked at potential implementation approaches for each of the three reactor sites. The approaches quantitatively addressed include production at a single unit with 1,000 TPBARs and maximum production at a single unit with 3,400 TPBARs.

5.2.9 Sensitivity Analysis

As discussed in Section 3.2.1, the maximum number of TPBARs to be fabricated, irradiated, and transported to the Tritium Extraction Facility under the proposed action is approximately 6,000 TPBARs per 18-month reactor operating cycle, or approximately 4,000 TPBARs per year. This requirement is based on a design production goal of 1.2 grams of tritium per TPBAR. The environmental consequences of the baseline tritium production CLWR configuration are evaluated in Sections 5.2.1 through 5.2.3 for the Watts Bar Nuclear Plant, the Sequoyah Nuclear Plant, and the Bellefonte Nuclear Plant, respectively.

This section provides a sensitivity analysis on the environmental consequences at a single reactor site that would result by considering some variations on assumptions made for the baseline analysis. These variations are: (1) reducing the number of TPBARs to be irradiated in a single reactor to 100 TPBARs, (2) changing the design production goal of tritium to 1.5 grams per TPBAR and, (3) reducing the length of the reactor operating cycle to 15.5 months or 12 months, in conjunction with the design tritium production goal of 1.5 grams per TPBAR. **Table 5–46** provides the values of key parameters used in the sensitivity analyses

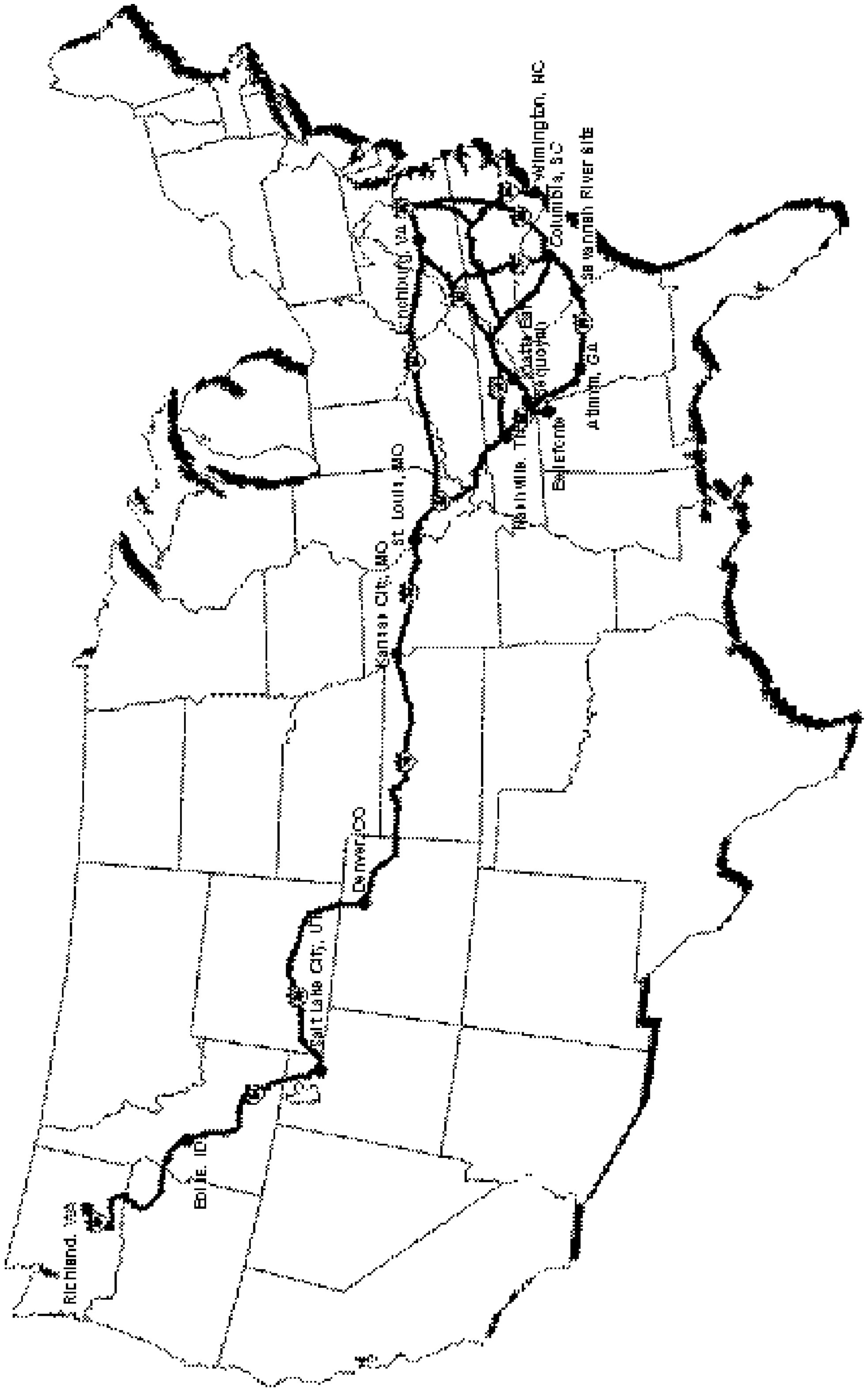


Figure 5–7 Representative Overland Truck Routes

Table 5–46 Sensitivity Analysis Key Parameters

Parameter	*Baseline*	*Sensitivity Analysis*		
TPBAR design goal (g)	1.2	1.2	1.5	1.5
Number of TPBARs in reactor core	3,400	100	3,400	3,400
Operating cycle (months)	18	18	15.5	12
Refueling time (months)	1	1	1	1
Tritium production /TPBAR (g)	1.0 [a]	1.0	1.2 [b]	1.0 [c]
Total tritium production (g)	3,400	100	4,080	3,400
Annualized tritium production (g)	2,267	67	3,160	3,400
TPBAR leakage to RCS (Ci/TPBAR per yr)	1	1	1	1
TPBAR leakage to RCS (Ci/TPBAR per cycle) [d]	1.5	1.5	1.3	1
Number of failed TPBARs during normal operation (released tritium)	2 (2.4 g)	2 (2.4 g)	2 (3.0 g)	2 (3.0 g)
Truck shipments/operating cycle (1 unit/shipment) [e]	12	1	12	12
Rail shipments/operating cycle (2 units/shipment) [e]	6	1	6	6

[a] Westinghouse estimated 0.84 gram average and 1.07 peak for the reference plant (WEC 1997).
[b] Westinghouse estimated 1.07 gram average and 1.31 peak for the reference plant (WEC 1997).
[c] Rounded up to 1.0.
[d] Nominal value. No credit taken for refueling outage.
[e] 1 unit = 1 consolidation unit array = 289 TPBARs
Key: RCS = Reactor Coolant System

discussed below. **Table 5–47** presents the public health and safety related results of the analyses in percent change from the baseline configuration for a single reactor facility.

Reduction of Number of TPBARs at a Single Reactor

Reducing the number of TPBARs to be irradiated in a single reactor could affect the need for fresh nuclear fuel and spent nuclear fuel production. As discussed in Section 3.2.1 and 5.2.6, the need for additional fresh fuel assemblies for a core reload starts at about 2,000 TPBARs for a single reactor. Therefore, if the implementation of the proposed action would take place in more than one reactor with less than 2,000 TPBARs to be irradiated in each, there would be no need for additional fuel assemblies and associated material resources. In addition, there would be no need for the construction and operation of additional dry storage spent fuel facilities at the reactor sites solely because of tritium production.

Reducing the number of TPBARs to be irradiated in a single reactor would reduce the tritium releases to the environment under normal operation and accident conditions. The reduction effect for normal operation would be linear if not for the conservative assumption made in the analysis that the number of TPBARs that assumed to fail remains constant (2 TPBAR failures) even for relatively small quantities of TPBARs (WEC 1998).

Reducing the number of TPBARs to be irradiated in a single reactor would reduce the low-level radioactive waste production and the number of irradiated TPBAR shipments from the reactor site. It would not affect environmental resources at a reactor site such as land, ecology, historical resources, aesthetics and socioeconomics and would have reduced already small impacts on resources such as noise, and aesthetics. Overall the baseline analysis of 3,400 TPBARs at a single reactor site bounds the effects of irradiation with fewer TPBARs at the site.

Table 5–47 Sensitivity Analysis Summary for a Single Reactor Site

CLWR Configuration	***Number of TPBARs in Core***	***100***	***3,400***	***3,400***
	Operating Cycle (months)	***18***	***15.5***	***12***
	Tritium Production Goal/TPBAR (g)	***1.2***	***1.5***	***1.5***
Normal Operation		**Percent Change from Baseline Configuration**		
Radiological liquid effluent (tritium)	Quantity per year	-18	37	72
Radiological gaseous emissions (tritium)	Quantity per year	-18	37	72
Hazardous chemical liquid emissions	Quantity per year	0	0	0
Hazardous chemical gaseous emissions	Quantity per year	0	0	0
Facility Accidents		**Percent Change from Baseline Configuration**		
Reactor design-basis accident[a]	Consequence[d]	-97	20	0
	Risk per year[e]	-97	13	-8
Reactor design-basis accident[b]	Consequence [d]	0	0	0
	Risk per year[e]	0	-6	-8
Nonreactor design-basis accident[a]	Consequence[d]	-18	18	15
	Risk per year[e]	-18	37	72
Nonreactor design-basis accident[b] (Thyroid dose consequences and risks)	Consequence[d]	-16	17	14
	Risk per year[e]	-16	35	70
Nonreactor design-basis accident[b] (Beta+gamma whole body dose consequences and risks)	Consequence[d]	-2	2	1
	Risk per year[e]	-2	18	52
TPBAR-handling accident	Consequence[d]	0	20	20
	Risk per year[e]	-97	39	80
Truck cask-handling accident	Consequence[d]	0	20	20
	Risk per year[e]	-94	39	80
Rail cask-handling accident	Consequence[d]	0	20	20
	Risk per year[e]	-83	39	80
Severe reactor accident	Consequence[d]	-1	0	0
	Risk per year[e]	-1	-6	-8
Hazardous chemical accident	Consequence[d]	0	0	0
	Risk per year[e]	0	0	0
Low-Level Radioactive Waste		**Percent Change from Baseline Configuration**		
Low level radioactive waste generation	Quantity per year	-96	16	50
Spent Fuel Space		**Percent Change from Baseline Configuration**		
Spent fuel storage space	Storage positions per year	[c]	16	50
Overland Transportation of Irradiated TPBARs from a Single Reactor Facility		**Percent Change from Baseline Configuration**		
Truck shipments	Number per year	-92	16	50
Rail shipments	Number per year	-83	16	50

[a] Design-basis accident consequences only reflect the incremental increase in accident consequences due to the production of tritium in TPBARs.
[b] Design-basis accident consequences estimated using NRC-based deterministic approach.
[c] The baseline configuration requires 56 to 69 additional fresh fuel assemblies and therefore requires 75-96 percent of additional spent fuel storage space for each core reload with 3,400 TPBARs. No additional fresh fuel assemblies are required for 2,000 TPBARs.
[d] Maximally exposed offsite individual, average individual in population, and noninvolved worker dose in rem.
[e] Maximally exposed offsite individual, average individual in population, and noninvolved worker increased likelihood of cancer fatality/year.

Design Tritium Production Goal of 1.5 grams/TPBAR

The increase of the design tritium production goal to 1.5 g/TPBAR, assuming the maximum number of 3,400 TPBARs to be irradiated at a reactor site, would increase the tritium emission to the environment under normal operating and accident conditions compared to the baseline case. The necessary shortening of the reactor operating cycle from 18 months to 15.5 month would also result in increases in low-level radioactive waste production and spent fuel generation and storage requirements. It would have no effect on all other environmental resources considered in this EIS such as land, aesthetics, archeological and historic resources, ecology, and socioeconomics. The increase in noise due to more frequent refuelings would be small.

From a program point of view, the increase of the design tritium production goal from 1.2 g/TPBAR to 1.5 g/TPBAR, would provide the potential for using fewer TPBARs for the same goal production of tritium. The number of TPBARs that would need to be fabricated, irradiated, and transported would be reduced to approximately 3,870 TPBARs per year producing the same amount of tritium. Fewer TPBARs would mean lesser environmental consequences from fabrication. The number of shipments of both nonirradiated and irradiated TPBARs would be reduced, thus reducing the incident-free risk to the health and safety of the public proportionately.

Length of Reactor Operating Cycle

Shortening the length of the reactor operating cycle to 12 months is discussed in conjunction with the 1.5-gram-per-TBAR design as opposed to the 1.2 grams per TPBAR. As discussed above, a shorter cycle (15.5 months) would be required to irradiate the maximum number of 3,400 TPBARs in a reactor. Shortening the reactor operating cycle even further, to 12 months, with the 1.5-gram-per-TPBAR design, would allow the increase of tritium production from 2,667 g/yr (baseline in a single reactor) to 3,400 g/yr. This tritium quantity is less than the quantity assumed to be needed for program, but it could be produced in a single reactor if the program requirements were reduced in the future.

Shortening the reactor operating cycle to 12 months would directly affect the number of TPBARs that are irradiated annually in a single reactor, from 3,400 in 18 months (2,267 g/year) to 3,400 per year. This would increase the annual generation of spent fuel, the annual generation of low-level radioactive waste, the annual gaseous emissions and liquid effluent releases of tritium, the activities required to handle the irradiated TPBARs at the site, and the number of refueling outages required at the reactor for the 40-year duration of the proposed action. Consequently, there will be proportional increases to impacts associated with air and water quality, ecological resources, and occupational and public health and safety.

Shortening the reactor operating cycle to 12 months would increase the environmental consequences associated with the construction and operation of a dry spent fuel facility at the reactor site by approximately 50 percent. It would have no effect on all other environmental resources considered in this EIS such as land, archaeological and historic resources, aesthetics, and socioeconomics. The increase to noise due to more frequent refuelings would be small.

From a program point of view, shortening the reactor operating cycle to 12 months would be practical if the program requirements for tritium production were reduced, so that the total number of TPBARs that would need to be fabricated and transported were reduced to approximately 3,400 TPBARs per year, which would be irradiated at a single rather than multiple reactor facilities.

5.2.10 Safeguards and Security

Commercial light water reactors are required by the provisions of their NRC license to have security and safeguard procedures to protect against a design-basis threat. On a site-specific basis, a design-basis threat characterizes: (1) a determined, violent, external attack by stealth or deception by several persons or a small group; (2) a well-trained and dedicated adversary group with suitable weapons and hand-carried equipment, tools, explosives, and may be aided by an insider; (3) an internal threat by an insider who may attempt theft and/or sabotage; and (4) other threat actions such as attacking computer systems. Requirements for developing the design-basis threat, as well as requirements for measures to guard against this threat for NRC-licensed facilities are provided in 10 CFR Parts 73 and 74.

Facilities and activities associated with the production of tritium for DOE are also required to comply with the requirements in DOE 5632.1C and 5633.3A. DOE Orders require a graded protection for all safeguard and security interests, classified matter, property and sensitive information from theft, diversion, industrial sabotage, radiological sabotage, espionage, unauthorized access or modification, loss or compromise, or other hostile acts which could cause unacceptable adverse impacts on national security, our business partners, or on the health and safety of employees and the public. The DOE Orders also require a facility associated with the production of tritium to provide protection against a design-basis threat. A CLWR used for the production of tritium must comply with NRC and DOE regulatory requirements. The transportation of DOE materials are also required to comply with a graded set of DOE safeguard and security requirements, in addition to complying with the NRC, DOE, and DOT safety requirements.

The DOE Safeguards and Security Protection Program defines procedures to ensure physical protection of material and equipment, materials control and accountability, nuclear materials control, nuclear materials accountability, security of personnel, personnel security awareness, information security, automated information security, and personnel training.

The project placed TPBARs in the Watts Bar Nuclear Plant for the Lead Test Assembly Demonstration Project. The Inspection Branch of DOE's Safeguards and Security Division, Oak Ridge Operations Office, conducted a security survey of the Watts Bar Nuclear Plant in preparation for the Lead Test Assembly Demonstration Project. The existing NRC Program was found to satisfactorily fulfill all DOE requirements. (DOE 1997b)

No environmental impacts are expected as a result of compliance with both NRC and DOE safeguard and security provisions based on the adequacy of the existing TVA security provisions. Before introducing any TPBARs into any CLWR, DOE would conduct an in-depth site-specific safeguards and security inspection. This rigorous review would ensure that the existing safeguards and security programs of any reactor used in the CLWR program satisfy the stringent DOE requirements. Any inadequacies would be resolved before the introduction of any DOE materials to the facility. Although it is not anticipated, if the safeguards and security review determined that additional security provisions were required, DOE would perform the appropriate NEPA review.

The CLWR EIS identifies credible accident scenarios caused by internal disturbances, addresses the probability of such accidents, and quantifies the releases and exposures resulting from such accidents. Accidents initiated as a result of sabotage are considered speculative and, accordingly, have not been addressed in the CLWR EIS.

5.2.11 Programmatic No Action

The DOE is preparing a separate EIS to analyze the environmental impacts of the construction and operation of an Accelerator Production of Tritium facility at DOE’s Savannah River Site in South Carolina. DOE published a Draft EIS in December 1997 (DOE 1997e). Since the No Action Alternative for the CLWR EIS entails production of tritium in the Accelerator Production of Tritium, this section summarizes the Accelerator Production of Tritium environmental impacts as presented in Chapter 4 of the Draft Accelerator Production of Tritium EIS. For a more detailed analysis of these potential impacts, the reader is referred directly to the draft environmental impact statement, Accelerator Production of Tritium, at the Savannah River Site.

The Draft Accelerator Production of Tritium EIS considered two design alternatives: klystron radio frequency power tubes (the preferred alternative), and inductive output radio frequency power tubes. It also considered two operating temperature alternatives for the design of the accelerator: operating electric components at essentially room temperature, and operating most components at superconducting temperatures and the rest at room temperature (the preferred alternative). Two feedstock alternatives were considered: helium 3 (the preferred alternative), and lithium 6. Four cooling water system designs were considered for the Draft Accelerator Production of Tritium EIS: mechanical-draft cooling towers with groundwater makeup; once-through cooling using river water; and use of the existing K-Area natural-draft cooling tower with river water makeup.

The Draft Accelerator Production of Tritium EIS also considered two design variations to the preferred alternative to enhance DOE's flexibility: a modular or staged accelerator configuration, a combination of tritium separation and tritium extraction facilities. It also considered two site alternatives. The preferred site is 4.8 kilometers (3 miles) northeast of the Tritium Loading Facility, and approximately 10.5 kilometers (6.5 miles) from DOE's Savannah River Site in South Carolina boundary. The alternative site is located 3.2 kilometers (2 miles) northwest of the Tritium Loading Facility and approximately 6.4 kilometers (4 miles) from the boundary of DOE's Savannah River Site in South Carolina. Due to the projected magnitude of the electric power usage (peak load as high as 600 megawatts for the room temperature alternative), the Draft Accelerator Production of Tritium EIS considered two electrical source alternatives: obtaining electricity from the construction and operating of a new coal-fired or natural gas–fired generating plant.

The potential environmental impacts are presented as construction impacts and operational impacts. This summary will provide the potential impacts of the preferred alternative and indicate where alternative impacts vary from the preferred alternative.

Construction Impacts

For the preferred alternative, construction of the Accelerator Production of Tritium facility would convert approximately 101 hectares (250 acres) of forested land into an industrialized area. Excavation of 20 meters (65 feet) in depth would be required. If DOE were to choose the modular design variation, construction impacts could be spread over a longer period of time and require the clearing of an additional 12 hectares (30 acres). New roads, bridge upgrades, and rail lines would also be required. At the preferred site, the construction excavation would reach the water table and thus require dewatering. Impacts on the water tables would be minimal due to the rather short period of dewatering and the fact that construction would only affect the shallowest portion. Air emissions (fugitive dust and exhaust emissions) should be well below applicable regulatory standards.

Potential impact to terrestrial ecology would result from clearing this land. DOE does not expect, however, that this would create a long-term reduction in the local or regional diversity of plants and animals. No threatened or endangered species occur at any of the alternative sites for the Accelerator Production of Tritium facility.

The generation of construction waste could require the construction of a state-permitted construction debris landfill at the DOE's Savannah River Site in South Carolina. Sanitary solid waste would be disposed of in the Three Rivers Regional Landfill. Construction noise at the Accelerator Production of Tritium site could be higher than the limits imposed by the Occupational Safety and Health Administration. However, DOE would ensure compliance with OSHA 8-hour noise exposure guidelines through the use of administrative controls, engineering, and protective equipment. Noise to offsite receptors would not present a nuisance.

DOE expects an incremental increase in occupational injuries based on historic Savannah River Site information for injuries requiring medical attention, and injuries resulting in lost work time during the construction phase. DOE also expects a slight increase in the potential for traffic fatalities.

The potential socioeconomic impacts of the Accelerator Production of Tritium facility should not stress existing regional infrastructure or result in a "boom" situation. Peak employment would add about 1,400 additional jobs during the construction period.

Operational Impacts

Operation of the Accelerator Production of Tritium facility could affect surrounding groundwater. If the groundwater makeup alternative were selected, the removal of 22,700 l/min (6,000 gal/min) on a sustained basis could result in changes or reductive groundwater flows to some streams surrounding the well field and compaction of clay layers. Operation of the Accelerator Production of Tritium facility would produce neutrons which have the potential to penetrate the accelerator's protective shielding and be absorbed by the soil and groundwater. The accelerator would be designed so that the dose associated with this activity would be less than one-eighth of the EPA drinking water standard of 4 mrem/yr.

The withdrawal of Savannah River water for cooling would result in the impingement of adult fish and the entrainment of fish eggs and larvae at the river water intake. The once-through cooling water alternative would result in considerably higher rates of impingement and entrainment than the various cooling tower alternatives, but losses of adult fish, fish eggs, and fish larvae under all alternatives would be small relative to total fish production in the upper and middle reaches of the Savannah River.

Operation of the Accelerator Production of Tritium facility would result in thermal discharges from the cooling water system to either Indian Grave or Pen Branch or the existing series of precooler ponds and ultimately Par Pond. For all cooling alternatives except the once-through cooling water alternative, water temperature in the receiving water bodies would not exceed 32
Environmental Control standards for fresh water. In the case of the once-through cooling water alternative, however, discharges would be well in excess of 32
be required to conduct a Clean Water Act Section 316a(1) Demonstration. Under each cooling water alternative, cesium 137 trapped in the fine sediments of Par Pond would be disturbed and remobilized. The once-through cooling water alternative would remobilize the most cesium 137, but in all cases, exposures of the public would be fewer than applicable regulatory limits. Par Pond and the precooler ponds, however, are utilized by American alligators and bald eagles. The alligators do not breed in Ponds 2 and 5 and would abandon the ponds and relocate if water temperature exceeded their tolerance range. In Par Pond and Pen Branch, potential effects on alligators could be positive in that the warmer waters could lengthen the active period for the reptiles. Bald eagles use the Par Pond system for feeding. Potential fish kills associated with the once-through cooling water alternative could provide the eagles with an additional food source.

Air emissions of both radiological and nonradiological pollutants would be well below applicable standards for the operation of the Accelerator Production of Tritium facility. Offsite concentrations would be slightly higher from the nonpreferred alternative site because it is closer to the Savannah River Site boundary. Tritium would constitute over 99 percent of the offsite dose, but would be well below the 100 mrem/yr dose limit for Savannah River Site atmospheric releases.

Operational waste would be managed and treated according to waste type using both Savannah River Site and offsite facilities. Potential impacts on other facilities should be negligible because of the low volume of waste generation.

From normal operations, DOE expects that the dose to the public from Accelerator Production of Tritium facility would be within regulatory limits. Similarly, all concentrations of noncarcinogenic materials would be well below all established limits and consequently there should be no health impacts. Of the materials expected to be released from the Accelerator Production of Tritium facility, only beryllium is a carcinogen. Using EPA's Integrated Risk Information System database, DOE calculated an additional lifetime latent cancer risk of 4.6×10^{-9} to the maximally exposed individual. This value is well below the 1×10^{-6} risk value that EPA typically uses as a threshold of concern. Impacts would be slightly higher at the alternative site because it is closer to the

Savannah River Site boundary, but would still be well below the EPA threshold of concern. Potential impacts on workers would be slightly higher.

All accidents with a postulated frequency of more than once during the 40-year operating life of the accelerator would have negligible consequences. Only four low-probability accidents (highest frequency = once per 2,000 years) would have offsite doses high enough (1 rem at site boundary) to warrant public protective actions under the Savannah River Site Emergency Plan.

There should be no significant socioeconomic impacts from the operation of the Accelerator Production of Tritium facility at the DOE's Savannah River Site in South Carolina. The workforce of 500 additional individuals would produce approximately one-third of the socioeconomic impacts during construction of the Accelerator Production of Tritium facility.

The preferred Accelerator Production of Tritium alternative would require approximately 350 megawatts of electricity to operate. DOE is considering either purchasing electricity from existing sources through market transactions, or obtaining electricity from a new electric power-generating plant. The purchasing of electricity would increase expected environmental impacts from 1 to 3 percent. If a new electricity-generating plan were to be constructed, potential impacts would depend upon its operation. If it were constructed at the Savannah River Site, impacts would probably be only slightly higher than those of the purchasing option.

Although impacts would depend upon the specific location and type of the new electric power-generating facility, such a facility could require about 45 hectares (110 acres) for a natural gas plant or 117 hectares (290 acres) for a coal plant. Although the specific constituents of air emissions and discharges to surface water would depend upon the actual location of the new electric power-generating plant, overall environmental impacts should be no higher than those of the preferred alternative. A peak workforce of about 1,100 workers would be required for the rather short construction period and a workforce of about 200 individuals for operation of the facility. Impacts on the socioeconomics of the region would depend upon the actual location of the facility.

In addition to the impacts on land use, waste would be generated from construction, the operation of such an electric power generating facility would generate greenhouse gas emissions. Of the greenhouse gases expected to be generated, carbon dioxide emissions would be the largest. **Table 5–48** summarizes the expected carbon dioxide emissions from the Accelerator Production of Tritium power plant options, and compares these emissions to existing U.S. and global carbon dioxide emissions.

Table 5–48 Estimated Accelerator Production of Tritium CO_2 Emissions

APT Power Plant Option	*Estimated CO_2 Emissions (Million Tons per Year)*	*% of U.S. Fossil Combustion CO_2 Emissions*[a]	*% of Global Combustion CO_2 Emissions*[b]
Existing capacity/market transactions	3.45	0.063	0.014
New coal-fired powerplant	3.60	0.066	0.014

[a] U.S. estimates of fossil fuel CO_2 emissions is 5.446 million tons per year (TVA 1997f).
[b] Global estimates of fossil fuel CO_2 emissions is 25.038 million tons per year (TVA 1997f).
Source: DOE 1997e.

5.2.11.1 CLWR Facility Accident Impact to Involved Workers

The range of accident impacts to involved workers would vary depending on the energy and radioactive material released during the accident. The involved workers would evacuate the immediate area of the accident to minimize exposure in accordance with general employee training and emergency procedures. **Table 5–49** summarizes accident impacts on involved workers.

Table 5–49 Accident Impacts on Involved Workers

Accident	Worker Location	Impact on Worker	Mitigation
Reactor design-basis accident (large break loss of coolant accident)	Reactor containment	Workers in containment at the time of the accident will die due to the energy (steam) released to the containment. Evacuation from the containment is not considered feasible.	The containment is not normally occupied during power operation. Entrance to containment during power operation is limited by work permits approved by the operations staff.
Nonreactor design-basis accident (waste gas decay tank rupture)	Auxiliary building waste gas tank area	If the accident is initiated by rupture of the tank or associated piping, the worker could be injured by debris or the stream of gas from the rupture. In addition, the worker could receive a radiation dose while evacuating the area.	The probability of this initiating event is extremely unlikely (in the range of 10^{-6} to 10^{-4} per year). Involved workers will evacuate the immediate area of the accident to minimize radiation exposure in accordance with general employee training and emergency procedures.
		If the accident is initiated by a valve failure or human error, the release will be vented out of the auxiliary building stack. The involved worker is not at risk of injury or an additional radiation dose.	
TPBAR handling accident	Auxiliary building spent fuel pool area	The involved worker would observe the drop and immediately evacuate the area. Adequate time will exist to evacuate the area before the release of tritium from the TPBARs. The worker would receive no additional radiological dose.	Involved workers will evacuate the immediate area of the accident to minimize radiation exposure in accordance with general employee training, emergency procedures, and TPBAR handling operating procedures.
Truck or rail cask handling accident	Auxiliary building spent fuel pool area	The involved worker would observe the drop and immediately evacuate the area. Adequate time will exist to evacuate the area before the release of tritium from the TPBARs. The worker would receive no additional radiological dose.	Involved workers will evacuate the immediate area of the accident to minimize radiation exposure in accordance with general employee training, emergency procedures, and TPBAR handling operating procedures.
Beyond-design-basis accident	Reactor containment	If the accident sequence is initiated by a large break loss of coolant accident or another high energy release mechanism, workers in containment at the time of the accident will die due to the energy (steam) released to the containment. Evacuation from the containment is not considered feasible.	The containment is not normally occupied during power operation. Entrance to containment during power operation is limited by work permits approved by the operations staff.
		Most of the postulated accident sequences have adequate time for workers to evacuate the containment before there is a radioactive release to the containment.	Involved workers will evacuate the containment to minimize radiation exposure. As the accident sequence progresses, all non-essential personnel will be directed to evacuate the site in accordance with site emergency procedures.

5.2.11.2 Secondary Impact of CLWR Facility Accidents

For purposes of this EIS, the primary impacts are measured in terms of public and worker exposures to radiation and toxic chemicals. Accidents could also affect elements of the environment other than humans. For example, a radiological release could contaminate farmland, surface water, recreational areas, industrial parks, historic sites, or the habitat of an endangered species. As a result, farm products might have to be destroyed; the supply of drinking water could be lowered; recreational areas could be closed; industrial parks could suffer economic losses during shutdown for decontamination; historical sites could have to be closed to visitors; and endangered species could move closer to extinction. These types of impacts are referred to as secondary impacts in this EIS.

There should be secondary impacts from design-basis accidents. The most severe class of design-basis accident, a core damage accident with no containment failure or bypass, occurred at the Three Mile Island Nuclear Plant, Unit 2, in Middletown, Pennsylvania, in 1979. There were no secondary impacts of this accident.

This section addresses the secondary impacts of a reactor beyond-design-basis accident with radiological release. Secondary impacts are addressed qualitatively; that is, the types of impacts that could result and a range of potential outcomes are identified. These secondary impacts are divided into two types: (1) habitation of land by humans (population dependent); and (2) agricultural uses of land (area dependent). Each of these impact types are discussed below.

Population Dependent—Secondary impacts could produce four possible outcomes: (1) land is immediately habitable; (2) land will be habitable after decontamination; (3) land will be habitable after a combination of decontamination and interdiction; and (4) land will not be habitable (condemnation).

Area Dependent—Secondary impacts could produce three possible outcomes: (1) no restrictions on agricultural use; (2) short-term restrictions on agricultural use; or (3) long-term restrictions on agricultural use (condemnation).

At Watts Bar and Sequoyah, tritium production would not change the potential secondary impacts that could result from a beyond-design-basis accident. This is due to the fact that secondary impacts would be dominated by the radionuclides other than tritium that would be released; any such impact would be independent of tritium production.

At Bellefonte, there would be a potential for secondary impacts arising from the proposed action. This is because Bellefonte reactors are currently not operating. While it is noted that any secondary impacts would be caused by the radionuclides other than tritium, these impacts would still represent a change from no action. As described above, these secondary impacts could range from no change to land habitability/use to long-term restrictions on agricultural use (condemnation). Any secondary impacts would have an extremely low probability of occurring, less than one in a million years.

5.3 CUMULATIVE IMPACTS

A cumulative impact is identified 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. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

5.3.1 TPBAR Fabrication

The fabrication and assembly process of the TPBARs does not result in environmental impacts beyond the impacts associated with the normal activities of the commercial facilities where fabrication and assembly would take place. Therefore, the fabrication and assembly process would not alter the cumulative impacts at these facilities.

5.3.2 TPBAR Irradiation

The only significant distinction between the effects of tritium production and those of the No Action Alternative at Watts Bar and Sequoyah would be the additional release of tritium and an associated small increase in the risk to occupational and public health and safety. No other known actions, Federal and non-Federal, could effect further changes in the radiological environment of the region of influence. Accordingly, the cumulative impacts at Watts Bar and Sequoyah, as reflected in **Tables 5–50** and **5–51**, respectively, are the sum of the impacts of the No Action Alternative and the small incremental impacts of tritium production.

Table 5–50 Cumulative Impacts at the Watts Bar Site

Resource/Material Categories	***Tritium Production Increment***	***Cumulative Total***
Land resources	Potential permanent land requirement - 3.1 acres of developed land at the independent spent fuel storage installation (ISFSI) if constructed.	1,770 acres (existing developed land, no additional undisturbed land requirement).
Air quality		
Nonradiological emissions	No additional emissions.	No change from current air quality conditions (See Table 4–1).
Greenhouse gases (CO_2)	No additional emissions	0.027 MT/yr
Radiological emissions	Annual radiological emissions of tritium: 1,000 TPBARs: 1,650 Ci 3,400 TPBARs: 1,890 Ci Other Emissions: 0 Ci	Annual radiological emissions of tritium: 1,000 TPBARs: 1,656 Ci 3,400 TPBARs: 1,896 Ci Other emissions: 283 Ci
Water quality		
Surface water	No additional surface water requirements, discharge, or water quality conditions.	No changes from current surface water requirements, discharge, or water quality conditions (see Table 4–3).
Radioactive effluent	Annual radiological effluent of tritium: 1,000 TPBARs: 14,850 Ci 3,400 TPBARs: 17,010 Ci Other releases: 0 Ci	Annual radiological effluent of tritium: 1,000 TPBARs: 15,489 Ci 3,400 TPBARs: 17,649 Ci Other releases: 1.32 Ci
Groundwater	No additional groundwater requirements or additional impacts to groundwater quality conditions	No change from current groundwater requirements or additional impacts to groundwater quality conditions
Socioeconomics	Less than 1% impact on regional economy.	No change from current regional socioeconomic conditions.
Public and occupational health and safety		
Normal operation	Annual dose for 1,000 TPBARs: *Average worker*: 5.4 millirem. *MEI*: 0.22 millirem *50-mile population*: 5.5 person-rem. Annual dose for 3,400 TPBARs: *Average worker*: 6.2 millirem. *MEI*: 0.27 millirem *50-mile population*: 6.4 person-rem.	Annual dose for 1,000 TPBARs: *Average worker*: 109 millirem. *MEI*: 0.51 millirem *50-mile population*: 6.1 person-rem. Annual dose for 3,400 TPBARs: *Average worker*: 110 millirem. *MEI*: 0.56 millirem *50-mile population*: 7.0 person-rem.
Waste management	Low-level radioactive waste: approximately 0.43 m^3 per year.	Low-level radioactive waste: approximately 41 m^3 per year.

Resource/Material Categories	*Tritium Production Increment*	*Cumulative Total*
Spent nuclear fuel generation	<2,000 TPBARs: 0 fuel assemblies 3,400 TPBARs: up to a maximum of 56 fuel assemblies per cycle	<2,000 TPBARs: 80 fuel assemblies per cycle 3,400 TPBARs: up to a maximum of 136 fuel assemblies per cycle

Table 5–51 Cumulative Impacts at the Sequoyah Site

Resource/Material Categories	*Tritium Production Increment*	*Cumulative Total* [a]
Land resources	Potential permanent land requirement - 3.2 acres of developed land at the ISFSI if constructed.	525 acres (existing developed land, no additional undisturbed land requirement).
Air quality		
Nonradiological emissions	No additional emissions.	No change from current air quality conditions (See Table 4–14).
Greenhouse gases (CO_2)	No additional emissions	0.039 MT/yr
Radiological emissions	Annual radiological emissions of tritium: 1,000 TPBARs: 1,650 Ci 3,400 TPBARs: 1,890 Ci Other emissions: 0 Ci	Annual radiological emissions of tritium: 1,000 TPBARs: 1,699 Ci 3,400 TPBARs: 1,939 Ci Other emissions: 239 Ci
Water quality		
Surface water	No additional surface water requirements, discharge, or water quality conditions.	No changes from current surface water requirements, discharge, or water quality conditions (see Table 4–16).
Radioactive effluent	Annual radiological effluent of tritium: 1,000 TPBARs: 14,850 Ci 3,400 TPBARs: 17,010 Ci Other releases: 0 Ci	Annual radiological effluent of tritium: 1,000 TPBARs: 16,327 Ci 3,400 TPBARs: 18,487 Ci Other releases: 2.3 Ci
Groundwater	No additional groundwater requirements or additional impacts to groundwater quality conditions	No change from current groundwater requirements or additional impacts to groundwater quality conditions
Socioeconomics	Less than 1% impact on regional economy.	No change from current regional socioeconomic conditions.
Public and occupational health and safety		
Normal operation	Annual dose for 1,000 TPBARs: *Average worker*: 3.9 millirem. *MEI*: 0.28 millirem *50-mile population*: 9.4 person-rem. Annual dose for 3,400 TPBARs: *Average worker*: 4.6 millirem. *MEI*: 0.32 millirem *50-mile population*: 10.5 person-rem.	Annual dose for 1,000 TPBARs: *Average worker*: 94 millirem. *MEI*: 0.38 millirem *50-mile population*: 12.6 person-rem. Annual dose for 3,400 TPBARs: *Average worker*: 95 millirem. *MEI*: 0.42 millirem *50-mile population*: 13.7 person-rem.
Waste management	Low-level radioactive waste: approximately 0.43 m^3 per year.	Low-level radioactive waste: approximately 383 m^3 per year.
Spent nuclear fuel generation	<2,000 TPBARs: 0 fuel assemblies 3,400 TPBARs: up to a maximum of 60 fuel assemblies per cycle	<2,000 TPBARs: 160 fuel assemblies per cycle 3,400 TPBARs: up to a maximum of 220 fuel assemblies per cycle

[a] Assumes tritium production in one unit while the other unit is operating in a normal mode (no tritium production).

As discussed in Chapter 5, operating the Bellefonte units as a nuclear power plant represents a change from the No Action Alternative with impacts to air, water, and ecological resources, socioeconomic characteristics, and increased risk to the human health and safety from potential radiological emissions. Expansion of industry and the planned development of new industries in the vicinity of the Bellefonte site would also affect the environmental and socioeconomic characteristics of the region. **Table 5–52** indicates that industrial expansion would occur in Jackson County and that additional population growth would occur in the absence of any developments at Bellefonte (TVA 1997f). **Table 5–53** shows the cumulative impacts for two unit operation at the Bellefonte site.

Table 5–52 Announced Major Recent and Future Expansions and New Industrial Facilities for Jackson County

Nature of Business	*Size of Expansion/Facility*	*Location*
Manufacturer of exhaust system gaskets for automobiles (NCI)	New facility - 30 new jobs	Scottsboro Industrial Park
Pulp and paper (Mead Container board)	Expansion - Doubling in capacity to 805,000 tpy. Addition of wood fired boiler and two dryers; $224 million	Stevenson
Industrial air handling systems (McQuay International)	Expansion - 125 jobs 50% increase in capacity	Scottsboro
Manufacturer of coaxial cable for electronics (CommScope)	Expansion - 60 jobs	Scottsboro Industrial Park
Textile mill (Willstown Apparel)	Expansion - 140 jobs	Section
Wallboard manufacturer (U.S. Gypsum) would use scrubber sludge from several power plants as a feedstock	New - 300 to 400 jobs	Bridgeport

Source: TVA 1997f.

Table 5–53 Cumulative Impacts at the Bellefonte Site

Resource/Material Categories	*Tritium Production Increment* [a]	*Cumulative Total* [b]
Land resources	Potential permanent land requirement - 3.4 acres of developed land at the ISFSI if constructed and a small amount of land for support buildings.	1,500 acres (existing developed land, no additional undisturbed land requirement).
Air quality		
Nonradiological emissions	Additional emissions within standards (see Tables 5–18 and 5–19)	Additional emissions within standards (see Tables 5–18 and 5–19)
Greenhouse gases (CO_2)	0.031 MT/yr	0.031 MT/yr
Radiological emissions	Annual radiological emissions of tritium: 1,000 TPBARs: 1,656 Ci 3,400 TPBARs: 1,896 Ci Other emissions: 283 Ci	Annual radiological emissions of tritium: 1,000 TPBARs: 1,661 Ci 3,400 TPBARs: 1,901 Ci Other emissions: 565 Ci

Resource/Material Categories	*Tritium Production Increment* [a]	*Cumulative Total* [b]
Water quality Surface water	Increased surface water use and discharge. Water usage less than 1% of Tennessee River flow. All water quality parameters within limits (see Tables 5–21, 5–22, and 5–23).	Increased surface water use and discharge. Water usage less than 1% of Tennessee River flow. All water quality parameters within limits (see Tables 5–21, 5–22, and 5–23).
Radioactive effluent	Annual radiological effluent of tritium: 1,000 TPBARs: 15,489 Ci 3,400 TPBARs: 17,649 Ci Other releases: 1.32 Ci	Annual radiological effluent of tritium: 1,000 TPBARs: 16,128 Ci 3,400 TPBARs: 18,288 Ci Other releases: 2.6 Ci
Groundwater	No groundwater requirements or additional impacts to groundwater quality conditions.	No change from current groundwater requirements or additional impacts to groundwater quality conditions
Ecological resources	Additional impacts on ecological resources including fish impingement and entrainment of aquatic biota and thermal impacts of less than 5 on resident aquatic communities in the vicinity of the diffuser.	Additional impacts on ecological resources including fish impingement and entrainment of aquatic biota and thermal impacts of less than 5 the vicinity of the diffuser.
Socioeconomics	800 to 1,000 workers. Increase in payment-in-lieu of taxes to state and local jurisdictions (approximately $5.5 to $8 million annually), decrease in the unemployment rate (from 7.9% to approximately 5.9%), and minor impacts to school resources.	1,555 to 1,755 workers including other industries. Increase in payment-in-lieu of taxes to state and local jurisdictions (approximately $5.5 to $8 million annually), decrease in the unemployment rate (from 7.9% to approximately 4.4%), and minor impacts to school resources.
Public and occupational health and safety Normal operation	Annual dose for 1,000 TPBARs: *Average worker*: 109 millirem. *MEI*: 0.31 millirem *50-mile population*: 5.8 person-rem. Annual dose for 3,400 TPBARs: *Average worker*: 110 millirem. *MEI*: 0.32 millirem *50-mile population*: 6.5 person-rem.	Annual dose for 1,000 TPBARs: *Average worker*: 109 millirem. *MEI*: 0.57 millirem *50-mile population*: 7.2 person-rem. Annual dose for 3,400 TPBARs: *Average worker*: 110 millirem. *MEI*: 0.58 millirem *50-mile population*: 7.9 person-rem.
Waste management	Low-level radioactive waste: approximately 41 m^3 per year.	Low-level radioactive waste: approximately 80 m^3 per year.
Spent nuclear fuel generation	<2,000 TPBARs: 72 fuel assemblies per cycle 3,400 TPBARs: up to a maximum of141 fuel assemblies per cycle	< 2,000 TPBARs: 144 fuel assemblies per cycle 3,400 TPBARs: up to a maximum of 213 fuel assemblies per cycle

[a] Assumes one unit operating in a tritium production mode.
[b] Assumes tritium production in one unit while the other unit is operating in a normal mode.

5.3.3 TPBAR Transportation

In determining the impacts of the transportation of DOE owned spent fuel, the *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DOE 1995a) analyzed the cumulative impacts of all transportation of radioactive materials, taking into account impacts from reasonably foreseeable actions that include transportation of radioactive material and general radioactive materials transportation that is not related to a particular action. The total worker and general population collective doses are summarized in **Table 5–54**. Total collective worker doses from all types of shipments (historical, the alternatives, reasonably foreseeable actions, and general transportation) were estimated to be 320,000 person-rem (130 latent cancer fatalities) for the period of time 1943 through 2035 (93 years). Total general population collective doses were also estimated to be 320,000 person-rem (160 latent cancer fatalities). The majority of the collective dose for workers and the general population resulted from the general transportation of radioactive material. Examples of these activities are shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial low-level radioactive waste to commercial disposal facilities. The total number of latent cancer fatalities estimated to result from radioactive materials transportation over the period between 1943 and 2035 was 290. Over this same period of time (93 years), approximately 28 million people would die from cancer, based on 300,000 cancer fatalities per year (NRC 1977). It should be noted that the estimated number of transportation-related latent cancer fatalities would be indistinguishable from other latent cancer fatalities, and the transportation-related latent cancer fatalities are 0.0010 percent of the total number of latent cancer fatalities.

Table 5–54 Cumulative Transportation-Related Radiological Collective Doses and Latent Cancer Fatalities (1943 to 2035)

Category	*Worker Dose (person-rem)*	*General Population Dose (person-rem)*
CLWR impacts		
Shipment of TPBAR and LLW	< 100	< 100
Latent cancer fatalities from TPBAR and LLW	<1	<1
Other nuclear material shipments		
Reasonably foreseeable actions[a]		
Truck	11,000	50,000
Rail	820	1,700
General transportation (1943–2035)	310,000	270,000
Total collective dose	320,000	320,000
Total latent cancer fatalities	130	160

LLW = Low-level radioactive waste.
[a] DOE 1995a.

5.3.4 Impacts at the Tritium Extraction Facility

An integral part of the program to produce tritium in a CLWR is the Tritium Extraction Facility proposed for construction and operation at DOE's Savannah River Site in South Carolina as discussed in Section 1.5.2 the associated draft environmental impact statement (DOE/EIS-0271D) was issued May 1998 (DOE 1998c). **Table 5–55** provides a summary of the environmental impacts associated with the preferred alternative in the Draft Tritium Extraction Facility EIS. This information is needed to provide the cumulative impacts of tritium production in a CLWR.

5.4 RESOURCE COMMITMENTS

This section describes the unavoidable adverse environmental impacts that could result from the proposed action, short term uses of the environment and the maintenance and enhancement of long term productivity, and irreversible and irretrievable commitments of resources.

5.4.1 Unavoidable Adverse Environmental Impacts

Construction and operation activities associated with the irradiation of TPBARs at the CLWR sites and the transportation of the irradiated TPBARs to the Tritium Extraction Facility at DOE's Savannah River Site in

South Carolina would result in unavoidable adverse impacts to the human environment. In general, the unavoidable adverse impacts from the operation of Watts Bar and Sequoyah are the incremental impacts attributed to the tritium production. For the Bellefonte units, the unavoidable adverse impacts are associated with the full operation of the units as a nuclear reactor plant.

Unavoidable adverse impacts at the Watts Bar and Sequoyah sites would be related to the construction activity if required to provide additional spent fuel dry storage. Workers will receive exposure from the direct and skyshine radiation of the spent fuel already stored there. These exposures are of the order of 40 to 50 person-rem. In addition, approximately 2 to 2.5 hectares (5 to 6 acres) of land within the site boundary at each site would be disturbed. Any liquid and solid waste generated during the construction activities, none

Table 5–55 Summary of Environmental Impacts, Tritium Extraction Facility

Resource	***SRS Baseline***	***Increment Above Baseline for Preferred Alternative***
Schedule and Operating Parameters		
Construction	Tritium Extraction Facility is not built	5 years
Annual electricity		20,600 MW-hrs
Annual sanitary wastewater (gallons)		770,000
Annual radioactive process wastewater (gallons)		11,000
Impacts to the Physical and Manmade Environment		
Geology	Existing sites are cleared and graded; grassed, paved, or graveled; and used for industrial purposes	Minimal construction impacts through application of best management practices and compliance with Federal and state regulations. Minor dewatering during construction activities near or below the water table. Design would prevent process water migration into the groundwater during operations. With an immediate response by SRS to contain and remediate spills, it is unlikely that a spill would impact groundwater.
Surface water	Construction in an industrial area with established stormwater control systems	Minimal construction impacts; construction would not disturb undeveloped areas.
	Permitted process wastewater discharges	Effluent treatment would remove radioactive cobalt from process water to safe levels before discharge to Upper Three Runs. Tritium concentration in the effluent would be less than the regulatory limit of 20,000 pCi/l.
	Permitted sanitary wastewater discharges	Effluent would be treated before release to Fourmile Branch. All discharges would be within permit limits. Minimal impacts expected.
Air resources Nonradiological constituent concentrations at the SRS and AGNS site boundaries	Concentrations vary from approximately 0 to 60 percent of applicable standards and average 25 percent.[a]	Concentrations vary from approximately 0 to 0.19 percent of applicable standards and average 0.02 percent.[a] Ozone concentrations (measured as VOCs) would be 0.19 percent of the regulatory standard of 235 μg/m^3. All other contaminant levels would be less than 0.02 percent of their respective regulatory standards.
Annual radiological dose to the maximally exposed (offsite) individual (millirem). Dose limit = 10 millirem/yr.	0.05 millirem	0.02 millirem; the emission is 0.2 percent of the dose limit

Resource	*SRS Baseline*	*Increment Above Baseline for Preferred Alternative*
Impacts to the Physical and Manmade Environment Continued		
Waste Total estimated construction debris (metric tons) Total operations waste by type (cubic meters) High-level Low-level Hazardous or mixed Transuranic	 N/A 150,750 (30 years) 343,710 (30 years) 90,450 (30 years) 18,090 (30 years)	 385 0 (40 years) 9,320 (40 years) 132 (40 years) 0 (40 years)
Impacts to Human Environment		
Aesthetics[b]	Area is not visible to and noise is not heard by offsite public. Historical and archaeological resources are not present.	Temporary increase in noise during construction phase, but it would not be heard by the offsite public. No adverse aesthetic impacts during TEF operation. Historical and archaeological resources are not present.
Socioeconomics	SRS employment is assumed to decline to 10,000 employees by 2001, and regional growth trends are expected to continue.	Regional temporary increase of 740 jobs during peak year of construction, which is 0.29 percent of projected baseline regional employment of 258,000 jobs. The number of jobs at SRS would decline to 108 for TEF operation. The overall effects would be positive in terms of assisting to stabilize the regional employment base.
Environmental justice	Minorities or low-income communities would not receive disproportionately high and adverse impacts.	Health effects would be minimal. Minority or low-income communities would not be disproportionately affected.
Public health Annual probability of fatal cancer to the maximally exposed (offsite) individual (annual fatal cancer risk from all natural causes is 3.4×10^{-3}).	 9.5×10^{-8}	 1.0×10^{-8}
Occupational health Total estimated number of additional latent cancer facilities to all involved workers from an annual dose. Number of construction worker injuries resulting in lost work time.	 0.066 N/A	 0.0016 11

Resource	***SRS Baseline***	***Increment Above Baseline for Preferred Alternative***
Impacts to Human Environment Continued		
Accidents[c] Additional latent cancer facilities in offsite population	N/A	
Annual frequency — Bounding accident		
$>10^{-2}$ — Hood or room fire		0.4
$^{-4}$ to $^{-2}$ — Area fire		0.4
$^{-6}$ to $<10^{-4}$ — Design-basis seismic event with a fire		0.7[d]
	Impacts to Ecological Resources	
Terrestrial ecology	The affected environment is within developed areas consisting of paved lots, graveled surfaces, buildings and trailers, providing minimal terrestrial wildlife habitat.	No physical alterations to the landscape outside of H Area but limited potential to disturb any nearby resident wildlife as a result of construction and operations noise.
Aquatic ecology	No aquatic habitat within H Area boundaries.	All construction activities would occur under best management practices to limit sedimentation in detention basins. Operations wastewater would be discharged through NPDES-permitted outfalls. DOE would continue to comply with the regulatory standards for water quality established for these outfalls.
Wetland ecology	No wetland habitat within H Area boundaries.	Wetlands in the Upper Three Runs watershed, including Crouch Branch, or the Fourmile Branch watershed would not be adversely affected by the construction and operation of the TEF.
Threatened and endangered species	No threatened and endangered species within H Area boundaries	No threatened or endangered species live or forage in H Area. There would be no adverse impact.

[a] Concentration increments that would be less than 0.1 percent of standard for both locations are not listed.
[b] Includes land use, visual resources and noise, and historical and archeological resources.
[c] Events with the most additional latent fatalities in offsite public are a full-facility fire and a design-basis earthquake with a secondary fire.
[d] Accidents involving targets of similar design would have substantially lower impacts.

N/A = Not applicable
AGNS = Allied General Nuclear Services Facility
NPDES = National Pollutant Discharge Elimination System
SRS = Savannah River Site
TEF = Tritium Extraction Facility
VOCs = Volatile Organic Compound

Source: DOE 1998c.

of which would be radioactive, would be collected at the site, stored and eventually removed for suitable recycling or disposal offsite in accordance with applicable EPA regulations.

The construction activities that could be required for the completion of the Bellefonte units and the associated spent fuel dry storage facility would result in unavoidable adverse impacts on land, air and water resources. Due to the limited area of land disturbance would result in small impacts to the ecological resources and the public and occupational health and safety would be small. More significant adverse effects associated with the completion of the Bellefonte units would be socioeconomic arising from the rapid increase of the work force in the region of influence. These effects are offset by the longer term benefits.

Operation of Watts Bar or Sequoyah in a tritium producing mode would result in unavoidable increases of radiation exposures to workers and the general public. Annual doses from routine radiological air emissions from the proposed action to the maximally exposed individual, general population and workers were discussed in Sections 5.2.1.9 and 5.2.2.9.

Operation of the Bellefonte units would result in unavoidable impacts to the air and water quality, to the visual resources, and the surrounding communities. Air quality would be affected by routine radioactive gaseous emissions typical of CLWR operations. Impacts to water resources could affect surface use and quality with routine radioactive liquid effluent releases and the need for cooling water. The routine emission of chemicals would affect the aquatic biota near the plant intake and discharge pipes. Socioeconomic resources of the community could be affected. These impacts would be associated with the operation of Bellefonte as a nuclear power plant regardless of tritium production. They have also been addressed in the EIS for the construction and operation Bellefonte 1 and Bellefonte 2, issued by Tennessee Valley Authority in 1974 (AEC 1974).

Spent nuclear fuel would be generated as an unavoidable result of reactor operations to produce tritium if more than approximately 2,000 TPBARs were to be irradiated at a single unit which could require the construction of a new spent fuel storage facility. Also unavoidable would be the generation of additional low-level radioactive waste which would be transported and managed offsite, at a low-level radioactive waste disposal facility at Barnwell, South Carolina, or the Savannah River Site.

5.4.2 Relationship Between Local Short-Term Uses of the Environment and Enhancement of Long-Term Productivity

Each reactor site would require additional land for the construction of a spent fuel storage facility. Such short term usage would remove this land from other beneficial uses for the facilities as CLWRs. This land which is within the site boundary at each candidate site is not expected to be used for any other activities as long as the plant is operating.

The use of CLWRs to produce tritium is significant in that carbon dioxide emissions associated with the accelerator option for producing tritium would be avoided. Producing tritium in a CLWR would not add to the "greenhouse" effect and global warming (see Sections 5.2.11 and 5.3).

The use of short-term resources to complete and operate the Bellefonte units for tritium production affects the long-term productivity of the site by providing a secure and reliable source of tritium to meet the Nation's needs and production of electricity. The purpose and need for the Bellefonte units as a nuclear power plant is the subject of the *Final Environmental Impact Statement Related to the Construction of Bellefonte Nuclear Plant Unit 1 and Bellefonte Unit 2* (AEC 1974).

5.4.3 Irreversible and Irretrievable Commitments of Resources

This section discusses the major irreversible and irretrievable commitments of resources resulting from the proposed action. A commitment of resources is irreversible when its primary or secondary impacts limit the future options for a resource. An irreversible commitment refers to the use or consumption of resources neither renewable nor recoverable for later use by future generations. The discussion is divided into the functional segments of the proposed action such as TPBAR fabrication and irradiation.

TPBAR Fabrication

Under the proposed action up to 4,000 TPBARs need to be fabricated annually for the 40 year duration of the program. The materials involved in the fabrication of the TPBARs, such as lithium, aluminum, stainless steel, zirconium are rendered radioactive during the tritium production process. These materials are then consumed, or reduced to unrecoverable forms of waste. In large part, however, the TPBARs replace the burnable absorber rods which are normally used in the operation of the CLWRs and produce no net change in the irretrievable material resources. None of the associated material resources associated with the fabrication of the TPBARs is in short supply. Material resources associated with the fabrication of the TPBARs are presented in Section 5.2.7.

TPBAR Irradiation

At the reactor facilities, where construction is necessary, such as the completion of the Bellefonte units, materials required include wood, concrete, sand, gravel, plastics, aluminum, steel, and other materials. No unusual construction materials requirements have been identified for any of the alternative sites. None of these identified construction resources is in short supply. No additional transmission lines, roads, rail line, water pipeline, wastewater pipeline, or wastewater treatment facilities are required for Watts Bar or Sequoyah a result of tritium production. Additional material (e.g., concrete and steel) would be required if an ISFSI is required.

Resources that would be consumed during completion of construction at Bellefonte 1 and 2 are summarized in **Table 5–56.**

Table 5–56 Resources Consumed During Construction–Bellefonte 1 and Bellefonte 2

Resources	*Total Consumed*	
	Bellefonte 1	*Bellefonte 2*
Utilities		
Electricity	575,000 MWe (80 MW peak demand [a])	500,000 MWe (80 MW peak demand [a])
Water	280,000 m^3 (330 m^3/day peak demand [a])	160,000 m^3 (280 m^3/day peak demand [a])
Solids		
Concrete	2,190 m^3	1,791 m^3
Steel	353 metric tons	98 metric tons
Liquids		
Fuel	9,652,872 liters	3,785,440 liters
Gases		
Industrial gases [b]	500 m^3	1,300 m^3

[a] Peak demand is the maximum rate expected during any hour.
[b] Standard cubic meter measured at 1 atmosphere and 15.55

Source: TVA 1995b.

Additional materials for nuclear fuel assemblies are required to operate reactors in a tritium producing mode. Materials associated with nuclear fuel assemblies are uranium, steel, and zircalloy. After irradiation, these materials and other material byproducts of the fission and irradiation process, constitute the high-level waste of the spent nuclear fuel. At this time, all constituents of the spent fuel are considered nonrecoverable, since no reprocessing of the spent fuel is allowed. Material resources associated with use of additional nuclear fuel assemblies were discussed in Section 5.2.7.

6. APPLICABLE LAWS, REGULATIONS, AND OTHER REQUIREMENTS

Chapter 6 identifies the Federal and state statutes and regulations that require licenses, permits, or other requirements related to environmental protection, emergency planning, and worker safety and health. In addition, the Chapter summarizes the U.S. Department of Energy's regulations and orders, as well as the regulatory compliance history of the three reactors being considered for tritium production.

6.1 INTRODUCTION AND BACKGROUND

Like most nuclear activities, the production of tritium in a commercial reactor would be closely regulated to ensure the health and safety of the public, protect the environment, and guard employee health. Most of these regulatory requirements already apply to the operating Watts Bar Nuclear Plant, Unit 1 (Watts Bar 1), and Sequoyah Nuclear Plant, Unit 1 and Unit 2 (Sequoyah 1 and Sequoyah 2) and have been accounted for in the planning and partial construction of the incomplete Bellefonte Nuclear Plant, Unit 1 and Unit 2 (Bellefonte 1 and Bellefonte 2). The addition of tritium production would necessitate few, if any, physical or substantive changes to current compliance plans and activities at the plants. The legal responsibility for continued U.S. Nuclear Regulatory Commission (NRC) regulatory compliance would remain with the Tennessee Valley Authority (TVA).

To ensure that individual facilities satisfy the established standards of nuclear safety and environmental protection, some of the applicable laws require the facilities to have licenses or permits. The most comprehensive of these are the operating licenses issued by the NRC under the Atomic Energy Act of 1954, as amended. Tritium production was not contemplated in the existing operating licenses for Watts Bar 1, Sequoyah 1, and Sequoyah 2, or in the construction permit (the precursor to an operating license) for Bellefonte 1 and Bellefonte 2. The NRC would, therefore, have to review the tritium production proposal under established processes to amend the operating licenses for Watts Bar 1, Sequoyah 1 and Sequoyah 2, and as part of the safety analysis and licensing review process associated with the construction of Bellefonte 1 and Bellefonte 2.

Permits for air pollution emissions and water pollution discharges are issued by the relevant state environmental agencies (the Alabama Department of Environmental Management and the Tennessee Department of Environment and Conservation) under state programs approved by the U.S. Environmental Protection Agency (EPA) pursuant to the Clean Air and Clean Water Acts. Continued compliance with the terms of these permits would be required. However, unless tritium production would be likely to change or increase air emissions or water discharges, no other changes to these permits should be necessary. If such changes or increases are projected, the state agencies would have to consider appropriate permit amendments. Similarly, state permits are issued under EPA-approved programs and might have to be transferred or amended for solid waste and/or hazardous waste activities at the facilities. TVA has noted, however, that it ships all hazardous wastes to permitted offsite facility contractors therefore, it does not need its own hazardous waste permits (TVA 1997d). Unless this practice changes as a result of tritium production, no new hazardous waste permits should be required. Each facility has a Hazardous Waste Generator Identification Number and a Special Waste Permit that would have to be transferred to DOE if it were to purchase the reactors.

Some applicable laws, such as the National Environmental Policy Act (NEPA), the Endangered Species Act, and the Emergency Planning and Community Right-To-Know Act, require specific reports and/or consultations rather than ongoing permits or activities. These will be satisfied through the legal/regulatory process, including the preparation of the *Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* (CLWR EIS) leading to the proposed tritium production.

The other applicable laws establish general requirements that must be satisfied, but do not include processes (such as the issuance of permits or licenses) to consider compliance prior to specific instances of violations or other events that trigger their provisions. These include the Toxic Substances Control Act (affecting polychlorinatedbiphenyl transformers and other designated substances), the Federal Insecticide, Fungicide, and Rodenticide Act (affecting pesticide/herbicide applications), the Hazardous Materials Transportation Act, and (if there were to be a spill of a hazardous substance) the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund).

Finally, both TVA and DOE have their own internal requirements which will be applicable to the proposed production of tritium. Occupational safety and health programs constitute the most important internal requirements. The Occupational Safety and Health Act (OSHA) and the Department of Labor regulations established under it do not apply directly to government agencies (such as DOE) or government-owned corporations (such as TVA). However, both are required by statute (29 CFR 1910, 29 U.S.C. 668) and Executive Order 12196 to have their own programs to protect worker safety and health "consistent" with the OSHA standards. Radiological aspects of worker safety and health are governed through the NRC licensing process.

DOE also has numerous requirements, set forth in DOE Orders, to ensure in its activities, general protection of health, safety, and the environment. Most of these, however, do not apply to activities at non-DOE facilities (such as DOE production of tritium in TVA reactors).

Section 6.2 of this chapter discusses the major Federal and state statutes and regulations that impose nuclear safety and environmental protection requirements on the subject facilities, and which might require the reactor facility to obtain a permit or license, or amendment thereof, prior to tritium production. Each of the applicable regulations and statutes establish how potential releases of pollutants and radioactive materials are to be controlled or monitored. These applicable regulations and statutes include requirements for the issuance of permits or licenses for new operations or new emission sources and for amendments to existing permits or licenses to allow new types of operations at existing sources. In addition to nuclear and environmental license and permit requirements, the regulations and statutes may require consultations with various authorities to determine if an action requires a permit to be obtained or amended or that protective or mitigative measures relative to the action's effect on cultural, natural, or biological resources need to be implemented. Sections 6.2.1 and 6.2.2 discuss the nuclear and environmental licensing and permitting processes, respectively, and list the licenses and permits applicable to tritium production in the subject facilities.

Section 6.3 addresses other general requirements regarding environmental protection, emergency planning, and worker safety and health. Section 6.4 discusses the DOE regulations and Orders which pertain to DOE activities.

6.2 STATUTES AND REGULATIONS REQUIRING LICENSES OR PERMITS

The Atomic Energy Act of 1954, as amended by the Energy Reorganization Act of 1974, gives NRC jurisdiction over the construction and operation of commercial nuclear reactors (including those of TVA) and over the possession, use, transportation, and disposal of radioactive materials (including wastes). The NRC carries out this role by applying extensive regulations and performance standards to specific facilities and operations through a required licensing process. Although most DOE facilities and operations are not subject to NRC jurisdiction, the proposed tritium production services provided to DOE by TVA would be subject to the NRC regulations and license requirements governing TVA.

Federal and state environmental laws establish standards for radiation exposure in the general environment (i.e., everything outside NRC- or DOE-regulated facilities) and for sources of air pollution, water pollution, and hazardous waste. Some of these standards are applied to specific facilities and operations through required permits. To obtain these permits, the facility operator (in the present case, TVA) must submit construction and operation plans and specifications for new or modified sources of pollutants for review by the appropriate government agencies. The environmental permits: (1) contain specific conditions governing construction and operation of a new or modified emission source; (2) describe pollution abatement and prevention methods to reduce pollutants; and (3) and contain emission limits for the pollutants that will be emitted from the facility. Section 6.2.2 discusses the environmental regulations and statutes under which new or amended permits may be required for tritium production at the candidate facilities.

6.2.1 Nuclear Regulatory Commission Permits and Licenses

Atomic Energy Act of 1954 (42 U.S.C. 2011), as amended (10 CFR 50)

The Atomic Energy Act, as amended, requires entities that operate nuclear power plants, such as TVA, to have a plant license issued by the NRC. The NRC regulations that implement this requirement provide for permits to be issued for the construction or alteration of such facilities. Operating licenses are applied for after completion of the construction or alteration of the facilities (10 CFR Sections 50.23, 50.56, 50.57). Construction permits and operating licenses include detailed provisions regarding their duration and the design, safety, and quality assurance requirements for the subject facilities (10 CFR Sections 50.54, 50.55).

Permits and licensing for completion of the Bellefonte 1 and Bellefonte 2 reactors for tritium and electricity production will be addressed as part of NRC's consideration of TVA's operating license application. TVA will be required to apply to the NRC for appropriate amendments to its operating license application to address tritium production at Bellefonte 1 and Bellefonte 2 and its existing operating licenses for its Watts Bar 1, Sequoyah 1, and Sequoyah 2 reactors. The NRC must grant Bellefonte 1 an operating license before it can produce tritium, and the NRC must approve TVA's license amendments for Watts Bar 1, Sequoyah 1, and Sequoyah 2 before those plants can produce tritium.

6.2.2 Environmental Protection Permits

Clean Air Act, as amended, and EPA regulations thereunder (42 U.S.C. 7401 *et seq.*), (40 CFR 50-99); Tennessee Air Quality Act and regulations thereunder (Title 68 Tennessee Code Chapter 201); Alabama Air Pollution Control Act and regulations thereunder (Title 22 Alabama Code Chapter 28); air pollution ordinances of the relevant municipal and county governments

The Clean Air Act, as amended, is intended to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." Section 118 of the Clean Air Act, as amended, requires each Federal agency (including TVA and DOE) with jurisdiction over any property or facility that might result in the discharge of air pollutants to comply with "all Federal, state, interstate, and local requirements" with regard to the control and abatement of air pollution.

The Act requires EPA to establish National Ambient Air Quality Standards as necessary to protect public health and welfare, with an adequate margin of safety, from any known or anticipated adverse effects of a regulated pollutant (42 U.S.C. 7409). The Act also requires the establishment of national standards of performance for new or modified stationary sources of atmospheric pollutants (42 U.S.C. 7411 and 7412) and requires specific emission increases to be evaluated to prevent a significant deterioration in air quality (42 U.S.C. 7470). Air emissions are regulated by the EPA in 40 CFR Parts 50 through 99. Hazardous air pollutants, including radionuclide emissions from Federal facilities, are regulated under the National Emission Standards for Hazardous Air Pollutants Program (40 CFR 61).

These national standards are implemented by states which have an air pollution control program approved by EPA. In Tennessee, the program is administered by the State Department of Environment and Conservation under the State Air Quality Act (Title 68 Tennessee Code Chapter 201). In Alabama, the program is administered by the State Department of Environmental Management under the Alabama Air Pollution Control Act (Title 22 Alabama Code Chapter 28). The National Emission Standards for Hazardous Air Pollutants Programs standards for radionuclides (40 CFR 61, Subparts H and I) are not applicable to NRC licensed facilities such as TVA reactors.

Federal Clean Water Act, as amended (33 U.S.C. 1251 *et seq.*); Tennessee Water Quality Act (Title 69 Tennessee Code Chapter 3) and regulations thereunder (regulations Chapter 1200-4); Alabama Water Pollution Control Act (Title 22 Alabama Code Chapter 22)

The Federal Water Pollution Act (commonly known as the Clean Water Act), was enacted to "restore and maintain the chemical, physical, and biological integrity of the Nation's water." The Clean Water Act prohibits the "discharge of toxic pollutants in toxic amounts" to navigable waters of the United States (Section 101). Section 313 of the Clean Water Act, as amended, requires all branches of the Federal Government engaged in any activity that might result in a discharge or runoff of pollutants to surface waters to comply with Federal, state, interstate, and local requirements.

In addition to setting water quality standards for the Nation's waterways, the Clean Water Act supplies guidelines and limitations (Sections 301-303) for effluent discharges from point-source discharges and provides authority (Sections 401-402) for the EPA to implement the National Pollutant Discharge Elimination System (NPDES) permitting program pursuant to 40 CFR 122 and subsequent revisions.

EPA has delegated primary enforcement authority for the Clean Water Act and the NPDES permitting program to the States of Tennessee and Alabama for the waters therein.

Federal Safe Drinking Water Act, as amended [42 U.S.C. 300 (F) *et seq.*, 40 CFR 100-149]; Tennessee Safe Drinking Water Act (Title 68 Tennessee Code Chapter 221); Alabama Water Pollution Control Act (22 Alabama Code Chapter 22)

The primary objective of the Safe Drinking Water Act, as amended (42 U.S.C. 300), is to protect the quality of the public water supplies and all sources of drinking water. The implementing regulations, administered by the EPA unless delegated to the states, establish standards applicable to public water systems. They promulgate maximum contaminant levels (including those for radioactivity), in public water systems, which are defined as water systems that serve at least 15 service connections used by year-round residents or regularly serve at least 25 year-round residents. Safe Drinking Water Act requirements have been promulgated by the EPA in 40 CFR 100-149; for tritium, a concentration limit of 20,000 picocuries per liter has been established per 40 CFR 141, Subpart b.

Solid Waste Disposal Act (42 U.S.C. 6901 *et seq.*), as amended by the Resource Conservation and Recovery Act (42 U.S.C. 6921 *et seq.*); Tennessee Hazardous Waste Management Act (Title 68 Tennessee Code Chapter 212); Alabama Hazardous Waste Management and Minimization Act (22 Alabama Code Chapter 30)

The treatment, storage, and/or disposal of hazardous and nonhazardous waste is governed by the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act (RCRA). Pursuant to Section 3006 of the Act, any state that seeks to administer and enforce a hazardous waste program pursuant to RCRA may apply for EPA authorization of its program. Tennessee and Alabama have such authorization. EPA regulations implementing RCRA (40 CFR 260-280) define hazardous wastes and specify hazardous waste transportation, handling, treatment, storage, disposal, record keeping, and reporting requirements. The regulations imposed on a generator or a treatment, storage, or disposal facility vary according to the type and quantity of material or waste generated, treated, stored, or disposed. The method of treatment, storage, or disposal also affects the extent and complexity of the requirements. These regulations require that facilities obtain a RCRA permit if they store hazardous waste onsite more than 90 days (for large quantity generators) or 180 days (for small quantity generators) or treat hazardous waste. TVA has stated that it does not store waste beyond the periods allowed for hazardous waste generators or conduct treatment of hazardous wastes that require a RCRA permit at its nuclear facilities; therefore, TVA does not have RCRA permits for those facilities. Each facility does have an EPA/state Hazardous Waste Generator identification number and files the documents required for the generation of hazardous waste.

RCRA does not apply to radioactive waste. However, the courts have held that it does apply to the hazardous (i.e., nonradioactive) component of mixed hazardous and radioactive wastes *Legal Environmental Assistance Foundation (L.E.A.F.) versus Hodel*.

Federal Facility Compliance Act (42 U.S.C. 6961)

The Federal Facility Compliance Act, enacted on October 6, 1992, amended RCRA. The Federal Facility Compliance Act waived sovereign immunity for fines and penalties for violations at the facilities of Federal agencies (including government-owned corporations such as TVA) associated with the management of mixed waste. However, TVA has stated in its submissions for Watts Bar 1, Bellefonte 1, and Bellefonte 2 that it does not store hazardous waste at any of its nuclear facilities.

6.3 Other Requirements Related to Environmental Protection, Emergency Planning, and Worker Safety and Health

6.3.1 Environmental Protection

National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. 4321 *et seq.*); DOE Order 451.1

NEPA establishes a national policy promoting awareness of the environmental consequences of human activity on the environment and consideration of environmental impacts during the planning and decision-making stages of a project. This Act requires Federal agencies to prepare a detailed statement on the environmental effects of proposed major Federal actions that might significantly affect the quality of the human environment.

This EIS has been prepared in response to NEPA requirements and policies and in accordance with the Council on Environmental Quality (40 CFR 1500-1508), DOE (10 CFR 1021, DOE Order 451.1), and TVA provisions for implementing the procedural requirements of NEPA. It discusses reasonable alternatives and their potential environmental consequences.

Radiation Protection of Public and Environment; DOE Order 5400.5

This Order states that it applies to radiation protection for "all DOE elements and contractors performing work for the Department." This statement of applicability is different from that of most DOE Orders, which are stated to apply to activities at "DOE Facilities." Furthermore, Order 5400.5, again unlike most DOE Orders, does not state that it excludes DOE activities that are regulated by the NRC. It therefore applies to the proposed tritium production, regardless of NRC regulations, because TVA would be a "contractor performing work for DOE." In effect, this would mean that the tritium production activities would have to satisfy the requirements of both the NRC and DOE Order 5400.5 or, where those requirements are different for the same aspect of the activity, whichever requirements are more stringent.

Executive Order 11514 (Protection and Enhancement of Environmental Quality)

Executive Order 11514 requires Federal agencies to monitor and control their activities continually to: (1) protect and enhance the quality of the environment, and (2) develop procedures to ensure the fullest practicable provision of timely public information and understanding of Federal plans and programs that may have potential environmental impacts so that the views of interested parties can be obtained.

Executive Order 11988 (Floodplain Management); (10 CFR 1022); (18 CFR 725)

Executive Order 11988 requires Federal agencies to establish procedures to ensure that the potential effects of flood hazards and floodplain management are considered for any action undertaken in a floodplain and that floodplain impacts be avoided to the extent practicable. The production of tritium in the subject TVA facilities would not require further consideration of this Executive Order.

Executive Order 11990 (Protection of Wetlands); (10 CFR 1022); (18 CFR 725)

Executive Order 11990 requires government agencies to avoid any short- and long-term adverse impacts on wetlands wherever there is a practicable alternative. The production of tritium in the subject TVA facilities would not require further consideration of this Executive Order.

Endangered Species Act, as amended (16 U.S.C. 1531 *et seq.*)

The Endangered Species Act prohibits Federal actions that might harm a listed endangered species or designated critical habitat, unless a special exemption is granted. Consultation with the U.S. Fish and Wildlife Service of the U.S. Department of Interior is required whenever a proposed action is likely to affect a listed species or critical habitat (50 CFR 17). Preparation of a biological assessment of potential effects on listed species is also required for Federal actions that are "major construction activities."

National Historic Preservation Act of 1966 (16 U.S.C. 470 *et seq.*)

This Act provides that sites with significant national historic value be placed on the *National Register of Historic Places* maintained by the Secretary of the Interior. No permits or certifications are required under the Act. However, if a particular Federal activity may impact a historic property resource, consultation with the Advisory Council on Historic Preservation is required by 16 U.S.C. 470(f). The National Historic Preservation Act provides for an expanded National Register and establishes the Advisory Council on Historic Preservation [36 CFR 800.3 (Section 106)]. Section 110 of the Act requires Federal agencies to identify, evaluate, inventory, and protect National Register resources on properties they control. Such consultation usually generates a Memorandum of Agreement that includes stipulations that must be followed to minimize adverse impacts. Coordination with the State Historic Preservation Officer also is done to ensure that potentially significant sites are properly identified and appropriate mitigative actions are implemented.

Pollution Prevention Act of 1990 (42 U.S.C. 13101)

The Pollution Prevention Act of 1990 establishes a national policy for waste management and pollution control that focuses first on source reduction, followed sequentially by environmentally safe recycling, treatment, and disposal. Disposal or releases to the environment should occur only as a last resort. In response, DOE has committed to participation in the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) Amendments and Reauthorization Act Section 313, U.S. EPA 33/50 Pollution Prevention Program. The goal for facilities already involved in Section 313 compliance is to achieve by 1997 a 33-percent reduction in the release of 17 priority chemicals from a 1993 baseline. On August 3, 1993, President Clinton issued Executive Order 12856, expanding the 33/50 program such that DOE must reduce its total release of all toxic chemicals by 50 percent by December 31, 1999. The Order applies to all Federal agencies (such as DOE) and government-owned corporations (such as TVA).

Comprehensive Guideline for Procurement of Products Containing Recovered Materials (40 CFR 247)

This regulation was issued under the authority of Section 6002 of RCRA and Executive Order 12873, which set forth requirements for Federal agencies (including government-owned corporations) to procure products containing recovered materials for use in their operations according to EPA guidelines. The purpose of these regulations is to promote recycling by using Government purchasing to expand markets for recovered materials. RCRA Section 6002 requires that any purchasing agency, when using appropriated funds to procure an item, must purchase it with the highest practicable percentage of recovered materials. The procurement of materials to be utilized in the tritium production program should be conducted in accordance with these regulations.

Executive Order 12856 (Right-to-Know Laws and Pollution Prevention Requirements)

Executive Order 12856 requires all Federal agencies to reduce the toxic chemicals entering any waste stream. This Order also requires Federal agencies to report toxic chemicals entering waste streams; improve emergency planning, response, and accident notification; and encourage clean technologies and testing of innovative prevention technologies.

Executive Order 12898 (Environmental Justice)

Executive Order 12898 requires Federal agencies to identify and address any disproportionately high, adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations. Chapter 5 and Appendix G of this EIS discuss Environmental Justice.

Executive Order 12902 (Energy Efficiency and Water Conservation at Federal Facilities)

Executive Order 12902 requires Federal agencies to develop and implement a program for conservation of energy and water resources.

6.3.2 Emergency Planning and Response

This section discusses laws that address the protection of public health and worker safety and require the establishment of emergency plans, and coordination with local and Federal agencies. These laws relate to the operation of facilities that engage directly or indirectly in the production of special nuclear material.

Atomic Energy Act of 1954, as amended (42 U.S.C. 2011) Quantities of Radioactive Materials Requiring Consideration of the Need for an Emergency Plan for Responding to a Release (10 CFR 30.72 Schedule C)

This list determines the need for emergency response plans for unscheduled releases of radiological materials at all NRC-regulated facilities. An emergency response plan addressing tritium production operations might need to be issued to comply with this regulation.

Commercial Nuclear Power Plant Emergency Preparedness Planning (44 CFR 352)

These regulations generally establish the policies, procedures, and responsibilities of the Federal Emergency Management Agency, NRC, and DOE as guidance for implementing a Federal Emergency Preparedness Program.

Emergency Planning and Community Right-to-Know Act of 1986 (42 U.S.C. 11001 *et seq.*) (also known as "SARA Title III")

The Emergency Planning and Community Right-to-Know Act of 1986 requires emergency planning and notice to communities and government agencies of the presence and release of specific chemicals. EPA implements this Act under regulations found in 40 CFR 355, 370, and 372. Under Subtitle A of this Act, Federal facilities (including those of government-owned corporations such as TVA) provide information (such as inventories of specific chemicals used or stored and any releases that occur) to the State Emergency Response Commission and the Local Emergency Planning Committee to ensure that emergency plans are sufficient to respond to unplanned releases of hazardous substances. Implementation of the provisions of this Act began voluntarily in 1987, and inventory and annual emissions reporting began in 1988.

Transportation of Hazardous Materials (49 U.S.C. 5101); Hazardous Materials Tables & Communications, Emergency Response Information Requirements (49 CFR 172)

The regulatory requirements for marking, labeling, placarding, and documenting hazardous material shipments are defined in these regulations. Requirements for providing hazardous material information and training also are specified. Materials shipped to and from the subject facilities would be required to comply with these regulations.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (42 U.S.C. 9601 *et seq.*) National Oil and Hazardous Substance Contingency Plan (40 CFR 300)

More popularly known as "Superfund," the Act and the implementing regulations provide the needed general authority for Federal and state governments to respond directly to hazardous substance incidents. The regulations require reporting spills of hazardous substances to the National Response Center of EPA, including (in the limited circumstances specified in 40 CFR 302.6(b)(2)) radionuclides specified in 40 CFR 302.4. Tritium production operations would be required to comply with these regulations if a hazardous substance(s) spill occurred.

6.3.3 Worker Safety and Health

Occupational Safety and Health Act (OSHA) of 1970, as amended (29 U.S.C. 651); Occupational Safety and Health Administration Emergency Response, Hazardous Waste Operations and Worker Right to Know (29 CFR 1910 *et seq.*)

The OSHA (29 U.S.C 651) establishes standards to enhance safe, healthy working conditions in places of employment throughout the United States. The Act is administered and enforced by the Occupational Safety and Health Administration, a U.S. Department of Labor agency. While the Occupational Safety and Health Administration and EPA both have a mandate to reduce exposure to toxic substances, the Occupational Safety and Health Administration's jurisdiction is limited to safety and health conditions that exist in the workplace environment. In general, under OSHA, it is the duty of each employer to furnish all employees a place of employment that is free of recognized hazards that are likely to cause death or serious physical harm. Employees have a duty to comply with the occupational safety and health standards and all OSHA-related rules, regulations, and orders. The Occupational Safety and Health Administration's regulations (29 CFR) establish specific standards that tell employers what must be done to achieve a safe, healthy working environment. These regulations set down the Occupational Safety and Health Administration's requirements for employee safety in a variety of working environments, including employee emergency and fire prevention plans (29 CFR 1910.38), hazardous waste operations and emergency response (29 CFR 1910.120), and hazards communication (29 CFR 1910.1200) to increase employee awareness of the dangers they face from hazardous materials at their workplace.

OSHA and the regulations thereunder do not directly apply to Federal agencies or government-owned corporations. However, Section 19 of OSHA (29 U.S.C. 668) requires all Federal agencies to have occupational safety programs "consistent" with OSHA standards. This requirement has been applied to government-owned corporations, as well as agencies, through 5 U.S.C. 7902 and Executive Order 12196.

Radiological protection for employees of NRC-licensed facilities is regulated by the NRC. DOE Order 440.1, "Worker Protection Management for DOE Federal and Contractor Employees," also applies at all DOE facilities, even if they are also regulated by the NRC. This Order would therefore apply, in addition to NRC worker protection requirements, if the reactors were purchased by DOE; but would not apply if they remain the property of TVA.

6.4 DOE Regulations and Orders

The Atomic Energy Act makes DOE responsible for establishing a comprehensive health, safety, and environmental program for its activities. DOE carries out this responsibility through the promulgation of regulations (set forth in 10 CFR 830) and the issuance of DOE Orders. The DOE regulations, however, do not apply to activities regulated by the NRC (see 10 CFR 830.2(a), 835.1(b)). Thus, the DOE regulations would not apply to tritium production at the TVA reactors, even if they were purchased by DOE.

Likewise, most of the DOE Orders do not apply to DOE activities regulated by the NRC, thus they would not apply to the proposed activity. Those Orders that do not expressly exclude NRC-regulated activities are primarily addressed to "DOE facilities." Orders applicable to "DOE facilities," regardless of NRC regulation, include Accident Investigation (DOE Order 225.1), Environment Safety and Health Reporting (DOE Order 231.1), and Worker Protection Management for DOE Federal and Contractor Employees (DOE Order 440.1).

The only DOE Safety and Environmental Order (other than 451.1, related to NEPA compliance) that appears to apply to the proposed activity regardless of NRC regulation or facility ownership is DOE Order 5400.5, "Radiation Protection of Public and Environment." It applies to "all DOE elements and contractors performing work for the Department." This DOE Order must be followed along with all applicable NRC, state, and EPA requirements.

6.5 Compliance History

This CLWR EIS considered three nuclear facilities for tritium production: Watts Bar 1; Sequoyah 1 and Sequoyah 2; and Bellefonte 1 and Bellefonte 2. A description is provided of each facility's performance in the following areas: (1) compliance with NRC regulations; (2) compliance with environmental and nonnuclear safety regulations; (3) NRC Performance Indicators; and (4) Systematic Assessments of License Performance. The assessment is based on the following information sources:

- Information submitted by TVA in response to DOE's Request for Proposal

- NRC documentation, including Systematic Assessments of Licensee Performance reports, transcripts of Commission briefings, and summaries of Notices of Violation

- Review of Industry Performance Indicators compiled by NRC.

6.5.1 Compliance Indicators

The purpose of this section is not for DOE to assess the adequacy of TVA's operation of its CLWRs. Such an assessment is the responsibility of NRC. The information contained in this section provides a basis for DOE to assess if there are any compliance issues that would interfere with the production of tritium or create a potentially significant environmental impact. Three selected compliance indicators which are used to describe TVA's compliance history are: (1) Systematic Assessment of Licensee Performance; (2) enforcement actions; and (3) performance indicators.

6.5.1.1 Systematic Assessments of Licensee Performance (SALP)

One of the NRC's evaluation tools, the Systematic Assessments of Licensee Performance Program, has been used to characterize this compliance performance. The Systematic Assessments of Licensee Performance Program is an integrated effort by the NRC to collect and evaluate observations and data to assess and better understand the reasons for a licensee's performance. The program was started in the early 1980s. The Systematic Assessments of Licensee Performance evaluation is based on a compilation of the NRC staff's regulatory experience with the plant over an extended period of time. Normally, the Systematic Assessments of Licensee Performance Program covers about 18 months. This period can be extended to 24 months for plants that are performing well and can be reduced to about 12 months for poorer performers.

Each plant is rated in four functional areas: plant operations, maintenance, engineering, and plant support. Each functional area is assigned a rating of 1, 2, or 3. The "1" rating represents a superior level of safety performance that may support a reduced NRC inspection effort. A "2" rating reflects a good level of performance. A rating of "3" designates an acceptable level of performance where the NRC will consider increased levels of inspection effort.

6.5.1.2 NRC Notices of Violations and Enforcement Actions

The review of each facility's NRC enforcement history also presents an overview of day-to-day compliance with NRC regulations. The NRC's Enforcement Program seeks to protect public health and safety by ensuring compliance with NRC regulations and license conditions; obtaining prompt correction of violations and conditions averse to quality; deterring future violations; and encouraging improvement of licensee performance.

Violations are identified through inspections and investigations. There are three primary enforcement sanctions available: Notices of Violation, civil penalties, and orders.

- A Notice of Violation summarizes the results of an inspection and formalizes a violation. Severity levels for Notices of Violation of NRC regulations range from Severity Level I, for the most significant violations, to Severity Level IV for those of more than minor concern.

- A civil penalty is a monetary fine issued under the authority of the Atomic Energy Act. Civil penalties may be assessed up to $110,000 per violation per day. Notices of Violation and civil penalties are issued based on violations.

- Orders may be issued for violations, or in the absence of a violation, because of a public health and safety issue.

6.5.1.3 Performance Indicators

Performance Indicators for Operating Commercial Nuclear Power Reactors (NRC 1998b), was most recently issued in December 1997. This document contains data through September 1997 for 109 commercial power reactors. The information focuses on eight performance indicators using information that has been submitted by the reactor operators in Licensee Event Reports, monthly operating reports, and information provided by the Institute of Nuclear Power Operations. The information is grouped in "Peer Groups" to provide a useful perspective to evaluate a unit's performance against reactors of similar operating history, age, and manufacturer. Also, performance indicator data were categorized by similar data to be characterized as a Peer Group. Plants were categorized by Nuclear Steam Supply System vendor, product line, generating capacity, and licensing date. The following are the Peer Group categories listed under *Performance Indicators for Operating Commercial Nuclear Power Reactors* (NRC 1998b):

- Pre-TMI General Electric Plants
- Post-TMI General Electric Plants
- Babcock and Wilcox Plants
- Combustion Engineering Plants without Core Protection Calculators
- Combustion Engineering Plants with Core Protection Calculators
- Westinghouse 2-Loop and Small 3 and 4-Loop Plants
- Westinghouse Older 3-Loop Plants
- Westinghouse New 3 and 4-Loop Plants
- Westinghouse Older 4-Loop Plants
- All New Plants Since 1/1/87

6.5.2 Watts Bar 1

Watts Bar 1 started commercial power operations in 1996. The compliance review includes an overview of the plant's regulatory performance from the latter stages of construction through current operations.

6.5.2.1 NRC Performance

NRC Overview

In discussing the compliance history in a September 1995 Commission briefing (NRC 1995d), the NRC Staff indicated that it had applied "unprecedented NRC inspection resources" to Watts Bar 1 to ensure that the systemic problems that created design and construction concerns in the pre-1985 time frame were effectively addressed by TVA as it completed construction and prepared the plant equipment, systems, and staff for full power operations. Stewart Ebneter, NRC Region II Administrator noted "I believe we have inspected Watts Bar 1 more than any other plant...I think this one is the most inspected plant." These inspections provided the NRC an effective forum to review all aspects of the construction, testing, and operation of Watts Bar 1 prior to approval of the Operating License in 1996. In a July 1995 Commission briefing (NRC 1995c), John S. Jaudon, NRC Deputy Director, Division of Reactor Safety, Region II characterized TVA's performance by saying, "Our inspections indicate that TVA performance on the site has been generally good since the fall of 1994."

This theme was reiterated in the September 1995 Commission briefing as NRC management reviewed the results of recent testing at Watts Bar 1 and summarized the progress of preparing Watts Bar 1 for operation (NRC 1995d).

Systematic Assessments of Licensee Performance Evaluations

Watts Bar 1 operations have been evaluated by the NRC in two Systematic Assessments of Licensee Performance inspections (NRC 1996c, NRC 1998a). As summarized in **Table 6–1**, Watts Bar 1 has an average Systematic Assessment of Licensee Performance score of 1.25 for these two evaluations (see Section 6.5.1.1).

Table 6–1 Systematic Assessment of Licensee Performance Results for the Watts Bar Nuclear Power Plant

Review Period	*Plant Operations*	*Maintenance*	*Engineering*	*Plant Support*
November 1995 to November 1996	2	1	1	1
November 1996 to December 1997	2	1	1	1

The NRC's January 1998 Systematic Assessment of Licensee Performance report for the period from November 1996 to December 1997 (NRC 1998a) characterized the engineering, maintenance, and plant support functional areas as "superior." However, the report indicated that, "configuration control of plant equipment remained problematic...component mispositions by nonlicensed operators continued to occur, including examples found by the NRC which rendered safety equipment inoperable." These issues are being addressed by the NRC.

NRC Notices of Violation and Enforcement Actions

TVA's compliance information (TVA 1997e, NRC 1998f), which was submitted in response to DOE's Request for Proposal, identified the following NRC Notices of Violation issued during the latter stages of construction:

- 1992 - 15 Level IV violations
- 1993 - 3 Level II violations with civil penalty of $100,000 and 46 Level IV violations
- 1994 - 50 Level IV violations
- 1995 - 25 Level IV violations

TVA's compliance information for Watts Bar 1 (TVA 1997e) indicates that there were 35 Level IV violations, and 1 Level II violation with a civil penalty of $80,000 (this penalty was withdrawn April 1998) during the period from initial operation in 1996 to mid-1997. These enforcement actions are summarized as follows:

Civil Penalties - Watts Bar 1

The Watts Bar 1 NRC Notices of Violation were found in all four violation levels dating back to 1988. There have been no further violations since 1992, except for one civil penalty notice in combination with the Sequoyah Nuclear Plant. This penalty was withdrawn in April 1998. The Sequoyah/Watts Bar Nuclear Plants received Level I and Level II Notices of Violation which proposed imposition of Civil Penalties regarding alleged acts of discrimination in violation of 10 CFR 50.7. These Notices of Violation dated back to 1988 on different discrimination act charges which totaled $200,000 in Civil Penalties. Twenty-six cases noted in the NRC letters of January 20 and 25, 1993 included: (1) two cases in which the final order of the Secretary of Labor determined that discrimination was a factor in the actions taken against the employees, (2) 13 cases which were conciliated after an initial U.S. Department of Labor determination of discrimination, and (3) 11 cases which were conciliated before an initial determination of discrimmination by the U.S. Department of Labor (NRC 1998f). Payment of these civil penalties were made by wire transfer on January 26, 1994.

The Watts Bar Nuclear Plant received a Level III violation for not following 10 CFR 55.53(J). This violation was for use of illegal drugs as evidenced by a confirmed positive test for marijuana resulting from a urine sample submitted on May 1, 1995 (notification dated June 23, 1995).

The Level IV violations have been found to fit in the following categories as stated: lack of site standard practices, failure to meet code requirements, deficiencies in quality control, improper work instructions, deficiencies in procedures, failure to establish adequate measures to assure that materials conformed to requirements, failure to train personnel properly, drawing errors, inadequate design control, failure to distribute agenda, design and construction practices, and failure to adequately control and secure safeguards. The overview of all Notices of Violation at this level fit into two classifications, a lack of management control and procedural interpretation (NRC 1998f).

Performance Indicators

Performance Indicators for Operating Commercial Nuclear Power Reactors (NRC 1998b), presents performance indicator information for Watts Bar 1 using a Peer Group defined as "All New Plants Since 1/1/87." Accordingly, the data presented in *Performance Indicators for Operating Commercial Nuclear Power Reactors* was reviewed for the six (of eight) performance indicators that address operational activities. The following data characterizes Watts Bar 1 performance since the second quarter of 1996 in these categories:

- *Automatic scrams while critical* (An automatic scram is a reactor shutdown that has been initiated by the plant's safety systems.) The industry average for this indicator was less than 0.3 scrams per quarter. Watts Bar 1's performance included four quarters with no automatic scrams, one quarter with one automatic scram and two quarters with two scrams, for an average of 0.7 scrams per quarter.

- *Safety System Actuations* The industry average for this indicator was approximately 0.005 actuations per quarter. Watts Bar 1's performance included six quarters with no actuations, and one quarter with three actuations (with two occurring with the reactor operating and one with the reactor shutdown), for an average of 0.14 actuations per quarter.

- *Significant Events* The industry average for this indicator was approximately zero significant events per quarter which equaled Watts Bar 1's performance of no significant events through seven quarters.

- *Safety System Failures* The industry average for this indicator was approximately 0.5 failures per quarter. Watts Bar 1's performance included three quarters with no failures, three quarters with one failure per quarter (all during operation), and one quarter with two failures (both with the reactor shutdown), for an average of 0.7 failures per quarter.

- *Forced Outage Rate* The industry average for this indicator was less than a 20 percent forced outage rate per quarter. Watts Bar 1's performance included three quarters with no forced outages, one quarter with a 1 percent forced outage rate, one quarter with a 2 percent forced outage rate, and one quarter with an 18 percent forced outage rate.

- *Equipment Forced Outages* The industry quarterly average for this indicator was approximately 0.2 equipment forced outages per 1,000 commercial critical hours. Watts Bar 1's performance included four quarters with no outages resulting from equipment problems, one quarter with a rate of 1.5 outages per 1,000 commercial critical hours, and one quarter with a rate of 1.65 outages per 1,000 commercial critical hours.

Also, a review of performance indicator criteria addressed Collective Radiation Exposure which is the total radiation dose accumulated by unit personnel. The industry average for this indicator was less than 50 man-rem per quarter. The performance of Watts Bar 1 was only reported in the *Performance Indicators for Operating Commercial Nuclear Power Reactors* (NRC 1998b) for two quarters with values of 3 man-rem per quarter.

6.5.2.2 Environmental, Safety & Health (Non-Nuclear) Performance

OSHA Compliance/Worker Safety Performance

As noted in TVA's summary of its OSHA performance indicators for the period from 1992 through mid-1997, (TVA 1997e) both the Recordable Injury Rate and the Lost-Time Injury Rate are below the rates reported by the industry in general and specifically for the electric industry. This reflects performance from 1992 to 1995, when Watts Bar 1 was completing construction, system testing, and related start-up activities. Similarly, 1996 to mid-1997 was a period in which facility staff were transitioning from a construction phase to a power generation phase (i.e., reactor and operating systems were energized and potentially radioactive, and discipline in all phases of facility operations was critical).

Environmental Performance

As noted in their submittal (TVA 1997e), Watts Bar 1 had no Notices of Violation from 1992 through 1994, only one in 1995, and again one in 1996. None were received in the first 7 months of 1997. The 1995 and 1996 Notices of Violation involved the following violations:

- 1995 Notice of Violation - Auxiliary boiler operating hours exceeded limit in air permit

- 1996 Notice of Violation - Unmonitored release from yard pond; in sewage treatment plant effluent stream.

6.5.3 Sequoyah 1 and Sequoyah 2

6.5.3.1 NRC Performance

NRC Overview

Sequoyah 1 and Sequoyah 2 initially achieved commercial operation in July 1981 and June 1982, respectively. The regulatory history of these plants includes the following:

- In 1985, TVA shut down five reactors (including Sequoyah 1 and Sequoyah 2) because of charges of mismanagement and inattention to safety requirements. Sequoyah 2 was the first of the shutdown units to be returned to operation in mid-1988 (TVA 1997e).

- The NRC added the Sequoyah Nuclear Plant to its "watch list" as a result of the 1985 shutdown. (The NRC's Watch List identifies power plants that require additional regulatory oversight because of declining performance. Once placed on the "watch list," a plant must demonstrate consistent improved performance before it is removed from the list.) Both Sequoyah 1 and Sequoyah 2 were removed from this list in 1989 (TVA 1997e).

- A reactor trip (i.e., automatic reactor shutdown) at Sequoyah 1 in March 1993 identified a problem with piping that resulted in the shutdown of both units. Sequoyah 2 was restarted in October 1993, and Sequoyah 1 was restarted after completion of a refueling outage.

Systematic Assessment of Licensee Performance Evaluations

A review of the most recent evaluations was conducted to determine the facility's current regulatory stature, as described in the NRC's Systematic Assessments of Licensee Performance inspections (NRC 1995a, NRC 1996b). As summarized in **Table 6–2**, the Sequoyah Nuclear Plant has an average Systematic Assessments of Licensee Performance score of around 2.0. These scores and the associated assessments by the NRC characterized the overall performance of Sequoyah 1 and Sequoyah 2 as "good."

Table 6–2 Systematic Assessments of Licensee Performance Results for the Sequoyah Nuclear Power Plant

Review Period	*Plant Operations*	*Maintenance*	*Engineering*	*Plant Support*
August 1992 to October 1993	3	3	2	1
October 1993 to January 1995	2	2	2	2
January 1995 to July 1996	2	2	2	2
July 1996 to February 1998	2	2	2	1

As noted in the Systematic Assessments of Licensee Performance reports, the NRC has acknowledged that progress and improvements have been made in many areas. However, additional improvements are warranted and expected in the remaining areas. Two examples of the NRC's comments in the recent Systematic Assessments of Licensee Performance reports are provided below.

The February 1995 Systematic Assessments of Licensee Performance reports for October 1993 to January 1995 (NRC 1995a) summarized the NRC's findings as:

> "Performance improved in the Operations and Maintenance functional areas, and remained the same in the Engineering functional area. However, emerging problems and operational occurrences continued to require reactive organizational responses. Performance declined in the Plant Support functional area due to weaknesses in corrective actions for long-standing problems in the fire protection, secondary chemistry, and post-accident sampling system areas." (NRC 1995a)

The September 1996 Systematic Assessments of Licensee Performance report (for January 1995 to July 1996) summarized its findings as:

> "Plant performance was characterized by an excessive number of reactor trips and transients early in the assessment period....Operations performance continued to be good in plant transient response, safety sensitivity, and problem identification. Improvement was noted in shutdown operations and personnel error reduction. Weak areas were found in root cause evaluations and controls for infrequently performed evolutions." (NRC 1996b)

The April 1998 Systematic Assessment of Licensee Performance report (for July 1996 through February 1998) summarized its findings as:

> "Performance in the plant support area improved to superior, and performance in maintenance, plant operations, and engineering areas was still characterized as good. The plant operated well during the last six months of the assessment period. However, it is unclear whether this positive performance indicates a consistent trend towards improved performance.
>
> The performance from a safety assessment and quality assurance perspective was mixed. Quality Assurance assessments were generally considered good as were self-assessments in maintenance and most plant support areas. However, the ability to conduct meaningful self-assessments in all areas was not demonstrated, nor was the identification of root causes and resulting corrective action universally effective." (NRC 1998c)

NRC Notices of Violation and Enforcement Actions

TVA's compliance information on Sequoyah 1 and Sequoyah 2 identifies the following NRC Notices of Violation issued since 1993 (TVA 1997e, NRC 1998e):

- 1993 - 4 Level III and 26 Level IV violations
- 1994 - 29 Level IV violations
- 1995 - 14 Level IV violations
- 1996 - 14 Level IV violations
- 1997 - 4 Level III violations with civil penalties of $80,000 (this penalty was withdrawn April 1998) and 18 Level IV violations. (These were the first violations to include civil penalties since 1993, according to the TVA data.)

The NRC Notices of Violation were found in all four levels of violation dating back to 1988. Although, since 1992 the Notices of Violation have only been at the Level III and Level IV categories.

The Level IV violations were found to fit in the following categories as stated: lack of maintenance and operating procedures, poor management, improper installation of safety controlled instrumentation, and failure to follow code. The overview of all Notices of Violation at this level fit into two classifications: a lack of management control and procedural interpretation.

The Level III violations were for failure to comply with technical specification requirements, for example: inoperation of mechanical mechanisms, mispositioned safety-system throttle valves, failure to maintain the refueling water storage tank solution temperature, and loss of reactor coolant pump seal injection flow during recovery. The Level III Notices of Violation fit into two classifications: a lack of operation of safety related devices and failure to maintain system operations guidelines.

Sequoyah received Level I and Level II Notices of Violation which proposed Imposition of Civil Penalties regarding alleged acts of discrimination against employees for engaging in certain protected activities in violation of 10 CFR 50.7. These Notices of Violation resulted in the impositon of a civil penalty in the amount of $200,000. Payment of this civil penalty was made on January 26, 1994.

Performance Indicators

Performance Indicators for Operating Commercial Nuclear Power Reactors (NRC 1998b) presents performance indicator information for Sequoyah 1 and Sequoyah 2 using a Peer Group defined as “Westinghouse New 3 and 4-Loop Plants.” The data presented in *Performance Indicators for Operating Commercial Nuclear Power Reactors* (NRC 1998b) was reviewed for the six (of eight) performance indicators that address operational activities. The following data characterizes Sequoyah 1 and Sequoyah 2 performance during the period from the fourth quarter of 1994 through the third quarter of 1997 in these categories:

- *Automatic scrams while critical* (An automatic scram is a reactor shutdown that has been initiated by the plant’s safety systems.) The industry average for this indicator was less than 0.19 scrams per quarter. The performance of Sequoyah 1 and Sequoyah 2 reflected an average of 0.3 scrams per quarter.

- *Safety System Actuations* The industry average for this indicator was approximately zero actuations per quarter. The performance of Sequoyah 1 and Sequoyah 2 reflected an average of 0.17 actuations per quarter.

- *Significant Events* The industry average for this indicator was approximately zero significant events per quarter while the performance of Sequoyah 1 and Sequoyah 2 reflected one significant event each during the reporting period for an average of 0.08 events per quarter.

- *Safety System Failures* The industry average for this indicator was less than one failure per quarter. The performance of Sequoyah 1 and Sequoyah 2 reflected one safety system failure for Sequoyah 1 and zero failures for Sequoyah 2 during the 12-month reporting period.

- *Forced Outage Rate* The industry average for this indicator was less than a 20 percent forced outage rate per quarter. The performance of Sequoyah 1 reflected one quarter with a forced outage rate of 26 percent and the remaining 11 quarters reflected a forced outage rate of 10 percent or less, with four quarters having an outage rate of zero. The performance of Sequoyah 2 reflected two quarters with forced outage rates which exceeded the industry rate and the remaining 10 quarters which reflected a forced outage rate of 4 percent or less, with 6 quarters having an outage rate of zero.

- *Equipment Forced Outages* The industry quarterly average for this indicator was approximately 0.3 equipment forced outages per 1,000 commercial critical hours. The performance of Sequoyah 1 included six quarters with forced outage rates caused by equipment problems which exceeded the industry rate and the remaining six quarters with a forced outage rate of zero. Sequoyah 2 performance included five quarters with forced outage rates which exceeded the industry rate and the remaining seven quarters with a forced outage rate of zero.

Also, a review of performance indicator criteria addressed Collective Radiation Exposure. The industry average for this indicator was less than 50 man-rem per quarter. The performance of Sequoyah 1 reflects four quarters with quarterly radiation exposures which exceeded the industry rate (with a peak of 165 man-rem) and the remaining seven quarters reflected exposures of 3 to 17 man-rem per quarter. The performance of Sequoyah 2 reflects two quarters with quarterly radiation exposures which exceeded the industry rate (with a peak of 213 man-rem) and the remaining nine quarters reflected exposures of 2 to 17 man-rem per quarter.

6.5.3.2 Environmental, Safety & Health (Non-Nuclear) Performance

OSHA Compliance/Worker Safety Performance

As noted in TVA's summary of its OSHA performance indicators for 1992 through mid-1997 (TVA 1998a), both the Recordable Injury Rate and the Lost-Time Injury Rate were below the rates reported by industry in general and the electric industry in specific.

Environmental Performance

Sequoyah 1 and Sequoyah 2 had a total of three Notices of Violation issued by the Tennessee Department of Environment and Conservation from 1992 through 1997 (TVA 1997e). These notices involved the following violations:

- 1992 Notice of Violation - Subsurface release of fuel oil.

- 1993 Notice of Violation - Storage of mixed waste (i.e., waste with radioactive and hazardous constituents) onsite for over 90 days without a permit.

- 1995 Notice of Violation - Failure to notify regulator of a waste stream that had existed since 1991.

6.5.4 Bellefonte 1 and Bellefonte 2

6.5.4.1 NRC Performance

NRC Overview

As noted earlier, the Bellefonte Nuclear Power Plant includes two partially completed reactor units. Construction was halted in 1988 when Bellefonte 1 was 90 percent complete and Bellefonte 2 was 57 percent complete. As a result, the regulatory history is limited. As noted in the TVA submittal, Bellefonte 1 and Bellefonte 2 had received no Notices of Violation since 1989 and have had no escalated enforcement actions, fines, or penalties during their construction history (TVA 1997e).

6.5.4.2 Environmental, Safety & Health (Non-Nuclear) Performance

OSHA Compliance/Worker Safety Performance

As noted in TVA's summary of its OSHA performance indicators for the period from 1992 through mid-1997, the Recordable Injury Rate was below the rates reported by industry in general and the electric industry in particular. The data also indicates that the Lost-Time Injury Rate was 0 for the same period, which is obviously well below the rates reported by industry in general and the electric industry in particular (TVA 1997e).

Environmental Performance

As noted in their submittal (TVA 1997e), Bellefonte 1 and Bellefonte 2 had one Notice of Violation, a fuel oil spill, issued by the Alabama Department of Environment and Conservation in 1993.

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Experience/ Technical Specialty:	Twenty-three years. Nuclear power plant safety, risk and reliability analysis, design analysis, criticality analysis, probabilistic risk assessment.

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General Public/Stakeholders

approximately 700 copies of the Draft EIS were sent to stakeholders
approximately 2800 copies of the Summary of the Draft EIS were sent to stakeholders

10. GLOSSARY

***Accident Sequence* —** With regard to nuclear facilities, an initiating event followed by system failures or operator errors, which can result in significant core damage, confinement system failure, and/or radionuclide releases.

***Activation Products* —** Nuclei, usually radioactive, formed by the bombardment and absorption in material with neutrons, protons, or other nuclear particles.

***Acute Exposure* —** The exposure incurred during and shortly after a radiological release. Generally, the period of acute exposure ends when long-term interdiction is established, as necessary. For convenience, the period of acute exposure is normally assumed to end 1 week after the inception of a radiological accident.

***Air Pollutant* —** Any substance in air which could, if in high enough concentration, harm man, other animals, vegetation, or material.

***Air Quality Control Region (AQCR)* —** Geographic subdivisions of the U.S., designed to deal with pollution on a regional or local level. Some regions span more than one state.

***Alpha Activity* —** The emission of alpha particles by radioactive materials.

***Alpha Particle* —** A positively charged particle, consisting of two protons and two neutrons, that is emitted during radioactive decay from the nucleus of certain nuclides. It is the least penetrating of the three common types of radiation (alpha, beta, and gamma).

***Alpha Wastes* —** Wastes containing radioactive isotopes which decay by producing alpha particles.

***Ambient* —** Surrounding.

***Ambient Air* —** The surrounding atmosphere as it exists around people, plants and structures. Air quality standards are used to provide a measure of the health-related and visual characteristics of the air.

***Ambient Air Quality Standards* —** The level of pollutants in the air prescribed by regulations that may not be exceeded during a specified time in a defined area.

***Aquatic* —** Living or growing in, on, or near water.

***Aquatic Biota* —** The sum total of living organisms within any designated aquatic area.

***Aquatic Macrophytes* —** Visible plants occurring in water.

***Aquifer* —** A saturated geologic unit through which significant quantities of water can migrate under natural hydraulic gradients.

***Archaic* —** Artifacts from the North American archaeological period dating from 8000 B.C. to 1000 B.C.

Archaeological Sites (resources) — Any location where humans have altered the terrain or discarded artifacts during either prehistoric or historic times.

Artifact — An object produced or shaped by human workmanship of archaeological or historical interest.

As Low as Reasonably Achievable (ALARA) — A concept applied to the quantity of radioactivity released and the quantity of radiation dose received by onsite workers in routine operation of a nuclear system or facility, including 'anticipated operational occurrences.' It takes into account the state of technology, economics of improvements in relation to benefits to public health and safety, and other societal and economic considerations in relation to the use of nuclear energy in the public interest.

Atmospheric Dispersion — The process of air pollutants being dispersed in the atmosphere. This occurs by the wind that carries the pollutants away from their source and by turbulent air motion that results from solar heating of the Earth's surface and air movement over rough terrain and surfaces.

Atomic Energy Act of 1954, as Amended — The statute that established U.S. requirements with respect to nuclear energy and nuclear materials. This Act, as amended, provides the statutory framework for government control of the possession, use, and production of atomic energy, special nuclear material, and other radioactive material, whether owned by the government or others.

Atomic Energy Commission — A five-member commission, established by the *Atomic Energy Act* of 1946, to supervise nuclear weapons design, development, manufacturing, maintenance, modification, and dismantlement. In 1974, the Atomic Energy Commission was abolished and all functions were transferred to the Nuclear Regulatory Commission and the Administrator of the Energy Research and Development Administration. The Energy Research and Development Administration was later terminated and its functions vested by law in the Administrator were transferred to the Secretary of Energy.

Background Radiation — Ionizing radiation present in the environment from cosmic rays and natural sources in the Earth; background radiation varies considerably with location.

Badged Worker — A worker who has the potential to be exposed to radiation and is equipped with dosimeter to measure his/her dose.

Barrier — Any material or structure that prevents or substantially delays movement of radionuclides toward the accessible environment.

Baseline — A quantitative expression of conditions, costs, schedule, or technical progress to serve as a base or standard for measurement during the performance of an effort; the established plan against which the status of resources and progress of a project can be measured. For this Environmental Impact Statement, the environmental baseline is the site environmental conditions as they exist or estimated to exist in the absence of the proposed action.

BEIR V — Biological Effects of Ionizing Radiation; referring to the fifth in a series of committee reports from the National Research Council.

Benthic — Plants and animals dwelling at the bottom of oceans, lakes, rivers, and other surface waters.

Beta Particle — A charged particle emitted from the nucleus of an atom during radioactive decay. A negatively charged beta particle is identical to an electron, a positively charged beta particle is called a positron.

***Biodiversity* —** The diversity of life in all its forms and all its levels of organization. Also termed 'biological diversity.'

***Biota (biotic)* —** The plant and animal life of a region (pertaining to biota).

***Block* —** U.S. Bureau of the Census term describing small areas bounded on all sides by visible features or political boundaries; used in tabulation of census data.

***Block Groups* —** U.S. Bureau of the Census term describing a cluster of blocks generally selected to include 250 to 550 housing units.

***Blowdown* —** A maintenance procedure to remove sediment in power plant components.

***Boiler* —** A pressurized system in which water is vaporized to steam, the desired end product, by heat transferred from a source of higher temperature, usually the products of combustion from burning fuels.

***Boiling Water Reactor* —** A type of nuclear reactor that uses fission heat to generate steam in the reactor core or vessel to drive turbines and generate electricity.

***Boost* —** The process by which fusion of deuterium-tritium gas inside the pit of a nuclear weapon produces neutrons that increase the fission output of the primary.

***Boron-10* —** An isotope of the element boron that has a high capture cross-section for neutrons. It is used in reactor absorber rods for reactor control.

***Burial Ground* —** With regard to radioactive wastes, a place for burying unwanted (i.e., radioactive) materials in which the earth acts as a receptacle to prevent the escape of radiation and the dispersion of wastes in the environment.

***Burnable Absorber* —** A material, such as boron or lithium, which captures neutrons and transmutes or changes to another isotope.

***Burnable Poison Rod* —** A nuclear reactor rod used to capture or absorb neutrons created in the core by the fission reactions during the early core life.

***Cancer* —** The name given to a group of diseases characterized by uncontrolled cellular growth with cells having invasive characteristics such that the disease can transfer from one organ to another.

***Capable Fault* —** A fault that has exhibited one or more of the following characteristics:

> Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years.
>
> Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault.
>
> A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

***Capacity Factor* —** The ratio of the annual average power production of a power plant to its rated capacity.

***Carbon Dioxide (CO_2)* —** A colorless, odorless, gas that is a normal component of the ambient air; it results from fossil fuel combustion and is an expiration production.

***Carboniferous Age* —** Noting or pertaining to a period of the Paleozoic era, including the Pennsylvanian, Mississippian, and formerly the Permian periods as epochs: from 270 million to 350 million years ago.

***Carbon Monoxide (CO)* —** A colorless, odorless, poisonous gas produced by incomplete fossil fuel combustion.

***Cask* —** A heavily shielded container that meets U.S. Nuclear Regulatory Commission and U.S. Department of Transportation regulatory requirements and is used to store and/or ship radioactive materials (e.g., spent nuclear fuel, irradiated tritium-producing burnable absorber rods, or high-level waste). Lead, depleted uranium, and steel are common materials used in the manufacture of casks.

***Cesium* —** A silver-white alkali metal. A radioactive isotope of cesium, cesium-137, is a common fission product.

***Chain Reaction* —** A reaction that initiates its own repetition. In a fission chain reaction, a fissionable nucleus absorbs a neutron and fissions spontaneously, releasing additional neutrons. These, in turn, can be absorbed by other fissionable nuclei, releasing still more neutrons. A fission chain reaction is self-sustaining when the number of neutrons is constant or increases over a period of time.

***Chemical Oxygen Demand* —** A measure of the quantity of chemically oxidizable components present in water.

***Chronic Exposure* —** Low-level radiation exposure incurred over a long time period due to residual contamination.

***Cladding* —** The metal tube that forms the outer jacket of a nuclear fuel rod or burnable absorber rod. It prevents the release of radioactive material into the coolant. Stainless steel, and zirconium alloys are common cladding materials.

***Class I Areas* —** National parks and wilderness areas designated by the Prevention of Significant Deterioration section of the Clean Air Act amendments. These amendments and the implementing regulations provide special protection to air quality and air quality-related values in such areas. Only very slight deterioration of air quality is allowed in Class I areas.

***Class II Areas* —** Most of the country not designated as Class I is designated as Class II. Class II areas are generally cleaner than air quality standards require and moderate increases in new pollution are allowed after a regulatory mandated impacts review.

***Claystone* —** A massive sedimentary rock made up largely of clay minerals having the composition of shale, but lacking its fine lamination.

***Clean Air Act* —** This Act mandates and provides for enforcement of regulations to control air pollution from various sources.

***Clear Air Act Amendments of 1990* —** Expands the Environmental Protection Agency's enforcement powers and adds restrictions on air toxics, ozone depleting chemicals, stationary and mobile emissions sources, and emissions implicated in rain and global warming.

***Clean Water Act of 1972, 1987* —** This Act regulates the discharge of pollutants from a point source into navigable waters of the United States in compliance with a National Pollution Discharge Elimination System permit as well as regulates discharges to or dredging of wetlands.

***Climatology* —** The science that deals with climates and investigates their phenomena and causes.

***Code of Federal Regulations* —** All Federal regulations in force are published in codified form in the Code of Federal Regulations.

***Cold Standby* —** Maintenance of a protected reactor condition in which the fuel is removed, the moderator is stored in tanks, and equipment and system lay up is performed to prevent deterioration, such that future refueling and restart are possible.

***Collective Committed Effective Dose Equivalent* —** The committed effective dose equivalent of radiation for a population.

***Commercial Light Water Reactor (CLWR)* —** A term used to describe commercially-operated power-producing U.S. reactors that use “light” (as opposed to “heavy”) water for cooling and neutron moderation.

***Committed Dose Equivalent* —** The predicted total dose equivalent to a tissue or organ over a 50-year period after an intake of radionuclide into the body. It does not include external dose contributions. Committed dose equivalent is expressed in units of rem or Sievert. The committed effective dose equivalent is the sum of the committed dose equivalents to various tissues of the body, each multiplied by the appropriate weighting factor.

***Community (biotic)* —** All plants and animals occupying a specific area under relatively similar conditions.

***Complex* —** The Nuclear Weapons Complex, which is a set of Federal sites and government-owned/contractor-operated facilities administered by the Department of Energy.

***Comprehensive Test Ban Treaty (CTBT)* —** A proposed treaty prohibiting nuclear tests of all magnitudes.

***Computational Modeling* —** The use of a computer to develop a mathematical model of a complex system or process and to provide conditions for testing it.

***Conformity* —** Conformity is defined in the Clean Air Act as the action’s compliance with an implementation plan’s purpose of eliminating or reducing the severity and number of violations of the National Ambient Air Quality Standards and achieving expeditious attainment of such standards; and that such activities will not: (1) cause or contribute to any new violation of any standard in any area; (2) increase the frequency or severity of any existing violation of any standard in any area; or (3) delay timely attainment of any standard or any required interim emission reduction or other milestones in any area.

***Consumptive Water Use* —** The difference in the volume of water withdrawn from a body of water and the amount released back into the body of water.

***Container* —** With regard to radioactive wastes, the metal envelope in the waste package that provides the primary containment function of the waste package and is designed to meet the containment requirements of 10 CFR 60.

***Containment Design Basis* —** For a nuclear reactor, those bounding conditions for the design of the containment, including temperature, pressure, and leakage rate. Because the containment is provided as an additional barrier to mitigate the consequences of accidents involving the release of radioactive materials, the containment design basis may include an additional specified margin above those conditions expected to result from the plant design-basis accidents to ensure that the containment design can mitigate unlikely or unforeseen events.

Control Rod — A rod containing material such as boron that is used to control the power of a nuclear reactor. By absorbing excess neutrons, a control rod prevents the neutrons from causing further fissions, i.e., increasing power.

Coolant — A substance, either gas or liquid, circulated though a nuclear reactor or processing plant to remove heat.

Cooperating Agency — Any other Federal agency having jurisdiction or special expertise with respect to any environmental issue.

Credible Accident — An accident that has a probability of occurrence greater than or equal to one in a million years.

Criteria Pollutants — The Clean Air Act required the Environmental Protection Agency to set air quality standards for common and widespread pollutants after preparing “criteria documents” summarizing scientific knowledge on their health effects. Today there are standards in effect for six “criteria pollutants”: sulfer dioxide (SO_2), carbon monoxide (CO), particulate matter less than or equal to 10 microns in diameter (PM_{10}) and less than or equal to 2.5 microns in diameter ($PM_{2.5}$), nitrogen dioxide (NO_2), ozone (O_3), and lead (Pb).

Critical Habitat — Defined in the *Endangered Species Act* of 1973 as ‘specific areas within the geographical area occupied by [an endangered or threatened] species, essential to the conservation of the species and which may require special management considerations or protection; and specific areas outside the geographical area occupied by the species ‘that are essential for the conservation of the species.

Criticality — A reactor state in which a self-sustaining nuclear chain reaction is achieved.

Cultural Resources — Archaeological sites, historical sites, architectural features, traditional use areas, and Native American sacred sites.

Cumulative Impacts — In an Environmental Impact Statement, 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), private industry, or individuals undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7).

Curie — A unit of radioactivity equal to 37 billion disintegrations per second; also a quantity of any nuclide or mixture of nuclides having 1 curie radioactivity.

Day-Night Average Sound Level (DNL) — The 24-hour A-weighted equivalent sound level expressed in decibels, with a 10-decibel penalty added to sound levels between 10:00 p.m. and 7:00 a.m. to account for increased annoyance due to noise during night time hours.

Decay Heat (radioactivity) — The heat produced by the decay of certain radionuclides.

***Decay (radioactive)* —** The decrease in the amount of any radioactive material with the passage of time, due to the spontaneous transformation of an unstable nuclide into a different nuclide or into a different energy state of the same nuclide; the emission of nuclear radiation (alpha, beta, or gamma radiation) is part of the process.

***Decibel (dB)* —** A logarithmic unit of sound measurement which describes the magnitude of a particular quantity of sound pressure-power with respect to a standard reference value. In general, a sound doubles in loudness for every increase of 10 decibels.

***Decibel, A-weighted (dB(A))* —** A unit of frequency weighted sound pressure level, measured by the use of a metering characteristic and the "A" weighting specified by the American National Standards Institution ANSI S1.4-1983 (R1594), that accounts for the frequency response of the human car.

***Deciduous* —** Trees which shed leaves at a certain season.

***Decontamination* —** The actions taken to reduce or remove substances that pose a substantial present or potential hazard to human health or the environment, such as radioactive or chemical contamination from facilities, equipment, or soils by washing, heating, chemical or electrochemical action, mechanical cleaning, or other techniques.

***Deposition* —** In geology, the laying down of potential rock-forming materials; sedimentation. In atmospheric transport, the settling out on ground and building surfaces of atmospheric aerosols and particles ('dry deposition') or their removal from the air to the ground by precipitation ('wet deposition' or 'rainout').

***Design Basis* —** For nuclear facilities, information that identifies the specific functions to be performed by a structure, system, or component and the specific values (or ranges of values) chosen for controlling parameters for reference bounds for design. These values may be: (1) restraints derived from generally accepted state-of-the-art practices for achieving functional goals; (2) requirements derived from analysis (based on calculation and/or experiments) of the effects of a postulated accident for which a structure, system, or component must meet its functional goals; or (3) requirements derived from Federal safety objectives, principles, goals or requirements.

***Design-Basis Accident* —** For nuclear facilities, a postulated abnormal event that is used to establish the performance requirements of structures, systems, and components that are necessary to: (1) maintain them in a safe shutdown condition indefinitely; or (2) prevent or mitigate the consequences of the design-basis accident so that the general public and operating staff are not exposed to radiation in excess of appropriate guideline values.

***Design-Basis Events* —** Postulated disturbances in process variables that can potentially lead to design-basis accidents.

***Deuterium* —** A nonradioactive isotope of the element hydrogen with one neutron and one proton in the atomic nucleus.

***Direct Economic Effects* —** The initial increases in output from different sectors of the economy resulting from some new activity within a predefined geographic region.

***Direct Effect Multiplier* —** The total change in regional earnings and employment in all related industries as a result of a one-dollar change in earnings and a one-job change in a given industry.

***Direct Jobs* —** The number of workers required at a site to implement an alternative.

Disposition — The ultimate 'fate' or end use of a surplus Department of Energy facility following the transfer of the facility to the Office of the Assistant Secretary for Environmental Waste Management.

Dose — The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad.

Dose Commitment — The dose an organ or tissue would receive during a specified period of time (e.g., 50 to 100 years) as a result of intake (as by ingestion or inhalation) of one or more radionuclides from a defined release, frequently over a year's time.

Dose Equivalent — The product of absorbed dose in rad (or gray) and a quality factor, which quantifies the effect of this type of radiation in tissue. Dose equivalent is expressed in units of rem or Sievert, where 1 rem equals 0.01 Sievert.

Dosimeter — A small device (instrument) carried by a radiation worker that measures cumulative radiation dose (e.g., film badge or ionization chamber).

Drift — Effluent mist or spray carried into the atmosphere from cooling towers.

Drinking Water Standards — The level of constituents or characteristics in a drinking water supply specified in regulations under the Safe Drinking Water Act as the maximum permissible.

Dual Use/Dual Benefit — Projects that have uses in or benefits for the defense sector and the private industry or civilian sector.

Effective Dose Equivalent — The summation of the products of the dose equivalent received by specified tissues of the body and a tissue-specific weighting factor. This sum is a risk-equivalent value and can be used to estimate the health effects risk of the exposed individual. The tissue-specific weighting factor represents the fraction of the total health risk resulting from uniform whole-body irradiation that would be contributed by that particular tissue. The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides, and the effective dose equivalent due to penetrating radiation from sources external to the body. Effective dose equivalent is expressed in units of rem (or Sievert).

Effluent — A gas or fluid discharged into the environment.

Effluent (liquid) — Waste water, treated or untreated, that flows out of a treatment plant, sewer, or industrial outfall; generally refers to wastes discharged into surface waters.

Electomagnetic Fields (EMF) — Two types of energy fields which are emitted from any device that generates, transmits, or uses electricity.

Emergency Condition — For a nuclear facility, occurrences or accidents that might occur infrequently during start-up testing or operation of the facility. Equipment, components, and structures might be deformed by these conditions to the extent that repair is required prior to reuse.

Emission — A material discharged into the atmosphere from a source operation or activity.

Emission Standards — Legally enforceable limits on the quantities and/or kinds of air contaminants that can be emitted into the atmosphere.

Empirical — Something that is based on actual measurement, observation, or experience rather than on theory.

***Endangered Species* —** Any species which is in danger of extinction throughout all or significant portions of its range. The Endangered Species Act of 1973, as amended, establishes procedures for placing species on the federal lists of endangered and threatened species.

***Endangered Species Act of 1973* —** The Act requires Federal agencies, with the consultation and assistance of the Secretaries of the Interior and Commerce, to ensure that their actions will not likely jeopardize the continued existence of any endangered or threatened species or adversely affect the habit of such species.

***Engineered Safety Features* —** For a nuclear facility, features that prevent, limit, or mitigate the release of radioactive material from its primary containment.

***Enriched Uranium* —** Uranium in which the abundance of the isotope uranium -235 is increased above the normal (naturally occurring) level of 0.711 weight percent.

***Entrainment* —** The involuntary capture and inclusion of organisms in streams of flowing water, a term often applied to the cooling water systems of power plants/reactors. The organisms involved may include phyto-and zooplankton, fish eggs and larvae (ichthyoplankton), shellfish larvae, and other forms of aquatic life.

***Environment, Safety, and Health Program* —** In the context of the Department of Energy, encompasses those Department of Energy requirements, activities, and functions in the conduct of all Department of Energy and Department of Energy-controlled operations that are concerned with: impacts to the biosphere; compliance with environmental laws, regulations, and standards controlling air, water, and soil pollution; limiting the risks to the well-being of both the operating personnel and the general public; and protecting property against accidental loss and damage. Typical activities and functions related to this program include, but are not limited to, environmental protection, occupational safety, fire protection, industrial hygiene, health physics, occupational medicine, and process and facilities safety, nuclear safety, emergency preparedness, quality assurance, and radioactive and hazardous waste management.

***Environmental Assessment* —** A written environmental analysis prepared pursuant to the National Environmental Policy Act (NEPA). This assessment is performed to determine whether a federal action could significantly affect the environment and thus require preparation of a more detailed environmental impact statement. If the action will not significantly affect the environment, then a finding of no significant impact (FONSI) is prepared.

***Environmental Impact Statement* —** A document required of Federal agencies by NEPA for major proposals or legislation significantly affecting the environment. A tool for decision-making, it describes the positive and negative effects of the undertaking and alternative actions.

***Environmental Justice* —** The fair treatment of people of all races, cultures, incomes, and educational levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment implies that no population of people should be forced to shoulder a disproportionate share of the negative environmental impacts of pollution or environmental hazards due to a lack of political or economic influence.

***Environmental Survey* —** A documented, multidisciplined assessment (with sampling and analysis) of a facility to determine environmental conditions and to identify environmental problems requiring corrective action.

***Epidemiology* —** The science concerned with the study of events that determine and influence the frequency and distribution of disease, injury, and other health-related events and their causes in a defined human population.

***Equivalent Sound (Pressure) Level* —** The equivalent steady sound level that, if continuous during a specified time period, would contain the same total energy as the actual time varying sound. For example, L_{eq} (1-h) and L_{eq} (24-h) are the 1-hour and 24-hour equivalent sound levels, respectively.

***Exposure Limit* —** The level of exposure to a hazardous chemical (set by law or a standard) at which or below which adverse human health effects are not expected to occur:

> Reference dose is the chronic exposure dose (mg or kg per day) for a given hazardous chemical at which or below which adverse human non-cancer health effects are not expected to occur.
>
> Reference concentration is the chronic exposure concentration (mg/m^3) for a given hazardous chemical at which or below which adverse human non-cancer health effects are not expected to occur.

***Fault* —** A fracture or a zone of fractures within a rock formation along which vertical, horizontal, or transverse slippage has occurred. A normal fault occurs when the hanging wall has been depressed in relation to the footwall. A reverse fault occurs when the hanging wall has been raised in relation to the footwall.

***Finding of No Significant Impact* —** A document by a Federal agency briefly presenting the reasons why an action, not otherwise excluded, will not have a significant effect on the human environment and will not require an environmental impact statement under the National Environmental Policy Act.

***Fissile Materials* —** Although sometimes used as a synonym for fissionable material, this term has acquired a more restricted meaning, namely, any material fissionable by thermal (slow) neutrons. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239.

***Fission (Fissioning)* —** The splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.

***Fission Products* —** Nuclei formed by the fission of heavy elements (primary fission products); also, the nuclei formed by the decay of the primary fission products, many of which are radioactive.

***Fissionable Material* —** Material that could undergo fission by fast neutrons.

***Floodplain* —** The lowlands adjoining inland and coastal waters and relatively flat areas.

***Flux* —** Rate of flow through a unit area; in reactor operation, the apparent flow of neutrons in a defined energy range (see neutron flux).

***Formation* —** In geology, the primary unit of formal stratigraphic mapping or description. Most formations possess certain distinctive features.

***Fuel Assembly* —** A cluster of fuel rods (or plates). Also called a fuel element. Approximately 200 fuel assemblies make up a reactor core.

***Fuel Rod* —** Nuclear reactor component that includes the fissile material.

***Fugitive Emissions* —** Emissions to the atmosphere from pumps, valves, flanges, seals, and other process points not vented through a stack. Also includes emissions from area sources such as ponds, lagoons, landfills, piles of stored material, and exposed soil.

***Fusion* —** Nuclear reaction in which light nuclei are fused together to form a heavier nucleus, accompanied by the release energy and fast neutrons.

***Gamma Rays* —** High-energy, short-wavelength, electromagnetic radiation accompanying fission and either emitted from the nucleus of an atom or emitted by some radionuclide or fission product. Gamma rays are very penetrating and can be stopped only by dense materials (such as lead) or a thick layer of shielding materials.

***Gaussian Plume* —** The distribution of material (a plume) in the atmosphere resulting from the release of pollutants from a stack or other source. The distribution of concentrations about the centerline of the plume, which is assumed to decrease as a function of its distance from the source and centerline (Gaussian distribution), depends on the mean wind speed and atmospheric stability.

***Genetic Effects* —** The outcome resulting from exposure to mutagenic chemicals or radiation which results in genetic changes in germ line or somatic cells.

> Effects on genetic material in reproductive cells cause trait modifications that can be passed from parents to offspring.
>
> Effects on genetic material in non-reproductive cells result in tissue or organ modifications (e.g. liver tumors) that do not pass from parents to offspring.

***Geology* —** The science that deals with the Earth: the materials, processes, environments, and history of the planet, including the rocks and their formation and structure.

***Getter* —** Material that absorbs free tritium gas and chemically binds it within its own structure. One such structure is zirconium alloy.

***Global Warming* —** The theory that certain gases such as carbon dioxide, methane, and chlorofluorocarbon in the earth's atmosphere effectively restrict radiation cooling, thus elevating the earth's ambient temperatures.

***Ground Shine* —** The radiation dose received from an area on the ground where radioactivity has been deposited by a radioactive plume or cloud.

***Groundwater* —** The supply of water found beneath the Earth's surface, usually in aquifers, which may supply wells and springs.

***Habitat* —** The environment occupied by individuals of a particular species, population, or community.

***Half-Life* —** The time in which half the atoms of a radioactive isotope decay to another nuclear form. Half-lives vary from millionths of a second to billions of years.

***Hazardous Chemical* —** Under 29 CFR 1910, Subpart Z, 'hazardous chemicals' are defined as 'any chemical which is a physical hazard or a health hazard.' Physical hazards include combustible liquids, compressed gases, explosives, flammables, organic peroxides, oxidizers, pyrophorics, and reactives. A health hazard is any chemical for which there is good evidence that acute or chronic health effects occur in exposed employees. Hazardous chemicals include carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, agents that act on the hematopoietic system, and agents that damage the lungs, skin, eyes, or mucous membranes.

Hazard Index — A summation of the Hazard Quotients for all chemicals now being used at a site and those proposed to be added to yield cumulative levels for a site. A Hazard Index value of 1.0 or less means that no adverse human health effects (non-cancer) are expected to occur.

Hazard Quotient — The value used as an assessment of non-cancer associated toxic effects of chemicals, e.g., kidney or liver dysfunction. It is a ratio of the estimated exposure to that expected to produce no adverse health effects. It is independent of a cancer risk, which is calculated only for those chemicals identified as carcinogens.

Hazardous Material — A material, including a hazardous substance, as defined by 49 CFR 171.8, which poses a risk to health, safety, and property when transported or handled.

Hazardous/Toxic Air Pollutants — Air pollutants known or suspected to cause serious health problems such as cancer, poisoning, or sickness, and may have immunological, neurological, reproductive, developmental, or respiratory effects.

Hazardous/Toxic Waste — Any solid waste (can also be semisolid or liquid, or contain gaseous material) having the characteristics of ignitability, corrosivity, toxicity, or reactivity, defined by the *Resource Conservation and Recovery Act* and identified or listed in 40 CFR 261 or by the *Toxic Substances Control Act.*

Hazardous Waste — A by-product of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity) or appears on special Environmental Protection Agency lists.

Heat Exchanger — A device that transfers heat from one fluid (liquid or gas) to another.

Heavy Metals — Metallic or semimetallic elements of high molecular weight, such as mercury, chromium, cadmium, lead, and arsenic, that are toxic to plants and animals at known concentrations.

Heavy Water — A form of water in which the hydrogen atoms are replaced by deuterium atoms. Deuterium is an isotope of the element of hydrogen with one neutron and one proton in the nucleus.

Heavy Water Reactor — A nuclear reactor in which circulating heavy water is used to cool the reactor core and to moderate (reduce the energy of) the neutrons created in the core by the fission reactions.

Helium-3 — A nonradioactive isotope of the element helium, that is produced as a tritium decay product.

Helium-4 — The naturally occurring isotope of the element helium, that is also a by-product in the atomic conversion of lithium to tritium.

High Efficiency Particulate Air Filter (HEPA) — A filter used to remove very small particulates from dry gaseous effluent streams.

High-Level Waste — The highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid. High-level waste contains a combination of transuranic waste and fission products in concentrations requiring permanent isolation.

Historic Resources — Archaeological sites, architectural structures, and objects produced after the advent of written history dating to the time of the first Euro-American contact in an area.

***Hold Down Assembly* —** The mechanical device that integrates the tritium-producing burnable absorber rods (TPBARs) into an assembly and secures this assembly into the reactor fuel assembly.

***HT* —** Tritiated hydrogen molecule which emits a low-energy beta particle and has a half-life of 12.3 years.

***Hydrology* —** The science dealing with the properties, distribution, and circulation of natural water systems.

***Hydrodynamics* —** The study of the motion of a fluid and of the interactions of the fluid with its boundaries, especially in the case of an incompressible inviscid fluid.

***Ignition* —** Self-sustained fusion burn of light nuclei.

***Impingement* —** The process by which aquatic organisms too large to pass through the screens of a water intake structure become caught on the screens and are unable to escape.

***Implosion* —** With respect to nuclear weapons, the sudden inward compression and reduction in volume of fissionable material with chemical explosives in a nuclear weapon.

***Incident-Free Risk* —** The radiological or chemical impacts resulting from emissions during normal CLWR operations and packages aboard vehicles in normal transport. This includes the radiation or hazardous chemical exposure of specific population groups and workers.

***Indirect Economic Effects* —** Indirect effects result from the need to supply industries experiencing direct economic effects with additional outputs to allow them to increase their production. The additional output from each directly affected industry requires inputs from other industries within a region (i.e., purchases of goods and services). This results in a multiplier effect to show the change in total economic activity resulting from a new activity in a region.

***Indirect Jobs* —** Within a regional economic area, jobs generated or lost in related industries as a result of a change in direct employment.

***Induced Economic Effects* —** The spending of households resulting from direct and indirect economic effects. Increases in output from a new economic activity lead to an increase in household spending throughout the economy as firms increase their labor inputs.

***Injection Wells* —** A well that takes water from the surface into the ground, either through gravity or by mechanical means.

***Ion* —** An atom that has too many or too few electrons, causing it to be electrically charged; an electron that is not associated (in orbit) with a nucleus.

***Ion Exchange* —** A unit physiochemical process that removes anions and cations, including radionuclides, from liquid streams (usually water) for the purpose of purification or decontamination.

***Ionizing Radiation* —** Alpha particles, beta particles, gamma rays, neutrons, high speed electrons, high speed protons, and other particles or electromagnetic radiation that can displace electrons from atoms or molecules, thereby producing ions.

***Isotope* —** An atom of a chemical element with a specific atomic number and atomic mass. Isotopes of the same element have the same number of protons but different numbers of neutrons and different atomic masses.

***Joule* —** A metric unit of energy, work, or heat, equivalent to 1 watt-second, 0.737 foot-pound, or 0.239 calories.

***Lacustrine* —** Found or formed in lakes; also, a type of wetland situated on or near a lake.

***Landscape Character* —** The arrangement of a particular landscape as formed by the variety and intensity of the landscape features (land, water, vegetation, and structures) and the four basic elements (form, line, color, and texture). These factors give an area a distinctive quality that distinguishes it from its immediate surroundings.

***Large Release* —** A release of radioactive material that would result in doses greater than 25 rem to the whole body or 300 rem to the thyroid at 1.6 kilometer (1 mile) from the control perimeter (security fence) of a reactor facility.

***Latent Fatalities* —** Fatalities associated with acute and chronic environmental exposures to chemical or radiation that occur within 30 years of exposure.

***Lead Test Assembly (LTA)* —** Tritium-producing burnable absorber rods (TPBARs) assembled and inserted in limited quantities into the Watts Bar CLWR to confirm the TPBARs' performance.

***Lentic* —** Pertaining to or living in still water.

***License Amendment* —** Changes to an existing reactor's operating license that are approved by the United States Nuclear Regulatory Commission.

***Light Water* —** The common form of water (a molecule with two hydrogen atoms and one oxygen atom, H_2O) in which the hydrogen atom consists completely of the normal hydrogen isotope (one proton).

***Light Water Reactor* —** A nuclear reactor in which circulating light water is used to cool the reactor core and to moderate (reduce the energy of) the neutrons created in the core by the fission reactions.

***Lithium-6* —** The isotope of the element lithium that changes to tritium and helium-4 when a neutron is absorbed by the lithium nucleus.

***Long-Lived Radionuclides* —** Radioactive isotopes with half-lives greater than about 30 years.

***Loss-of-Coolant Accident* —** An accident that results from the loss of reactor coolant because of a break in the reactor coolant system.

***Low-Level Waste* —** Waste that contains radioactivity but is not classified as high-level waste, transuranic waste, spent nuclear fuel, or by-product material as defined by Section 11e (2) of the *Atomic Energy Act* of 1954, as amended. Test specimens of fissionable material irradiated for research and development only, and not for the production of power or plutonium, may be classified as low-level waste, provided the concentration of transuranic waste is less than 100 nanocuries per gram. Some low-level waste is considered classified because of the nature of the generating process and/or constituents, because the waste would tell too much about the process.

***Macrophyte* —** A member of the macroscopic plant life, especially in a body of water.

***Maximum Contaminant Level* —** The maximum permissible level of a contaminant in water delivered to any user of a public drinking water system. Maximum contaminant levels are enforceable standards under the Safe Drinking Water Act.

***Maximally Exposed Offsite Individual* —** A hypothetical person who could potentially receive the maximum dose of radiation or hazardous chemicals.

***Megajoule* —** A unit of heat, work, or energy equal to 1 million joules. See 'joule.'

***Megawatt (MW)* —** A unit of power equal to 1 million watts. Megawatt thermal is commonly used to define heat produced, while megawatt electric defines electricity produced.

***Meteorology* —** The science dealing with the atmosphere and its phenomena, especially as relating to weather.

***Migration* —** The natural movement of a material through the air, soil, or groundwater; also, seasonal movement of animals from one area to another.

***Migratory Bird Treaty Act* —** This act states that it is unlawful to pursue, take, attempt to take, capture, possess, or kill any migratory bird, or any part, nest, or egg of any such bird other than permitted activities.

***Mississippian* —** Artifacts from the North American archaeological period dating from 500 AD to 1200 AD.

***Mixed Waste* —** Waste that contains both 'nonradioactive hazardous waste' and 'radioactive waste' as defined in this glossary.

***Moderator* —** A material used to decelerate neutrons in a reactor from high energies to low energies.

***Mollusks* —** Unsegmented, invertebrate animals including gastropods, pelecypods, and cephalopods.

***National Ambient Air Quality Standards* —** Uniform, national air quality standards established by the Environmental Protection Agency under the authority of the *Clean Air Act* that restrict ambient levels of criteria pollutants to protect public health (primary standards) or public welfare (secondary standards), including plant and animal life, visibility, and materials. Standards have been set for ozone, carbon monoxide, particulates, sulfur dioxide, nitrogen, nitrogen dioxide, and lead.

***National Emission Standards for Hazardous Air Pollutants* —** A set of national emission standards for listed hazardous pollutants emitted from specific classes or categories of new and existing sources.

***National Environmental Policy Act of 1969* —** This Act is the basic national charter for the protection of the environment. It requires the preparation of an environmental impact statement for every major Federal action that may significantly affect the quality of the human or natural environment. Its main purpose is to provide environmental information to decisionmakers so that their actions are based on an understanding of the potential environmental consequences of a proposed action and its reasonable alternatives.

***National Historic Preservation Act* —** This Act provides that property resources with significant national historic value be placed on the national Register of Historic Places. It does not require any permits but, pursuant to Federal code, if a proposed action might impact an historic property resource, it mandates consultation with the proper agencies.

***National Pollutant Discharge Elimination System* —** Federal permitting system required for water pollution effluents under the *Clean Water Act*, as amended.

***National Register of Historic Places* —** A list maintained by the Secretary of the Interior of districts, sites, buildings, structures, and objects of prehistoric or historic local, state or national significance under Section 2(b) of the *Historic Sites Act of 1935* (16 U.S.C. 462) and Section 101(a) (1) (A) of the *National Historic Preservation Act* of 1966, as amended.

***Neutron* —** An uncharged elementary particle with a mass slightly greater than that of the proton, found in the nucleus of every atom heavier than hydrogen-1; a free neutron is unstable and decays with a half-life of about 13 minutes into an electron and a proton; used in the fission process.

***Neutron Flux* —** The product of neutron number density and velocity (energy) giving an apparent number of neutrons flowing through a unit area per unit time.

***Neutron Poison* —** A chemical solution (e.g., boron or a burnable absorber rod) injected into a nuclear reactor or spent fuel pool to absorb neutrons and end criticality. Any material with a strong affinity for absorbing neutrons without generating new neutrons and, therefore, can be used to control the nuclear chain reaction.

***Nitrogen (N_2)* —** Colorless, odorless gaseous element that constitutes about four fifths of the volume of the atmosphere.

***Nitrogen Oxides* —** Refers to the oxides of nitrogen, primarily NO (nitrogen oxide) and NO_2 (nitrogen dioxide). These are produced in the combustion of fossil fuels and can constitute an air pollution problem. NO_2 emission contribute to acid deposition and formation of atmospheric ozone.

***Noise* —** Any sound that is undesirable becuase it interferes with speech and hearing, or is intense enough to damage hearing, or is otherwise annoying (unwanted sound).

***Nonattainment Area* —** An air quality control region (or portion thereof) in which the Environmental Protection Agency has determined that ambient air concentrations exceed national ambient air quality standards for one or more criteria pollutants.

***Notice of Intent* —** Announces the scoping process. The NOI is usually published in the Federal Register and a local newspaper. The scoping process includes holding at least one public meeting and requesting written comments on what issues and environmental concerns an EIS should address.

***Nuclear Assembly* —** Collective term for the primary, secondary, and radiation case of a nuclear warhead.

***Nuclear Component* —** A part of a nuclear weapon that contains fissionable or fussionable material.

***Nuclear Criticality* —** (see ‘criticality’).

***Nuclear Fuel Cycle* —** The path followed by the nuclear fuel in its various states from mining the ore to waste disposal. The basic fuel materials for the generation of nuclear power are the elements uranium and thorium.

***Nuclear Grade* —** Material of a quality adequate for use in a nuclear application.

***Nuclear Material* —** Composite term applied to: (1) special nuclear material; (2) source material such as uranium or thorium or ores containing uranium or thorium; and (3) by-product material, which is any radioactive material that is made radioactive by exposure to the radiation incident to the process of producing or using special nuclear material.

***Nuclear Nonproliferation Treaty* —** An international treaty signed in 1968 and extended in 1996 that seeks to limit nuclear weapons capabilities to the five countries (U.S., France, England, Russia, and China) that possessed such weapons before 1967.

Nuclear Power Plant — A facility that converts nuclear energy into electrical power. In a CLWR, heat produced in a nuclear reactor is used to make steam which drives a turbine connected to an electric generator.

Nuclear Radiation — Particles (alpha, beta, neutrons) or photons (gamma) emitted from the nucleus of unstable radioactive atoms as a result of radioactive decay.

Nuclear Reaction — A reaction in which an atomic nucleus is transformed into another isotope of that respective nuclide, or into another element altogether; it is always accompanied by the liberation of either particles or energy.

Nuclear Reactor — A device that sustains a controlled nuclear fission chain reaction that releases energy in the form of heat.

Nuclear Regulatory Commission (NRC) — The Federal agency that regulates the civilian nuclear power industry in the United States.

Nuclear Weapon — The general name given to any weapon in which the explosion results from the energy released by reactions involving atomic nuclei, either fission, fusion, or both.

Nuclear Weapons Complex — The sites supporting the research, development, design, manufacture, testing, assessment, certification and maintenance of the Nation's nuclear weapons and the subsequent dismantlement of retired weapons.

Nuclide — A species of atom characterized by the constitution of its nucleus and hence by the number of protons, the number of neutrons, and the energy content.

Numerical Simulation — The use of mathematical algorithms and models of physical processes to calculationally simulate the behavior or performance of a device or complex system.

Occupational Safety and Health Administration (OSHA) — Oversees and regulates workplace health and safety, created by the Occupational Safety and Health Act of 1970.

Offsite — As used in the EIS, the term denotes a location, facility, or activity occurring outside of the boundary of the reactor facility.

Outfall — The discharge point of a drain, sewer, or pipe as it empties into a body of water.

Ozone — The triatomic form of oxygen; in the stratosphere, ozone protects the Earth from the sun's ultraviolet rays, but in lower levels of the atmosphere ozone, is considered an air pollutant.

Packaging — With regard to hazardous or radionuclide materials, the assembly of components necessary to ensure compliance with Federal regulations. It may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, and devices for cooling or absorbing mechanical shocks. The vehicle tie-down system and auxiliary equipment may be designated as part of the packaging.

Palustrine — Found or formed in marshes; also, a type of wetland situated in or near a marsh.

Particulate Matter — Air pollutants including dust, dirt, soot, smoke, or liquid droplets emitted into the air. Total suspended particulate (TSP) was first used as the indicator for particulate concentrations. Current standards use the indicators PM_{10} and $PM_{2.5}$ which include only those particles with aerodynamic diameter smaller than or equal to 10 micrometers and 2.5 micrometers, respectively. The smaller particles are more responsible for adverse health effects because they reach further into the respiratory tract.

***Permeability* —** Geology, the ability of rock or soil to transmit a fluid.

***Permutation* —** Changing the order of elements arranged in a particular order.

***Person-Rem* —** The unit of collective radiation dose to a given population; the sum of the individual doses received by a population segment.

***Plume* —** A flowing, often somewhat conical, trail of emissions from a continuous point source.

***Plume Immersion* —** With regard to radiation, the situation in which an individual is enveloped by a cloud of radiation gaseous effluent and receives an external radiation dose.

***Plutonium* —** A heavy, radioactive, metallic element with the atomic number 94. It is produced artificially in a reactor by bombardment of uranium with neutrons and is used in the production of nuclear weapons.

***Pounds per Square Inch* —** A measure of pressure; atmospheric pressure is about 14.7 pounds per square inch.

***Pressurized Water Reactor (PWR)* —** A light water reactor in which heat is transferred from the core to an exchanger by water kept under pressure in the primary system. Steam is generated in a secondary circuit. Many reactors producing electric power are pressurized water reactors.

***Prevention of Significant Deterioration (PSD)* —** An Environmental Protection Agency program, mandated by the *Clean Air Act*, in which state or Federal permits are required that are intended to limit increases in air pollutant concentrations by restricting emissions for new or modified sources in places where air quality is already better than required to meet primary and secondary ambient air quality standards.

***Primary System* —** With regard to nuclear reactors, the system that circulates a coolant (e.g., water) through the reactor core to remove the heat of reaction.

***Prime Farmland* —** Land that has the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, oil-seed, and other agricultural crops with minimum inputs of fuel, fertilizer, pesticides, and labor without intolerable soil erosion, as determined by the Secretary of Agriculture (Farmland Protection Act of 1981, 7 CFR 7, paragraph 658).

***Probabilistic Risk Assessment* —** A comprehensive, logical, and structured methodology to identify and quantitatively evaluate significant accident sequences and their consequences.

***Probable Maximum Flood* —** Flood levels predicted for a scenario having hydrological conditions that maximize the flow of surface waters.

***Programmatic Environmental Impact Statement (PEIS)* —** A legal document prepared in accordance with the requirements of 102(2)(C) of NEPA which evaluates the environmental impacts of proposed Federal Actions that involve multiple decisions potentially affecting the environment at one or more sites.

***Proliferation (Nuclear)* —** The spread of nuclear weapons and the materials and technologies used to produce them.

Qualitative environmental impacts — 10 CFR 51, Appendix B defines the qualitative terms “small,” “moderate,” and “large” as follows.

Small	Environmental effects are not detectable or are so minor that they would neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Nuclear Regulatory Commission has concluded that those impacts that do not exceed permissible levels in the Nuclear Regulatory Commission’s regulations are considered small.
Moderate	Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
Large	Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

Quality factor — The principal modifying factor that is employed to derive dose equivalent from absorbed dose.

Rad — See ‘radiation absorbed dose.’

Radiation — The emitted particles or photons from the nuclei of radioactive atoms. Some elements are naturally radioactive; others are induced to become radioactive by bombardment in a reactor. Naturally occurring radiation is indistinguishable from induced radiation.

Radiation Absorbed Dose (rad) — The basic unit of absorbed dose equal to the absorption of 0.01 joule per kilogram of absorbing material.

Radioactive Waste — Materials from nuclear operations that are radioactive or are contaminated with radioactive materials, and for which use, reuse, or recovery are impractical.

Radioactivity — The spontaneous decay or disintegration of unstable atomic nuclei, accompanied by the emission of radiation.

Radioisotopes — Radioactive nuclides of the same element (same number of protons in their nuclei) that differ in the number of neutrons.

Radionuclide — A radioactive element characterized according to its atomic mass and atomic number which can be man-made or naturally occurring.

Radon — Gaseous, radioactive element with the atomic number 86 resulting from the radioactive decay or radium. Radon occurs naturally in the environment, and can collect in unventilated enclosed areas, such as basements. Large concentrations of radon can cause lung cancer in humans.

RADTRAN — A computer code combining user-determined meteorological, demographic, transportation packaging, and material factors with health physics data to calculate the expected radiological consequences and accident risk of transporting radioactive material.

Reactor Accident — See ‘design-basis accident; severe accident.’

Reactor Coolant System — The system used to transfer energy from the reactor core either directly or indirectly to the heat rejection system.

Reactor Core — In a heavy water reactor: the fuel assemblies, including the fuel and target rods, control assemblies, blanket assemblies, safety rods, and coolant/moderator. In a light-water reactor; the fuel assemblies, including the fuel and target rods, control rods, and coolant/moderator. In a modular high-temperature gas-cooled reactor: the graphite elements, including the fuel and target elements, control rods, and other reactor shutdown mechanisms, and the graphite reflectors.

Reactor Facility — Unless it is modified by words such as containment, vessel, or core, the term reactor facility includes the housing, equipment, and associated areas devoted to the operation and maintenance of one or more reactor cores. Any apparatus that is designed or used to sustain nuclear chain reactions in a controlled manner, including critical and pulsed assemblies and research, tests, and power reactors, is defined as a reactor. All assemblies designed to perform subcritical experiments that could potentially reach criticality are also to be considered reactors.

Record of Decision — A document prepared in accordance with the requirements of the CEQ NEPA regulations 40 CFR 1505.2, that provides a concise public record of the decision on a proposed Federal action for which an EIS was prepared. A ROD identifies the alternatives considered in reaching the decision, the environmentally preferable alternative(s), factors balanced in making the decision, whether all practicable means to avoid or minimize environmental harm have been adopted, and if not, why they were not.

Recycling — With regard to tritium in nuclear weapons, the recovery, purification, and reuse of tritium contained in tritium reservoirs within the nuclear weapons stockpile.

Refueling Outage — The period of time that a reactor is shut down for refueling operations. A refueling outage usually lasts four to eight weeks.

Regional Economic Area — A geographic area consisting of an economic node and the surrounding counties that are economically related and include the places of work and residences of the labor force. Each regional economic area is defined by the U.S. Bureau of Economic Analysis.

Region of Influence (ROI) — A site-specific geographic area that includes the counties where approximately 90 percent of the current DOE and/or contractor employees reside.

Rem — See ‘roentgen equivalent man.’

Remediation — The process, or a phase in the process, of rendering radioactive, hazardous, or mixed waste environmentally safe, whether through processing, entombment, or other methods.

Resource Conservation and Recover Act, as Amended — The Act that provides ‘cradle to grave’ regulatory program for hazardous waste which established, among other things, a system for managing hazardous waste from its generation until its ultimate disposal.

Riparian — Of, on, or relating to the banks of a natural course of water.

Risk — A quantitative or qualitative expression of possible loss that considers both the probability that a hazard will cause harm and the consequences of that event.

Risk Assessment (chemical or radiological) — The qualitative and quantitative evaluation performed in an effort to define the risk posed to human health and/or the environment by the presence or potential presence and/or use of specific chemical or radiological materials.

Roentgen — A unit of exposure to ionizing X- or gamma radiation equal to or producing 1 electrostatic unit of charge per cubic centimeter of air. It is approximately equal to 1 rad.

Roentgen Equivalent Man (rem) — A measure of radiation dose (i.e., the average background radiation dose is 0.3 rem per year). The unit of biological dose equal to the product of the absorbed dose in rads; a quality factor, which accounts for the variation in biological effectiveness of different types of radiation; and other modifying factors.

Runoff — The portion of rainfall, melted snow, or irrigation water that flows across the ground surface and eventually enters streams.

Safe Drinking Water Act — This Act protects the quality of public water supplies, water supply and distribution systems, and all sources of drinking water.

Safety — With regard to nuclear weapons, minimizing the possibility that a nuclear weapon will be exposed to accidents and preventing the possibility of nuclear yield or plutonium dispersal should there be an accident involving a nuclear weapon.

Safety Analysis Report (SAR) — A safety document that provides a complete description and safety analysis of a reactor design, normal and emergency operations, hypothetical accidents and their predicted consequences, and the means proposed to prevent such accidents or mitigate their consequences.

Safety Evaluation Report (SER) — A document prepared by the Nuclear Regulatory Commission that evaluates documentation (i.e., technical specifications, safety analysis reports, and special safety reviews and studies) submitted by a reactor licensee for its approval. This ensures all of the safety aspects of part or all of the activities conducted at a reactor are formally and thoroughly analyzed, evaluated, and recorded.

Sanitary waste — Wastes generated by normal housekeeping activities, liquid or solid (includes sludge), which are not hazardous or radioactive.

Scope — In a document prepared pursuant to the *National Environmental Policy Act* of 1969, the range of actions, alternatives, and impacts to be considered.

Scoping — The solicitation of comments from interested persons, groups, and agencies at public meetings, public workshops, in writing, electronically, or via fax to assist in defining the proposed action, identifying alternatives, and developing preliminary issues to be addressed in an EIS.

Secondary System — The system that circulates a coolant (water) through a heat exchanger to remove heat from the primary system.

Security — With regard to nuclear weapons, minimizing the likelihood of unauthorized access to or loss of custody of a nuclear weapon or weapon system, and ensuring that the weapon can be recovered should unauthorized access or loss of custody occur.

Seismic — Pertaining to any earth vibration, especially an earthquake.

Seismic Zone — An area defined by the Uniform Building Code (1991), designating the amount of damage to be expected as the result of earthquakes. The United States is divided into six zones: (1) Zone 0: no damage; (2) Zone 1: minor damage, corresponds to intensities V and VI of the modified Mercalli intensity scale; (3) Zone 2A: moderate damage, corresponds to intensity VII of the modified Mercalli intensity scale (eastern U.S.); (4) Zone

2B: slightly more damage than 2A (western U.S.); (5) Zone 3: major damage, corresponds to intensity VII and higher of the modified Mercalli intensity scale; (6) Zone 4: areas within Zone 3 determined by proximity to certain major fault systems.

***Severe Accident* —** An accident with a frequency rate of less than 10^{-6} per year that would have more severe consequences than a design-basis accident, in terms of damage to the facility, offsite consequences, or both. Also called "beyond design basis reactor accidents" for this EIS.

***Sewage* —** The total of organic waste and wastewater generated by an industrial establishment or a community.

***Shielding* —** With regard to radiation, any material of obstruction (bulkheads, walls, or other construction) that absorbs radiation in order to protect personnel or equipment.

***Short-Lived Activation Products* —** An element formed from neutron interaction that has a relatively short half-life and which is not produced from the fission reaction (e.g., a cobalt isotope formed from impurities in the metal of the reactor piping).

***Short-Lived Nuclides* —** Radioactive isotopes with half-lives no greater than about 30 years (e.g., cesium-137 and strontium-90).

***Shrink-Swell Potential* —** Refers to the potential for soils to contract while drying and expand after wetting.

***Shutdown* —** For a Department of Energy reactor, that condition in which the reactor has ceased operation and the Department has declared officially that it does not intend to operate it further (see DOE Order 5480.6, *Safety of Department of Energy-Owned Nuclear Reactors*).

***Silt* —** A sedimentary material consisting of fine mineral particles intermediate in size between sand and clay.

***Source Term* —** The estimated quantities of radionuclides or chemical pollutants released to the environment.

***Special Nuclear Materials* —** As defined in Section 11 of the Atomic Energy Act of 1954, special nuclear material means: (1) plutonium, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Nuclear Regulatory Commission determines to be special nuclear material; or (2) any material artificially enriched by any of the above. Tritium is NOT a special nuclear material.

***Standardization (Epidemiology)* —** Techniques used to control the effects of differences (e.g., age) between populations when comparing disease experience. The two main methods are:

> Direct method, in which specific disease rated in the study population are averaged, using as weights the distribution of the comparison population.
>
> Indirect method, in which the specific disease rates in the comparison population are averaged, using as weights the distribution of the study population.

***START I and II* —** Terms which refer to negotiations between the United States and Russia (the former Soviet Union during START I negotiations) aimed at limiting and reducing strategic nuclear weapons. START I discussions began in 1982 and eventually led to a ratified treaty in 1988. The START II protocol, which has not been fully ratified, will attempt to further reduce the acceptable levels of nuclear weapons ratified in START I.

Sulfur Oxides — Common air pollutants, primarily sulfur dioxide (SO_2), a heavy, pungent, colorless gas (formed in the combustion of fossil fuels, which is considered a major air pollutant, and sulfur trioxide). SO_2 is involved in the formation of acid rain. It can also irritate the upper respiratory tract and cause lung damage.

Surface Water — Water on the Earth's surface, as distinguished from water in the ground (groundwater).

Technical Specifications — With regard to Nuclear Regulatory Commission (NRC) regulations, part of an NRC license authorizing the operation of a nuclear reactor facility. A technical specification establishes requirements for items such as safety limits, limiting safety system settings, limiting control settings, limiting conditions for operation, surveillance requirements, design features, and administrative controls.

Threatened Species — Any species designated under the Endangered Species Act as likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Threshold Limit Values — The recommended highest concentrations of contaminants to which workers may be exposed according to the American Conference of Governmental Industrial Hygienists.

Toxic Substances Control Act of 1976 — This Act authorizes the Environmental Protection Agency to secure information on all new and existing chemical substances and to control any of these substances determined to cause an unreasonable risk to public health or the environment. This law requires that the health and environmental effects of all new chemicals be reviewed by the Environmental Protection Agency before they are manufactured for commercial purposes.

Transients — Events that could cause a change or disruption of plant thermal, hydraulic, or neutronic behavior.

Tritium — A radioactive isotope of the element hydrogen with two neutrons and one proton. Common symbols for the isotope are H-3 and T. Tritium has a half-life of 12.3 years.

Tritium Extraction Facility — A facility used for the extraction of tritium from the TPBARs. This facility is planned for construction at the Savannah River Site in Aiken, South Carolina.

Tritium-Producing Burnable Absorber Rods (TPBARs) — Rods that replace the normally used burnable absorber rods in a reactor for the purpose of producing tritium. TPBARs contain lithium-6.

Turbine — A machine for directly converting the kinetic energy and/or thermal energy of a flowing fluid (air, hot gas, steam, or water) into useful rotational energy.

Unusual Occurrence — Any unusual or unplanned event that adversely affects or potentially affects the performance, reliability, or safety of a facility.

Uranium — A heavy, silvery-white metallic element (atomic number 92) with several radioactive isotopes that is used as fuel in nuclear reactors.

Viewshed — The extent of an area that may be viewed from a particular location. Viewsheds are generally bounded by topographic features such as hills or mountains.

Visual Resource Management Class — A class defines the different degrees of modification allowed to the basic elements of landscape. They are Class 1-applied to wilderness areas, wild and scenic rivers, and other similar situations; Class 2-contrasts are seen but do not attract attention; Class 3-contrasts caused by a cultural activity are evident, but remain subordinate to the existing landscape; Class 4-contrasts that attract attention and are dominant features of the landscape in terms of scale, but repeat the contrast of the characteristic landscape; Class 5-applied to areas where unacceptable cultural modification has lowered scenic quality (where the natural character of the landscape has been disturbed to a point where rehabilitation is needed to bring it up to one of the four other classifications).

Volatile Organic Compounds (VOCs) — A broad range of organic compounds, often halogenated, that vaporize at ambient or relatively low temperatures, such as benzene, chloroform, and methyl alcohol. With regard to air pollution, any organic compound that participates in atmospheric photochemical reaction, except for those designated by the Environmental Protection Agency administrator as having negligible photochemical reactivity.

Warhead — Collective term for the package of nuclear assembly and nonnuclear components that can be mated with a delivery vehicle or carrier to produce a deliverable nuclear weapon.

Waste Minimization and Pollution Prevention — An action that economically avoids or reduces the generation of waste and pollution by source reduction, reducing the toxicity of hazardous waste and pollution, improving energy use, or recycling. These actions will be consistent with the general goal of minimizing present and future threats to human health, safety, and the environment.

Weighting Factor — With regard to radiation, the fraction of the total health risk resulting from uniform whole-body irradiation that could be contributed to that particular tissue.

Whole-Body Dose — With regard to radiation, dose resulting from the uniform exposure of all organs and tissues in a human body. (Also, see ‘effective dose equivalent.’)

Wind Rose — A depiction of wind speed and direction frequency for a given period of time.

Woodland — Artifacts from the North American archaeological period dating from 1000 BC to 500 AD.

X/Q (Chi/Q) — The relative calculated air concentration due to a specific air release and atmospheric dispersion; units are (sec/m^3). For example (Ci/m^3)/(Ci/sec)=((sec/m^3) or (g/m^3)/(g/sec)= (sec/m^3).

Zebra Mussel — An imported mussel which interferes with, among other things, water intake structures.

Zircaloy-4 — An alloy of zirconium metal used as getter material in TPBARs.

APPENDIX A
TRITIUM PRODUCTION OPERATIONS—APPLICATION TO PRODUCTION OF TRITIUM IN COMMERCIAL LIGHT WATER REACTORS

This appendix addresses the operation of a nuclear power plant in relation to its use as a tritium production facility. The first section provides a brief description of the nuclear processes necessary to operate a fission reactor as a nuclear power plant. The next section addresses aspects of the reactor design for commercial light water reactors (CLWRs). The boiling water reactor and the pressurized water reactor are discussed. (Much of the information in this section describes Westinghouse reactors and fuel. Differences between this and other operating reactor designs exist, but are not described in detail in this appendix.) Descriptions of the refueling operations at a nuclear facility and some environmentally relevant systems are included in this appendix. Also, a description of the nucleonics of tritium production and the structure of tritium-producing burnable absorber rods (TPBARs) is presented. Finally, the impacts of tritium production on the CLWR fuel cycle is addressed.

A.1 NUCLEAR FISSION REACTORS

Most commercial electric power generation plants produce electricity by converting heat into electricity. Typically, these plants heat water to generate steam, and the steam is used to drive a turbine generator. In the turbine generator, the energy in the steam is first converted into mechanical energy (spinning a turbine shaft), which creates electricity by driving a generator. Fossil plants generate heat through a chemical process; the burning of fuels such as natural gas or coal. When fossil fuels are burned, energy is released when the carbon in the fossil fuel combines with oxygen and burns. Commercial nuclear power plants generate heat through the nuclear fission process. The nuclear fission process occurs at a subatomic level and involves the interaction of some component part of the atoms. The following section describes the fission process and its control in a nuclear reactor.

A.1.1 Nuclear Fission

Nuclear fission is a nuclear reaction caused by the interaction between a free neutron and the nucleus of some atoms such as uranium or plutonium. An atom consists of a relatively heavy, positively charged nucleus with a number of much lighter, negatively charged particles in various orbits around the nucleus. The nucleus is the central part of the atom and consists of subparticles called nucleons. There are principally two types of nucleons: neutrons which are electrically neutral and protons which are positively charged. The number of protons in the nucleus is called the atomic number of that atom; all atoms of the same element have the same number of protons. The total number of nucleons in the nucleus is called the mass number, designated as A. Using X to represent the chemical symbol for the element and Z to represent the atomic number, each element is presented as X^A, ${}_ZX^A$, or as “the chemical name” - A. When atoms of an element differ in their number of nucleons, they are called isotopes of that element. For example, there are three isotopes of hydrogen: hydrogen with a single proton, deuterium with a single proton and a single neutron, and tritium with one proton and two neutrons. Tritium can be expressed as H^3, ${}_1H^3$, or hydrogen 3. Uranium has an atomic number of 92; that is, each atom has 92 protons. The more common isotopes of uranium have either 143 or 146 neutrons. These two isotopes are designated as uranium 238, ${}_{92}U^{238}$, or U^{238} (approximately 99 percent of all naturally occurring uranium), and uranium 235, ${}_{92}U^{235}$, or U^{235} (approximately 0.7 percent of naturally occurring uranium). These are two of the three naturally occurring isotopes of uranium. In all, there are 18 known isotopes of uranium. Different isotopes of the same element behave identically chemically, but can have significantly different nuclear characteristics.

Fission, as it occurs in a nuclear power plant, is the process by which the atoms of one element (such as uranium or plutonium) are converted into atoms of lighter elements through the capture of a neutron and the subsequent "splitting" of the atom's nucleus (**Figure A–1**). This results in the release of energy; fission products (atoms of the lighter elements), and neutrons. Not all isotopes of an element are capable of fission. For uranium, only 4 of the 18 known isotopes are capable of fission. Of these four, the two most important isotopes are uranium 235 and uranium 233.

Fission produces energy in the form of radiation and the kinetic energy of neutrons and fission products. Most of the energy released in the fission process is produced as the kinetic energy of the fission products. Lesser amounts are released as the kinetic energy of the neutrons and the energy produced from the radioactive decay of the fission products generated in the fission process. It is these forms of energy that are used to heat water in the core of a nuclear reactor.

Fission of an atom is initiated with a single neutron, but can result in the creation of many free neutrons (neutrons released from the nucleus). These neutrons can potentially initiate additional fission reactions. When exactly one neutron generated in a fission reaction initiates another fission reaction, the process is said to be a critical chain reaction. Criticality is an important characteristic of the nuclear power reaction. When a reactor is maintained in a critical state, the fission reaction proceeds at a constant rate. Since each fission reaction releases approximately the same amount of power, this condition will result in the reactor constantly operating at a steady power level. Therefore, it is important to control the number of neutrons available for fission. A critical chain reaction is represented in **Figure A–2**. If a series of fission reactions produce, on average, more than one neutron per fission that results in additional fissions, the process is said to be supercritical. In this state, the power level of the reactor increases. If, on the other hand, a series of fission reactions produce, on average, less than one neutron per fission that results in additional fissions, the process is said to be subcritical. In this condition, the power level of the reactor drops until eventually the fission process stops.

A.1.2 Control of Nuclear Reactions in a Reactor

Fission is not the only reaction that can take place when a neutron interacts with the nucleus of an atom. One of three interactions is possible: (1) the neutron is scattered—i.e., it essentially bounces off the nucleus (an elastic collision); (2) the neutron is absorbed—the neutron and atom combine to make the next higher isotope of the element; or (3) the neutron is absorbed and initiates a fission reaction. These different reactions are all important in the operation of a nuclear reactor. The first reaction, scattering, results in a change in the energy of the free neutrons. The second reaction, absorption, results in the loss of neutrons from the reactor. Neutrons that are absorbed are not available to initiate fission reactions. As discussed in the preceding paragraphs, the third reaction, fission, is the process by which energy is produced in a nuclear reactor and additional neutrons are produced to sustain the chain reaction. The likelihood of each of these interactions depends primarily on the following two factors: the energy of the free neutrons and the isotope of the atom being struck by the neutron.

In U.S. commercial nuclear reactors, only uranium 235 is used as the nuclear fuel. Uranium 235 is found naturally in uranium ore, although natural uranium consists predominantly of uranium 238. Enriched uranium is used in U.S. commercial nuclear power plants. This is uranium in which the percentage of uranium 235 has been increased from the less than 1 percent found in natural uranium to 3–5 percent. With approximately 100 metric tons of enriched uranium (3–5 metric tons of uranium 235) in the reactor core, a nuclear power plant can operate for approximately 18 months without refueling. When the uranium fuel is removed from the reactor, much of the uranium 235 has been consumed and the spent fuel contains approximately 1 percent uranium 235.

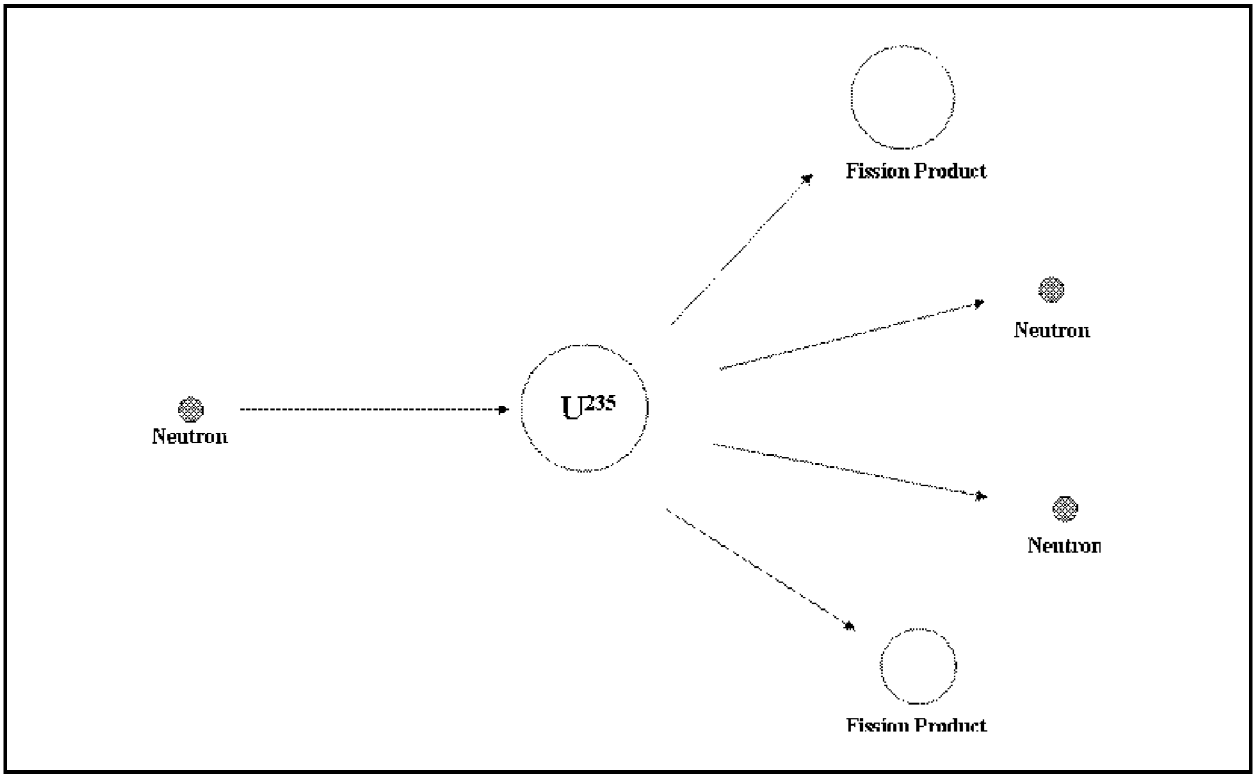

Figure A–1 Fission of Uranium 235 Atom

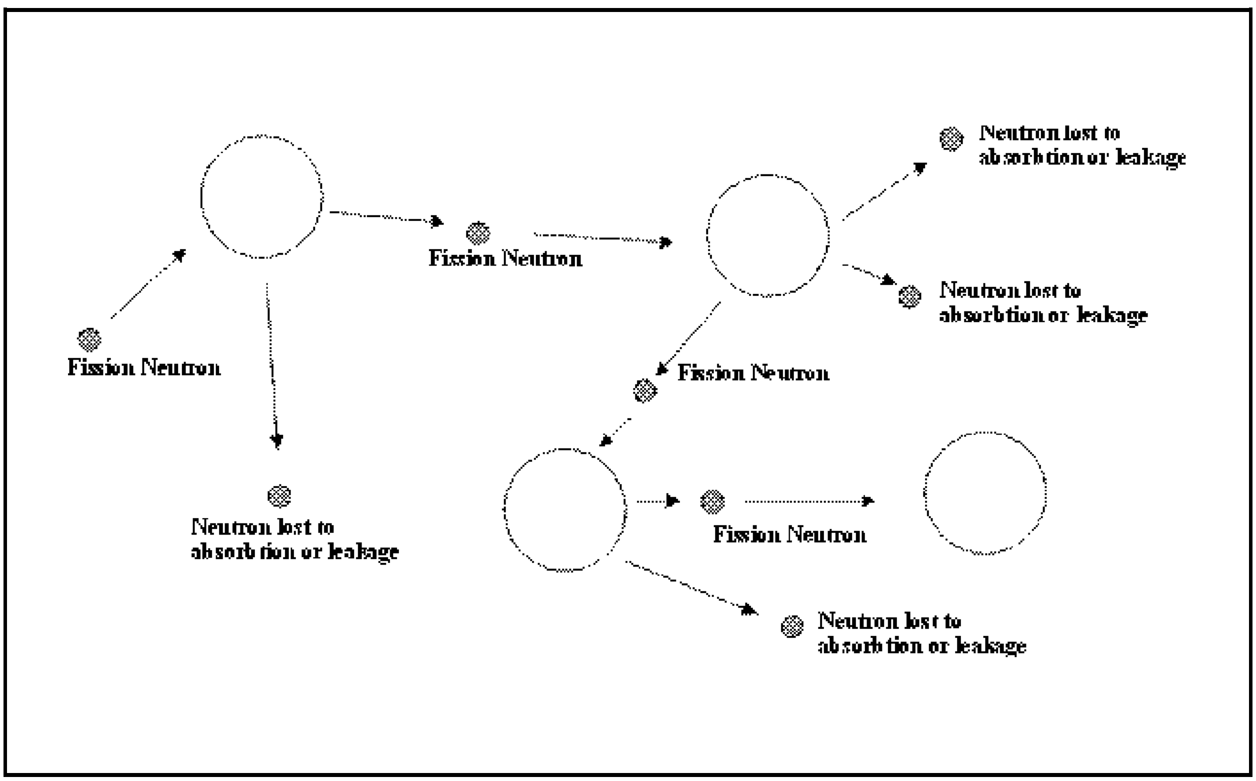

Figure A–2 Critical Chain Reaction

The fission reaction of a uranium 235 atom produces approximately 2.5 neutrons. Neutrons produced in fission are called fast neutrons. This refers to the amount of kinetic energy associated with the neutrons. However, the fission process using uranium 235 works better with slower moving neutrons; that is, neutrons with significantly less energy than the neutrons produced from the fission process. These neutrons are called thermal neutrons. Neutrons are slowed via collisions with nuclei of atoms in the reactor core. In the collisions, energy is transferred from the neutron to the atom it collides with. Generally, the closer in weight the neutron and atom are, the more energy is transferred to the atom. This transfer of energy from the neutron to other materials results in the slowing down of the neutron and is called moderation. The moderator in U.S. commercial nuclear power plants, both pressurized and boiling water reactors, is ordinary light water. (Because the moderator used in U.S. commercial power reactors is light water and the fission reaction of uranium 235 requires slower moving (thermal) neutrons, these types of reactors are referred to as thermal light water reactors.) The hydrogen in light water (with a nucleus containing a single proton) is nearly the same mass as the neutron. Collisions between neutrons and the hydrogen atoms result in a relatively rapid reduction in the energy of the neutrons. After many such collisions, the neutrons are traveling slow enough to be considered thermal neutrons.

Neutrons that are not lost from the reactor core between the time they are created as fast neutrons and the time they are moderated to thermal energy levels are available for fission. Neutrons are lost from the reactor core in several ways. Some are lost to leakage; that is, they escape from the reactor core and are captured in the reactor vessel or shielding. Some are absorbed by material in the core without producing fission. (Other materials in the core, including uranium 238 and core internal structures, contribute to the absorption of neutrons. Some neutrons that collide with uranium 235 atoms are absorbed without resulting in fission.) Specific materials, referred to as neutron poisons or simply poisons, are inserted in the reactor core to intentionally capture neutrons and provide control over the fission rate by controlling the number of neutrons available for fission. Poisons, contained in control and shutdown rods, are necessary for several reasons. These devices provide control of the rate of fission, thereby controlling the reactor power level. In addition, these devices also allow for the prompt termination of fission if the rods are fully inserted into the reactor core, shutting down the reactor. The material used in control and shutdown rods is usually boron; a strong neutron absorber. In a collision between boron and a neutron, there is a high likelihood that the neutron will be absorbed into the boron, thus generating a different boron isotope. Therefore, the position of the control rods determine the power level of the reactor by controlling the number of neutrons available for fission.

Other poisons, called burnable poisons (because during the time the fuel is in the reactor the burnable poisons are used up and gradually become less effective as neutron absorbers), are placed in a reactor core in addition to the poisons that are contained in the control and shutdown rods. These burnable poisons are necessary for a reactor to operate over an extended period without loading fresh fuel into the reactor. Commercial reactors typically load fresh fuel once every one to two years. As the power plant operates during this period, uranium 235 is burned up (consumed in the fission process or by neutron absorption). Since the source of the neutrons is devoured during the generation of power, it is necessary to start the fuel cycle with more uranium 235 than is necessary to sustain a critical reaction at the desired power level. Extra uranium 235 is loaded into the reactor core, necessitating the use of burnable poisons to keep the power at the appropriate level. The reactor's power levels are controlled by using either fixed burnable poisons (burnable poison rods) in areas that would have higher than average free neutron flux or by adding boron (in the form of boric acid) to the coolant in a pressurized water reactor. As the fuel burns it becomes less reactive, because less fissionable uranium is available. Since there are fewer uranium 235 atoms per unit volume, fewer neutrons are being produced. With fewer neutrons produced, the percentage of neutrons lost to leakage and absorption must be reduced to maintain the number of neutrons available for fission. Control of neutron loss due to absorption is accomplished by reducing the concentration of boron in the coolant and the reduction of burnable poison in the burnable absorber rods placed in the core.

A.2 COMMERCIAL NUCLEAR POWER PLANT DESCRIPTIONS

A.2.1 Commercial Nuclear Reactors

In the United States there are two types of commercial nuclear power plants currently in operation; the boiling water reactor and the pressurized water reactor.

The boiling water reactor is a single-loop system. The fission energy in the core causes the water to boil in the reactor vessel. In the reactor vessel, above the fuel, the steam passes through steam separators and steam dryers, which are used to ensure dry steam exits the reactor vessel, and travels through steam pipes to the turbine generator. The steam drives the turbine, which in turn powers the generator to create electricity. As steam passes through the turbine, it loses most of its energy but remains as steam as it passes to the main condenser. In the main condenser, where additional heat is removed by a cooling water system, the steam condenses into water. This water is pumped back to the reactor vessel where it is forced through the reactor core and is again converted to steam. **Figure A–3** provides a simplified representation of a boiling water reactor. Boiling water reactors typically operate at pressures of approximately 70 kilograms/meter^2 (1,000 pounds/inch^2), and the temperature of the water and steam in the reactor vessel approaches 288

A pressurized water reactor uses a primary and secondary system to transfer heat from the reactor core to the turbine generator (see **Figure A–4** for a simplified representation of a pressurized water reactor). In the primary loop (the reactor coolant system) water is forced up through the core, where it is heated but does not boil. After the water exits the reactor vessel it passes through steam generators. The number of steam generators used in the power plant depends on the design and power level. Combustion Engineering and Babcock & Wilcox designs have two steam generators. Westinghouse designs can have from two to four steam generators. The more recent (larger power plants) have four steam generators (**Figure A–5** is an isometric of a Representative Reactor Four-Loop Primary System). Each steam generator is connected to the reactor vessel in a separate, independent coolant loop. In the steam generators, the primary coolant heats water in the secondary loop and converts the water to steam. After the primary coolant leaves the steam generator, it is pumped back to the reactor vessel where it is again heated in the reactor core. The primary system has a pressurizer, which is used to control the pressure of the primary system. The pressurizer is connected to one of the primary loops and is located above the reactor core. It contains heaters and sprays that are used to control the water level in the pressurizer which, in turn, controls the pressure of the primary coolant system. The steam in the secondary loop (referred to as the steam and power conversion system) is used to drive the turbine generator and produce electricity. As in the boiling water reactor, after the steam passes through the turbine it is condensed by cooling water in the main condenser. This cooled water is then pumped back to the secondary side of the steam generator. A pressurized water reactor primary system operates at pressures of about 158 kilograms/meter^2 (2,250 pounds/inch^2) and temperatures of up to approximately 315 F), with the secondary loop operating at approximately 70 kilograms/meter^2 (1,000 pounds/inch^2) and 288

In addition to the difference in the number of cooling loops associated with a boiling water reactor and a pressurized water reactor, there are some differences in the design of the reactor cores. In a pressurized water reactor, the control and shutdown rods enter the reactor core from above. In a boiling water reactor these rods are driven into the core (via a control rod driven system) from the bottom of the core. Also, pressurized water reactors use soluble neutron poison (a boric acid solution) in the primary coolant to help control reactivity. The concentration of the soluble neutron poison is controlled by the chemical and volume control system. Typically, the concentration of boric acid is highest at the beginning of a fuel cycle when there is fresh fuel in the core. A boiling water reactor does not use this means of reactivity control.

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Figure A–3 Boiling Water Reactor Schematic

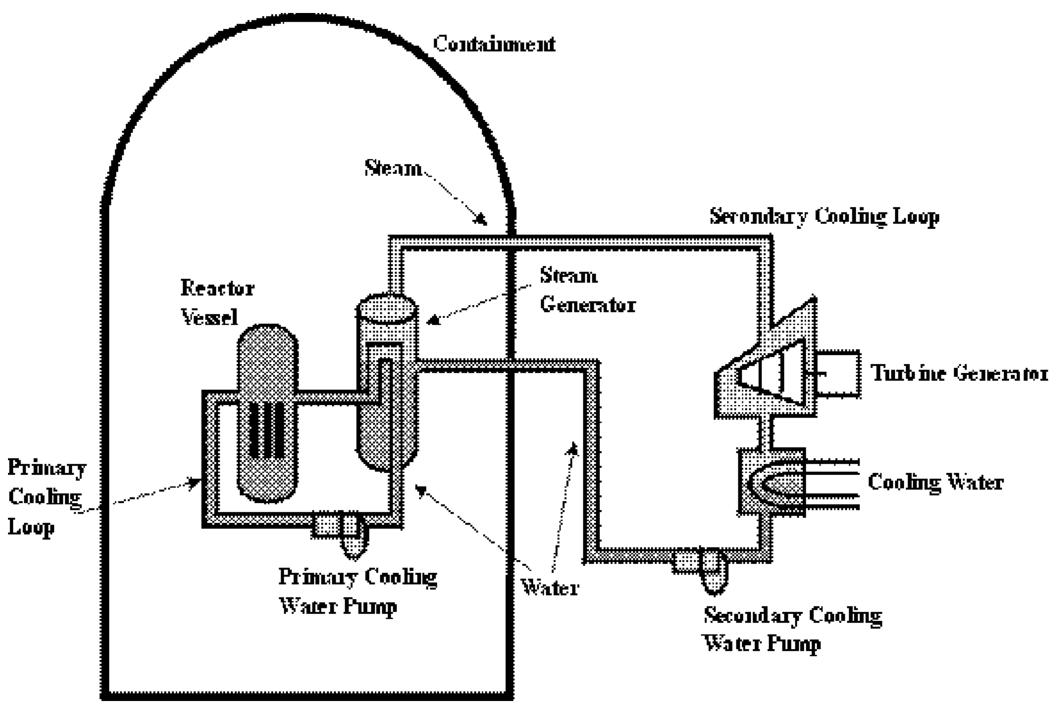

Figure A–4 Pressurized Water Reactor Schematic

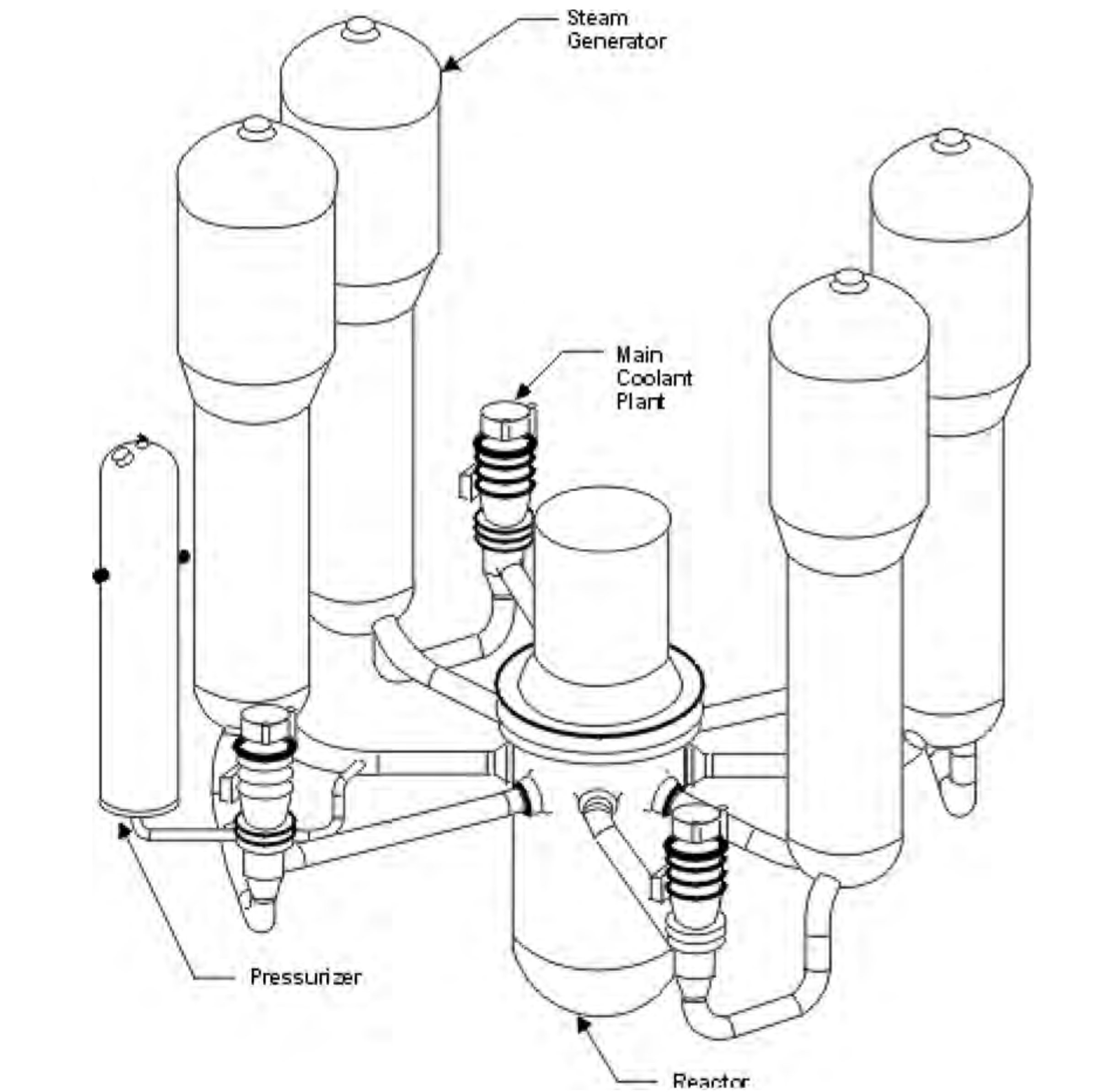

Figure A–5 Representative Four-Loop Reactor Coolant System

A.2.2 Reactor Core Description

Fuel in a nuclear reactor is slightly enriched (up to 5 percent) uranium dioxide and is sealed in fuel rods. These rods are approximately 3.6 to 3.9 meters (12 to 13 feet) long and slightly less than a half inch in diameter. Uranium, in the form of approximately half-inch long cylindrical uranium dioxide pellets, is placed in a fuel rod and enclosed in a zircaloy cladding. This cladding holds the pellets in position and provides a barrier against the release of fission products into the reactor coolant system.

In a pressurized water reactor, the fuel rods are collected in a fuel assembly that also contains several guide tubes and an instrumentation channel (illustrated in **Figure A–6**). The number of fuel rods in an assembly varies depending on the design of the reactor. Assemblies contain fuel rods arranged in 14 × 14, 15 × 15, or 17 × 17 arrays. The more recent reactors tend to use the 17 × 17 array. The guide tubes denote the location where the control rods of the control element assemblies are inserted into the reactor core. The fuel rods, guide tubes, and the instrumentation channel are held in place by a series of grids at several locations along the full length of the fuel assembly. In a reactor core, fuel assemblies are all structurally identical and have space reserved for control element assemblies. In the Westinghouse designs, between a third and a fourth of the fuel assemblies have an associated control element assembly. In a large pressurized water reactor, one with an electrical power rating of over 1,000 megawatts, the core will consist of approximately 200 fuel assemblies. Of these, 50 to 60 fuel assemblies (depending on the reactor design) have associated control element assemblies. The remaining fuel assemblies may have burnable poison rods in the locations used by control element assemblies, or these locations may be empty. The burnable poison rods are rods with the same shape as the control and shutdown rods. However, they are not connected to the control rod-driven mechanism and cannot be removed from the reactor without shutting it down and performing refueling activities that involve removing the fuel assembly containing the burnable poison rods from the reactor core. Loading of the burnable poison rods in these locations for the assemblies without control element assemblies is dictated by the need to balance the power distribution in the core.

The control element assembly consists of a collection of control rods and a spider assembly at the top of the rods. **Figure A–7** shows a control element assembly for a Representative Reactor 17 × 17 fuel assembly design. The spider assembly is connected to a control rod drive mechanism that can be used to move the control element assemblies. These assemblies serve two purposes—to limit the effects of reactivity changes during power operation and to shutdown the reactor. The rods are made of a strong neutron absorber (typically a boron or cadmium compound). When not needed, the control element assemblies are pulled out of the core by their control rod drives. For reactivity control during operation, the control rod drive can be used to insert the rods into the core at a controlled pace. If needed, the rods can be rapidly inserted to shut down the reactor. It is possible for the control element assemblies to be inserted into the core using only the force of gravity as the driving force. When fully inserted, the poison in the control rods absorbs enough neutrons to make the nuclear reaction become subcritical, shutting down the reactor.

As mentioned earlier, one of the ways in which neutrons are lost from the core and become unavailable for fission is through leakage. The neutrons leak from the edges of the core, and those that do not hit an atom and reflect back into the core are lost. (Reactor core designs address this problem of neutron loss by incorporating a neutron reflector, a layer of water around the core.) Neutrons generated at the center of the core are less likely to be lost through leakage than those generated at the edge of the core. Therefore, in a reactor with no burnable poisons and a uniform fuel enrichment, the number of neutrons available for fission is greater at the center of the core. The center of the core, which is about 3 meters (10 feet) in diameter and 3.6 to 3.9 meters (12 to 13 feet) tall, has a higher power density than the areas at the top, bottom, and edge of the core.

Designers of the reactor core control the distribution of power within the reactor core by using burnable poisons and varied fuel rod enrichments. **Figure A–8** displays a possible arrangement of fuel assemblies within a reactor core. Other fuel loading patterns also exist, but the concept is fully expressed by a simple loading pattern described here. This figure shows fresh fuel (typically with the highest enrichment of uranium 235) loaded around the core periphery. Fuel in the center of the core is referred to as once or twice burned fuel and has been in the core for one or two fuel cycles. A fuel cycle is the period from one refueling outage to another. The older fuel in the reactor core has been producing power for one to two years and has burned up some of its uranium 235. This fuel is no longer as enriched as the fresh fuel. With less material available for fission in this fuel, the extra neutrons present in the center of the core will not result in overly high

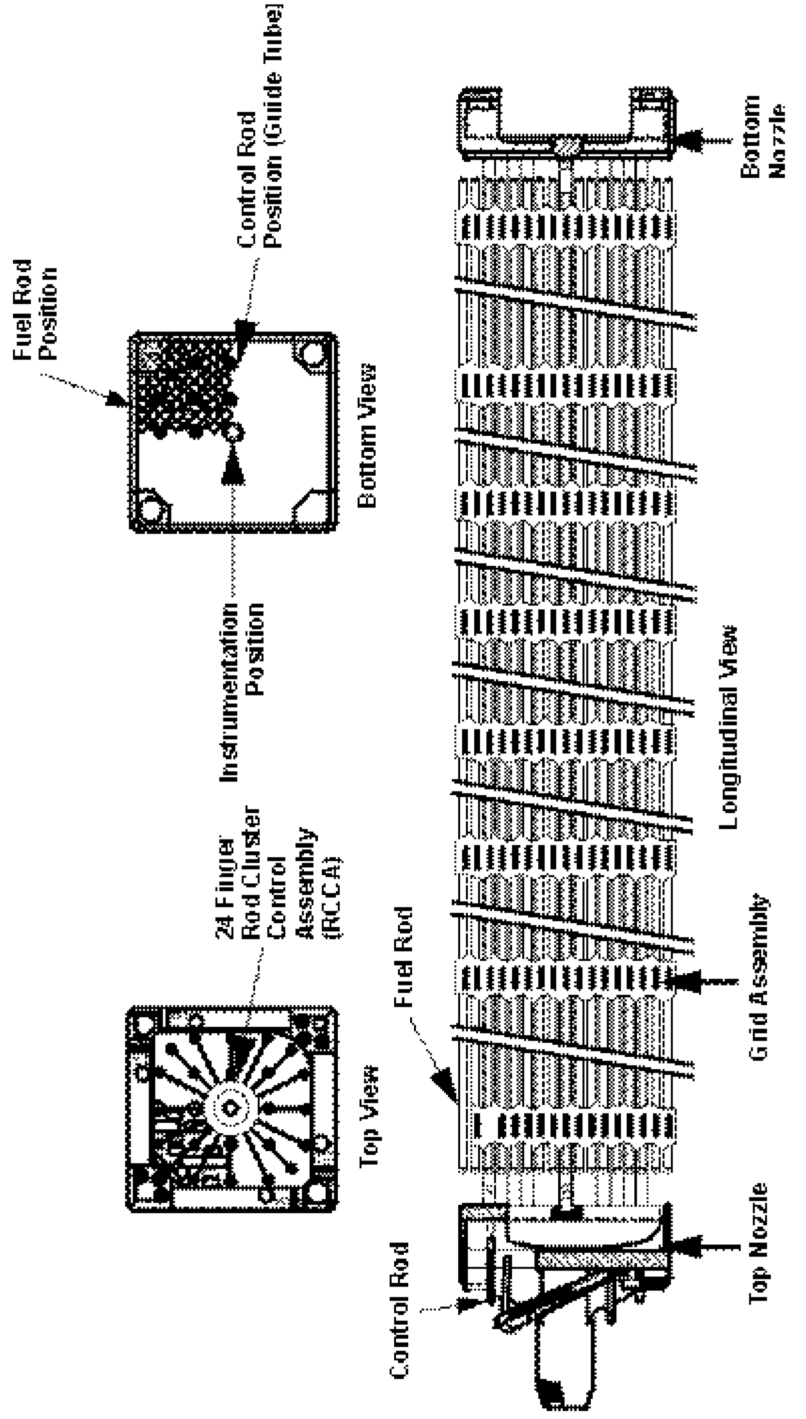

Figure A–6 Typical 17 × 17 Reactor Fuel Assembly

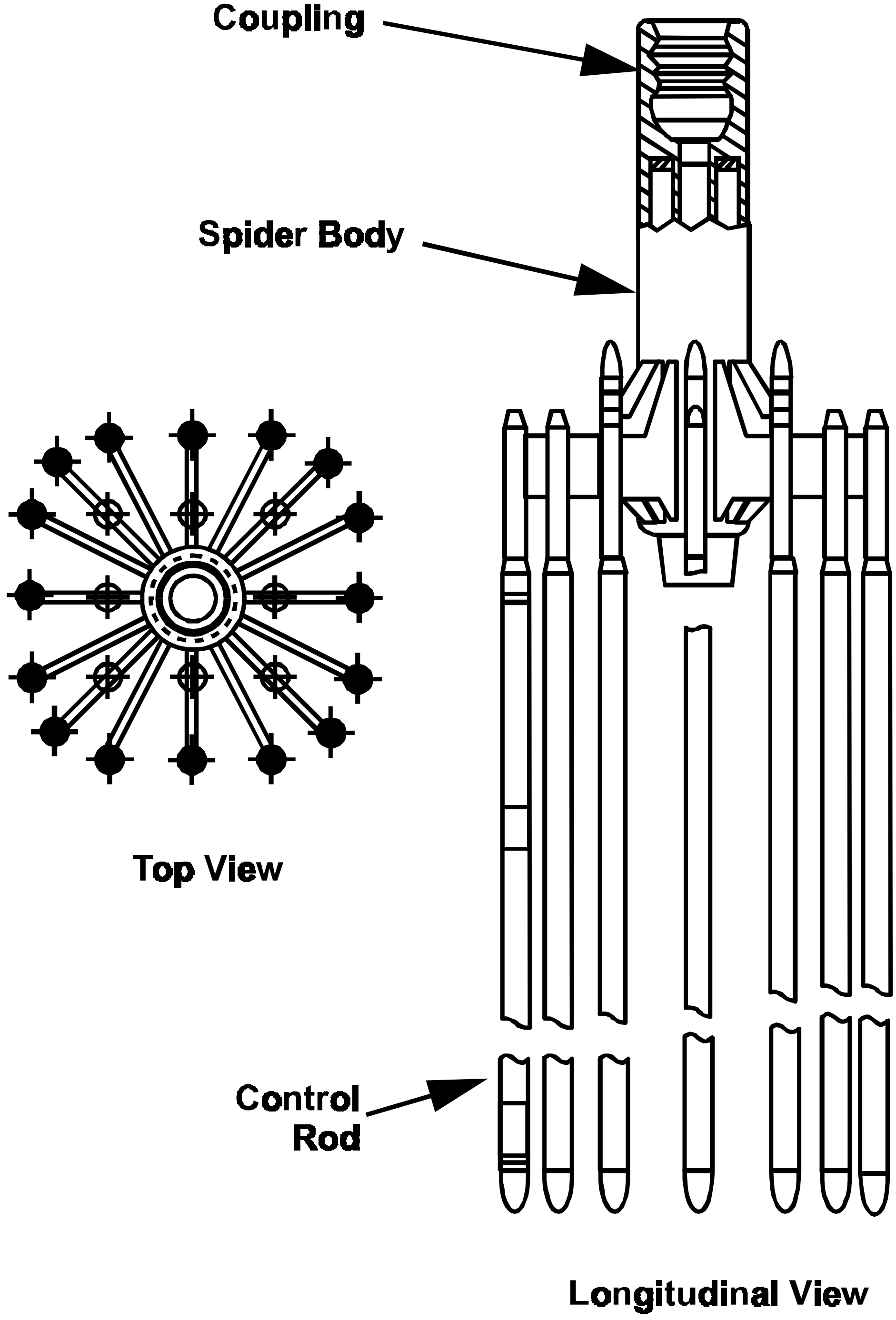

Figure A–7 Representative Reactor Control Element Assembly

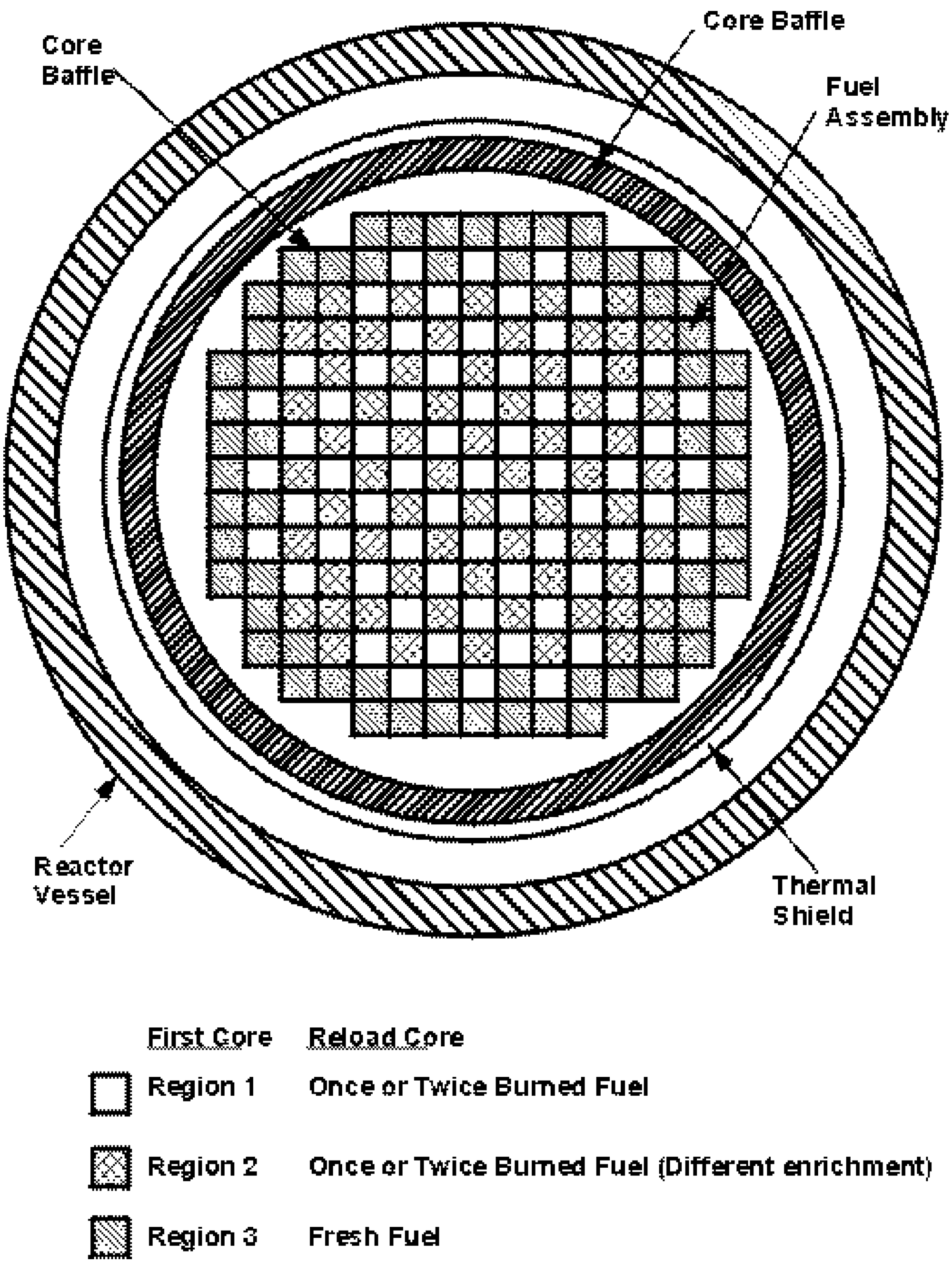

Figure A–8 General Arrangement of a Possible Reactor Core Fuel Loading Pattern

power levels. While controlling the enrichment level alone is not sufficient to properly shape the core power, burnable poison rods are included in the fuel assemblies.

The burnable poison rods will be replaced with TPBARs in a tritium production facility (see Section A.3). The TPBARs act as neutron absorbers in much the same way as the burnable poison, although there are some differences that may result in changes to the fuel management practices at the facility using the TPBARs. The control and shutdown control element assemblies will remain unchanged in a reactor containing TPBARs and will still enable complete shutdown of the reactor at all times during the fuel cycle.

A.2.3 Reactor Refueling

Unlike fossil-fueled electricity-generating plants that are continually fuel fed, nuclear power plants operate over extended periods without the need for fresh fuel. Typically, reactors will operate for 12 to 18 months between refueling outages. As stated earlier, as the uranium 235 is burned up, the reactor becomes increasingly less able to maintain a critical condition. Eventually, when enough fuel is burned up, the reactor will not be able to remain critical even if all of the neutron poisons are removed from the core. Before this point is reached, the reactor is shut down and refueled. When the power plant is shut down during the refueling outage, some (between one-third and two-fifths) of the fuel assemblies are removed and replaced with fresh fuel, and some of the assemblies are shuffled to different locations within the reactor core. The removed fuel is called spent fuel. The refueling outage usually lasts less than two months, during which various maintenance activities are performed. The reactor refueling is a small fraction of the overall outage.

Spent fuel is stored onsite in a spent fuel pool, located in a separate building attached to the containment structure. The spent fuel is stored onsite for several years, allowing the assemblies to cool and the radioactivity levels to drop sufficiently so that the spent fuel can be safely transported to a temporary or permanent waste disposal site.

The refueling operation of a nuclear power plant can be divided into four separate phases: preparation, reactor disassembly, fuel handling, and reactor assembly.

Preparation

During preparation, the reactor is shut down, all control and shutdown rods are inserted into the reactor core, and the nuclear chain reaction is stopped. Heat is still generated in the reactor core, principally by the radioactive decay of the fission products. The amount of heat produced during decay gradually decreases, and the reactor is brought to a condition called cold shutdown where the average reactor coolant temperature is below the boiling point of water at atmospheric pressure.

Reactor Disassembly

The area above the reactor vessel is referred to as the reactor cavity, illustrated in **Figure A–9**. Adjacent to this cavity is the refueling cavity. During reactor disassembly, these two cavities are flooded with borated water to provide a medium for the transfer of spent and new fuel. The water provides a means to remove heat from the spent fuel assemblies and a radiation shield for the plant workers. The reactor vessel is disassembled in stages. Most items connected to the reactor vessel head are removed. The refueling cavity is partially flooded and the reactor vessel head is unbolted and slightly raised. At this time, borated water is added to the reactor coolant system and allowed to flow out of the top of the reactor vessel, ultimately flooding the reactor cavity and the refueling cavity. The reactor vessel head is completely removed, along with the control rod-driven mechanism and the upper core internals. The fuel assemblies are then free of any obstructions and can be removed from the reactor core.

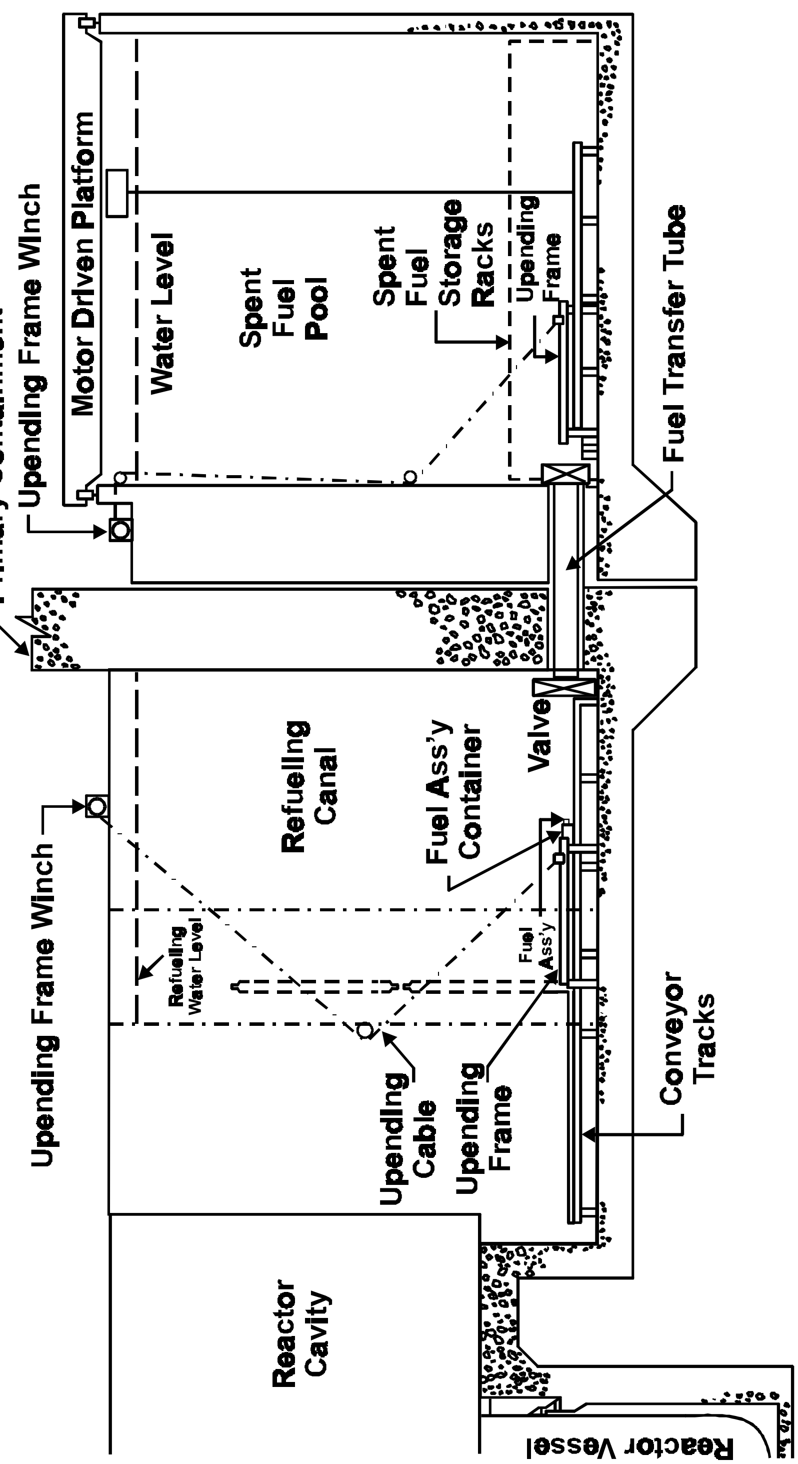

Figure A–9 Typical Fuel Transfer System

Fuel Handling

Fuel is removed from the core, one assembly at a time. Fuel assemblies are lifted out of the core using an overhead crane. If the spent fuel assembly contains a control element assembly, it is placed in a control element assembly changing device upon its removal from the core; otherwise it is moved to a fuel transfer system. In this device, the control element assembly is removed from the spent fuel assembly and transferred to another fuel assembly placed in the reactor core. Once the control element assembly is removed from the spent fuel assembly, it is transferred to the spent fuel pool.

The fuel transfer system lowers the fuel to a horizontal position and passes the fuel through a fuel transfer tube (which penetrates the containment structure) and into the spent fuel pool. Here, the fuel transfer system lifts the spent fuel assembly into a vertical position, and another crane places the spent fuel assembly into its location within the spent fuel racks in the pool. Spent fuel is stored in the spent fuel pool beneath over 20 feet of water. Storage under this amount of water provides two functions: the spent fuel pool has a cooling system to remove decay heat after it is transferred to the pool water, and the water provides a radiation protection barrier for the plant workers.

Fresh new fuel is brought into the reactor core using the same equipment used to remove the spent fuel. New fuel handling equipment is used to unload, inspect, and prepare the fuel for insertion into the reactor. It is then transferred to the fuel transfer machine.

Reactor Assembly

After all of the spent fuel is removed from the reactor, the fuel is moved to its new location, fresh fuel is added to the reactor core, and the reactor is reassembled. This is essentially the reverse of the reactor disassembly phase. After some startup tests, the reactor is ready to begin power operations.

A.2.4 Commercial Light Water Reactor Systems Important to Environmental Impacts

The sections below describe the plant systems that are directly associated with environmental impacts from plant operation. These are the cooling water systems and radioactive and nonradioactive waste treatment systems.

A.2.4.1 Cooling and Auxiliary Water Systems

Water use at a nuclear power plant is predominantly for removing excess heat generated in the reactor by condenser cooling. The quantity of water used for condenser cooling is a function of several factors, including the capacity rating of the plant and the increase in cooled water temperature from the intake to the discharge. The larger the plant, the greater the quantity of waste heat and cooling water required to dissipate the waste heat.

In addition to removing heat from the reactor, cooling is also provided to the service and auxiliary cooling water systems. The volume of water required for once-through cooling is usually less than 15 percent of the volume required for condenser cooling. In closed-cycle cooling, the additional water needed is usually less than 5 percent of that needed for condenser cooling. Of all the CLWR plants operating in the United States, approximately 40 percent use closed-cycle cooling systems and 60 percent use once-through (open-cycle) cooling systems.

In closed-cycle systems, the cooled water is recirculated through the condenser after the waste heat is removed by dissipation to the atmosphere, usually by circulating the water through large cooling towers constructed for that purpose. Several types of closed-cycle cooling systems are currently used by the nuclear power industry. Recirculating cooling systems consist of either natural-draft or mechanical-draft cooling towers, cooling ponds, cooling lakes, or cooling canals. Because the predominant cooling mechanism associated with closed-cycle systems is evaporation, most of the water used for cooling is consumed and not returned to a water source.

In a once-through cooling (open-cycle) system, circulating water for condenser cooling is drawn from an adjacent body of water such as a lake or river, passed through the condenser tubes, and returned at a higher temperature to the adjacent body of water.

For both once-through and closed-cycle cooling systems, the water intake and discharge structures are of various configurations to accommodate the source water body and to minimize impact to the aquatic ecosystem. The intake structures are generally located along the shoreline of the body of water and are equipped with fish protection devices. The discharge structures are most often the jet or diffuser outfall type and are designed to promote rapid mixing of the effluent stream with the receiving body of water. Biocides and chemicals used for corrosion control and other water treatment purposes are mixed with the condenser cooling water and discharged from the system.

In addition to surface water sources, some nuclear power plants use groundwater as a source for service water, makeup water, or potable water. Other plants operate dewatering systems to intentionally lower the groundwater table, either by pumping or by a system of drains, in the vicinity of building foundations.

A.2.4.2 Radioactive Waste Treatment Systems

During the fission process, a large inventory of radioactive fission products will build up within the fuel rods. A small fraction of these fission products escape the fuel rods and contaminate the reactor coolant. The primary system coolant also has radioactive contaminants as a result of neutron activation. These contaminants are removed from the coolant by a radioactive waste treatment system prior to any release to the environment. Typically, the plants include treatment systems for gaseous, liquid, and low-level radioactive solid waste.

The impacts to the environment are driven by gaseous emissions, liquid effluent, or generation of solid low-level radioactive waste after treatment.

Gaseous Radioactive Emissions

CLWRs have three primary sources of gaseous radioactive emissions:

- Discharges from the gaseous waste management system
- Discharges associated with the exhaust of noncondensable gases at the main condenser (in the event of leakage between primary and secondary cooling systems)
- Discharges from the building ventilation exhaust, including the reactor building, reactor auxiliary building, and fuel-handling building

The gaseous waste management system collects fission products, mainly noble gases, that accumulate in the primary coolant. A small portion of the primary coolant flow is continually diverted to the primary coolant purification, volume, and chemical control system to remove contaminants and adjust the coolant chemistry and volume. During this process, noncondensable gases are stripped and routed to the gaseous waste management system, which consists of a series of gas storage tanks. The storage tanks allow the short-half-life radioactive gases to decay, leaving only relatively small quantities of long-half-life radionuclides to be released to the atmosphere via the plant vent at a controlled rate. These releases pass through both high-efficiency particulate air (HEPA) and charcoal filters before entering the environment.

Discharges from the condenser vacuum exhaust and building ventilation exhaust are released to the environment with no filtration. All potential release points are monitored.

Liquid Radioactive Effluents

Radionuclide contaminants in the primary coolant are the source of liquid radioactive waste in CLWRs. Liquid wastes resulting from CLWR plant operation are classified into the following categories: clean wastes, dirty wastes, detergent wastes, turbine building floor drain water, and steam generator blowdown. Clean wastes include all liquid wastes with a normally low conductivity and variable radioactivity content. They consist of reactor-grade water, which is amenable to processing for reuse as reactor coolant makeup water. Clean wastes are collected from equipment leaks and drains, certain valve and pump seal leakoffs not collected in the reactor coolant drain tank, and other aerated leakage sources. In addition, these wastes include primary coolant. Dirty wastes include all liquid wastes with a moderate conductivity and variable radioactivity content that, after processing, may be used as reactor coolant makeup water. Dirty wastes consist of liquid wastes collected in the containment building sump, auxiliary building sumps and drains, laboratory drains, sample station drains, and other miscellaneous floor drains. Detergent wastes consist principally of laundry wastes and personnel and equipment decontamination wastes and normally have a low radioactivity content. Turbine building floor-drain wastes usually have a high conductivity and low radionuclide content. Steam generator blowdown can have relatively high concentrations of radionuclides depending on the amount of primary-to-secondary leakage. After processing, the water may be reused or discharged.

Each source of liquid waste receives varying degrees and types of treatment before storage for reuse or discharge to the environment under the site National Pollutant Discharge Elimination System (NPDES) permit. The extent and types of treatment depend on the chemical radionuclide content of the waste. To increase the efficiency of waste processing, wastes of similar characteristics are batched before treatment.

The degree of processing, storing, and recycling of liquid radioactive waste has steadily increased among operating plants. For example, extensive recycling of steam generator blowdown is now the typical mode of operation, and secondary side wastewater is routinely treated. In addition, the plant systems used to process wastes are often augmented with the use of commercial mobile processing systems. As a result, radionuclide releases in liquid effluent from CLWR plants have generally declined or remained the same.

Solid Waste

Solid low-level radioactive waste from commercial nuclear power plants is generated by removal of radionuclides from liquid waste streams, the filtration of airborne gaseous emissions, and the removal of contaminated material from various reactor areas. Liquid waste contaminated with radionuclides comes from primary and secondary coolant systems, spent-fuel pools, decontaminated wastewater, and laboratory operations. Concentrated liquid, filter sludge, waste oil, and other liquid sources are segregated by type, flushed to storage tanks, stabilized for packaging in a solid form by dewatering, slurried into 55-gallon steel drums, and stored onsite in shielded Butler-style buildings or other facilities until suitable for offsite disposal. These buildings usually contain volume reduction and solidification facilities to prepare low-level radioactive waste for disposal at a certified low-level radioactive waste disposal facility.

HEPA filters are used to remove radioactive material from gaseous plant effluents. These filters are compacted and are disposed of as solid waste.

Solid low-level radioactive waste consists of contaminated protective clothing, paper, rags, glassware, compactible and noncompactible trash, and irradiated and nonirradiated reactor components and equipment. Most of this waste comes from plant modifications and routine maintenance activities. Additional sources include tools and other material exposed to the reactor environment. Before disposal, compactible trash is usually taken to onsite or offsite volume reduction facilities. Compacted dry active waste is the largest single form of low-level radioactive waste disposed from commercial nuclear plants, comprising one-half of the total average annual volume from pressurized water reactors.

Volume reduction efforts have been undertaken in response to increased disposal costs and the passage of the *Low-Level Radioactive Waste Policy Act* of 1980 and the *Low-Level Radioactive Waste Policy Amendments Act* of 1985, which require low-level radioactive waste disposal allocation systems for nuclear plants. Volume reduction is performed both on and offsite. The most common onsite volume reduction techniques are ultra-high-pressure compaction of waste drums, monitoring waste streams to segregate wastes, minimizing the exposure of routine equipment to contamination, and decontaminating and sorting of radioactive or nonradioactive batches before offsite shipment. Offsite waste management vendors incinerate dry-activated waste; separate and incinerate oily, organic wastes; solidify the ash; and occasionally undertake supercompaction, waste crystallization, and asphalt solidification of resins and sludges.

A.2.4.3 Nonradioactive Waste Systems

Nonradioactive wastes from commercial nuclear power plants include steam-generator blowdown, water treatment wastes (sludges and high saline streams that have residues that are disposed of as solid wastes and biocides), steam generator metal cleaning, floor and yard drains, and stormwater runoff. Principal chemical and biocide waste sources include the following:

Hydrazine, which is used for corrosion control (it is released in steam generator blowdown)

Sodium hydroxide and sulfuric acid, which are used to regenerate resins that capture wastes (these are discharged after neutralization)

Phosphates in cleaning solutions

Biocides used for condenser defouling

Other small volumes of wastewater are released from plant systems and depend on the design of each plant. These are discharged as the service water and auxiliary cooling systems, water treatment plant, laboratory and sampling wastes, floor drains, stormwater runoff, and metal treatment wastes. These waste streams are discharged as separate point sources or are combined with the cooling water discharges.

A.3 TRITIUM-PRODUCING BURNABLE ABSORBER RODS

A.3.1 Nucleonics of Tritium-Producing Burnable Absorber Rods

TPBARs serve two functions in a nuclear power reactor: they absorb excess neutrons and help make the power distribution more even in the reactor core, and they produce tritium. The neutron absorber material in a TPBAR is lithium, in the form of lithium aluminate, enriched in lithium 6 (Li^6). When lithium 6 absorbs a neutron, as would happen in the core of an operating power reactor, the neutrons and protons in the lithium would recombine into two parts: tritium (hydrogen 3 or H^3) and helium 4. This process would result in the release of 4.8 million electron volts (Mev) of energy. This process can be written:

Lithium 6 + neutron

or

$$Li^6 + n^1 \quad {}^4 + H^3 + 4.8 \text{ Mev}$$

Once the tritium (H^3) is produced inside the TPBAR, it is captured and held in a getter, as described in Section A.3.2. However, the tritium, itself unstable, slowly decays by emitting a beta particle (an electron), and becomes helium 3:

Hydrogen 3

or

$$H^3 \qquad {}^3 + \text{electron}$$

Tritium's rate of decay, or "half-life," is 12.3 years, which means that every 12.3 years half of the tritium will decay and become helium 3. Helium 3 is stable, but it has a strong affinity for neutrons; it is a good neutron absorber. As the inventory of tritium accumulates in the TPBARs during irradiation in the core, the amount of helium 3 increases as a result of the decay of tritium. This has the effect of adding a material to the reactor core that is a strong neutron absorber.

Both lithium 6 and helium 3 are considered neutron poisons. The amount of lithium 6 in the TPBARs is reduced or "burned" (hence the term "burnable") during its irradiation in the core, effectively reducing its poisonous effect. However, an increase in the amount of the helium 3 poison during irradiation in the reactor core somewhat balances the reduction of the amount of lithium 6. As a result, the effectiveness of the TPBARs in absorbing neutrons during the 18 months (one fuel cycle) they are in the core is only slightly reduced from the start of the fuel cycle to its finish.

In a normal burnable absorber rod, the rod that TPBARs will replace, the neutron absorber is boron 10, which absorbs a neutron and promptly decays into lithium 7 and helium 4:

Boron 10 + neutron

or

$$B^{10} + n^1 \qquad {}^7 + He^4$$

Boron 10 is a strong poison, but lithium 7 has little capacity to absorb neutrons. Therefore, as the boron 10 is converted to lithium 7 during irradiation in the core, the burnable absorber rod absorbs fewer neutrons and loses its poisonous effect on the reactor core. By design, at the end of an 18-month fuel cycle, the burnable absorber rods are no longer effective neutron absorbers.

Therefore, the result of using TPBARs instead of boron 10 burnable absorber rods is that, over the 18-month fuel cycle, the TPBARs act as a stronger overall poison than the burnable absorber rods that they replace. This, coupled with the fact that there will be many more TPBARs than there were burnable absorber rods, results in a significant increase in neutron poison in the core of the tritium production CLWR compared to the nontritium production CLWR.

To compensate for the added TPBAR poison, the core may need to have more new fuel assemblies loaded during each refueling, and the enrichment of those assemblies may need to be increased. As described previously, enrichment of the fuel is the amount of uranium 235 contained in the fuel. The higher the uranium 235 content in the fuel, the more fissions the fuel is capable of producing. Enrichment of the new fuel placed in the core of a tritium production CLWR may need to be increased to just under 5 percent, compared to the 4.2 to 4.5 percent currently being used in CLWRs. Five percent enrichment is the upper limit for reactor licensing by the U.S. Nuclear Regulatory Commission (NRC).

A.3.2 Physical Description of the Tritium-Producing Burnable Absorber Rod

Lithium, the active ingredient in tritium production, is in the form of an annular-shaped ceramic lithium-aluminate pellet. The pellets are contained in sub-assemblies called pencils. Each pencil is about 30 centimeters (12 inches) long and consists of a stack of pellets, a zirconium inner liner inside of the pellets, a zirconium tube or getter outside of the pellets, and a getter disc at the bottom of the pellet stack. Inside the zirconium liner is a gas plenum. The components of a TPBAR are illustrated in **Figures A–10 and A–11**.

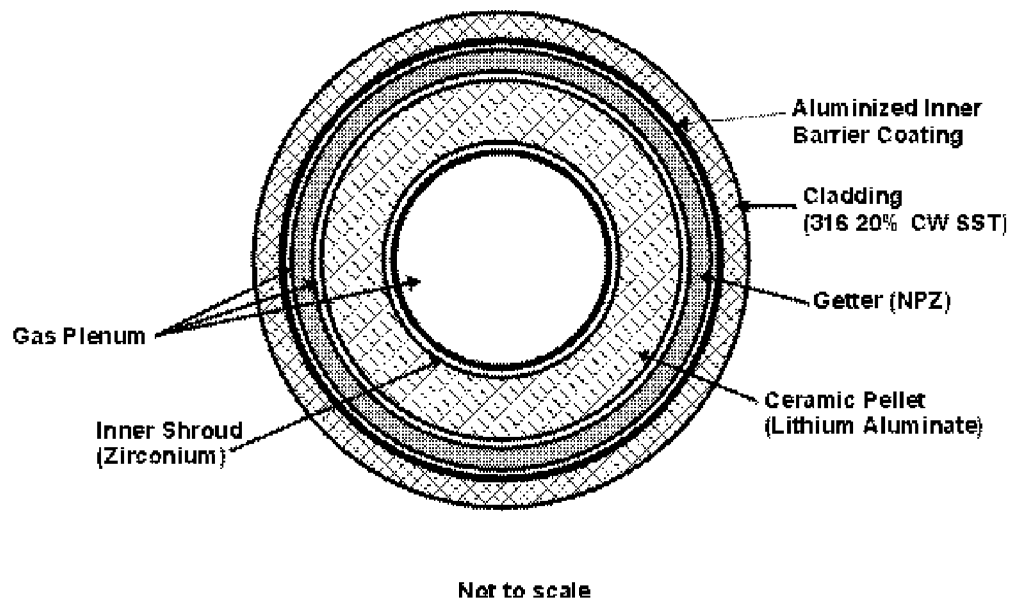

Figure A–10 TPBAR Transverse Cross Section

Tritium is generated as a gas, almost all of which is captured by the zirconium getter as a tritide compound of zirconium (ZrT_x). Tritium that becomes tritiated water vapor before it can be absorbed by the getter is disassociated by the zirconium inner liner. The getter is nickel-plated to protect it from tritiated water vapor, which would oxidize its surface and block further absorption of tritium gas. The zirconium inner liner also serves to maintain the overall geometry of the pellets, should they fragment.

Twelve pencils, a getter disc, and a spring loaded inside a stainless steel tube creates a TPBAR. The spring holds the pencils in place during handling and allows for thermal expansion during operation. The inside surface of the stainless steel tube, or cladding, has an aluminized barrier coating to retard the permeation of hydrogen into and tritium out of the TPBAR. Loss of tritium through the cladding would increase the tritium released into the reactor coolant and, therefore, reduce the amount of tritium available for processing. Ingress of hydrogen into the TPBAR would be absorbed by the getter, diminishing the ability of the getter to absorb tritium. A less effective getter would increase the partial pressure of tritium inside the TPBAR, which would increase tritium loss through the cladding. The TPBARs are evacuated, backfilled with helium at one atmosphere pressure, and seal welded. TPBARs would be put in the fuel assembly's nonfuel positions designed for burnable poison rods. Therefore, the exterior dimensions of the TPBARs are the same as those of burnable absorber rods. For the

Westinghouse 17 × 17 design fuel assembly, the TPBARs would have anoutside diameter or 0.381 inches, which

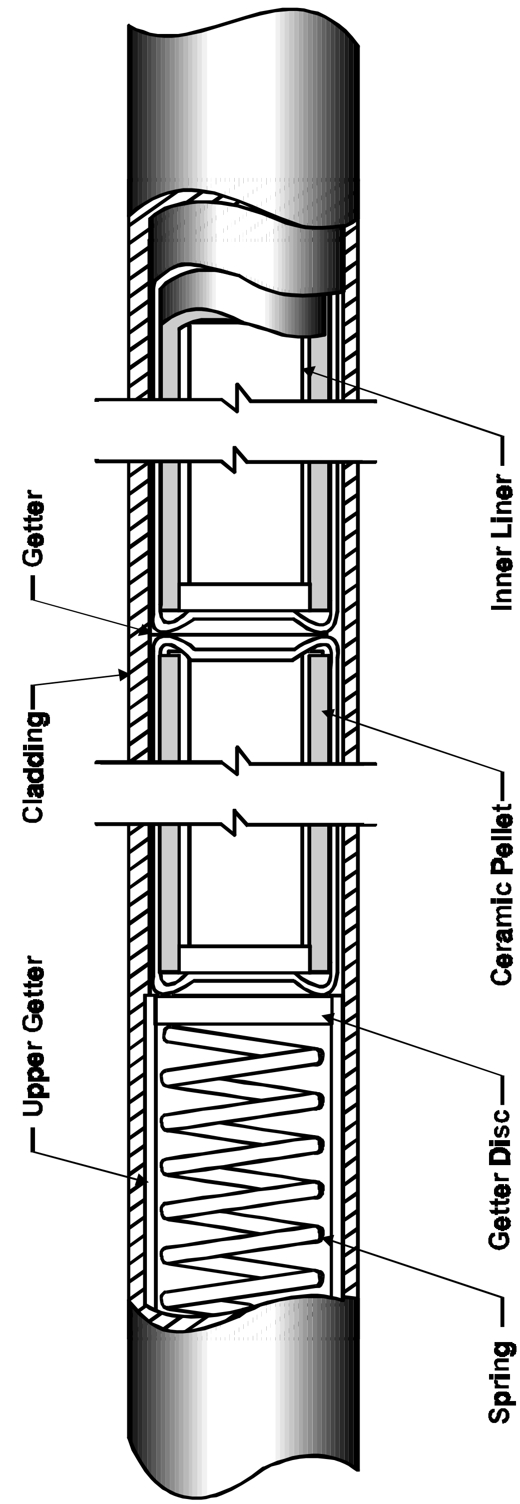

Figure A–11 TPBAR Longitudinal Cross Section

is exactly that of a burnable absorber rod. The cladding of the TPBAR would be stainless steel, type 316. The cladding of absorber rods would be either 304 type stainless steel or zircaloy 4.

All of the TPBARs inserted into a given fuel assembly are attached to a base plate, forming a TPBAR assembly. The base plate is part of the hold-down assembly, which also includes a spring and a locking device. The base plate not only maintains the spacing of the TPBARs for insertion and withdrawal, but also allows the TPBARs to be handled in groups rather than one-at-a-time. **Figure A–12** illustrates the base plate as part of the hold-down assembly.

A.3.3 Handling of Tritium-Producing Burnable Absorber Rods

The individual TPBARs would be mounted on the hold-down assembly through holes in the base plate and locked in place. The TPBAR assemblies would then be inserted into new fuel assemblies at the fuel manufacturer. The TPBARs would be transported to the reactor site and loaded into the reactor core as an integral part of the new fuel assembly. After irradiation in the core for approximately 18 months (one fuel cycle), the spent fuel, along with their TPBARs, would be removed from the core. In a normal refueling of a reactor core used for tritium production, some of the fuel assemblies would be re-inserted into the core for use during the second fuel cycle, while the rest of the fuel assemblies would go to the spent fuel pool. The TPBARs in fuel assemblies destined for the spent fuel pool would be left in their host fuel assemblies until after the refueling.

Some TPBARs could reside in fuel that would be re-inserted in the core and used during a second fuel cycle. Each of the fuel assemblies that are to be re-inserted in the core would be moved to the spent fuel pool and placed in a stand where the TPBAR assembly would be remotely removed. These fuel assemblies would then be returned to the reactor core. The removed TPBARs would be placed in other spent fuel assemblies in the spent fuel pool, where they would be stored under water until transported from the site.

After a short period of time following refueling, all of the TPBARs would be removed from the storage position in their host spent fuel and placed in a handling stand. In the handling stand, the individual TPBARs would be separated from the base plate and moved to the consolidation rack, where they would be inserted in the consolidation assemblies. The consolidation assemblies are essentially square cans with a 17×17 array of positions capable of accepting TPBARs. Once loaded, a handling fixture would be placed on the ends of the assemblies, and the assemblies would be handled with the same tools as fuel assemblies. The consolidation assemblies would then be placed in transportation cask positions designed for fuel assemblies and transported to the DOE Tritium Extraction Facility at the Savannah River Site in South Carolina.

A.4 IMPACT OF TRITIUM PRODUCTION ON THE FUEL CYCLE

The introduction of TPBARs into the fuel assemblies used in a CLWR would impact the fuel management strategy currently in use by the operator of the CLWR. The replacement of burnable poison rods with the TPBARs affects the core physics (the utilization of neutrons to produce power and to produce tritium) and could alter the design of the core. Because the TPBARs have a large residual reactivity penalty, the tritium production core designs require higher enrichments and may require larger feed (fresh fuel) regions than the commercial core designs with a comparable power level and cycle length. These two fuel cycle characteristics were assumed to be unchanged with the introduction of TPBARs into the commercial core. Several core parameters were identified that could be impacted by the replacement of burnable poison rods with TPBARs. The most important among these are the power peaking factors. The distribution of power within the core is limited so that no single area produces significantly more than the average amount of power generated throughout the core. The differences between the average power and local power are quantified in several power peaking factors. By limiting the values of these peaking factors, the plant operator and the

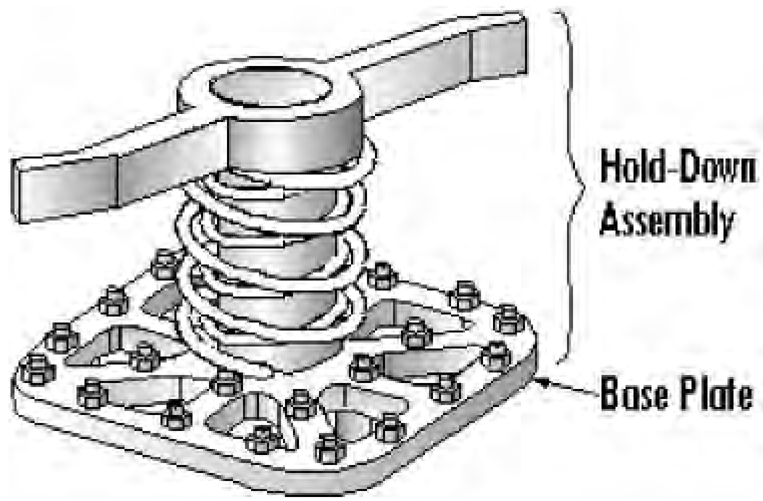

Figure A–12 TPBAR Hold-Down Assembly

NRC ensure that the power plant operates within safety limits and would respond to accidents as described in the accident analysis required of all licensed nuclear power plants. With limitations on the number and distribution of TPBARs in the core used in this EIS, the power peaking factors in the commercial power production core and the tritium production core are very similar and the safety limits are not expected to be exceeded. Therefore, tritium production can be performed without the need to modify the CLWR core design, and only changes in the fuel enrichment would be required.

The maximum number of TPBARs that could be placed in the core (or irradiated) at each reactor unit without significantly disturbing the normal electricity producing mode of reactor operation is approximately 3,400 (the exact number depends on the specific design of the reactor). This section evaluates the impact of tritium production on the fuel cycle by irradiating a range of 1000 TPBARs to a maximum of 3,400 TPBARs at each reactor unit. The fuel cycle would be assumed to remain unchanged at 18 months. Irradiating a maximum number of TPBARs in each reactor core would require each nonfuel position (guide tube location) inside the core that is not reserved for the control element be filled by a TPBAR, and the number of fresh fuel assemblies loaded into the core at each refueling be increased. Irradiation of 1000 TPBARs can be accomplished by placing the TPBARs in positions currently occupied by burnable poison rods. This action would not change the number of fresh fuel assemblies that are currently loaded into the core during refueling for commercial operation with no TPBARs.

Power Operation with Maximum Number of TPBARs

As stated earlier, irradiation of a maximum number of TPBARs requires their insertion in every possible guide tube location. For Watts Bar 1, this means that TPBARs would be located in the 24 guide tubes of 136 fuel assemblies (141 in Bellefonte 1, or Bellefonte 2 and 140 in Sequoyah 1, or Sequoyah 2) that do not have a control assembly (TVA 1991, TVA 1995, TVA 1996, TVA 1998). Commercial operation of Watts Bar 1 without tritium production consists of an 18-month fuel cycle and replacement of 80 spent fuel assemblies (72 for Bellefonte 1, or Bellefonte 2 and 80 for Sequoyah 1, or Sequoyah 2) at each refueling.

The main premise of using a CLWR to produce tritium is that the reactor power would remain unchanged. Since TPBARs use lithium (a strong neutron absorber), to produce tritium and the reactor power level is dependent on the number of neutrons available for fission; additional neutrons must be generated to maintain the reactor power level when the CLWR is used for tritium production. To meet the increased demand for neutrons, the enrichment of the reactor fuel would need to be increased. This would result in more uranium 235 in the reactor core. The maximum fuel enrichment for the fresh fuel is limited to 5 percent. Because of limitations on the distribution of power and the limits on the maximum enrichment of uranium fuel (5 percent), tritium production would require more fresh fuel to be loaded into the reactor at each refueling to maintain the same fuel cycle. For Watts Bar 1, these factors would result in the need to replace 136 of the 193 fuel assemblies (141 of 205 for Bellefonte 1, or Bellefonte 2 and 140 of 193 for Sequoyah 1, or Sequoyah 2) with fresh fuel every fuel cycle. The remaining 57 fuel assemblies (64 for Bellefonte 1, or Bellefonte 2 and 53 for Sequoyah 1, or Sequoyah 2) that have been burnt once would be moved to the positions where the control element assemblies are located. Fresh fuel would contain the TPBARs and be positioned in the locations without a control element assembly.

Based on the above discussion and the consideration that each CLWR unit would operate to produce tritium for 40 years, Watts Bar 1 would generate 1,512 additional spent fuel assemblies (1,863 by Bellefonte 1, or Bellefonte 2 and 1,620 by Sequoyah 1, or Sequoyah 2), see also **Table A-1**.

Power Operation with 1000 TPBARs

The operation of CLWRs with 1000 TPBARs would not affect the number of fuel assemblies replaced during each refueling. As stated earlier, TPBARs are scattered in the core in places of burnable absorber rods. Production of tritium in a CLWR with less than 2000 TPBARs is not expected to increase spent fuel generation per fuel cycle (WEC 1998). However, to maintain an 18-month fuel cycle, similar to the maximum TPBAR loading, a higher fuel enrichment is required.

Table A–1 Summary of Increase in Spent Fuel Generation From 40 Years of Tritium Production with Maximum Number of TPBARs

Data Parameters	*Watts Bar 1*	*Sequoyah 1, or Sequoyah 2*	*Bellefonte 1, or Bellefonte 2*
Operating cycle (months)	18	18	18
Fresh fuel assemblies per cycle–no tritium production	80	80	72
Fresh fuel assemblies per cycle–maximum TPBARs	136	140	141
Increase in fresh fuel assemblies per cycle due to tritium production	56	60	69
Number of operating cycles in 40 years (rounded up)	27	27	27
Number of additional fuel assemblies for 40 years of tritium production	1,512	1,620	1,863

A.5 REFERENCES

TVA (Tennessee Valley Authority), 1991, *Bellefonte Nuclear Plant Final Safety Analysis Report*, through Amendment 30, Chattanooga, Tennessee, December 20.

TVA (Tennessee Valley Authority), 1995, *Watts Bar Nuclear Plant Final Safety Analysis Report*, through Amendment 91, Chattanooga, Tennessee, October 24.

TVA (Tennessee Valley Authority), 1996, *Sequoyah Nuclear Plant Updated Final Safety Analysis Report*, through Amendment 12, Chattanooga, Tennessee, December 6.

TVA (Tennessee Valley Authority), 1998, Data collected from TVA personnel by Science Applications International Corporation personnel, January—August.

WEC (Westinghouse Electric Corporation), 1998, letter from M.L. Travis to J.E. Kelly, Sandia National Laboratory, Albuquerque, New Mexico, "Transmittal of Information to Support the CLWR Tritium Program Environmental Impact Statement," NDP-MLT-98-156, May 6.

APPENDIX B
METHODS FOR ASSESSING ENVIRONMENTAL IMPACTS—APPLICATION TO PRODUCTION OF TRITIUM IN COMMERCIAL LIGHT WATER REACTORS

This appendix describes the methods for assessing environmental impacts and addresses the application of those methods to the production of tritium in commercial light water reactors (CLWRs). The methods and applications are designed to comply with the Council on Environmental Quality and U.S. Department of Energy (DOE) regulations implementing the National Environmental Policy Act. A summary of Federal environmental, safety, and health statutes, regulations, and orders applicable to relevant resource/issue areas is provided in **Table B–1** and a list of relevant DOE Orders and U.S. Nuclear Regulatory Commission (NRC) guides is given in **Table B–2** at the end of this appendix.

The following resources and issues are covered in this environmental impact statement (EIS):

- Land resources
- Air quality and noise
- Water resources
- Geology and soils
- Ecology
- Archaeological and historic resources
- Socioeconomics
- Public and occupational health and safety
- Waste management
- Spent fuel management
- Transportation
- Environmental justice.

The *Draft Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor* covers CLWR production of tritium in one or more of the following reactors:

- Watts Bar Nuclear Plant, Unit 1 (Watts Bar 1)
- Sequoyah Nuclear Plants, Unit 1 and Unit 2 (Sequoyah 1 and Sequoyah 2)
- Bellefonte Nuclear Plant, Unit 1 and Unit 2 (Bellefonte 1 and Bellefonte 2).

The level of detail for the assessment of environmental impacts on each resource depends on the status of each reactor. For the currently operating reactors (Watts Bar 1, Sequoyah 1, and Sequoyah 2), only the resources that would be affected by activities associated with tritium production would need to be discussed and these impacts would need to be evaluated in detail. For partially completed reactors (Bellefonte 1 and Bellefonte 2), a detailed evaluation of the impacts on all resources would be needed.

The assessment of the environmental impacts from the production of tritium in CLWRs would be based on the following general assumptions:

- For Watts Bar 1, Sequoyah 1, and Sequoyah 2, the impacts attributed to the production of tritium would be those impacts that are associated with the additional activities required to produce tritium which are beyond the current power operation activities.

- For Bellefonte 1 and Bellefonte 2, the impacts attributed to the production of tritium would be: (1) the impacts from the completion of construction of the facilities; and (2) the full impacts from the operation of the reactors.

B.1 LAND RESOURCES

B.1.1 Land Use

Method

The analysis of the impacts on land resources are based on the type and extent of land that will be affected, the degree to which activities will alter the land (including irretrievable usages), and the existing Federal, state, and local land use ordinances and policies (e.g., zoning).

Application

For currently operating CLWRs, no additional land would be disturbed.

For partially completed CLWRs, the production of tritium could generate additional land-use impacts related to the completion of the reactor. The land-use impacts would be evaluated in the same way as any other large-scale construction program.

B.1.2 Visual Resources

Method

Visual resource assessments are based on the Bureau of Land Management's visual resource management method. A qualitative visual resource analysis, adapted from the Bureau of Land Management's visual contrast rating system (DOI 1986a, DOI 1986b) will be conducted, as applicable, to:

- Identify key viewing positions (such as public travel routes, nearby residential/commercial areas, and public use facilities such as parks, recreation areas, and scenic areas)

- Assess the degree of visibility of new or modified facilities (buildings, stacks, access roads, parking areas, facility and perimeter lighting, steam and emission plumes) from these key viewing positions

- Assess the compatibility of such facilities with the existing setting.

Sensitivity will be assessed based on the potential for public concern about adverse effects on specific views within the affected environment.

Application

For currently operating CLWRs, minimal changes in visual resources would take place if storage facilities need to be constructed for spent fuel. Because these storage facilities would be a small part of a much larger industrial facility, their overall impact would be essentially zero.

For partially completed CLWRs, the additional impacts would depend on the modifications necessary to complete construction of the facilities.

B.2 AIR QUALITY AND NOISE

B.2.1 Air Quality

Method

In currently operating reactors where the production of tritium is expected to result in some additional release of tritium to the atmosphere, the additional release will be quantified and the expected concentration in air will be calculated and compared with existing conditions and standards.

In partially completed reactors where construction activities will take place and the impacts of the full reactor operations are attributed to the production of tritium, assessments of air quality impacts will include identification of applicable criteria for assessing impacts, development of emission inventories, and estimation of air pollutant concentrations. Ambient air monitoring data will be used to determine background concentrations of pollutants for the specific site. The assessment of impacts will be based on estimated pollutant concentrations, data on the existing environment, and assessment criteria. Human health effects due to air pollutant emissions are discussed in Section B.8; potential impacts of airborne radioactive and chemical releases are included.

Assessment criteria for pollutants include the U.S. Environmental Protection Agency's (EPA's) primary and secondary National Ambient Air Quality Standards for criteria pollutants specified in 40 CFR 50, and those established by each state. The more stringent of either the EPA or state standards will serve as the assessment criteria. The hazardous and toxic air pollutants include those listed in Title III of the 1990 Clean Air Act amendments, in the National Emission Standards for Hazardous Air Pollutants in 40 CFR 61, and in standards and guidelines proposed or adopted by the respective states. Site-specific emissions will be modeled using the EPA-recommended ISCST3 model and EPA's Guidelines on Air Quality Models (40 CFR 51, Appendix W).

Application

For currently operating CLWRs, production of tritium would result in some additional release of tritium to the ambient air. No additional nonradiological pollutant concentrations would be expected.

For partially completed CLWRs, the activities required to complete reactor construction and to operate the reactors would result in both radioactive and nonradioactive emissions attributable to tritium production.

B.2.2 Noise

Method

Noise impacts will be assessed on the basis of the potential change at residences near the site boundary. The potential for exposure of workers to noise and the measures taken to protect worker hearing will be qualitatively discussed.

Application

For currently operating CLWRs, no increase in noise levels would be expected unless substantial modifications are necessary (e.g., construction of dry cask spent fuel storage facilities).

For partially completed CLWRs, noise sources from construction equipment and traffic would depend on the amount of construction required to complete the reactors. The noise impacts from the operation of the facilities would be attributed to the production of tritium.

B.3 WATER RESOURCES

Method

In currently operating CLWRs, tritium production is expected to result in some additional release of tritium as a liquid effluent. This additional release will be quantified and the expected concentrations in the liquid environment will be calculated and compared to existing conditions and standards. In partially completed CLWRs where construction activities are required and the impacts of the full operation of the reactor are attributed to tritium production, comprehensive water resource and quality assessments will be performed. Water resource impacts (surface water, groundwater, and floodplain) will be reviewed in relation to: the Clean Water Act, specifically Sections 402 (National Pollutant Discharge Elimination System [NPDES]), 307(b) (toxic and pretreatment effluent standards), and 316 (thermal discharge); the Safe Drinking Water Act; DOE Regulation 10 CFR 1022; Compliance with Flood Plains/Wetlands Environmental Review Requirements; Executive Order 11988, *Floodplain Management*; and applicable state water quality standards. Potential effects on surface water and groundwater availability and quality will be assessed by considering whether the proposed action or alternatives would significantly affect the quantity or quality of water available for local consumption, as well as compliance with legislative or regulatory requirements and the risk of flooding.

Surface Water

Impact assessments to surface water will include the following factors:

- Changes in rate of water consumption and wastewater discharges for operation and construction phases (as applicable)
- Changes in chemical, physical, and thermal characterization of all wastewater discharges
- Changes in the annual low flows of surface water resulting from proposed withdrawals and discharges
- Existing water supply to support the demand by comparing projected increases with the capacity of the supplier and by considering existing water rights, agreements, and allocations.

Water quality impacts will be determined by reviewing current monitoring data reports for nonradiological effluents. Potential radiological impacts from the discharge of tritium are discussed in the Public and Occupational Health and Safety Section (see Section B.8). Water quality management practices at each site will be reviewed. Monitoring reports for discharges permitted under the NPDES program will be examined for compliance with permit limits and requirements. In most cases, current available data in the monitoring reports will include information on the constituents present or the rate of discharge. A qualitative assessment of water quality impacts from wastewater (sanitary and process), storm water runoff, stream channel erosion and sedimentation, stream bank flooding, and thermal impacts will be identified.

Where possible, the proposed location will be compared with the 500-year floodplain. Where these data are unavailable, potential impacts associated with the 500-year floodplain will be addressed in terms of design and siting mitigation measures.

Groundwater

Effluents will be analyzed for effects on aquifers, groundwater usage, and groundwater quality within the regions. Available data on existing groundwater quality conditions will be compared to Federal and state groundwater quality standards, effluent limitations, and safe drinking water standards. Additionally, Federal and state permitting requirements for groundwater withdrawal and discharge will be identified. Impacts of groundwater withdrawals on existing contaminant plumes due to construction and facility operation will be assessed to determine the potential for changes in their rates of migration and the effects of any changes in the plumes on groundwater users. Impacts will be assessed by the degree to which groundwater quality, drawdown of groundwater levels, and groundwater availability to other users would be affected.

Application

For currently operating CLWRs, no change in water consumption, surface runoff, floodplain impacts, etc., would be expected. Some additional tritium in the liquid waste effluent of the facilities would be expected.

For partially completed CLWRs, the activities required to complete reactor construction and conduct facility operations would affect water resources and water quality. The impacts associated with the completion and operation of the reactors would be attributed to tritium production.

B.4 GEOLOGY AND SOILS

Method

Soil types at construction sites will be described and the capability for supporting construction will be assessed. Shrinking or swelling of the ground as a result of landscaping, irrigation, or construction-related dewatering and soil erosion susceptibility also will be addressed.

Application

For currently operating CLWRs, no changes to the current condition of geology and soils from tritium production would be expected.

For partially completed CLWRs, the associated impacts would depend on the level of modifications necessary to complete construction of the facility.

B.5 ECOLOGY

Method

Ecological impacts will be addressed as applicable for terrestrial resources, wetlands, aquatic resources, and threatened and endangered species. Sources of impacts that will be considered include land use changes, salt drift (residual salts left behind as a result of the evaporation of cooling tower water), chemical or radionuclide emissions, water withdrawal, wastewater discharges, and human disturbance and noise. Potential impacts will be assessed based on both the Federal and state protection regulations and standards and on the degree to which various habitats or species could be affected by the project.

Terrestrial Resources

The key considerations in assessing the effects on terrestrial resources are: the presence and regional importance of affected habitats and the size of the habitat area to be disturbed by construction or operations. Impacts to wildlife will be based on plant community loss, which is closely associated with animal habitat. The potential for disturbance, displacement, or loss of wildlife in accordance with wildlife protection laws, such as the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act, will be evaluated.

Wetlands

Most impacts on wetlands are related to displacement of wetlands by filling, draining, or clearing activities. Operational impacts to wetlands may occur from effluents, surface or groundwater withdrawals, or creation of new wetlands. The loss of wetlands resulting from construction and operation will be addressed in the same way as for terrestrial plant communities—by comparing data onsite wetlands to proposed land requirements. Sedimentation impacts will be evaluated based on the nearness of wetlands to project areas, assuming standard construction erosion and sedimentation control measures. Impacts resulting from increased flows will be evaluated based on a comparison of expected discharge rates with present stream flow rates.

Aquatic Resources

Impacts to aquatic resources will be assessed for sedimentation, increased flows, effluent discharge, impingement, entrainment, loss of spawning habitat, and introduction of waste heat and chemicals.

Threatened and Endangered Species

Potential impacts to threatened and endangered species will be determined in a manner similar to that described for terrestrial and aquatic resources, since the impact sources are similar.

Application

For currently operating CLWRs, no additional impacts to biological resources would be expected from tritium production. Tritium releases into the atmosphere, when added to baseline releases, would be expected to be well below the regulatory limits established to protect workers and the public. Since humans have been shown to be the most sensitive organism to radiation, therefore these regulatory limits also should protect biota (ORNL 1995, NCRP 1991), and no detailed evaluation of impacts on biota should be required (DOE 1995). Impacts to biota from hazardous chemicals (excluding tritium) during normal operations would be unlikely, since hazardous and toxic materials would be handled, stored, transported, and disposed of in accordance with the requirements of the Resource Conservation and Recovery Act. As biota would be unlikely to be exposed to hazardous chemicals, such impacts will not be discussed in detail.

For partially completed CLWRs, the baseline and associated impacts would depend on the level of modification necessary to complete construction and the effluents resulting from the reactors' operation activities. The impacts would be attributed to tritium production.

B.6 ARCHAEOLOGICAL AND HISTORIC RESOURCES

Method

The archaeological and historic resources impact analysis determines the potential effects on prehistoric, historic, Native American, and paleontological resources.

Application

For currently operating CLWRs, no changes to the archaeological and historic resources would be expected.

For partially completed CLWRs, the associated impacts would depend on the level of modifications necessary to complete construction of the facilities. Any new construction would require an evaluation and possibly a Phase I survey to determine if there are any archaeological resources in the area of potential effects pursuant to Section 106 of the National Historic Preservation Act, specifically 36 CFR 800.4. If archaeological resources are present, a Phase II or Phase III survey may be required.

B.7 SOCIOECONOMICS

Method

Socioeconomic impacts will be assessed for the region of influence in the areas of:

- Demographics (population growth)
- Economics (employment and income)
- Housing
- Public finance
- Public infrastructure (schools, transportation, hospitals, recreational facilities, etc.).

The region of influence is the area containing roughly 90 percent of the current and potential employees at the site. Local impacts from a concentration of activity or a relatively large change in activity will be noted. Changes are projected over 40 years. Employment impacts are estimated using the Bureau of Economic Analysis' Regional Input-Output Multiplier System.

Application

For currently operating CLWRs, the estimated addition of 10 tritium-related workers per reactor would generate little or no measurable impact within any region of influence.

For partially completed CLWRs, the impacts would depend on the scope and duration of the activities required to complete construction and the size of the region of influence. The impacts from the completion and operation of the facility would be attributed to the production of tritium.

B.8 PUBLIC AND OCCUPATIONAL HEALTH AND SAFETY

Method

For currently operating CLWRs where the production of tritium is expected to result only in some additional release of tritium to the environment under either normal operations or accident conditions, the incremental impact to the public and facility workers will be assessed by using the method in the facilities' Environmental Reports and the associated NRC's Final Environmental Statements and by adding the effects of the increase in the amounts of released tritium.

For the partially completed CLWRs, the impacts of the full reactor operations are attributed to the production of tritium, the impact to the public and facility workers will be assessed using current NRC guidelines and practices.

The public and occupational health and safety analysis will determine the potential adverse effects on human health from exposure to ionizing radiation and hazardous chemicals. Health effects will be determined by identifying the types and quantities of additional material (radioactive and chemical) to which one may be exposed, estimating doses, and then calculating the resultant health effects (latent cancer fatalities). The impacts from various releases during normal operation and postulated accidents on the human health of workers and the public residing within 80 kilometers (50 miles) of each site will be assessed. The assessment will use site-specific factors such as meteorology, population distribution, and agricultural production. Models will be used to project the impacts on the health of workers and the public due to radiological and chemical releases during normal operation and postulated accidents. These models include:

- MACCS2 (SNL 1997) for radioactive material releases during beyond design-basis accidents

- GENII (PNL 1988) for all radioactive material releases during normal operations and other accidents (design-basis and TPBAR handling accidents)

- ISCST3 (EPA 1995) and ALOHA (NSC 1990) for hazardous chemical releases during normal operation and accident conditions.

Health Impacts on Plant Workers During Normal Operation—Because radiation workers are individually monitored, experiences from past and current operations that are similar to future operation will be used to estimate the radiological health impacts to workers. Health impacts from chemicals, if any, will be discussed qualitatively. There are no individual exposure data on workers for chemicals. Therefore, it will be assumed that individuals will be exposed to low air chemical emission concentrations during an 8-hour day for a 40-hour week at a point (~100 meters/330 feet) downstream from the release point.

Health Impacts on General Public During Normal Operation—Public health impacts from exposure to radiological or hazardous chemical materials released during operations will be calculated. The effect will be the sum of: (1) internal exposure resulting from breathing, eating, and drinking; and (2) external exposure resulting from standing on contaminated ground, being exposed to the air, and being submerged in water. The type and amount of material released will be estimated and the associated radiological and chemical doses will be determined. These doses will be converted to health effects using appropriate health risk estimators, both radiological (NRC/NAS 1990, NCRP 1993) and chemical (EPA 1997).

Accident Analysis for Postulated Accident Scenarios—Risks to both the individual member of the public and the general population residing within the affected area will be calculated. The magnitude and consequences of impacts associated with each alternative will be determined using site-specific and/or reactor-specific safety analyses. Although the concepts used are analogous to a formal probabilistic risk assessment, the accident analysis involve less detail and only address a spectrum of beyond design-basis accidents (severe core disruptive reactor accidents) that represent high consequence events with low probability of occurrences (often $^{-6}$ per year) and a spectrum of possible design-basis and other operational accidents that represent low consequence events with high probability of occurrences (frequency greater than 1.0×10^{-6} per year). These accidents are similar to those that have been postulated in the plant's environmental report and the corresponding NRC Final Environmental Statement.

Accident risk to a noninvolved[1] worker is calculated for a hypothetical worker at 0.64 kilometers (0.4 mile) (or the site boundary, whichever is closer) from the facility release point. Risk to facility workers from radiological accidents will be addressed qualitatively, since precise placement of the workers during accidents cannot be made.

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[1]*Noninvolved workers are only applicable to DOE sites, since each DOE site usually contains many facilities. At a CLWR, there are no facilities that do not directly support reactor operation. Therefore, noninvolved workers, as defined in DOE documents, do not exist. For consistency, however, this calculation will be performed.*

Uncertainties—The sequence of analyses needed to generate the radiological impact estimates from normal operations and facility accidents include: (1) a selection of normal operational modes and accident sequences, (2) estimation of source terms, (3) estimation of environmental transport and uptake of radionuclides, (4) calculation of radiation doses to exposed individuals, and (5) estimation of health effects.

The analyses would use conservative models, and scenarios to bound the risks. As a result, even though the range of uncertainty in a quantity might be large, the value calculated for the quantity will be close to the upper extreme in the range, so that the chance of the actual quantity being greater than the calculated value (or the chance of the quantity being less than the calculated value if the criteria are such that the quantity has to be maximized) is low.

Application

For currently operating CLWRs, the list of accident scenarios analyzed in the plant EIS and/or the updated plant probabilistic risk assessment would be reviewed, and the corresponding source terms would be identified. For each accident scenario, the incremental source terms associated with the TPBARs would be determined. The list of accidents and source terms along with the appropriate model and data, as described earlier, would be used to determine the incremental impacts. This information would be included in a separate Appendix.

For partially completed CLWRs, the impacts would be evaluated using the total source terms (as opposed to the incremental) associated with each accident.

B.8.1 Emergency Preparedness

Method

Emergency preparedness plans exist for all operating reactor sites and are summarized in the EIS for each site. For non-operating reactor sites, approximate plans need to be developed.

Application

For currently operating CLWRs, incremental impacts could be expected to result from tritium production. The impact analysis would be based on the existing analysis in the plant's Environmental Report, the associated EIS, and the added impact that could be expected from the increase in tritium levels.

For partially completed CLWRs, an impact analysis based on the risk assessment studies of similar, standard (sister plant) reactors could be used.

B.9 WASTE MANAGEMENT

Method

The volumes of each waste type (low-level radioactive, low-level mixed, hazardous, nonhazardous, high-level radioactive) will be estimated. Methods of minimizing each of the waste streams will be discussed. Impacts will be assessed in the context of site practices for treatment, storage, and disposal. Wastes related to decontamination and decommissioning will also be discussed. Decontamination and decommissioning could range from performing a simple radiological survey to completely dismantling and removing a radioactively contaminated facility.

Application

For currently operating CLWRs, depending on the level of activities needed to package and transport tritium-producing burnable absorber rods (TPBARs) offsite, some changes in the generation of low-level radioactive wastes would be expected. Tritium production is not expected to change the decontamination and decommissioning requirements at the plant.

For partially completed CLWRs, the baseline and impacts depend on the level of modification necessary to complete construction, and on the discharges (spent fuel, effluent treatments, etc.) resulting from operation of the reactor. Construction activities may be required to handle these additional discharges.

B.10 TRANSPORTATION

Method

The impacts of transporting program-related materials would be described. The packages required for the shipment of materials would also be described. For transporting irradiated TPBARs and radioactive waste, the following elements would be considered: transport mode, weight of material, curies, proximity dose rates (transport index), type of package, number of shipments, and/or distance. Road and railroad routes would be identified using HIGHWAY (ORNL 1993a) and INTERLINE (ORNL 1993b) codes, respectively. Radiological transportation health impacts would be calculated using RADTRAN and TICLD (SNL 1993) codes for both the incident-free and accident conditions. In addition to the radiological risks posed by the transportation activities, vehicle-related risks would be assessed for nonradiological causes (i.e., causes related to the transport vehicles and not the TPBAR packages). Nonradiological risks during incident-free transportation conditions would be caused by potential exposure to increased vehicle exhaust emissions. Nonradiological risks resulting from accident conditions unrelated to the shipment cargo would be assessed using state-specific transportation fatality rates.

Application

Four transportation segments would be evaluated in this EIS: (1) shipment of fabricated TPBARs to an assembly facility, (2) shipment of TPBAR assemblies to each of the CLWRs, (3) shipment of irradiated TPBARs to DOE's Savannah River Site in South Carolina, and (4) shipment of irradiated hardware to the Barnwell disposal facility in South Carolina. Additionally, the possibility of shipping fabricated TPBARs directly to the CLWRs would be evaluated.

Transportation segments 1 and 2 would involve shipment of nonhazardous, nonradioactive material in secure commercial containers. Transportation segment 3 would involve shipment of irradiated TPBARs from the CLWRs to the Tritium Extraction Facility at the Savannah River Site using truck casks on trucks, truck casks on trains, and rail casks on trains. Transportation segment 4 would involve shipment of irradiated hardware from the CLWRs for disposal as low-level radioactive waste. Irradiated hardware includes base plates and thimble plugs removed from the TPBARs at the CLWR site. This information is included in a separate Appendix.

B.11 SPENT FUEL MANAGEMENT

Method

"Spent fuel" is the terminology used for nuclear reactor fuel that has been irradiated to the point that it no longer contributes to the continued operation of the reactor. The spent fuel is removed from the reactor core and stored in the spent fuel storage pool or basin. The Nuclear Waste Policy Act of 1982, as amended, assigned the Secretary of Energy the responsibility for developing a repository for the disposal of high-level radioactive waste and spent fuel. When such a repository is available, spent fuel would be transported for disposal from the nuclear power reactors to the repository. Until a repository is available, spent fuel would be stored in the reactor pools or in other acceptable, NRC-licensed storage locations. Because of the uncertainty associated with opening a repository, this EIS assumes that spent fuel would be stored at the reactor facility for the 40-year duration of the proposed action.

Application

Based on the assumption that no central spent fuel repository would be available for the duration of the proposed action, each reactor would need an NRC-licensed spent fuel dry cask storage facility located away from the reactor spent fuel pool to store any additional spent fuel that could be generated from tritium production. Therefore, for each of the proposed reactors estimates of the potential increase in spent fuel assemblies and the corresponding dry cask storage capacity attributable to tritium production would be made. This EIS presents a quantitative assessment of the environmental impact associated with the construction of a generic, NRC-licensed, dry cask independent spent fuel storage installation (ISFSI).

B.12 ENVIRONMENTAL JUSTICE

Method

Executive Order 12898, *Federal Action to Address Environmental Justice in Minority Populations and Low Income Populations*, requires an assessment of incidence and mitigation related to disproportionately high and adverse human health or environmental effects on minority and low-income populations. In May 1996, the Council on Environmental Quality released its initial guidance on environmental justice (CEQ 1996). This guidance forms the basis of the environmental justice analysis. The following definitions will be used during the analysis:

- *Minority Individuals*—Persons self-designated as Hispanic (of any race), Native American, Asian or Pacific Islander, or Black,
- *Minority Population*—The total number of minority individuals residing within a specified area,
- *Low-Income Individuals*—Any persons whose income is below the poverty threshold, and
- *Low-Income Population*—The total number of low-income individuals residing within a specified area.

Demographic data provided by the U.S. Bureau of the Census will be used to quantify minority and low-income populations in the affected area, i.e., within a radius of 80 kilometers (50 miles) from the site. Poverty thresholds, which are a function of family size and the number of unmarried children under 18, will be used to identify the low-income populations. To avoid significant uncertainties in the population estimate due to partial inclusions of geographic units (such as census tracts, block groups, and blocks) at the boundaries of potentially affected areas, the unit area of spatial resolution will be significantly less than the affected area. Uncertainty bounds will be calculated by total inclusion (the upper bound) and total exclusion (the lower bound) of the populations residing within the affected area.

If the analysis finds no significant impacts on the general population, no further analysis of impacts on minority populations and low-income populations will be required. Instead, the discussion will state that no significant impacts are likely for the general population or any particular segment of the population. If the analysis shows significant impacts for the general population, then the same computational procedures will be performed separately for the minority and majority populations residing within the affected area. Disproportionate impacts will be quantified and discussed and mitigation measures presented.

Application

Since the environmental justice issue post-dates the EIS for every operating and partially completed reactor, it will be developed for each reactor under consideration.

Table B–1 Federal Environmental Statutes, Regulations, and Executive Orders[1]

Resource Category	*Statute/Regulation/Order*	*Citation*	*Responsible Agency*	*Potential Applicability: Permits, Approvals, Consultations, and Notifications*
Air Resources	CAA[2], as amended	42 U.S.C. §§7401 et seq.	EPA/State	Requires sources to meet standards and obtain permits to satisfy: NAAQS, State Implementation Plans, Standards of Performance for New Stationary Sources, NESHAP, and Prevention of Significant Deterioration regulations.
	NAAQS/State Implementation Plans	42 U.S.C. §§7409 et seq.	EPA/State	Requires compliance with primary and secondary ambient air quality standards governing SO_2, NO_x, CO, O_3, Pb, and PM_{10} and emission limits/reduction measures as designated in each state's State Implementation Plan.
	Standards of Performance for New Stationary Sources	42 U.S.C. §7411	EPA/State	Establishes control/emission standards and record keeping requirements for new or modified sources specifically addressed by a standard.
	NESHAP	42 U.S.C. §7412	EPA/State	Requires sources to comply with emission levels of carcinogenic or mutagenic pollutants; may require a preconstruction approval, depending on the process being considered and the level of emissions that will result from the new or modified source.
	Prevention of Significant Deterioration	42 U.S.C. §§7470 et seq.	EPA/State	Applies to areas that are in compliance with NAAQS. Requires comprehensive preconstruction review and the application of Best Available Control Technology to major stationary sources (emissions of 100 tons/year) and major modifications; requires a preconstruction review of air quality impacts and the issuance of a construction permit from the responsible state agency setting forth emission limitations to protect the Prevention of Significant Deterioration increment.
	Noise Control Act of 1972	42 U.S.C. §§4901 et seq.	EPA	Requires facilities to maintain noise levels that do not jeopardize the health and safety of the public.
Water Resources	CWA	33 U.S.C. §§1251 et seq.	EPA/State	Requires EPA or state-issued permits and compliance with provisions of permits regarding discharge of effluents to surface waters.
	NPDES (Section 402 of CWA)	33 U.S.C. § 1342	EPA/State	Requires permit to discharge effluents to surface waters and storm waters; permit modifications are required if discharge effluents are altered.
	Dredged or Fill Material (Section 404 of CWA)/Rivers and Harbors Appropriations Act of 1899	33 U.S.C. §1344/ 33 U.S.C. §§401 et seq.	U.S. Army Corps of Engineers	Requires permits to authorize the discharge of dredged or fill material into navigable waters or wetlands and to authorize certain structures.
	Wild and Scenic Rivers Act	16 U.S.C. §§ 1271 et seq.	FWS), Bureau of Land Management, Forest Service, National Park Service	Requires consultation before construction of any new Federal project associated with a river designated or under study as wild and scenic in order to minimize and mitigate any adverse effects on the physical and biological properties of the river.

Resource Category	Statute/Regulation/Order	Citation	Responsible Agency	Potential Applicability: Permits, Approvals, Consultations, and Notifications
Water Resources (continued)	SDWA	42 U.S.C. §§ 300f et seq.	EPA/State	Requires permits for construction/operation of underground injection wells and subsequent discharging of effluents to ground aquifers.
	Executive Order 11988: Floodplain Management	3 CFR, 1977 Comp., p. 117	Water Resources Council, Federal Emergency Management Agency, CEQ	Requires Federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative.
	Executive Order 11990: Protection of Wetlands	3 CFR, 1977 Comp., p. 121	U.S. Army Corps of Engineers/ FWS	Requires Federal agencies to avoid the long- and short-term adverse impacts associated with the destruction or modification of wetlands.
	Compliance with Floodplain/Wetlands Environmental Review Requirements	10 CFR 1022	DOE	Requires DOE to comply with all applicable floodplain/wetlands environmental review requirements.
Hazardous Wastes and Land Resources	RCRA/Hazardous and Solid Waste Amendments of 1984	42 U.S.C. §§6901 et seq. PL 98-616	EPA/State	Requires notification and permits for operations involving hazardous waste treatment, storage, or disposal facilities; changes to site hazardous waste operations could require amendments to RCRA hazardous waste permits involving public hearings.
	Farmland Protection Policy Act of 1981	7 U.S.C. §§4201 et seq.	Soil Conservation Service	Requires avoidance of any adverse effects to prime and unique farmlands.
	Federal Facility Compliance Act of 1992	42 U.S.C. §6961	States	Requires waivers of sovereign immunity for Federal facilities under RCRA and requires DOE to develop plans and enter into agreements with states as to specific management actions for specific mixed waste streams.
Ecology (Biotic Resources)	Fish and Wildlife Coordination Act	16 U.S.C. §§661 et seq.	FWS	Requires consultation on the possible effects on wildlife if there is construction, modification, or control of bodies of water in excess of 10 acres in surface area.
	Bald and Golden Eagle Protection Act	16 U.S.C. §§668 et seq.	FWS	Requires consultations to be conducted to determine if any protected birds are found to inhabit the area. If so, DOE must obtain a permit prior to moving any nests due to construction or operation of project facilities.
	Wilderness Act of 1964	16 U.S.C. §§1131 et seq.	DOC and DOI	Requires consultations with the DOC and DOI to minimize impact.
	Migratory Bird Treaty Act	16 U.S.C. §§703 et seq.	FWS	Requires consultation to determine if there are any impacts on migrating bird populations due to construction or operation of project facilities. If so, DOE will develop mitigation measures to avoid adverse effects.
	Wild Free-Roaming Horses and Burros Act of 1971	16 U.S.C. §§1331 et seq.	DOI	Requires consultation with DOI to minimize impact.
	Endangered Species Act of 1973	16 U.S.C. §§1531 et seq.	FWS/ National Marine Fisheries Service	Requires consultation to identify endangered or threatened species and biological opinions and, if necessary, develop mitigation measures to reduce or eliminate adverse effects of construction or operation.
Cultural Resources	National Historic Preservation Act of 1966, as amended	16 U.S.C. §§470 et seq.	President's Advisory Council on Historic Preservation	Requires consultation with the State Historic Preservation Office (SHPO) prior to construction to ensure that no historical properties will be affected.
	Archaeological and Historical Preservation Act of 1974	16 U.S.C. §§469 et seq.	DOI	Requires authorization for any disturbance of archaeological resources.
	Archaeological Resources Protection Act of 1979	16 U.S.C. §§470aa et seq.	DOI	Requires authorization for any excavation or removal of archaeological resources.

Resource Category	***Statute/Regulation/Order***	***Citation***	***Responsible Agency***	***Potential Applicability: Permits, Approvals, Consultations, and Notifications***
Cultural Resources (continued)	Antiquities Act	16 U.S.C. §§431-33	DOI	Requires compliance with all applicable sections of the Act.
	American Indian Religious Freedom Act of 1978	42 U.S.C. §1996	DOI	Requires consultation with local Native American Indian tribes prior to construction to ensure that their religious customs, traditions, and freedoms are preserved.
	Native American Graves Protection and Repatriation Act of 1990	25 U.S.C. §3001	DOI	Requires consultations with local Native American Indian tribes prior to construction to guarantee that no Native American graves are disturbed.
	Executive Order 11593: Protection and Enhancement of the Cultural Environment	3 CFR 154, 1971-1975 Comp., p. 559	DOI	Requires agencies to aid in the preservation of historic and archaeological data that may be lost during construction activities.
Public and Occupational Health and Safety	OSHA	5 U.S.C. §5108	OSHA	Requires agencies to comply with all applicable worker safety and health legislation (including guidelines of 29 CFR Part 1960) and to prepare, or have available, Material Safety Data Sheets.
	Standards for Protection Against Radiation	10 CFR 20	NRC	Establishes standards for protection of workers and the general public against radiation hazards arising out of activities under licenses issued by the NRC.
	Occupational Radiation Protection	10 CFR Part 835	DOE	Establishes radiation protection standards, limits, and program requirements for protecting individuals from ionizing radiation resulting from conduct of DOE activities.
	Hazard Communication Standard	29 CFR 1910.1200	OSHA	Requires agencies to ensure that workers are informed of, and trained to handle, all chemical hazards in the workplace.
Other	Atomic Energy Act of 1954	42 U.S.C. §2011	DOE	Requires DOE to follow its own standards and procedures to ensure the safe operation of its facilities.
	NEPA	42 U.S.C. §§4321 et seq.	DOE	Requires DOE to comply with NEPA implementing procedures in accordance with 10 CFR Part 1021.
	Toxic Substances Control Act 15 (TSCA)	U.S.C. §§2601 et seq.	EPA	Requires compliance with inventory reporting requirements and control provisions of TSCA to protect the public from the risks of exposure to chemicals; TSCA imposes strict limitations on use and disposal of PCB-contaminated equipment.
	Hazardous Materials Transport Action Act	49 U.S.C. §§1801 et seq.	DOT	Requires compliance with the requirements governing hazardous materials and waste transportation.
	Hazardous Materials Transportation Uniform Safety Act of 1990	49 U.S.C. §1801	DOT	Restricts shippers of highway route-controlled quantities of radioactive materials to use only permitted carriers.
	Emergency Planning and Community Right-To-Know Act of 1986	42 U.S.C. §§11001 et seq.	EPA	Requires the development of emergency response plans and reporting requirements for chemical spills and other emergency releases, and imposes right-to-know reporting requirements covering storage and use of chemicals which are reported in toxic chemical release forms.
	Pollution Prevention Act of 1990	42 U.S.C. 11001 - 11050	EPA	Establishes a national policy that pollution should be reduced at the source and requires a toxic chemical source reduction and recycling report for an owner or operator of a facility required to file an annual toxic chemical release form under Section 313 of SARA.
	Executive Order 12843: Procurement Requirements and Policies for Federal Agencies for Ozone-Depleting Substances	April 21, 1993	EPA	Requires Federal agencies to minimize procurement of ozone depleting substances and conform their practices to comply with Title VI of CAA Amendments (stratospheric ozone protection) and to recognize the increasingly limited availability of Class I substances until final phaseout.

Resource Category	*Statute/Regulation/Order*	*Citation*	*Responsible Agency*	*Potential Applicability: Permits, Approvals, Consultations, and Notifications*
Other (continued)	Executive Order 12856: Federal Compliance with Right-To-Know Laws and Pollution Prevention Requirements	August 3, 1993	EPA	Requires Federal agencies to achieve 50 percent reduction of agency's total releases of toxic chemicals to the environment and offsite transfers, to prepare a written facility pollution prevention plan not later than 1995, and to publicly report toxic chemicals entering any waste stream from Federal facilities, including any releases to the environment, and to improve local emergency planning, response, and accident notification.
	Executive Order 12873: Federal Acquisition, Recycling, and Waste Prevention	October 20, 1993	EPA	Requires Federal agencies to develop affirmative procurement policies and establishes a shared responsibility between the system program manager and the recycling community to effect use of recycled items for procurement.
	Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations	February 11, 1994	EPA	Requires Federal agencies to identify and address as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations.
	Executive Order 12088: Federal Compliance with Pollution Control Standards	3 CFR, 1978 Comp., p. 243	Office of Management and Budget	Requires Federal agency landlords to submit to OMB an annual plan for the control of environmental pollution and to consult with EPA and state agencies regarding the best techniques and methods.
	Executive Order 11514: Protection and Enhancement of Environmental Quality	3 CFR, 1966-1970 Comp., p. 902	CEQ	Requires Federal agencies to demonstrate leadership in achieving the environmental quality goals of NEPA; provides for DOE consultation with appropriate Federal, state, and local agencies in carrying out their activities as they affect the environment.
	Nuclear Waste Policy Act of 1982	42 U.S.C. §§10101 et seq.	DOE	Requires DOE to dispose of radioactive waste per 40 CFR 191 standards.
	Low-Level Radioactive Waste Policy Act	42 U.S.C. §§2021b -2021d	NRC	Requires DOE to dispose of low-level radioactive waste per compacts of the states in which it operates.

[1]The applicability of these may vary depending on the reactor and options under consideration.
[2]All acronyms used in this table are listed below.

CAA = Clean Air Act
CEQ = Council on Environmental Quality
CFR = Code of Federal Regulations
CWA = Clean Water Act
DOC = Department of Commerce
DOE = Department of Energy
DOI = U.S. Department of Interior
DOT = Department of Transportation
EPA = U.S. Environmental Protection Agency
FWS = U.S. Fish & Wildlife Service
NAAQS = National Ambient Air Quality Standards
NEPA = National Environmental Policy Act
NESHAP = National Emission Standards for Hazardous Air Pollutants
NPDES = National Pollutant Discharge Elimination System
NRC = U.S. Nuclear Regulatory Commission
OMB = Office of Management and Budget
OSHA = Occupational Safety and Health Administration
PCB = Polychlorinated Biphenyls
RCRA = Resource Conservation and Recovery Act
SARA = Superfund Amendments and Reauthorization Act
SDWA = Safe Drinking Water Act
SHPO = State Historic Preservation Office
TSCA = Toxic Substances Control Act
U.S.C. = United States Code

Table B–2 Relevant DOE Orders and NRC Guides

DOE Order	***DOE Order Title***
151.1	Comprehensive Emergency Management System
225.1	Accident Investigation
231.1	Environment Safety and Health Reporting
232.1	Occurrence Reporting and Processing of Operations Information
420.1	Facility Safety
425.1	Startup and Restart of Nuclear Facilities
440.1	Worker Protection Management for DOE Federal and Contractor Employee
451.1	National Environment Policy Act Compliance Program
460.1A	Packaging and Transportation Safety
470.1	Safeguards and Security Program
1230.2	American Indian Tribal Government Policy
5400.5	Radiation Protection of Public and Environment
5480.30	Nuclear Reactor Safety Design Criteria
5610.12	Packaging and Offsite Transportation of Nuclear Components, and Special Assemblies Associated with the Nuclear Explosion
List of NRC Regulatory Guides	
NRC Guide No.	***NRC Guide Title***
1.101	Emergency Planning and Preparedness for Nuclear Power Reactors
1.109	Calculation of Annual Dose to Man from Routine Releases of Reactor Effluents for the Purposes of Evaluating Compliance with 10 CFR Part 50, Appendix I
1.111	Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors
1.112	Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Reactors
1.113	Estimating Aquatic Dispersions of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I
1.145	Atmospheric Dispersion Models for Potential Accident Consequences Assessments at Nuclear Power Plants

B.13 REFERENCES

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DOE (U. S. Department of Energy), 1995, *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling*, DOE/EIS-0161, Office of Reconfiguration, Washington, DC, October 19.

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EPA (U.S. Environmental Protection Agency), 1997, *Integrated Risk Information System (IRIS), Substance Files*, Washington, DC, March 1.

NCRP (National Council On Radiation Protection and Measurements), 1991, *Effects of Ionizing Radiation on Aquatic Organisms*, NCRP Report No. 109, Bethesda, Maryland, August 30.

NCRP (National Council On Radiation Protection and Measurements), 1993, *Risk Estimates for Radiation Protection*, NCRP Report No. 115, Bethesda, Maryland, December 31.

NRC/NAS (National Research Council/National Academy of Sciences), 1990 *Health Effects of Exposure to Low Levels of Ionizing Radiation*, BEIR V, Washington, DC: National Academy Press, 1990.

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ORNL (Oak Ridge National Laboratory), 1993a, *HIGHWAY 3.1, An Enhanced Transportation Routing Model: Program Description, Methodology, and Revised User's Manual*, ORNL/TM-12124, Chemical Technology Division, Oak Ridge, Tennessee, March.

ORNL (Oak Ridge National Laboratory), 1993b, *INTERLINE 5.0, An Expanded Railroad Routing Model: Program Description, Methodology, and Revised User's Manual*, ORNL/TM-12090, Chemical Technology Division, Oak Ridge, Tennessee, March.

ORNL (Oak Ridge National Laboratory), Environmental Science Division, 1995 *Effects of Ionizing Radiation on Terrestrial Plants and Animals: A Workshop Report*, ORNL/TM-13141, Oak Ridge, Tennessee, December.

PNL (Pacific Northwest Laboratory), 1988, *GENII - The Hanford Environmental Radiation Dosimetry Software System*, PNL-6584, Richland, Washington, November.

SNL (Sandia National Laboratory), 1993, *RADTRAN 4 Volume II: Technical Manual*, SAND89-2370, Albuquerque, New Mexico, August.

SNL (Sandia National Laboratory), 1997, *Code Manual for MACCS2: Volume 1, User's Guide*, SAND97-0594, Albuquerque, New Mexico, March.

APPENDIX C
EVALUATION OF HUMAN HEALTH EFFECTS FROM NORMAL OPERATIONS

C.1 INTRODUCTION

This appendix provides a brief general discussion on radiation and its associated health effects and describes the method and assumptions used for estimating the potential impacts and risks to individuals and the general public from exposure to the releases of radioactivity and hazardous chemicals during normal operations at the proposed reactor facilities. This information is intended to present the assessment of impacts from normal operation during tritium production in the proposed reactors, as described in Chapter 5 of this environmental impact statement (EIS). Information regarding potential radiological impacts resulting from facility accidents is provided in Appendix D of this EIS.

This appendix presents numerical information using engineering and/or scientific notation. For example, the number 100,000 can also be expressed as 1×10^5. The fraction 0.00001 can also be expressed as 1×10^{-5}. The following chart defines the equivalent numerical notations that may be used in this appendix.

FRACTIONS AND MULTIPLES OF UNITS

Multiple	*Decimal Equivalent*	*Prefix*	*Symbol*
1×10^6	1,000,000	mega-	M
1×10^3	1,000	kilo-	k
1×10^2	100	hecto-	h
1×10	10	deka-	da
1×10^{-1}	0.1	deci-	d
1×10^{-2}	0.01	centi-	c
1×10^{-3}	0.001	milli-	m
1×10^{-6}	0.000001	micro-	
1×10^{-9}	0.000000001	nano-	n
1×10^{-12}	0.000000000001	pico-	p
1×10^{-15}	0.000000000000001	femto-	f
1×10^{-18}	0.000000000000000001	atto-	a

C.2 RADIOLOGICAL IMPACTS ON HUMAN HEALTH

Radiation exposure and its consequences are topics of interest to the general public. For this reason, this EIS places much emphasis on the consequences of exposure to radiation, provides the reader with background information on the nature of radiation, and explains the basic concepts used in the evaluation of radiation health effects. In addition, this section provides a brief description of the characteristics of tritium and its potential health effects.

C.2.1 Background Information

C.2.1.1 Nature of Radiation and Its Effects on Humans

What Is Radiation?

Radiation is energy transferred in the form of particles or waves. Globally, human beings are exposed constantly to radiation from the solar system and from the earth's rocks and soil. This radiation contributes to the natural background radiation that always surrounds us. Manmade sources of radiation also exist, including medical and dental x-rays, household smoke detectors, and materials released from nuclear and coal-fired power plants.

All matter in the universe is composed of atoms. Radiation comes from the activity of tiny particles within an atom. As stated earlier in Appendix A, an atom consists of positively charged nucleus (central part of an atom) with a number of negatively charged electron particles in various orbits around the nucleus. There are two types of particles in the nucleus; neutrons which are electrically neutral and protons which are positively charged. Atoms of different types are known as elements. There are more than 100 natural and manmade elements. An element has equal number of electrons and protons. When atoms of an element differ in their number of neutrons they are called isotopes of that element. All elements have three or more isotopes, some or all of which could be unstable (decays with time). For example, tritium, also known as hydrogen-3, has two neutrons and one protons is an unstable isotope of hydrogen which has one neutron and one proton. All isotopes of elements that have more than 83 protons in their nucleus are unstable.

The unstable isotopes undergo spontaneous change, known as radioactive disintegration or radioactive decay. The process of continuously undergoing spontaneous disintegration is called radioactivity. The radioactivity of a material decreases with time. The time it takes a material to lose half of its original radioactivity is its half-life. An isotope's half-life is a measure of its decay rate. For example, an isotope with a half-life of eight days, will lose one-half of its radioactivity in that amount of time. In eight more days, one-half of the remaining radioactivity will be lost, and so on. Each radioactive element has a characteristic half-life. The half-lives of various radioactive elements may vary from millionths of a second to millions of years.

As unstable isotopes change into more stable forms, they emit electrically charged particles. These particles may be either an alpha particle (a helium nucleus) or a beta particle (an electron), with various levels of kinetic energy. Sometimes these particles are emitted in conjunction with gamma rays. The alpha and beta particles are frequently referred to as ionizing radiation. Ionizing radiation refers to the fact that the charged particle energy force can ionize, or electrically charge, an atom by stripping off one of its electrons. Gamma rays, even though they do not carry an electric charge as they pass through an element, can ionize its atoms by ejecting electrons. Thus, they cause ionization indirectly. Ionizing radiation can cause a change in the chemical composition of many things, including living tissue (organs), which can affect the way they function.

When a radioactive isotope of an element emits a particle, it changes to an entirely different element, one that may or may not be radioactive. Eventually, a stable element is formed. This transformation, which may take several steps, is known as a decay chain. For example, radium which is a member of radioactive decay chain of uranium has a half-life of 1,622 years. It emits an alpha particle and becomes radon, a radioactive gas with a half-life of only 3.8 days. Radon decays first to polonium, then through a series of further decay steps to bismuth, and ultimately to lead, which is a stable element. Meanwhile, the decay products will build up, and will eventually die away as time progresses.

The characteristics of various forms of ionizing radiation are briefly described below and in the box at right (see Glossary for further definition):

Radiation Type	Typical Travel Distance in Air	Barrier
	Couple of centimeters	Sheet of paper or skin's surface
	Few meters	Thin sheet of aluminum foil or glass
	Very Large [a]	Thick wall of concrete, lead, or steel
n	Very Large	Water, Paraffin, Graphite

[a] *Would be infinite in a vacuum*

Alpha (

Alpha particles are the heaviest type of ionizing radiation. They can travel only a couple centimeters in air. Alpha particles lose their energy almost as soon as they collide with anything. They can be stopped easily by a sheet of paper or by the skin's surface.

Beta (

Beta particles are much (7,330 times) lighter than alpha particles. They can travel a longer distance than alpha particles in the air. A high energy beta particle can travel a few meters in the air. Beta particles can pass through a sheet of paper, but may be stopped by a thin sheet of aluminum foil or glass. Tritium emits a very low energy beta particle.

Gamma (

Gamma rays (and x-rays), unlike alpha or beta particles, are waves of pure energy. Gamma rays travel at the speed of light. Gamma radiation is very penetrating and requires a thick wall of concrete, lead, or steel to stop it.

Neutrons (n)

Neutrons are particles that contribute to radiation exposure both directly and indirectly. The most prolific source of neutrons is a nuclear reactor. Indirect radiation exposure occurs when gamma rays and alpha particles are emitted following neutron capture in matter. A neutron has about one quarter the weight of an alpha particle. It will travel in the air until it is absorbed in another element.

Units of Radiation Measure

During the early days of radiological experience, there was no precise unit of radiation measure. Therefore, a variety of units were used to measure radiation. These units were used to determine the amount, type, and intensity of radiation. Just as heat can be measured in terms of its intensity or effects using units of calories or degrees, amounts of radiation or its effects can be measured in unit of curies (Ci), radiation absorbed dose (rad), or dose equivalent (rem). The following summarizes those units (see also the definition in Glossary).

Curie

The curie, named after the French scientists Marie and Pierre Curie, describes the "intensity" of a sample of radioactive material. The rate of decay of 1 gram (g) of radium is the basis of this unit of measure. It is equal to 3.7×10^{10} disintegrations (decays) per second.

Rad

Radiation Units and Conversions to SI units

1 Ci = 3.7×10^{10} Becquerel (Bq)
1 rad = 0.01 Gray (Gy)
1 rem = 0.01 Sievert (Sv)
1 Gy = 1 Joule/kg
1 Bq = 1 disintegration per second

The rad is the unit of measurement for the physical absorption of radiation. The total energy absorbed per unit quantity of tissue is referred to as absorbed dose (or simply dose). As sunlight heats pavement by giving up an amount of energy to it, similarly radiation gives up rads of energy to objects in its path. One rad is equal to the amount of radiation that leads to the deposition of 0.01 Joule of energy per kilogram of absorbing material.

Rem

A rem is a measurement of the dose equivalent from radiation based on its biological effects. The rem is used in measuring the effects of radiation on the body as degrees Centigrade are used in measuring the effects of sunlight heating pavement. Thus, 1 rem of one type of radiation is presumed to have the same biological effects as 1 rem of any other kind of radiation. This allows comparison of the biological effects of radionuclides that emit different types of radiation.

The units of radiation measure in the International Systems of Units (referred to as SI units) are: Becquerel (a measure of source intensity [activity]), Gray (a measure of absorbed dose), and Sievert (a measure of dose equivalent).

An individual may be exposed to ionizing radiation externally (from a radioactive source outside the body) or internally (from ingesting or inhaling radioactive material). The external dose is different from the internal dose because an external dose is delivered only during the actual time of exposure to the external radiation source, but an internal dose continues to be delivered as long as the radioactive source is in the body. The dose from internal exposure is calculated over 50 years following the initial exposure; both radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate with the passage of time.

Sources of Radiation

The average American receives a total of approximately 300 mrem per year from all sources of radiation, both natural and manmade (NCRP 1987b). The sources of radiation can be divided into six different categories: (1) cosmic radiation, (2) terrestrial radiation, (3) internal radiation, (4) consumer products, (5) medical diagnosis and therapy, and (6) other sources (NCRP 1987b). These categories are discussed in the following paragraphs.

Cosmic Radiation

Cosmic radiation is ionizing radiation resulting from energetic charged particles from space continuously hitting the earth's atmosphere. These particles, and the secondary particles and photons they create, are cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with the altitude above sea level. The average dose to people in the United States from this source is approximately 27 mrem per year.

External Terrestrial Radiation

External terrestrial radiation is the radiation emitted from the radioactive materials in the Earth's rocks and soils. The average dose from external terrestrial radiation is approximately 28 mrem per year.

Internal Radiation

Internal radiation results from the human body metabolizing natural radioactive material that has entered the body by inhalation or ingestion. Natural radionuclides in the body include isotopes of uranium, thorium, radium, radon, polonium, bismuth, potassium, rubidium, and carbon. The major contributor to the annual dose equivalent for internal radioactivity are the short-lived decay products of radon, which contribute approximately 200 mrem per year. The average dose from other internal radionuclides is approximately 39 mrem per year.

Consumer Products

Consumer products also contain sources of ionizing radiation. In some products, such as smoke detectors and airport x-ray machines, the radiation source is essential to the products' operation. In other products, such as televisions and tobacco, the radiation occurs as the product's function. The average dose from consumer products is approximately 10 mrem per year.

Medical Diagnosis and Therapy

Radiation is an important diagnostic medical tool and cancer treatment. Diagnostic x-rays result in an average exposure of 39 mrem per year. Nuclear medical procedures result in an average exposure of 14 mrem per year.

Other Sources

There are a few additional sources of radiation that contribute minor doses to individuals in the United States. The dose from nuclear fuel cycle facilities (e.g., uranium mines, mills, and fuel processing plants), nuclear power plants, and transportation routes has been estimated to be less than 1 mrem per year. Radioactive fallout from atmospheric atomic bomb tests, emissions of radioactive material from nuclear facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials contribute less than 1 mrem per year to the average dose to an individual. Air travel contributes approximately 1 mrem per year to the average dose.

Exposure Pathways

As stated earlier, an individual may be exposed to ionizing radiation both externally and internally. The different ways that could result in radiation exposure to an individual are called exposure pathways. Each type of exposure is discussed separately in the following paragraphs.

External Exposure

External exposure can result from several different pathways, all having in common the fact that the radiation causing the exposure is external to the body. These pathways include exposure to a cloud of radiation passing over the receptor (e.g., an individual member of the public), standing on ground that is contaminated with radioactivity, and swimming or boating in contaminated water. If the receptor departs from the source of radiation exposure, the dose rate will be reduced. It is assumed that external exposure occurs uniformly during the year. The appropriate measure of dose is called the effective dose equivalent.

Internal Exposure

Internal exposure results from a radiation source entering the human body through either inhalation of contaminated air or ingestion of contaminated food and water. In contrast to external exposure, once a radiation source enters the body, it remains there for a period of time that varies depending on decay and biological half-lives. The absorbed dose to each organ of the body is calculated for a period 50 years following the intake. The dose equivalent of this absorbed dose is called the committed dose equivalent. Various organs have different susceptibilities to harm from radiation. The quantity that takes these different susceptibilities into account is called the committed effective dose equivalent, and it provides a broad indicator of the risk to the health of an individual from radiation. The committed effective dose equivalent is a weighted sum of the committed dose equivalent in each major organ or tissue. The concept of committed effective dose equivalent applies only to internal pathways.

Radiation Protection Guides

Various organizations have issued radiation protection guides. The responsibilities of the main radiation safety organizations, particularly those that affect policies in the United States, are summarized.

International Commission on Radiological Protection

This Commission has the responsibility for providing guidance in matters of radiation safety. The operating policy of this organization is to prepare recommendations to deal with basic principles of radiation protection and to leave to the various national protection committees the responsibility of introducing the detailed technical regulations, recommendations, or codes of practice best suited to the needs of their countries.

National Council on Radiation Protection and Measurements

In the United States, this Council is the national organization that has the responsibility to adapt and provide detailed technical guidelines for implementing the International Commission on Radiological Protection recommendations. The organization consists of technical experts who are specialists in radiation protection and scientists who are experts in disciplines that form the basis for radiation protection.

National Research Council/National Academy of Sciences

The National Research Council is an organization within the National Academy of Sciences that associates the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the Federal Government.

Limits of Radiation Exposure

Limits of exposure to members of the public and radiation workers are based on International Commission on Radiological Protection recommendations. Each regulatory organization adopts the International Commission on Radiological Protection's recommendations and sets specific annual exposure limits (usually less than those specified by the Commission). For nuclear facilities, annual exposure limits to the public are provided by the U.S. Nuclear Regulatory Commission (NRC) in 10 CFR 20, and 10 CFR 50, Appendix I. For accidents of unlikely probability of occurrence, (a likelihood of between 1-in-100 to 1-in-10,000 years), 10 CFR 100 provides the maximum exposure to the public residing at the site boundary. The dose limits for radiation workers are provided in 10 CFR 20. The U.S. Department of Energy (DOE) also has established a set of limits for radiation workers in 10 CFR 835. **Table C–1** provides the various exposure limits set by the NRC, DOE, and U.S. Environmental Protection Agency (EPA) for radiation workers and members of the public.

Table C–1 Exposure Limits for Members of the Public and Radiation Workers

Guidance Criteria (organization)	Public Exposure Limits at the Site Boundary	Worker Exposure Limits
Normal Operations		
10 CFR 20 (NRC)	100[a] mrem/yr, all pathways	5,000 mrem/yr
10 CFR 50, Appendix I (NRC)	5 mrem/yr, air (external); 3 mrem/yr, liquid (total body) 15 mrem/yr, air (maximum organ) 10 mrem/yr, liquid (maximum organ)	-
40 CFR 190 (EPA)	25 mrem/yr, all pathways	-
10 CFR 835 (DOE)	-	5,000 mrem/yr
DOE Order 5400.5 (DOE)	10 mrem/yr (all air pathways) 4 mrem/yr (drinking water pathway) 100 mrem/yr (all pathways)	-
40 CFR 61 (EPA)	10 mrem/yr (all air pathways)	-
Facility Accidents		
10 CFR 100.11 (NRC)[b]	25 rem (Total body dose from Gamma and Beta) 300 rem (Thyroid Inhalation Dose)	-

[a] An NRC licensee may apply for prior NRC authorization to operate up to an annual dose limit of 500 mrem for an individual member of the public.

[b] This guidance criteria is used to determine exclusion area and low population zone for a nuclear power plant site.

C.2.1.2 Health Effects

Radiation exposure and its consequences are topics of interest to the general public. To provide the background for discussions of impacts, this section explains the basic concepts used in the evaluation of radiation effects.

Radiation can cause a variety of damaging health effects in people. The most significant effects are induced cancer fatalities. These effects are referred to as "latent" cancer fatalities because the cancer may take many years to develop. In the discussions that follow, all fatal cancers are considered latent; therefore, the term "latent" is not used.

The National Research Council's Committee on the Biological Effects of Ionizing Radiation (BEIR) has prepared a series of reports to advise the U.S. Government on the health consequences of radiation exposures. *Health Effects of Exposure to Low Levels of Ionizing Radiation*, BEIR V, (NAS 1990), provides the most current estimates for excess mortality from leukemia and cancers other than leukemia that are expected to result from exposure to ionizing radiation. BEIR V provides estimates that are consistently higher than those in its predecessor, BEIR III. This increase is attributed to several factors, including the use of a linear dose response model for cancers other than leukemia, revised dosimetry for the Japanese atomic bomb survivors, and additional follow-up studies of the atomic bomb survivors and other cohorts. BEIR III employs constant relative and absolute risk models, with separate coefficients for each of several sex and age-at-exposure groups. BEIR V develops models in which the excess relative risk is expressed as a function of age at exposure, time after exposure, and sex for each of several cancer categories. The BEIR III models were based on the assumption that absolute risks are comparable between the atomic bomb survivors and the U.S. population. BEIR V models were based on the assumption that the relative risks are comparable. For a disease such as lung cancer, where baseline risks in the United States are much larger than those in Japan, the BEIR V approach leads to larger risk estimates than the BEIR III approach.

The models and risk coefficients in BEIR V were derived through analyses of relevant epidemiologic data that included the Japanese atomic bomb survivors, ankylosis spondylitis patients, Canadian and Massachusetts fluoroscopy (breast cancer) patients, New York postpartum mastitis (breast cancer) patients, Israeli Tinea Capitis (thyroid cancer) patients, and Rochester thymus (thyroid cancer) patients. Models for leukemia, respiratory cancer, digestive cancer, and other cancers used only the atomic bomb survivor data, although results of analyses of the ankylosis spondylitis patients were considered. Atomic bomb survivor analyses were based on revised dosimetry, with an assumed relative biological effectiveness of 20 for neutrons, and were restricted to doses less than 400 rads. Estimates of risks of fatal cancers other than leukemia were obtained by totaling the estimates for breast cancer, respiratory cancer, digestive cancer, and other cancers.

The National Council on Radiation Protection and Measurements (NCRP 1993), based on the radiation risk estimates provided in BEIR V and the International Commission on Radiological Protection Publication 60 recommendations (ICRP 1991), has estimated the total detriment resulting from low dose[1], or low dose rate exposure to ionizing radiation to be 0.00073 per rem for the general population and 0.00056 per rem for the working population. The total detriment includes fatal and nonfatal cancer and severe hereditary (genetic) effects. The major contribution to the total detriment is from fatal cancer and is estimated to be 0.0004 and 0.0005 per rem for the radiation workers and the general population, respectively. **Table C–2** provides the breakdown of the risk factors for both the workers and the general population.

Table C–2 Nominal Health Effects Coefficients (Risk Factors) from Ionizing Radiation

Exposed Population	*Fatal Cancer*[a,c]	*Nonfatal Cancer*[b]	*Genetic Disorders*[b]	*Total*
Working Population	0.0004	0.00008	0.00008	0.00056
General Population	0.0005	0.0001	0.00013	0.00073

a For fatal cancer, the health effect coefficient is the same as the probability coefficient.
b In determining a means of assessing health effects from radiation exposure, the International Commission on Radiological Protection (ICRP) has developed a weighting method for nonfatal cancers and genetic effects. Genetic effects can only be applied to a population, not individuals.
c For high individual exposures (

Source: NCRP 1993.

The numerical estimates of cancer fatalities presented in this EIS were obtained using a linear extrapolation from nominal risk estimated for lifetime total cancer mortality at 0.1 Cy (10 rad). Other methods of extrapolation to the low-dose region could yield higher or lower numerical estimates of cancer fatalities. Studies of human populations exposed to low doses are inadequate to demonstrate the actual level of risk. There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiologic observation, and the possibility of no risk cannot be excluded (CIRRPC 1992).

Health Effect Risk Factors Used in This EIS

Health impacts from radiation exposure, whether from sources external or internal to the body, generally are identified as "somatic" (i.e., affecting the exposed individual) or "genetic" (i.e., affecting descendants of the exposed individual). Radiation is more likely to produce somatic effects than genetic effects. The somatic risks of most importance are induced cancers. Except for leukemia, which can have an induction period (time between

[1]*The low dose is defined as the dose level where DNA repair can occur in a few hours after irradiation-induced damage. Currently, a dose level of about 0.2 Gy (20 rad), or a dose rate of 0.1m Gy (0.01 Rad) per minute is considered to allow the DNA to repair itself in a short period (EPA 1994).*

exposure to carcinogen and cancer diagnosis) of as little as 2 to 7 years, most cancers have an induction period of more than 20 years.

For a uniform irradiation of the body, the incidence of cancer varies among organs and tissues; the thyroid and skin demonstrate a greater sensitivity than other organs. Such cancers, however, also produce relatively low mortality rates because they are relatively amenable to medical treatment. Because of the readily available data for cancer mortality rates and the relative scarcity of prospective epidemiologic studies, somatic effects leading to cancer fatalities rather than cancer incidence are presented in this EIS. The numbers of cancer fatalities can be used to compare the risks among the various alternatives.

Based on the preceding discussion and the values presented in Table C–2, the fatal cancers to the general public during normal operations and for accidents in which individual doses are less than 20 rem are calculated using a health risk factor of 0.0005 per person-rem. For workers, a risk factor of 0.0004 excess fatal cancer per person-rem is used. This lower value reflects the absence of children (who are more radiosensitive than adults) in the workforce. Nonfatal cancer and genetic disorders among the public are 20 and 26 percent, respectively, of the fatal cancer risk factor. For workers, the health risk estimators are both 20 percent of the fatal cancer risk factor. These factors are not used in this EIS.

The risk factors are used to calculate the statistical expectance of the effects of exposing a population to radiation. For example, in a population of 100,000 people exposed only to natural background radiation (300 mrem per year), it is expected that about 15 latent cancer fatalities per year of exposure would result from this radiation (100,000 persons × 0.3 rem per year × 0.0005 latent cancer fatalities per person-rem = 15 latent cancer fatalities per year).

Calculations of the number of excess cancer fatalities associated with radiation exposure do not always yield whole numbers; calculations may yield numbers less than 1.0, especially in environmental impact applications. For example, if a population of 100,000 were exposed to a total dose of only 0.001 rem per person, the collective dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons × 0.001 rem × 0.0005 latent cancer fatalities per person-rem = 0.05 latent cancer fatalities). The latent cancer fatality of 0.05 is the *expected* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people. In most groups, no person (0 people) would incur a latent cancer fatality from the 0.001 rem dose each member would have received. In a small fraction of the groups, 1 latent cancer fatality would result; in exceptionally few groups, 2 or more latent cancer fatalities would occur. The *average* expected number of deaths over all the groups would be 0.05 latent cancer fatalities (just as the average of 0, 0, 0, and 1 is 1/4, or 0.25). The most likely outcome is 0 latent cancer fatalities.

These same concepts apply to estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The "number of latent cancer fatalities" corresponding to a single individual's exposure over a (presumed) 72-year lifetime to 0.3 rem/yr is 0.011 latent cancer fatalities (1 person × 0.3 rem/yr × 72 yr × 0.0005 latent cancer fatalities/person-rem = 0.011 latent cancer fatalities).

Again, this is a statistical estimate. That is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.1 percent chance that the individual might incur a latent cancer fatality caused by the exposure over his full lifetime. Presented another way, this method estimates that approximately 1.1 percent of the population might die of cancers induced by background radiation.

C.2.2 Tritium Characteristics and Biological Properties

C.2.2.1 Tritium Characteristics

Ordinary hydrogen (also called protium), deuterium, and tritium are the three isotopes of hydrogen. Tritium is the only one of the three isotopes that is radioactive. The nucleus of a hydrogen atom contains one proton, a positively charged particle. Around this nucleus orbits a single electron, a negatively charged particle that has a significantly smaller mass than the proton. The most common form of hydrogen, comprising over 99.9 percent of all naturally occurring hydrogen, has one proton and no neutrons. The nucleus of a deuterium atom, comprising approximately 0.015 percent of all hydrogen, contains one proton and one neutron. The nucleus of the tritium atom contains one proton and two neutrons. Tritium makes up only 1×10^{-18} percent of natural hydrogen. The chemical symbol for hydrogen is H. When designating the different isotopes, the isotopic number is added to the symbol so that protium becomes H^1, deuterium H^2, and tritium H^3. Deuterium and tritium are also represented as D and T, respectively.

In the radioactive decay of tritium, the nucleus emits a beta particle, a negatively charged particle similar to an electron. Upon emission of the beta particle the tritium atom is transformed into a helium atom with two protons and one neutron. Tritium has a half life of approximately 12.3 years. Any amount of tritium will be reduced by 10 percent in two years, 25 percent in five years, 50 percent in 12.3 years, and 90 percent in 42 years.

As stated earlier, the emitted beta particle is a form of ionizing radiation. It will interact with the atoms and molecules in the environment around the tritium atom, ionizing atoms by removing electrons from their orbit. The beta particles emitted from a decaying tritium atom are relatively low energy particles and can be stopped by a sheet of paper or skin. Therefore, health effects on humans may result from ingestion (either eating or drinking), inhalation, or skin absorption of tritium. External exposure to tritium does not pose a significant health risk.

Because tritium undergoes radioactive decay, it must be constantly created through either natural or manmade processes. Natural sources of tritium result from the interaction of cosmic radiation and gases in the upper atmosphere. Nuclear power reactors are one manmade source for producing tritium. In a reactor core, lithium can be transformed into tritium via neutron capture. The lithium atom, with three protons and three neutrons, and the captured neutron combine to form a lithium atom with three protons and four neutrons that will instantaneously split to form an atom of tritium (one proton and two neutrons) and an atom of helium (two protons and two neutrons).

The following information on the biological impact of tritium is taken from the *Primer on Tritium Safe Handling Practices* (DOE 1994).

C.2.2.2 Biological Properties of Tritium

At most tritium facilities, the most commonly encountered forms of tritium are tritium gas (HT) and tritium oxide, also called "tritiated water." Other forms of tritium may be present, such as metal tritides, tritiated pump oil, and tritiated gases like methane and ammonia. Deuterated and tritiated compounds generally have the same chemical properties as their protium counterparts, although some minor isotopic differences in reaction rates exist. These various tritiated compounds have a wide range of metabolic properties in humans under similar exposure conditions. For example, inhaled tritium gas is only slightly incorporated into the body during exposure, and the remainder is rapidly removed by exhalation following the exposure. On the other hand, tritiated water vapor is readily taken up and retained in the body water. This discussion is limited to the effects of tritium gas and tritium oxide, the two compounds with the potential to have the most significant impact on workers and the public.

Metabolism of Gaseous Tritium

During a brief exposure to tritium gas, the gas would be inhaled and a small amount would be dissolved in the bloodstream. The dissolved gas would circulate in the bloodstream before being exhaled along with the gaseous waste products (carbon dioxide) and normal water vapor. If the exposure persists, the gas will reach other body fluids. A small percentage of the gaseous tritium would be converted to tritium oxide, most likely by oxidation in the gastrointestinal tract. Early experiments involving human exposure to a concentration of 9 µCi/ml resulted in an increase in the tritium oxide concentration in urine of 7.7×10^{-3} µCi/ml per hour of exposure. Although independent of the breathing rate, this conversion can be expressed as the ratio of the tritium oxide buildup to the tritium inhaled as tritium gas at a nominal breathing rate (20 liters per minute). In this context, the conversion is 0.003 percent of the total gaseous tritium inhaled. More recent experiments with six volunteers resulted in a conversion of 0.005 percent. For gaseous tritium exposures, there are two doses: (1) a lung dose from the tritium in the air inside the lung, and (2) a whole body dose from the tritium gas that has been converted to tritium oxide. The tritiated water converted from the gas in the body behaves as an exposure to tritiated water. Intake of gaseous tritium through the skin has been found to have negligible effects compared with those from inhalation. Small amounts of tritium can enter the skin through unprotected contact with contaminated metal surfaces, which results in organically bound tritium in skin and in urine.

Metabolism of Tritiated Water

The biological incorporation (uptake) of airborne tritium oxide can be extremely efficient—up to 99 percent of inhaled tritium oxide would be taken into the body by the circulating blood. Ingested liquid tritium oxide also would be almost completely absorbed by the gastrointestinal tract and would quickly appear in the blood stream. Within minutes, it would be found in varying concentrations in the organs, fluids, and tissues of the body. Skin absorption of airborne tritium oxide is also important, especially during hot weather, because of the normal movement of water through the skin. For skin temperatures between 30 and 40

of tritium oxide is about 50 percent of that for tritium oxide by inhalation (assuming an average breathing rate associated with light work, 20 liters per minute). No matter how it is absorbed, the tritium oxide would be uniformly distributed in all biological fluids within one to two hours. In addition, a small fraction of the tritium would be incorporated into easily exchanged hydrogen sites in organic molecules. Hence, retention of tritiated water can be described as the sum of several terms: (1) shorter-term retention time associated with the tritium oxide that characteristically behaves like body water, and (2) longer-term retention time that represents the tritium incorporated in body organs.

Biological Half-Life of Tritium Oxide (Tritiated Water)

Biological half-life is a measure of how long tritium would remain in the human body. Studies of biological elimination rates of body water in humans date back to 1934, when the body water turnover rate was measured using deuteriated water, a water molecule containing deuterium (H^2). Since that time, several additional studies have been conducted with deuteriated water and tritiated water. A simple average of the data suggests a value of 9.5 days for the measured biological half-life of water in the body with a deviation of ±50 percent.

Calculations based on total fluid intake indicate a similar value. This is reasonable because the turnover rate of tritiated water should be identical to that of body water. In other words, the biological half-life of tritium is a function of the average daily throughput of water. The biological half-life of tritium oxide has been studied when outdoor temperatures varied at the time of tritium uptake. The data suggest that biological half-lives are shorter in warmer months (a measured 7.5-day half-life in an environment with a mean outdoor temperature of 27

(~81 an environment with a mean outdoor temperature

of 17 3

perspiration. As such, the skin absorption and perspiration pathways can become an important part of body water exchange routes. It is important to note that personnel who are perspiring will have a greater absorption of tritium from contact with tritiated surfaces.

Prolonged exposures can be expected to affect the biological half-life. This results from the longer-term components of the retention of tritium in the body. Tritium's interaction with organic hydrogen can result in additional half-life components ranging from 21 to 30 days and 250 to 550 days. The shorter duration indicates that organic molecules in the body retain tritium relatively briefly. The longer duration indicates long-term retention by other compounds in the body that do not readily exchange hydrogen or that metabolize more slowly. However, the overall contribution from organically bound tritium is relatively small, that is, less than about 5 percent for acute exposures and about 10 percent for chronic exposures. Methods used to compute the annual limits on intake of air and water specify only the body water component and include the assumption of a 10-day biological half-life, as mentioned above.

Bioassay and Internal Dosimetry

Exposure to tritium oxide is by far the most important type of tritium exposure. The tritium oxide enters the body by inhalation or skin absorption. When immersed in tritiated water vapor, the body takes in approximately twice as much tritium through the lungs as through the skin. Once in the body, it is circulated by the blood stream and finds its way into fluids both inside and outside the cells.

According to the International Commission on Radiological Protection (ICRP 1980), the derived air concentration for tritium gas and tritium oxide are 540,000 $\mu Ci/m^3$ and 21.6 $\mu Ci/m^3$, respectively. The derived air concentration is defined as that concentration of a gas which, if a worker were exposed to it for one working year (2,000 hours), would result in an annual dose of 5 rem. The ratio of these derived air concentrations (25,000) is based on a lung exposure from the gas and a whole body exposure from the oxide. However, as was noted earlier, when a person is exposed to tritium gas in the air, an additional dose actually results—one to the whole body. During exposure to tritium gas, a small fraction of the tritium exchanges in the lung and is transferred by the blood to the gastrointestinal tract where it is oxidized by enzymes. This process results in a buildup of tritium oxide until the tritium gas is removed by exhalation at the end of the exposure. The resultant dose from exposure to this tritium oxide is roughly comparable to the lung dose from exposure to tritium gas. Thus, the total effective dose from a tritium gas exposure is about 10,000 times less than the total effective dose from an equal exposure to airborne tritium oxide.

C.2.2.3 Genetic Effects of Tritium

As stated earlier, tritium moves readily through the blood stream after uptake in the body. The low energy of tritium beta particle emissions limit its range in tissue and results in a unique radiation dose pattern. The potential genetic hazard of tritium has been studied in a variety of systems using both prokaryotes[2] and eukaryotes[3]. This research, presented at the "Workshop on Tritium Radiobiology and Health Physics," has been summarized in NCRP Report No. 63 (NCRP 1979). A review of these studies, as given in the NCRP Report No. 89 (NCRP 1987a), concluded that, although transmutational effects exist in both whole animals and *in vitro* cell systems, their effects in the whole animal relative to the effect from a beta particle dose from tritium are small and should receive minor consideration in estimating genetic risks from tritium.

Additional studies were performed as a result of: (1) allegations of links between tritium releases and deaths from congenital anomalies around Canada's Pickering Nuclear Generating Station, and (2) concerns about excess

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[2]*Prokaryotes are cellular organisms, such as bacteria or blue-green algae, that do not have a distinct nucleus.*

[3]*Eukaryotes are organisms with one or more cells that have a visible, evident nucleus.*

cancers from tritium releases during a 1960's detonation in an underground salt dome in Lamar County, Mississippi.

In the first study (AECB 1991), conducted for the Atomic Energy Board of Canada, the analysis did not support the hypothesis of increased rates of stillbirths, neonatal mortality, increased prevalence of birth defects, or significant correlation between tritium release and Down's Syndrome. In the second study (Richter and Stockwell 1998), conducted by the DOE Office of Epidemiological Studies, the investigators found no association between cancer mortality and distance from the center of detonation.

C.3 METHODOLOGY FOR ESTIMATING RADIOLOGICAL IMPACTS

The radiological impacts from normal operation of the reactor facilities were calculated using Version 1.485 of the GENII computer code (PNL 1988). Site-specific input data were used, including location, meteorology, population, food production and consumption, and source terms. Section C.3.1 briefly describes GENII and outlines the approach used for normal operations.

C.3.1 GENII Computer Code

The GENII computer model, developed by Pacific Northwest Laboratory, is an integrated system of various computer modules that analyze environmental contamination resulting from acute or chronic releases to, or initial contamination in, air, water, or soil. The model calculates radiation doses to individuals and populations. The GENII computer model is well documented for assumptions, technical approach, method, and quality assurance issues (PNL 1988). The GENII computer model has gone through extensive quality assurance and quality control steps, including comparing results from model computations with those from hand calculations and performing internal and external peer reviews. Recommendations given in these reports were incorporated into the final GENII computer model, as appropriate.

For this EIS, only the ENVIN, ENV, and DOSE computer modules were used. The codes are connected through data transfer files. The output of one code is stored in a file that can be used by the next code in the system. The functions of the three GENII computer modules used in this EIS are discussed below.

ENVIN

The ENVIN module of the GENII code controls the reading of input files and organizes the input for optimal use in the environmental transport and exposure module, ENV. The ENVIN code interprets the basic input, reads the basic GENII data libraries and other optional input files, and organizes the input into sequential segments based on radionuclide decay chains.

A standardized file that contains scenario, control, and inventory parameters is used as input to ENVIN. Radionuclide inventories can be entered as functions of releases to air or water, concentrations in basic environmental media (air, soil, or water), or concentrations in foods. If certain atmospheric dispersion options have been selected, this module can generate tables of atmospheric dispersion parameters that will be used in later calculations. If the finite plume air submersion option is requested in addition to the atmospheric dispersion calculations, preliminary energy-dependent finite plume dose factors can be prepared as well. The ENVIN module prepares the data transfer files that are used as input by the ENV module; ENVIN generates the first portion of the calculation documentation—the run input parameters report.

ENV

The ENV module calculates the environmental transfer, uptake, and human exposure to radionuclides that result from the chosen scenario for the user-specified source term. The code reads the input files from ENVIN and then, for each radionuclide chain, sequentially performs the precalculations to establish the conditions at the start of the exposure scenario. Environmental concentrations of radionuclides are established at the beginning of the scenario by assuming decay of preexisting sources, considering biotic transport of existing subsurface contamination, and defining soil contamination from continuing atmospheric or irrigation depositions. For each year of postulated exposure, the code then estimates the air, surface soil, deep soil, groundwater, and surface water concentrations of each radionuclide in the chain. Human exposures and intakes of each radionuclide are calculated for: (1) pathways of external exposure from finite atmospheric plumes; (2) inhalation; (3) external exposure from contaminated soil, sediments, and water; (4) external exposure from special geometries; and (5) internal exposures from consumption of terrestrial foods, aquatic foods, drinking water, animal products, and inadvertent intake of soil. The intermediate information on annual media concentrations and intake rates are written to data transfer files. Although these may be accessed directly, they are usually used as input to the DOSE module of GENII.

DOSE

The DOSE module reads the intake and exposure rates defined by the ENV module and converts the data to radiation dose.

C.3.2 Data and General Assumptions

To perform the dose assessments for this EIS, different types of data were collected and generated. In addition, calculational assumptions were made. This section discusses the data collected and generated (SAIC 1998) for use in performing the dose assessments and the assumptions made for this EIS.

Meteorological Data

The meteorological data used for all normal operational scenarios discussed in this EIS were in the form of joint frequency data files. A joint frequency data file is a table listing the fractions of time the wind blows in a certain direction, at a certain speed, and within a certain stability class. The joint frequency data files were based on measurements taken over a period of several years at different locations and heights at each of the sites. Average annual meteorological conditions (averaged over the measurement period) as given in the plant's final safety analysis reports were used for normal operation.

Population Data

Population distributions were based on the *1990 Census of Population and Housing* data (DOC 1992). Projections were determined for the year 2025 (approximate midlife of operations) for areas within 80 kilometers (50 miles) of the release location at the three candidate reactor sites. The site population in 2025, assumed to be representative of the population over the operational period evaluated, was used in the impact assessments. The population was spatially distributed on a circular grid with 16 directions and 10 radial distances up to 80 kilometers (50 miles). The grid was centered at the precise location from which the radionuclides were assumed to be released.

Source Term Data

The TPBAR source terms (i.e., quantities of tritium [in the form of tritium oxide] released to the environment over a given period) were estimated based on anticipated TPBAR characteristic releases. The source terms used to generate the estimated incremental impacts of normal operations are provided in Section C.3.4 for each of the three candidate reactor sites evaluated in this EIS.

Food Production and Consumption Data

Data from the *1992 Census of Agriculture* (DOC 1993) were used to generate site-specific data for food production. Food production was spatially distributed on the same circular grid used for the population distributions. The consumption rates used in GENII were those for the maximum individual and average individual. People living within the 80 kilometer (50 mile) assessment area were assumed to consume only food grown in that area.

Calculational Assumptions

Dose assessments were performed for both members of the general public and workers for each reactor site examined in this EIS. These assessments were made to determine the *incremental* doses that would be associated with the tritium production alternatives addressed in this EIS. Incremental doses for members of the public were calculated (via GENII) for two different types of receptors:

- **Maximally Exposed Offsite Individual**—The maximally exposed individual was assumed to be located at a position on the site boundary that would yield the highest impacts during normal operations of a given alternative.

- **Population—**The general population living within 80 kilometers (50 miles) of the facility in the year 2025.

To estimate radiological impacts from normal operations, the following additional assumptions and factors were considered in using GENII:

- Radiological gaseous emissions were assumed to be released to the atmosphere through the plant stack; for Watts Bar 1 and Sequoyah 1 or 2 the stack height is 40 meters (131 feet) and for Bellefonte 1 or 2 it is 83 meters (272 feet);

- Ground surfaces were assumed to have no previous deposition of radionuclides;

- The annual external exposure time to the plume and to soil contamination was 0.7 year (16.8 hours per day) for the maximally exposed offsite individual (NRC 1977b);

- The annual external exposure time to the plume and to soil contamination was 0.5 year (12 hours per day) for the population (NRC 1977b);

- The inhalation exposure time to the plume was 1.0 year for the maximally exposed individual and general population;

- The exposed individual or population was assumed to have the characteristics and habits (e.g., inhalation and ingestion rates) of an adult human;

- A semi-infinite/finite plume model was used for air immersion doses. Other pathways evaluated were ground exposure, inhalation, ingestion of food crops and animal products contaminated by either deposition of radioactivity from the air or irrigation, ingestion of fish and other aquatic food raised in contaminated water, swimming and boating in contaminated surface water, and drinking contaminated water. All applicable pathways (e.g., inhalation, drinking water, external exposure) were analyzed at each of the three reactor site locations;

- Reported release heights were used for atmospheric releases and were assumed to be the effective stack height. The resultant doses were conservative, as use of the actual stack height negates plume rise;

- The calculated doses were 50-year committed doses from 1 year of intake;

- Average volumetric river flow rates (measured locally downstream of each site; see Table C–6) were used;

- Individual annual exposure times to swimming, boating and shoreline recreation were taken from site environmental reports and NRC Regulatory Guide 1.109, as appropriate (TVA 1997, NRC 1995, TVA 1974a, TVA 1974b, NRC 1977b);

- For conservatism, a transit time of zero was assumed for releases to reach aquatic recreation areas;

- The year 2025 drinking water population was estimated by applying the same growth factor as given for the entire 80 kilometer (50 mile) radius population within each respective plant's final environmental statement (NRC 1995, AEC 1974, TVA 1974a). The estimated fish eating population in year 2025 was conservatively assumed to equal the drinking water population;

- Drinking water treatment was assumed, with a holdup (transit) time of 0.5 days for Watts Bar and Sequoyah Nuclear Plants and 0.2 days for Bellefonte Nuclear Plant;

- Annual drinking water quantities for the average and maximally exposed individual were referenced from NRC Regulatory Guide 1.109 (NRC 1977b); and

- Fish consumption data were referenced from NRC Regulatory Guide 1.109 (NRC 1977b).

The exposure, uptake, and usage parameters used in the GENII model for normal operations are provided in **Table C–3, Table C–4, Table C–5** and **Table C–6**.

Incremental worker doses associated with tritium production activities were determined from historical data associated with similar operations (TVA 1998b). Very small incremental doses to reactor facility workers may result from refueling outage activities and increased resin bed handling. Estimated baseline and incremental worker doses at the reactor sites are supplied in referenced data reports (TVA 1998a, NRC 1997). Worker doses are provided in Section 5 of this EIS.

C.3.3 Uncertainties

The sequence of analyses performed to generate the radiological impact estimates from normal operation include: (1) selection of normal operational modes, (2) estimation of source terms, (3) estimation of environmental transport and uptake of radionuclides, (4) calculation of radiation doses to exposed individuals, and (5) estimation of health effects. There are uncertainties associated with each of these steps. Uncertainties exist in the way the physical systems being analyzed are represented by the computational models and in the data required to exercise the models (due to measurement, sampling, or natural variability).

Table C–3 GENII Exposure Parameters to Plumes and Soil Contamination (Normal Operations)

Maximum Individual				*General Population*			
External Exposure		*Inhalation of Plume*		*External Exposure*		*Inhalation of Plume*	
Plume (hours)	*Soil Contamination (hours)*	*Exposure Time (hours)*	*Breathing Rate (cm^3/sec)*	*Plume (hours)*	*Soil Contamination (hours)*	*Exposure Time (hours)*	*Breathing Rate (cm^3/sec)*
6,136	6,136	8,766	270	4,383	4,383	8,766	270

cm^3/sec = cubic centimeter per second
Source: PNL 1988.

Table C–4 GENII Usage Parameters for Consumption of Terrestrial Food (Normal Operations)

	Maximum Individual				*General Population*			
Food Type	*Growing Time (days)*	*Yield (kg/m^2)*	*Holdup Time (days)*	*Consumption Rate (kg/yr)*	*Growing Time (days)*	*Yield (kg/m^2)*	*Holdup Time (days)*	*Consumption Rate (kg/yr)*
Leafy Vegetables	90.0	1.5	1.0	30.0	90.0	1.5	14.0	15.0
Root Vegetables	90.0	4.0	5.0	220.0	90.0	4.0	14.0	140.0
Fruit	90.0	2.0	5.0	330.0	90.0	2.0	14.0	64.0
Grains/Cereals	90.0	0.8	180.0	80.0	90.0	0.8	180.0	72.0

kg/m^2 = kilogram per square meter   kg/yr = kilogram per year
Source: PNL 1988.

Table C–5 GENII Usage Parameters for Consumption of Animal Products (Normal Operations)

			Animal Stored Feed				*Animal Fresh Forage*			
Food Type	*Human Consumption Rate (kg/yr)*	*Holdup Time (days)*	*Diet Fraction*	*Growing Time (days)*	*Yield (kg/m^2)*	*Storage Time (days)*	*Diet Fraction*	*Growing Time (days)*	*Yield (kg/m^2)*	*Storage Time (days)*
Maximum Individual										
Beef	80.0	15.0	0.25	90.0	0.80	180.0	0.75	45.0	2.00	100.0
Poultry	18.0	1.0	1.00	90.0	0.80	180.0	–	–	–	–
Milk	270.0	1.0	0.25	45.0	2.00	100.0	0.75	30.0	1.50	0.00
Eggs	30.0	1.0	1.00	90.0	0.80	180.0	–	–	–	–
General Population										
Beef	70.0	34.0	0.25	90.0	0.80	180.0	0.75	45.0	2.00	100.0
Poultry	8.5	34.0	1.0	90.0	0.80	180.0	–	–	–	–
Milk	230.0	3.0	0.25	45.0	2.00	100.0	0.75	30.0	1.50	0.00
Eggs	20.0	18.0	1.0	90.0	0.80	180.0	–	–	–	–

kg/yr = kilogram per year kg/m^2 = kilogram per square meter
Source: PNL 1988.

Table C–6 GENII Liquid Pathway Parameters (Normal Operations)

	Plant		
Parameter	*Sequoyah*	*Watts Bar*	*Bellefonte*
Average river volumetric flow rate (m^3/s)	850	940	1,100
Swimming exposure time per year (hr)	918 – Maximum 22 – Average	918 – Maximum 22 – Average	918 – Maximum 22 – Average

Parameter	Plant		
	Sequoyah	Watts Bar	Bellefonte
Boating exposure time per year (hr)	1,500 – Maximum 104 – Average	1,500 – Maximum 104 – Average	1,500 – Maximum 104 – Average
River shoreline exposure time per year (hr)	500–Maximum 8.3–Average	500–Maximum 8.3–Average	500–Maximum 8.3–Average
Transit time for releases to reach aquatic recreation	0	0	0
Yr. 2025 population ingesting drinking water and fish	524,000	274,000	230,000
Drinking water holdup time (days)	0.5	0.5	0.2[a]
Drinking water consumption rate (l/yr)	730–Maximum 370–Average	730–Maximum 370–Average	730–Maximum 370–Average
Fish Consumption Rate (lb/yr)	45–Maximum 15.2–Average	45–Maximum 15.2–Average	45–Maximum 15.2–Average

[a] This value is calculated based on average river water velocity and the distance between the plant discharge location to water treatment plant given in TVA 1974a.

Sources: NRC 1995, NRC 1977a, AEC 1974, TVA 1974b, TVA 1974a, TVA 1997, TVA 1991, TVA 1995, and TVA 1996.

In principle, one can estimate the uncertainty associated with each source and predict the remaining uncertainty in the results of each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final results. However, conducting such a full-scale quantitative uncertainty analysis is neither practical nor standard practice for a study of this type. Instead, the analysis is designed to ensure—through judicious selection of release scenarios, models, and parameters—that the results represent the potential risks. This is accomplished by making conservative assumptions in the calculations at each step. The models, parameters, and release scenarios used in the calculations are selected in such a way that most intermediate results and, consequently, the final estimates of impacts, are greater than what would be expected. As a result, even though the range of uncertainty in a quantity might be large, the value calculated for the quantity is close to one of the extremes in the range of possible values, so that the chance of the actual quantity being greater than the calculated value is low (or the chance of the quantity being less than the calculated value if the criteria are such that the quantity has to be maximized). The goal of the radiological assessment for normal operation in this study has been to produce results that are conservative.

The degree of conservatism in the calculated results is closely related to the range of possible values the quantity can have. This range is determined by what can be expected to realistically occur. Thus, the only processes considered are those credible for the conditions under which the physical system being modeled operates. This consideration has been employed for normal operation analyses.

Although the radionuclide composition of source terms are reasonable estimates, there are uncertainties in the radionuclide inventory and release reactions that affect estimated impacts.

C.3.4 Radiological Releases to the Environment and Associated Impact

The NRC has assessed the potential radiation doses to individuals and surrounding populations that could result from the operation of Watts Bar, Sequoyah, and Bellefonte Nuclear Plants in the related facilities' Final Environmental Statements (NRC 1995, AEC 1974, TVA 1974a). To assess the potential radiation dose to the individual and population from the operation of these plants in a tritium producing mode, this EIS uses the results in those statements and superimposes the doses that would result from additional releases of tritium. The dose assessment uses the method prescribed by the NRC in the Regulatory Guides 1.109 (NRC 1977b), 1.111 (NRC 1977a), and 4.2 (NRC 1976), with the adjustments as needed.

Radiological Releases to the Environment

Normal operational radiological assessments were determined (modeled) for two tritium production scenarios at each candidate reactor site: (1) production of tritium via the loading of 1,000 TPBARs into a reactor core, and (2) production of tritium via the loading of a maximum number of TPBARs into a reactor core. The "maximum" number of TPBARs that can be loaded in each reactor varies among the three candidate sites. For calculational purposes in this EIS, the maximum number of TPBARs was assumed to be 3,400. Anticipated increases in tritium releases (in curies) to both the atmosphere and the water pathways as a result of normal tritium leakage with no TPBAR failure and an assumed condition of two TPBAR failures in the reactor coolant system, are shown in **Table C–7**. These values are based on the following assumptions:

- Each TPBAR would contain, on the average, 1 gram, with a design maximum of 1.2 grams, of tritium per rod in an 18-month fuel cycle; 1 gram of tritium is 9,640 curies (CRC 1982);
- Tritium leakage into the reactor coolant system is 1 Ci/TPBAR per year;
- Annually, two failed TPBARs could release a total of 15,500 Ci of tritium to the reactor coolant system. The failure is assumed to occur at the beginning of the cycle; therefore, a design maximum of 1.2 grams of tritium per rod could be released to the reactor coolant system; and
- About 90 percent of the tritium in the reactor coolant system would be released in the liquid pathway and 10 percent would be released to the atmosphere.

Table C–7 Annual Increases in Tritium Releases to the Environment at Each Candidate Reactor Site

Conditions	*Tritium Ci Release to Air per Unit for 1,000 TPBARs*	*Tritium Ci Release to Liquid per Unit for 1,000 TPBARs*	*Tritium Ci Release to Air per Unit for 3,400 TPBARs*	*Tritium Ci Release to Liquid per Unit for 3,400 TPBARs*
No TPBAR Failure	100	900	340	3,060
2 TPBAR Failures	1,650	14,850	1,890	17,010

Radiological Impacts

As stated earlier, doses to members of the public from tritium releases during normal operations were calculated using GENII code (PNL 1988). GENII uses "special" transport assumptions in its evaluation of the tritiated water movement through various food chains. The concentration of tritium in each food type is assumed to have the same specific activity as the contaminating medium (PNL 1988). The assumption is approximately valid for situations involving continuous replenishment of tritium in the medium and represents a conservative approximation for residual tritium in soil (NRC 1994). When soil is contaminated with residual tritium and no tritium from air and water is continually added to the soil, the contamination would be expected to rapidly escape (by evaporation) from the soil or plants that had taken up this tritium. GENII, however, conservatively assumes that the soil tritium is retained and remains available for plant uptake over time.

As a result, the effective dose associated with the ingestion pathway calculated by GENII is very conservative. The calculated ingestion dose is between 80 to 95 percent of the total body dose. In addition, the assumption that people living within 80 kilometers (50 miles) of each site would eat all the contaminated food produced within that area makes the dose calculations even more conservative. Even with this overestimation, all calculated doses resulting from tritium releases during normal operation are within the limits set forth for the operation of each reactor (see **Table C-8, Table C–9, and Table C-10**). Tables C–8, C–9, and C–10 present potential radiological impacts to two individual receptor groups that may be exposed to releases associated with a "No TPBAR Failure" and a "2 TPBAR Failure" tritium production scenario for each of the three candidate sites. These two groups are the maximally exposed member of the public and the population living within 80 kilometers (50 miles) of each of the sites in the year 2025. Each table presents the estimated doses from gaseous emissions (air) and liquid effluents (liquid) under the No Action Alternative (current plant conditions), and the estimated incremental doses from tritium releases to air and liquid resulting from 1,000 and 3,400 TPBAR irradiations in each reactor. For Watts Bar and Sequoyah, actual air and liquid doses included in their current (1997 operation year) environmental reports were used for the No Action Alternative (operation with 0 TPBARs). For Bellefonte, since the plant is not yet operational, the estimated dose values given in the final environmental statement (AEC 1974) were used for the plant operation with 0 TPBARs. The air doses provided in the final environmental statement include external exposure due to gamma rays and beta particles emanating from the gaseous radioactive emissions and thyroid organ dose due to inhalation and ingestion of contaminated air and food (milk), respectively. GENII calculates air doses by considering both the external exposure and the internal exposure to all organs and provides the total effective dose equivalent. Therefore, the results presented in the plant Final Environmental Statements were adjusted (i.e., the organ dose is presented in terms of equivalent whole body dose to enable combination with the external dose) before they are added to the incremental doses resulting from tritium releases. The no action liquid doses given in the plant final environmental statement is the total body dose; therefore, no adjustment was needed.

The following text summarizes the calculated doses presented for the two public groups:

No Action

- The maximally exposed offsite individual doses from air releases were taken directly from plant environmental reports for Watts Bar and Sequoyah units (TVA 1998a), and from the Final Environmental Statement report for the Bellefonte (AEC 1974). For Bellefonte, the dose value given for the external air immersion "total body dose" was added to the maximum thyroid organ dose that accounts for exposures via inhalation and ingestion pathways. The thyroid dose was multiplied by the ICRP 26 weighting factor of 0.03 (PNL 1988) to get a "weighted committed dose equivalent" prior to being added to the external air immersion dose;

- Liquid doses to the maximally exposed offsite individual were directly cited from the referenced reports (TVA 1998a, AEC 1974);

- Population doses from air releases were cited directly from the referenced reports (TVA 1998a, AEC 1974) and subsequently adjusted for the projected population in the year 2025 by applying demographic growth factors presented in the EIS; and

- Population dose from liquid releases were cited from the referenced reports and were also adjusted for the projected population in the year 2025.

Tritium Production:

- Incremental doses from tritium releases (per air and liquid pathways) were calculated for 1,000 and 3,400 TPBARs via the method described in Sections C.3.1 and C.3.2; and

- Total doses (No Action doses + Incremental doses) from reactor operation under tritium production are separately presented for the air and the liquid releases and then combined to demonstrate regulatory compliance with the applicable standards shown in Table C–1.

Table C–8 Annual Radiological Impacts to the Public from Incident-Free Tritium Production Operations at Watts Bar 1

Receptors	*No Action*		*Incremental Dose For 1,000 TPBARs*		*Operation with 1,000 TPBARs*			*Incremental Dose for 3,400 TPBARs*		*Operation with 3,400 TPBARs*		
	Air	*Liquid*	*Air*	*Liquid*	*Air*	*Liquid*	*Total*	*Air*	*Liquid*	*Air*	*Liquid*	*Total*
No TPBAR Failures												
Maximally Exposed Offsite Individual												
Dose (mrem)	0.036	0.25	0.012	0.0014	0.048	0.25	0.30	0.042	0.0050	0.078	0.26	0.34
Fatal Cancer Risk	1.8×10^{-8}	1.3×10^{-7}	6.0×10^{-9}	7.0×10^{-10}	2.4×10^{-8}	1.3×10^{-7}	1.5×10^{-7}	2.1×10^{-8}	2.5×10^{-9}	3.9×10^{-8}	1.3×10^{-7}	1.7×10^{-7}
Population Dose Within 80 km for Year 2025												
Dose (person-rem)	0.071	0.48	0.15	0.19	0.22	0.67	0.89	0.50	0.69	0.57	1.2	1.8
Fatal Cancers	0.000036	0.00024	0.000075	0.000095	0.00011	0.00034	0.00045	0.00025	0.00035	0.00029	0.00060	0.00090
2 TPBAR Failures												
Maximally Exposed Offsite Individual												
Dose (mrem)	0.036	0.25	0.20	0.024	0.24	0.27	0.51	0.24	0.027	0.28	0.28	0.56
Fatal Cancer Risk	1.8×10^{-8}	1.3×10^{-7}	1.0×10^{-7}	1.2×10^{-8}	1.2×10^{-7}	1.4×10^{-7}	2.6×10^{-7}	1.2×10^{-7}	1.4×10^{-8}	1.4×10^{-7}	1.4×10^{-7}	2.8×10^{-7}
Population Dose Within 80 km for Year 2025												
Dose (person-rem)	0.071	0.48	2.3	3.2	2.4	3.7	6.1	2.8	3.6	2.9	4.1	7.0
Fatal Cancers	0.000036	0.00024	0.0012	0.0016	0.0012	0.0019	0.0031	0.0014	0.0018	0.0015	0.0021	0.0035

Source: TVA 1998a.
Note: The values given in this table are rounded up to two significant figures.

Table C–9 Annual Radiological Impacts to the Public from Incident-Free Tritium Production Operations at Sequoyah 1 or Sequoyah 2

	No Action		*Incremental Dose For 1,000 TPBARs*		*Operation with 1,000 TPBARs*			*Incremental Dose for 3,400 TPBARs*		*Operation with 3,400 TPBARs*		
Receptors	***Air***	***Liquid***	***Air***	***Liquid***	***Air***	***Liquid***	***Total***	***Air***	***Liquid***	***Air***	***Liquid***	***Total***
No TPBAR Failures												
Maximally Exposed Offsite Individual												
Dose (mrem)	0.031	0.022	0.015	0.0016	0.046	0.024	0.070	0.052	0.0054	0.083	0.027	0.11
Fatal Cancer Risk	1.6×10^{-8}	1.1×10^{-8}	7.5×10^{-9}	8.0×10^{-10}	2.3×10^{-8}	1.2×10^{-8}	3.5×10^{-8}	2.6×10^{-8}	2.7×10^{-9}	4.2×10^{-8}	1.4×10^{-8}	5.6×10^{-8}
Population Dose Within 80 km for Year 2025												
Dose (person-rem)	0.49	1.1	0.16	0.41	0.65	1.5	2.2	0.54	1.4	1.0	2.5	3.5
Fatal Cancers	0.00025	0.00055	0.000080	0.00021	0.00033	0.00075	0.0011	0.00027	0.00070	0.00050	0.0013	0.0018
2 TPBAR Failures												
Maximally Exposed Offsite Individual												
Dose (mrem)	0.031	0.022	0.25	0.026	0.28	0.048	0.33	0.29	0.030	0.32	0.052	0.37
Fatal Cancer Risk	1.6×10^{-8}	1.1×10^{-8}	1.3×10^{-7}	1.3×10^{-8}	1.4×10^{-7}	2.4×10^{-8}	1.7×10^{-7}	1.5×10^{-7}	1.5×10^{-8}	1.6×10^{-7}	2.6×10^{-8}	1.9×10^{-7}
Population Dose Within 80 km for Year 2025												
Dose (person-rem)	0.49	1.1	2.5	6.9	3.0	8.0	11.0	3.0	7.5	3.5	8.6	12.1
Fatal Cancers	0.00025	0.00055	0.0013	0.0035	0.0015	0.0040	0.0055	0.0015	0.0038	0.0018	0.0043	0.0061

Source: TVA 1998a.
Note: The values given in this table are rounded up to two significant figures.

Table C–10 Annual Radiological Impacts to the Public from Incident-Free Tritium Production Operations at Bellefonte 1

Receptors	*No Action*		*Incremental Dose For 1,000 TPBARs*		*Operation with 1,000 TPBARs*			*Incremental Dose for 3,400 TPBARs*		*Operation with 3,400 TPBARs*		
	Air	*Liquid*	*Air*	*Liquid*	*Air*	*Liquid*	*Total*	*Air*	*Liquid*	*Air*	*Liquid*	*Total*
No TPBAR Failures												
Maximally Exposed Offsite Individual												
Dose (mrem)	0[a]	0[a]	0.0020	0.0012	0.25[c]	0.013[c]	0.26	0.0065	0.0042	0.26[c]	0.016[c]	0.28
Fatal Cancer Risk	0	0	1.0×10^{-9}	6.0×10^{-10}	1.3×10^{-7}	6.5×10^{-9}	1.3×10^{-7}	3.3×10^{-9}	2.1×10^{-9}	1.3×10^{-7}	8.0×10^{-9}	1.4×10^{-7}
Population Dose Within 80 km for Year 2025												
Dose (person-rem)	0[b]	0[b]	0.13	0.14	0.40[c]	1.2[c]	1.6	0.44	0.47	0.71[c]	1.6[c]	2.3
Fatal Cancers	0	0	0.000065	0.000070	0.00020	0.0006	0.0008	0.00022	0.00024	0.00036	0.0008	0.0012
2 TPBAR Failures												
Maximally Exposed Offsite Individual												
Dose (mrem)	0[a]	0[a]	0.032	0.021	0.28[c]	0.033[c]	0.31	0.037	0.023	0.29[c]	0.035[c]	0.32
Fatal Cancer Risk	0	0	1.6×10^{-8}	1.1×10^{-8}	1.4×10^{-7}	1.7×10^{-8}	1.6×10^{-7}	1.9×10^{-8}	1.2×10^{-8}	1.5×10^{-7}	1.8×10^{-8}	1.6×10^{-7}
Population Dose Within 80 km for Year 2025												
Dose (person-rem)	0[b]	0[b]	2.1	2.3	2.4[c]	3.4[c]	5.8	2.5	2.6	2.8[c]	3.7[c]	6.5
Fatal Cancers	0	0	0.0011	0.0012	0.0012	0.0017	0.0029	0.0013	0.0013	0.0014	0.0019	0.0033

[a, b] These no action values represent the absence of impacts associated with the non-operational status of Bellefonte Nuclear Plant. For a single operational Bellefonte Nuclear Plant unit (operation without tritium production activities), the impacts to the public have been estimated to be: 0.26 mrem (0.25 mrem from the air pathway and 0.012 mrem from the liquid pathway) to the Maximally Exposed Individual and 1.4 person-rem (0.27 person-rem from the air pathway and 1.1 person-rem from the liquid pathway) to the surrounding population within 80 kilometers (50 miles) in the year 2025.

[c] These values are a summation of incremental impacts attributable to TPBAR tritium releases and estimated single Bellefonte Nuclear Plant unit operational impacts.

For Bellefonte 1 and 2 operation, the potential impacts are twice the values given in this table.

Source: AEC 1974.

Note: The values given in this table are rounded up to two significant figures.

C.4 IMPACTS OF EXPOSURES TO HAZARDOUS CHEMICALS ON HUMAN HEALTH

The potential impacts of exposure to hazardous chemicals released to the atmosphere as a result of tritium production were evaluated for the routine operation of the reactor facilities.

The receptors considered in these evaluations are the maximally exposed individual and the offsite population living within an 80 kilometers (50 miles) radius of the facilities. Impacts of exposures to hazardous chemicals for workers directly involved in reactor operation and tritium production were not quantitatively evaluated because the use of personal protective equipment and engineering process controls would limit their exposure to levels within applicable Occupational Safety and Health Administration Permissible Exposure Limits or American Conference of Governmental Industrial Hygienists Threshold Limit Values.

As a result of releases from the routine operation of the reactor facilities, receptors are expected to be potentially exposed to concentrations of hazardous chemicals that are below those that could cause acutely toxic health effects. Acutely toxic health effects generally result from short-term exposure to relatively high concentrations of contaminants, such as those that may be encountered during facility accidents. Long-term exposure to relatively lower concentrations of hazardous chemicals can produce adverse chronic health effects that include both carcinogenic and noncarcinogenic effects. The health effect endpoints evaluated in this analysis include excess incidences of latent cancers for carcinogenic chemicals and a spectrum of chemical-specific noncancer health effects (e.g., headaches, membrane irritation, neurotoxicity, immunotoxicity, liver toxicity, kidney toxicity, developmental toxicity, reproductive toxicity, and genetic toxicity) for noncarcinogens.

Methodology

Estimates of airborne concentrations of hazardous chemicals were developed using the Industrial Source Complex (ISC3) air dispersion model (EPA 1995). This model was developed by the EPA for regulatory air dispersion modeling applications. ISC3 is the most recent version of the model and is approved for use for a wide variety of emission sources and conditions. The ISC3 estimates atmospheric concentrations based on the airborne emissions from the processing facility for each block in a circular grid comprised of 16 directional sectors (e.g., north, north-northeast, northeast) at radial distances out to 80 kilometers (50 miles) from the point of release, producing a distribution of atmospheric concentrations. The maximally exposed individual is located in the block with the highest estimated concentration. The short-term version of the model (ISCST3) was used to estimate potential exposures to offsite populations.

This EIS estimates noncancer health risks by comparing modeled air concentrations of contaminants produced by ISC3 to EPA Reference Concentrations as published in the Integrated Risk Information System. For each noncarcinogenic chemical, potential health risks are estimated by dividing the estimated airborne concentration by the chemical-specific Reference Concentrations value to obtain a noncancer hazard quotient:

Noncancer Hazard Quotient = air concentration/Reference Concentrations

Reference Concentrations are estimates (with an uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of harmful effects during a lifetime. Hazard Quotients are calculated for each hazardous chemical to which receptors may be exposed. Hazard Quotients for each chemical are summed to generate a Hazard Index. The Hazard Index is an estimate of the total noncancer toxicity potential from exposure to hazardous chemicals. According to EPA risk assessment guidelines (EPA 1989), if the Hazard Index value is less than or equal to 1.0, the exposure is unlikely to produce adverse toxic effects. If the Hazard Index exceeds 1.0, adverse noncancer health effects may result from the exposure.

For carcinogenic chemicals, risk is estimated by the following equation:

$$\text{Risk} \quad \text{CA} \times \text{URF}$$

where:

Risk = a unitless probability of cancer incidence
CA = contaminant concentration in air (in µg/m^3)
URF = cancer inhalation unit risk factor (in units of cancers per µg/m^3)

CA is estimated by multiplying the output of the ISC3 model by the process duration to obtain estimates of total airborne exposure for each process.

Cancer unit risk factors are used in risk assessments to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen.

Assumptions

The airborne pathway is assumed to be the principal exposure route by which the offsite population maximally exposed individual is exposed to hazardous chemicals released from reactor facilities. No synergistic or antagonistic effects are assumed to occur from exposure to the hazardous chemicals released from reactor facilities. Synergistic effects among released contaminants may result in adverse health effects that are greater than those estimated, whereas, antagonistic effects among released chemicals may result in less severe health effects than those estimated.

Analysis

The potential impacts of exposure to hazardous chemicals released to the atmosphere during routine operations of the reactor facilities to produce tritium is presented in Chapter 5 for each alternative.

C.5 References

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APPENDIX D
EVALUATION OF HUMAN HEALTH EFFECTS FROM FACILITY ACCIDENTS

This appendix presents the method and assumptions used for estimating potential impacts and risks to individuals and the general public from exposure to releases of radioactive and hazardous chemical materials during hypothetical accidents at the proposed reactor facilities. The impacts from accidental radioactive material releases are given in Section D.1, and the impacts from releases of hazardous chemicals are provided in Section D.2.

D.1 RADIOLOGICAL ACCIDENT IMPACTS ON HUMAN HEALTH

D.1.1 Accident Scenario Selection and Description

D.1.1.1 Accident Scenario Selection

This accident analysis assessment considers a spectrum of potential accident scenarios. The range of accidents considered includes reactor design-basis accidents, nonreactor design-basis accidents, tritium-producing burnable absorber rod (TPBAR) handling accidents, transportation cask handling accidents, and beyond-design-basis accidents (i.e., severe reactor accidents).

The spectrum of reactor and nonreactor design-basis accidents presented in the Watts Bar, Sequoyah, and Bellefonte Safety Analysis Reports were reviewed for evaluation in this EIS. The large break loss-of-coolant accident was selected as the representative reactor design-basis accident because it has the potential to damage more TPBARs than any other reactor design-basis accident (see Section D.1.1.2). Based on assumptions used in this EIS for the postulated accident scenario, the waste gas decay tank failure accident was selected as the nonreactor design-basis accident for evaluation in this EIS because it has the potential to release more tritium than other nonreactor design-basis accidents.

Following irradiation in the reactor's tritium production core, the fuel assemblies and the TPBAR assemblies inserted into the fuel assemblies would be removed from the reactor and transferred to the spent fuel pool. There, the TPBAR assemblies would be removed from the fuel assemblies. Next, the TPBARs would be removed from the TPBAR assemblies and inserted in a consolidation container. The consolidation container is a 17 × 17 array of tubes that holds the TPBARs. The consolidation container has the same footprint as a fuel assembly and can accommodate up to 289 TPBARs.

Three TPBAR handling accident scenarios are evaluated. Scenario 1 postulates that the consolidation container with 289 TPBARs is dropped while loading into a transportation cask. The evaluation further postulates that, if the consolidation container lands vertically on the spent fuel pool floor, no TPBARs would be damaged by the impact. If, however, the consolidation container lands on an edge or strikes an object (e.g., an unoccupied fuel rack or the shelf in the cask loading pit), the consolidation container shell and up to one row of tubes containing TPBARs could be damaged and up to 17 TPBARs possibly could be breached.

Scenario 2 postulates that an irradiated fuel assembly with a TPBAR assembly containing 24 TPBARs is dropped in the spent fuel pool. The evaluation also postulates that, if the fuel assembly lands vertically, no TPBARs would be damaged by the impact. If the assembly lands on an edge or is struck by an object on the side or corner of the fuel assembly, up to three TPBARs could be damaged by the impact.

Scenario 3 postulates that a TPBAR assembly containing 24 TPBARs is dropped in the spent fuel pool as it is being removed from an irradiated fuel assembly and that all TPBARs are breached by the impact. Scenario 3 was selected for evaluation in this EIS because it has the potential to damage more TPBARs than the other postulated TPBAR handling accidents.

Two truck or rail transportation cask drop accidents that could cause a release of tritium from the casks are evaluated in this EIS. The evaluations consider: (1) cask drops before the cask is sealed and (2) drops that could breach a sealed cask.

The postulated beyond-design-basis reactor accident analyses selected for use in this EIS address core damage accident scenarios leading to the loss of containment integrity. This includes scenarios that fall into three performance categories: (1) early containment failures, (2) late containment failures, and (3) containment bypass. Accident scenarios that do not fall into these categories lead to significantly lower consequences and, therefore, are not evaluated.

D.1.1.2 Reactor Design-Basis Accident

A reactor design-basis accident is designated as a Condition IV occurrence. Condition IV occurrences are faults that are not expected to take place, but are postulated because they have the potential to release significant amounts of radioactive material. The postulated reactor design-basis accident for this EIS is a large break loss-of-coolant accident. This postulated accident has the potential to damage more TPBARs than any other reactor loss-of-coolant design-basis accident (WEC 1998a). This accident scenario postulates a double-ended rupture of a pipe, greater than 15 centimeters (6 inches) in diameter, in the reactor coolant system. During the initial phase of the accident, the reactor water (coolant) level would drop below the top of the reactor core for a short period of time before the emergency systems would automatically inject additional water to cover the core. During this period the core would overheat, and the cladding on some of the fuel rods and 100 percent of the TPBARs would be breached due to the overheating (WEC 1998b). The analysis assumes that the entire tritium content in the TPBARs would be released to the containment. Each TPBAR produces 1 gram of tritium on average through the 18-month irradiation cycle (DOE 1996). For the purpose of analyses in this EIS, 1 gram of tritium contains 9,640 curies (CRC 1982). The analysis also assumes that all of the tritium released to the reactor coolant system from the TPBARs during 17 months of normal operation would be released to the containment during the accident. This would include the release of an amount of tritium corresponding to 1 curie per year per TPBAR (PNNL 1997) and an additional 1.2 grams of tritium (the production design limit) for each of 2 TPBARs with clad failure (WEC 1998c). The accident consequence calculations consider applicable, reactor site-specific, protective action guidelines.

Table D–1 shows the total source term released to the containment that would be attributable to 1,000 and a maximum of 3,400 TPBARs in a tritium production core configuration. The analysis assumes that 10 percent of the tritium released to the containment during the accident would be available in the containment atmosphere in the form of tritiated water vapor that would be released to the environment (WHC 1991). The reduction in the amount of tritium available for release would be the result of postaccident processing of the containment atmosphere to reduce iodine leakage to the environment, operation of hydrogen recombiners, and absorption of elemental and oxidized tritium by water in the containment. In the design-basis accident, tritium would be released from the containment to the atmosphere through containment leakage. Release pathways from the containment are discussed in Section D.1.2.5.2. The analysis assumes tritiated water vapor would be released to the atmosphere for 30 days following the accident. After 30 days, all the tritiated water vapor in the containment atmosphere would be condensed and, therefore, would not be available for further release. **Table D–2** presents the tritium source term released to the environment, and **Table D–3** presents the accident frequency estimates.

Table D–1 Reactor Design-Basis Accident Tritium Inventory

Source Term	*Tritium Production*	
	1,000 TPBARs (Ci)	*Maximum - 3,400 TPBARs (Ci)*
TPBARs breached during accident	9.62×10^6	3.28×10^7
TPBAR leakage during normal operations [a]	24,633	28,233
Total released to containment	9.62×10^6	3.28×10^7
Total available to be released to environment [b]	962,000	3.28×10^6

[a] Includes 23,100 curies from two TPBARs with clad failure.
[b] All tritium released to environment is in oxide form.

Table D–2 Reactor Design-Basis Accident Tritium Source Term Released to Environment

Accident Site	*Tritium Production*	*Tritium Released (Curies)* [a, b]		
		0-24 Hours	*24-720 Hours*	*Total 0-30 Days*
Watts Bar	1,000 TPBARs	814	10,700	11,600
	3,400 TPBARs	2,780	36,600	39,400
Sequoyah	1,000 TPBARs	890	11,900	12,800
	3,400 TPBARs	3,040	40,500	43,500
Bellefonte	1,000 TPBARs	338	3,880	4,220
	3,400 TPBARs	1,150	13,200	14,400

[a] All tritium released to environment is in oxide form.
[b] Source terms for a single reactor.

Table D–3 Reactor Design-Basis Accident Frequency Estimates for Large Break Loss-of-Coolant Accident

Reactor Site	*Frequency (per year)*
Watts Bar	0.0002[a]
Sequoyah	0.0002[b]
Bellefonte	0.0002[c]

[a] TVA 1992b.
[b] TVA 1992a.
[c] Value currently assigned in Individual Plant Examinations.

D.1.1.3 Nonreactor Design-Basis Accident

The waste gas decay tank rupture, a Condition III occurrence, was selected as the nonreactor design-basis accident for this EIS. The consequences of a Condition III occurrence would be less severe than a Condition IV occurrence. The release of radioactivity would not be sufficient to interrupt or restrict public use of those areas beyond the exclusion area radius (TVA 1996). The frequency of design-basis accidents are normally expected to be in the range of 0.0001 to 0.01 per year. For the purpose of this EIS, the accident frequency is assumed to be 0.01, the high end of the range.

The gaseous waste processing system is designed to remove fission product gases from the reactor coolant. The maximum storage of waste gases occurs before a refueling shutdown, at which time the gas decay tanks store the radioactive gases that are stripped from the reactor coolant. The accident analysis conservatively assumes that 10 percent of the TPBAR generated tritium in the reactor coolant, as well as radioactive xenon and krypton fission product gases would be stripped from the reactor coolant before a refueling shutdown and stored in waste decay tanks. Therefore, it has the potential to release more tritium than other nonreactor design-basis accidents. This assumption is conservative because the analysis postulates that all of the tritium released from the TPBARs to the reactor coolant during the entire fuel cycle would be retained in the coolant, and it is anticipated that significantly less than 1 percent of the tritium in the reactor coolant would actually be present in the waste decay tank as tritiated water vapor.

The postulated nonreactor design-basis accident is defined as an unexpected, uncontrolled release of the gases contained in a single gas decay tank due to the failure of the tank or the associated piping. The analysis assumes that tritium would be released directly to the environment in an oxide form. Accident consequence calculations consider applicable reactor site-specific protective action guidelines. **Table D–4** presents the tritium source term that would be released to the environment.

Table D–4 Nonreactor Design-Basis Accident Tritium Source Term

Source Term (Ci tritium)	
1,000 TPBARs	*3,400 TPBARs*
2,460	2,820

D.1.1.4 TPBAR Handling Accident

The TPBAR handling accident scenario postulated that a TPBAR assembly containing 24 TPBARs was dropped when removing the assembly from an irradiated fuel assembly during the TPBAR consolidation process. The evaluation postulates that all TPBARs would be unprotected and would breach when they impact the spent fuel pool floor. The gaseous tritium in the 24 breached TPBARs would be released into the fuel pool and directly to the environment. The gaseous tritium in a TPBAR is less than 1 percent of the total inventory (SAIC 1998a). All of the gaseous tritium would be in elemental form (SAIC 1998b). Tritium released in elemental form oxidizes slowly in the environment. Experimental results estimate the long-term dose from elemental tritium releases would be about 1 percent of that from the oxidized form (DOE 1997). For this analysis, it is assumed that 1 percent of the gaseous tritium would be in oxidized form (i.e., instantaneous oxidation) before its release to the environment. Therefore, releases that occur as elemental tritium are multiplied by a factor of 0.01 to convert them to an equivalent release of tritium oxide. The postulated TPBAR handling accident would release the equivalent of 23 curies of tritium in oxide form to the environment. Accident consequence calculations consider applicable reactor site-specific protective action guidelines. **Table D–5** presents the accident frequency estimates. The frequency estimates are derived from data presented in NUREG/CR-4982, *Severe Accidents in Spent Fuel Pool in Support of Generic Safety Issue 82* (NRC 1987).

Table D–5 TPBAR Handling Accident Frequency Estimates

Frequency (per year)	
1,000 TPBARs	*3,400 TPBARs*

0.0017	0.0058

D.1.1.5 Truck Transportation Cask Handling Accident at the Reactor Site

The truck cask would be loaded under water in the spent fuel pool cask loading pit. A single TPBAR consolidation container containing a maximum of 289 TPBARs would be loaded into the cask. For the purpose of this EIS, the analysis postulates, that following insertion of the consolidation container, the cask cover would be installed but not tightly sealed. The cask would be raised above the water level where it would be hosed down and drained before to moving it to the decontamination area. There, it would be sealed, backfilled with inert gas, and decontaminated before loading on the truck trailer bed.

The evaluation also considered an option to seal the cask cover before lifting the cask; in this case the only potential for a tritium release would be if the cask was breached by the drop. The truck cask is designed in accordance with the requirements of 10 CFR 71, and is required to withstand a 9.1 meter (30 foot) drop onto an unyielding surface without loss or dispersal of the radioactive contents of the cask. The cask could drop more than 9.1 meters (30 feet) in the spent fuel pool cask loading pit. It could fall approximately 2.7 meters (9 feet) through the air and approximately 12.2 meters (40 feet) through the water. The terminal velocity of such a fall would exceed that reached in a 9.1 meter (30 foot) drop through air (TVA 1996). The analysis assumes that the cask would be breached by such a fall.

Spent fuel pool designs were reviewed to determine if there was any potential for cascading effects of the cask drop that would initiate releases of additional radionuclides. In the event that the spent fuel pool liner in the cask pit area is breached and the water level in the spent fuel pool drops, the water level would not drop to a level that would uncover the spent fuel in the storage racks. The cask loading area of the spent fuel pool is separated from the storage area by a shelf. The shelf height maintains the water level in the spent fuel pool storage area above the top of the spent fuel when the cask pit area is drained. Additional defense-in-depth is provided when the spent fuel pool gates are installed after loading the cask. With the gates in place, one on each side of the cask loading pit access channel to the spent fuel pool, a breach of the liner in the cask loading pit area will result in a drop in the spent fuel water level to the top of the gates.

The analysis assumed that, in the event the cask is dropped onto the floor of the fuel pool area, the cask would not penetrate the floor or damage equipment located at an elevation below the potential drop zone. Analyses will be performed to verify this assumption during the U.S. Nuclear Regulatory Commission (NRC) operating license process and/or license amendment process.

It is anticipated that no TPBARs would be damaged by the drop. The TPBARs in the cask would be not only protected from damage by the cask, but also by the consolidation container structure. However, the analysis conservatively assumes that the structural loads on the TPBARs resulting from the drop could breach up to 17 TPBARs, the same number considered for a dropped TPBAR consolidation container. The gaseous tritium in the 17 breached TPBARs would be released into the fuel pool and directly to the environment. The gaseous tritium in a TPBAR would be less than 1 percent of the total inventory. All of the gaseous tritium would be in elemental form. Therefore, releases that occur as elemental tritium are multiplied by a factor of 0.01 to convert them to an equivalent release of tritium oxide. The postulated cask handling accident would release the equivalent of 16.4 curies of tritium in oxide form to the environment. Accident consequence calculations consider applicable reactor site-specific protective action guidelines. **Table D–6** presents the frequency estimates for the truck transportation cask handling accident. The frequency estimates are derived from data presented in NUREG/CR-4982, *Severe Accidents in Spent Fuel Pool in Support of Generic Safety Issue 82* (NRC 1987).

Table D–6 Truck Transportation Cask Handling Accident Frequency Estimates

Frequency (per year)	
1,000 TPBARs	***3,400 TPBARs***
5.3×10^{-7}	1.6×10^{-6}

D.1.1.6 Truck Transportation Cask Handling Accident at the Tritium Extraction Facility

Cask handling accidents at the Tritium Extraction Facility are in the scope of the Tritium Extraction Facility EIS and are not within the scope of this EIS.

D.1.1.7 Rail Transportation Cask Handling Accident at the Reactor Site

The rail cask would be loaded under water in the spent fuel pool cask loading pit with 3 to 12 TPBAR consolidation containers. For the purpose of this EIS, the analysis postulates that, following insertion of the consolidation containers, the cask cover would be installed but not tightly sealed. The cask would be raised above the water level, where it would be hosed down and drained before moving it to the decontamination area. There, it would be sealed, backfilled with inert gas, and decontaminated before loading on the rail car.

The evaluation also considers an option to seal the cask cover before lifting the cask; in this case the only potential for a tritium release would be if the cask was breached by the drop. The rail cask is designed in accordance with the requirements of 10 CFR 71 which requires that the cask withstand a 9.1 meter (30 foot) drop onto an unyielding surface without loss or dispersal of the radioactive contents of the cask. The cask could drop more than 9.1 meters (30 feet) in the spent fuel pool cask loading pit. Here the cask could fall approximately 2.7 meters (9 feet) through air and approximately 12.2 meters (40 feet) through water. The terminal velocity reached in such a fall would exceed that reached in a 9.1 meter (30 foot) drop through air (TVA 1996). The analysis assumes that the cask would be breached by such a fall.

Spent fuel pool designs were reviewed to determine if there was any potential for cascading effects of the cask drop that would initiate releases of additional radionuclides. In the event that the spent fuel pool liner in the cask pit area was breached and the water level in the spent fuel pool dropped, the water level would not drop to a level that would uncover the spent fuel in the storage racks. The cask loading area of the spent fuel pool is separated from the storage area by a shelf. The shelf height maintains the water level in the spent fuel pool storage area above the top of the spent fuel when the cask pit area is drained.

The analysis assumes that, in the event the cask was dropped onto the floor of the fuel pool area, the cask would not penetrate the floor or damage equipment located at an elevation below the drop zone. Analyses will be performed to verify this assumption during the NRC operating license process and/or license amendment process.

It is anticipated that no TPBARs would be damaged by the drop. The TPBARs in the cask would be not only protected from damage by the cask, but also by the TPBAR consolidation container structure. However, the analysis conservatively assumes that the structural loads on the TPBARs resulting from the drop could breach up to 17 TPBARs, the same number considered for a dropped TPBAR consolidation container. The gaseous tritium in the 17 breached TPBARs would be released into the fuel pool and directly to the environment. The gaseous tritium in a TPBAR would be less than 1 percent of the total inventory. All of the gaseous tritium would be in elemental form. Therefore, releases that occur as elemental tritium are multiplied by a factor of 0.01 to convert them to an equivalent release of tritium oxide. The postulated cask handling accident would release the equivalent of 16.4 curies of tritium in oxide form to the environment. Accident consequence calculations consider applicable reactor site-specific protective action guidelines. **Table D–7** presents the frequency estimates for the rail transportation cask handling accident. The frequency estimates were derived from data presented in

NUREG/CR-4982, *Severe Accidents in Spent Fuel Pool in Support of Generic Safety Issue 82* (NRC 1987) and the assumption that each rail cask would contain three TPBAR consolidation containers.

Table D–7 Rail Transportation Cask Handling Accident Frequency Estimates

Frequency (per year)	
1,000 TPBARs	***3,400 TPBARs***
2.7×10^{-7}	5.3×10^{-7}

D.1.1.8 Rail Transportation Cask Handling Accident at the Savannah River Site Rail Transfer Station

Rail service is provided on DOE's Savannah River Site in South Carolina, but not directly to the Tritium Extraction Facility. Rail casks would be transferred to a truck at an onsite rail transfer station for transport to the Tritium Extraction Facility. The rail cask is designed in accordance with the requirements of 10 CFR 71, which requires that the cask be able to withstand a 9.1 meter (30 foot) drop onto an unyielding surface without loss or dispersal of the radioactive contents of the cask. During transfer of the cask from the rail car to the truck, the cask elevation above the ground would not exceed 9.1 meters (30 feet). Therefore, postulated cask handling accidents at the rail transfer station (i.e., cask drop events) would not cause breach of the cask and the release of radioactive material.

D.1.1.9 Rail Transportation Cask Handling Accident at the Tritium Extraction Facility

Cask handling accidents at the Tritium Extraction Facility are in the scope of the Tritium Extraction Facility EIS and are not within the scope of this EIS. The scope of the Tritium Extraction Facility EIS starts with the delivery of irradiated TPBARs at the Tritium Extraction Facility.

D.1.1.10 Beyond-Design-Basis Accident

The beyond-design-basis accident is limited to the severe reactor accidents. Severe reactor accidents are less likely to occur than reactor design-basis accidents. The consequences of these accidents could be more serious if no mitigative actions are taken. In the reactor design-basis accidents, the mitigating systems are assumed to be available. In the severe reactor accidents, even though the initiating event could be a design-basis event (e.g., large break loss-of-coolant accident), additional failures of mitigating systems would cause some degree of physical deterioration of the fuel in the reactor core and a possible breach of the containment structure leading to releases of radioactive materials to the environment. For the purposes of this EIS, only the severe reactor accident scenarios that lead to containment bypass or failure are considered. Accident scenarios that do not lead to containment bypass or failure are not presented because the public and environmental consequences would be significantly less in those cases.

In 1988, the NRC asked all licensees of operating plants to perform individual plant examinations for severe accident vulnerabilities (NRC 1988). In the request, the NRC indicated that a probabilistic risk assessment is an acceptable approach to use in performing the individual plant examination. This analysis evaluates, in full detail (quantitatively), the consequences of all potential events caused by the operating disturbances (known as internal initiating events) within each plant. [See the discussion under severe reactor accident scenarios presented below.] The state-of-the-art probabilistic risk assessment uses realistic criteria and assumptions in evaluating the accident progression and the systems required to mitigate each accident.

In 1991, the NRC requested that all licensees of operating plants should conduct individual plant examinations of external events for severe accident vulnerabilities (NRC 1991). This analysis covers the accidents that could be initiated naturally (e.g., earthquakes, tornadoes, floods, strong winds) and/or manmade (e.g., aircraft crash and fire). The individual plant examination of external event analyses are less quantitative and results-oriented than those performed under individual plant examination. The analyses were done to confirm that no vulnerabilities or issues exist and that the plant would have sufficient capacity to continue functioning in beyond-design-basis external events.

Currently, plant-specific severe accident analyses are only available for operating plants such as the Sequoyah and Watts Bar Nuclear Plants. No such analyses are available for the Bellefonte Nuclear Plant. However, the results of such studies will be available prior to operation of the Bellefonte Nuclear Plant.

Severe Reactor Accident Scenarios

Before identifying the accident scenarios that lead to failure of the containment, it is important to provide a brief overview of the present severe accident analysis techniques used in plant-specific probabilistic risk assessments or individual plant examinations for severe accident vulnerabilities (NRC 1990b). The analysis starts with identification of initiating events (i.e., challenges to normal plant operation or accidents) that require successful mitigation to prevent core damage. These events are grouped into initiating event classes which have similar characteristics and require the same overall plant response.

For example, a loss of offsite power to a plant could be caused by severe weather events (high wind, tornado, hurricane, and snow and ice storms), power substation breaker faults, instability in the power transmission lines, unbalanced loading of power lines, etc. Each of these events would lead to loss of main generator power and a reactor trip, which would challenge the same safety functions. These events are grouped together and analyzed under the loss of offsite power initiating event.

Event trees are developed for each initiating event class. These event trees depict the possible sequence of events that could occur during the plant's response to each initiating event class. The trees delineate the possible combinations (sequences) of functional and/or system successes and failures that lead to either successful mitigation of the initiator or core damage. Functional and/or system success criteria are developed based on the plant response to the class of accidents. Failure modes of systems that are functionally important to preventing core damage are modeled. This modeling process is usually done with fault trees that define the combinations of equipment failures, equipment outage, and human errors that cause the failure of systems to perform the desired function.

Quantification of the event trees lead to hundreds, or even thousands, of different end states representing various accident sequences that lead to core damage. Each accident sequence and its associated end state has a unique "signature" because of the particular combination of system successes and failures events. These end states are grouped together into plant damage states, each of which collects sequences for which the progression of core damage, the release of fission products from the fuel, the status of containment and its systems, and the potential for mitigating source terms are similar. The sum of all core damage accident sequences will then represent an estimate of plant core damage frequency. The analysis of core damage frequency calculations is called a level 1 probabilistic risk assessment, or front-end analysis.

Next, an analysis of accident progression, containment loading resulting from the accident, and the structural response to the accident loading is performed. The primary objective of this analysis, which is called a level 2 probabilistic risk assessment, is to characterize the potential for, and magnitude of, a release of radioactive material from the reactor fuel to the environment, given the occurrence of an accident that damages the core. The analysis includes an assessment of containment performance in response to a series of severe accidents. Analysis of the progression of an accident (an accident sequence within a plant damage state) generates a time history of loads imposed on the containment pressure boundary. These loads would then be compared against the containment's structural performance limits. If the loads exceed the performance limits, the containment would be expected to fail; conversely, if the containment performance limits exceed the calculated loads, the containment is expected to survive. Three modes of containment failures are defined: containment bypass, early containment failure, and late containment failure (see **Table D–8**).

Table D–8 Definition and Causes of Containment Failure Mode Classes

Failure mode	***Definition and Causes***
Containment Bypass	Involves failure of the pressure boundary between the high-pressure reactor coolant and low-pressure auxiliary system. For pressurized water reactors, steam generator tube rupture, either as an initiating event or as a result of severe accident conditions, will lead to containment bypass. In these scenarios, if core damage occurs, a direct path to the environment can exist.
Early Containment Failure	Involves structure failure of the containment before, during, or slightly after (within a few hours) reactor vessel failure. A variety of mechanisms can cause structure failure such as: direct contact of core debris with containment, rapid pressure and temperature loads, hydrogen combustion, and fuel coolant interaction (ex-vessel steam explosion). Failure to isolate containment and an early vented containment after core damage are also classified as an early containment failures.
Late Containment Failure	Involves structural failure of the containment several hours after reactor vessel failure. A variety of mechanisms can cause late structure failure such as: gradual pressure and temperature increase, hydrogen combustion, and basemat melt-through by core debris. Venting containment late in the accident is also classified as a late containment failure.

The magnitude of the radioactive release to the atmosphere in an accident is dependent on the timing of the reactor vessel failure and the containment failure. To determine the magnitude of the release, a containment event tree representing the time sequence of major phenomenological events that could occur during the formation and relocation of core debris (after core melt), availability of the containment heat removal system, and the expected mode of containment failures (i.e., bypass, early, and late), is developed. A reduced set of plant damage states are defined by culling the lower frequency plant damage states into higher frequency ones that have relatively similar severity and consequence potential. This condensed set is known as the key plant damage states (a functional sequence that either has a core damage frequency $^{-6}$ per reactor year or leads to containment bypass at a frequency of $^{-7}$ per reactor year (NRC Generic Letter 88-20, NRC 1988). These key plant states would then become the initiating events for the containment event tree. The outcome of each sequence in this event tree represents a specific release category. Release categories that can be represented by similar source terms are grouped. Source terms associated with various release categories describe the fractional releases for representative radionuclide groups, as well as the timing, duration, and energy of release.

Most of the current plant probabilistic risk assessment analyses end at this stage. Only a limited number of plants have performed an evaluation of resulting consequences to the public and environment from releases of radioactive materials following a core melt and containment failure. This type of analysis, which is known as a level 3 probabilistic risk assessment, was first performed by the NRC in WASH-1400 (NRC 1975). In the late 1980s, the NRC performed a comprehensive, full-scope severe accident analyses for five different plant types and documented the results in NUREG-1150 (NRC 1990b). The analyses provided in this EIS use the insights gained from this NRC report and follow the methods applied, as well as the assumptions made to estimate the consequences to the public and the environment.

Representative Severe Reactor Accident Scenarios for the Sequoyah and Watts Bar Nuclear Plants

As stated earlier, only the plant damage states that lead to containment failure (failure mode defined as bypass, early, and late) and release of radioactive materials to the environment are considered in this EIS. The description of the representative accident scenarios is limited to the dominant sequence (or sequences) within a plant damage state that is a major contributor to the release level categories associated with each of the containment failures defined above. For Sequoyah 1 or Sequoyah 2 and Watts Bar 1, the information will be based on the most recent analysis of severe accidents performed by the Tennessee Valley Authority (TVA) under the individual plant examination program that covers both the level 1 and level 2 probabilistic risk assessment in detail. TVA's analyses of Sequoyah 1 or Sequoyah 2 and Watts Bar 1 individual plant examinations were submitted to the NRC in September 1992 (TVA 1992a, TVA 1992b). Both of these analyses have been revised (TVA 1995b, TVA 1994) and the Watts Bar 1 analysis has been revised further (TVA 1998).

The selected release categories and examples of various accident scenarios leading to containment failure and/or bypass are presented below, for the Sequoyah and Watts Bar Nuclear Plants. **Table D–9** shows reactor core inventories for the Watts Bar 1 and Sequoyah Nuclear Plants. **Table D–10** provides important information on time to core damage, containment failure, release duration, and the isotope release fractions associated with each of the release levels. **Table D–11** provides a representation of the dominant accident scenarios that lead to each release category, along with its likelihood of occurrence. Release Category I results from reactor vessel breach with early containment failure, Release Category II results from reactor vessel breach with containment bypass, and Release Category III results from reactor vessel breach with late containment failure.

Table D–9 Watts Bar 1 and Sequoyah Nuclear Plant Reactor Core Inventory

Nuclide	***Isotope***	***Inventory (Ci)***
Cobalt:	Co-58 Co-60	874,000 668,000
Krypton:	Kr-85 Kr-85m Kr-87 Kr-88	671,000 3.14×10^7 5.74×10^7 7.76×10^7
Rubidium:	Rb-86	51,200
Strontium:	Sr-89 Sr-90 Sr-91 Sr-92	9.73×10^7 5.25×10^6 1.25×10^8 1.30×10^8
Yttrium:	Y-90 Y-91 Y-92 Y-93	5.64×10^6 1.19×10^8 1.31×10^8 1.48×10^8
Zirconium:	Zr-95 Zr-97	1.50×10^8 1.56×10^8
Niobium:	Nb-95	1.42×10^8
Molybdenum:	Mo-99	1.65×10^8
Technetium:	Tc-99m	1.43×10^8
Ruthenium:	Ru-103 Ru-105 Ru-106	1.23×10^8 8.01×10^7 2.80×10^7
Rhodium:	Rh-105	5.55×10^7
Antimony:	Sb-127 Sb-129	7.56×10^6 2.68×10^7
Technetium:	Te-127 Te-127m Te-129 Te-129m Te-131m Te-132	7.30×10^6 966,000 2.51×10^7 6.62×10^6 1.27×10^7 1.26×10^8

Nuclide	***Isotope***	***Inventory (Ci)***
Iodine:	I-131	8.69×10^{7}
	I-132	1.28×10^{8}
	I-133	1.84×10^{8}
	I-134	2.02×10^{8}
	I-135	1.73×10^{8}
Xenon	Xe-133	1.84×10^{8}
	Xe-135	3.45×10^{7}
Cesium:	Cs-134	1.17×10^{7}
	Cs-136	3.57×10^{6}
	Cs-137	6.55×10^{6}
Barium:	Ba-139	1.70×10^{8}
	Ba-140	1.69×10^{8}
Lanthanum:	La-140	1.72×10^{8}
	La-141	1.58×10^{8}
	La-142	1.52×10^{8}
Cerium:	Ce-141	1.53×10^{8}
	Ce-143	1.49×10^{8}
	Ce-144	9.23×10^{7}
Praseodymium:	Pr-143	1.46×10^{8}
Neodymium:	Nd-147	6.54×10^{7}
Neptunium:	Np-239	1.75×10^{9}
Plutonium:	Pu-238	99,300
	Pu-239	22,400
	Pu-240	28,200
	Pu-241	4.76×10^{6}
Americium:	Am-241	3,140
Curium:	Cm-242	1.20×10^{6}
	Cm-244	70,400

Source: NUREG/CR-4551 (NRC 1990c)

Table D–10 Release Category Timing and Source Terms

Release Times, Heights, Energies, and Source Terms for Selected Sequoyah and Watts Bar Nuclear Plants Release Categories					
Release Category	***Release Height (m)***	***Warning Time (hr)***	***Release Time (hr)***	***Release Duration (hr)***	***Release Energy[a] (MW)***
I	10.00	8	10	2	28
II	10.00	20	24	4	1
III	10.00	20	30	10	3.5

Fission Product Source Terms (fraction of total Inventory):										
Release Category	***NG***	***I***	***Cs***	***Te***	***Sr***	***Ru***	***La***	***Ce***	***Ba***	***Mo***
I	0.90	0.042	0.043	0.044	0.0027	0.0065	0.00048	0.004	0.0046	0.0065
II	0.91	0.21	0.19	0.0004	0.0023	0.07	0.00028	0.00055	0.025	0.07
III	0.94	0.0071	0.011	0.0052	0.00036	0.00051	2.2×10^{-6}	4.0×10^{-6}	0.0013	0.00051

[a] These values were taken from similar accident scenarios as given in NUREG/CR-4551 (NRC 1990c).
Key: NG, noble gases
Source: TVA 1992a, TVA 1992b.

Table D–11 Release Category Frequencies and Related Accident Sequences for the Sequoyah and Watts Bar Nuclear Plants

Sequoyah Nuclear Plant:		
Release Category	***Release Frequency***	***Representative Accident Scenario(s)***
I	6.8×10^{-7}	The major accident contributors to this release event are initiated by loss of 125 V battery boards and loss of all offsite power with the failure of emergency diesels to start (station blackout: loss of all AC power to all emergency core cooling systems), as well as the failure of the auxiliary feedwater system (loss of secondary cooling) with no recovery before core melt.
II	4.0×10^{-6}	The main contributor to this release event is initiated by the steam generator tube rupture in conjunction with either an operator error or random failure of electrical distribution systems, leading to failure to the coolant system and failure to control the affected steam generator before core melt occurs.
III	9.2×10^{-6}	The major accident contributors to this release event are initiated by: loss of offsite power with various failures in the AC and/or DC distribution systems and no recovery of power before core melt, and by reactor coolant system small break loss-of-coolant accident (caused by either loss of component cooling system leading to development of reactor coolant pump seals failure or another nonisolatable break in the reactor coolant system) with failure to depressurize the reactor and/or establish long-term reactor core cooling.
Watts Bar Nuclear Plant:		
I	6.8×10^{-7}	The major accident contributors to this release event are initiated by loss of offsite power and loss of the essential raw cooling water system with failures of the emergency diesels to start and/or failures in the 125 VDC distribution system, in conjunction with loss of secondary cooling and no recovery before core melt.
II	6.9×10^{-6}	The accident scenario for this release event is similar to that given for Sequoyah Nuclear plant, above.
III	9.1×10^{-6}	The major accident contributors to this release event are initiated by: loss of offsite power with various failures in the AC distribution systems and no recovery of power before core melts, and by reactor coolant system LOCA (large and medium sized LOCA) with failure to establish long- term core cooling.

Representative Severe Accident Scenarios for the Bellefonte Nuclear Plant

For Bellefonte Nuclear Plant, no plant-specific severe accident analysis information is available. This plant will have a complete probabilistic risk assessment covering both the internal and the external initiating events prior to the issuance of an operating license by the NRC. For the purposes of this EIS, a surrogate list of accident scenarios will need to be selected based on the review of accident analyses of similar plants. For this selection process, the publicly available reports on individual plant examinations results from Three Mile Island 1 (GPUN 1993), Arkansas Nuclear One, Unit 1 (Entergy 1993), and Oconee Nuclear Station (Duke 1990), as well as a limited scope level 1 probabilistic risk assessment (core damage frequency calculation) report on the uncompleted Washington Nuclear Plant, Unit 1 (WHC 1992), were reviewed. The review process identified Washington Nuclear Plant 1 as the most similar, in the nuclear steam supply system and the containment structure, to the Bellefonte Nuclear Plant.

Based on the above review, the Washington Nuclear Plant Unit 1 limited level 1 probabilistic risk assessment report was used as surrogate for the Bellefonte Nuclear Plant. The core damage frequency calculations in this report includes the estimate for the original design as well as that for a modified safety system. For the purposes of this EIS, the core damage frequency associated with the original (as built) design was considered. For the level 2 analysis, e.g., determination of containment performance in severe accidents and corresponding release categories, the analyses presented in WHC-EP-0263 (WHC 1991) was used. Again, the release category frequencies given in this report were modified to reflect that of the original design. In addition, in order to present the release categories consistent with those given for the Watts Bar and Sequoyah Nuclear Plants, the release categories were regrouped (WHC 1991), as Release Category I, II, and III, and the bounding release fractions and the shortest timings in each group were assigned to the new release categories.

The selected release categories and examples of various accident scenarios leading to containment failure and/or bypass are presented below for the Bellefonte Plant. **Table D–12** presents the reactor core inventory for the Bellefonte Nuclear Plant. **Table D–13** provides relevant information on time to core damage, containment failure, release duration, and the isotope release fractions associated with each of the release levels. **Table D–14** provides a brief representation of dominant accident scenarios that lead to each release category level, along with its likelihood of occurrence.

Table D–12 Bellefonte Nuclear Plant Reactor Core Inventory

Nuclide	***Isotope***	***Inventory (Ci)***
Cobalt:	Co-58 Co-60	919,000 703,000
Krypton:	Kr-85 Kr-85m Kr-87 Kr-88	706,000 3.30×10^7 6.04×10^7 8.17×10^7
Rubidium:	Rb-86	53,800
Strontium:	Sr-89 Sr-90 Sr-91 Sr-92	1.02×0^8 5.53×10^6 1.32×10^8 1.37×10^8
Yttrium:	Y-90 Y-91 Y-92 Y-93	5.93×10^6 1.25×10^8 1.37×10^8 1.56×10^8
Zirconium:	Zr-95 Zr-97	1.58×0^8 1.64×10^8
Niobium	Nb-95	1.49×10^8
Molybdenum:	Mo-99	1.74×10^8
Technetium:	Tc-99m	1.50×10^8

Nuclide	*Isotope*	*Inventory (Ci)*
Ruthenium:	Ru-103	1.30×10^{8}
	Ru-105	8.42×10^{7}
	Ru-106	2.94×10^{7}
Rhodium:	Rh-105	5.83×10^{7}
Antimony:	Sb-127	7.95×10^{6}
	Sb-129	2.81×10^{7}
Technetium:	Te-127	7.68×10^{6}
	Te-127m	1.02×10^{6}
	Te-129	2.64×10^{7}
	Te-129m	6.97×10^{6}
	Te-131m	1.33×10^{7}
	Te-132	1.33×10^{8}
Iodine:	I-131	9.14×10^{7}
	I-132	1.35×10^{8}
	I-133	1.93×10^{8}
	I-134	2.12×10^{8}
	I-135	1.82×10^{8}
Xenon:	Xe-133	1.93×10^{8}
	Xe-135	3.63×10^{7}
Cesium:	Cs-134	1.23×10^{7}
	Cs-136	3.75×10^{6}
	Cs-137	6.89×10^{6}
Barium:	Ba-139	1.79×10^{8}
	Ba-140	1.77×10^{8}
Lanthanum:	La-140	1.81×10^{8}
	La-141	1.66×10^{8}
	La-142	1.60×10^{8}
Cerium:	Ce-141	1.61×10^{8}
	Ce-143	1.57×10^{8}
	Ce-144	9.71×10^{7}
Praseodymium:	Pr-143	1.54×10^{8}
Neodymium:	Nd-147	6.88×10^{7}
Neptunium:	Np-239	1.84×10^{9}
Plutonium:	Pu-238	104,000
	Pu-239	23,600
	Pu-240	29,700
	Pu-241	5.00×10^{6}
Americium:	Am-241	3,300
Curium:	Cm-242	1.26×10^{6}
	Cm-244	74,000

Source: Derived from NUREG/CR-4551 (NRC 1990c), by multiplying the values given in Table D–9 by the 1.055 (core thermal ratio of Bellefonte over Sequoyah Nuclear Plants).

Table D–13 Release Category Timing and Source Term

Release Times, Heights, Energies, and Source Terms for Selected Bellefonte Nuclear Plant Release Categories					
Release Category	*Release Height (m)*	*Warning Time (hr)*	*Release Time (hr)*	*Release Duration (hr)*	*Release Energy (MW)*
I	15	2.0	3.0	5	40
II	30	2.0	3.0	1	30
III	15	10	24	5	40

Fission Product Source Terms (fraction of total inventory)										
Release Category	*NG*	*I*	*Cs*	*Te*	*Sr*	*Ru*	*La*	*Ce*	*Ba*	*Mo*
I	1.0	0.003	0.003	0.006	0.0004	3.0×10^{-6}	3.0×10^{-6}	3.0×10^{-5}	0.0002	0.0002
II	1.0	0.07	0.07	0.1	0.01	6.0×10^{-5}	6.0×10^{-5}	0.0007	0.005	0.004
III	0.7	0.001	0.001	0.007	8.0×10^{-5}	8.0×10^{-7}	8.0×10^{-7}	9.0×10^{-6}	0.0001	3.0×10^{-6}

Key: NG, noble gases
Source: WHC 1991.

Table D–14 Release Category Frequencies and the Related Accident Sequences for the Bellefonte Nuclear Plant

Release Category	*Release Frequency*	*Representative Accident Scenario(s)*
I	9.0×10^{-7}	The major accident contributors to this release event would be initiated by a loss of offsite power with failure of the diesel generators (station blackout) and long-term failure of the auxiliary feedwater system. Containment fails early.
II	9.1×10^{-7}	The major accident contributors to this release event would be initiated by: a small loss-of-coolant accident followed by failure of emergency recirculation, containment spray recirculation, and containment isolation, and by a loss of offsite power with failure of the diesel generators (station blackout) with no recovery of power before core melt and containment isolation fails.
III	3.3×10^{-6}	The major accident contributors to this release event are initiated by a loss of offsite power with failure of the diesel generators (station blackout) and long-term failure of the auxiliary feedwater system. Containment fails late.

The information presented in the preceding three tables represent the best available estimate for the core damage frequency and characteristics without a plant-specific probabilistic assessment, such as those performed for the Watts Bar and Sequoyah Nuclear Plants. The Washington Nuclear Plant design was selected as the most representative design, but differences between this plant and the Bellefonte Nuclear Plant are to be expected. The referenced probabilistic analysis is a limited scope analysis and the Washington Nuclear Plant, like the Bellefonte Nuclear Plant, is not in commercial operation. [The lack of operational data results in the use of some more conservative assumptions that impact the analysis results.] However, use of this data with Bellefonte Nuclear Plant site-specific population and weather data does allow a representative calculation of risk to be performed.

D.1.2 Methodology for Estimating Radiological Impacts

D.1.2.1 Introduction

The GENII and MACCS2 computer codes were used to perform probabilistic analyses of radiological impacts. The GENII computer code was used to estimate the consequences of the reactor design-basis, nonreactor design-basis, TPBAR handling, and cask handling accidents. The MACCS2 computer code was used for the beyond design-basis accidents. In addition, deterministic analyses, using the method in the reactor facility safety analysis reports, were performed for the release of tritium in the reactor and nonreactor design-basis accidents. This additional analysis provides a basis for direct comparison between design-basis analysis results with and without the release of tritium from TPBARs.

A discussion of the GENII code is provided in Appendix C. A general discussion of the MACCS2 computer code is provided in Section D.1.2.2. A detailed description of the MACCS model is provided in NUREG/CR-4691 (NRC 1990a). The enhancements incorporated in MACCS2 are described in the MACCS2 User's Guide (SNL 1997).

D.1.2.2 MACCS2 Computer Code

The MACCS2 computer code, Version 1.12, is used to estimate the radiological doses and health effects that could result from postulated accidental releases of radioactive materials to the atmosphere. The specification of the release characteristics, designated a "source term," can consist of up to four Gaussian plumes that are often referred to simply as "plumes."

The radioactive materials released are modeled as being dispersed in the atmosphere while being transported by the prevailing wind. During transport, whether or not there is precipitation, particulate material can be modeled as being deposited on the ground. If contamination levels exceed a user-specified criterion, mitigative actions can be triggered to limit radiation exposures.

There are two aspects of the code's structure that are basic to understanding its calculations: (1) the calculations are divided into modules and phases and (2) the region surrounding the facility is divided into a polar-coordinate grid. These concepts are described in the following sections.

MACCS2 is divided into three primary modules: ATMOS, EARLY, and CHRONC. Three phases are defined as the emergency, intermediate, and long-term phases (EPA 1992). The relationship among the code's three modules and the three phases of exposure are summarized below.

The ATMOS module performs all of the calculations pertaining to atmospheric transport, dispersion, and deposition, as well as the radioactive decay that occurs before release and while the material is in the atmosphere. It utilizes a Gaussian plume model with Pasquill-Gifford dispersion parameters. The phenomena treated include building wake effects, buoyant plume rise, plume dispersion during transport, wet and dry deposition, and radioactive decay and ingrowth. The results of the calculations are stored for use by EARLY and CHRONC. In addition to the air and ground concentrations, ATMOS stores information on wind direction, arrival and departure times, and plume dimensions.

The EARLY module models the time period immediately following a radioactive release. This period is commonly referred to as the emergency phase. The emergency phase begins, at each successive downwind distance point, when the first plume of the release arrives. The duration of the emergency phase is specified by the user, and it can range between one and seven days. The exposure pathways considered during this period are direct external exposure to radioactive material in the plume (cloudshine), exposure from inhalation of radionuclides in the cloud (cloud inhalation), exposure to radioactive material deposited on the ground (groundshine), inhalation of resuspended material (resuspension inhalation), and skin dose from material deposited on the skin. Mitigative actions that can be specified for the emergency phase include evacuation, sheltering, and dose-dependent relocation.

The CHRONC module performs all of the calculations pertaining to the intermediate and long-term phases. CHRONC calculates the individual health effects that result from both direct exposure to contaminated ground and from inhalation of resuspended materials, as well as indirect health effects caused by the consumption of contaminated food and water by individuals who could reside both on and off of the computational grid.

The intermediate phase begins, at each successive downwind distance point, upon the conclusion of the emergency phase. The user can configure the calculations with an intermediate phase that has a duration as short as 0 or as long as 1 year. Essentially, there is no intermediate phase and a long-term phase begins immediately upon conclusion of the emergency phase.

These models are implemented on the assumption that the radioactive plume has passed and the only exposure sources (groundshine and resuspension inhalation) are from ground-deposited material. It is for this reason that MACCS2 requires the total duration of a radioactive release be limited to no more than four days. Potential doses from food and water ingestion during this period are not considered.

The mitigative action model for the intermediate phase is very simple. If the intermediate phase dose criterion is satisfied, the resident population is assumed to be present and subject to radiation exposure from groundshine and resuspension for the entire intermediate phase. If the intermediate phase exposure exceeds the dose criterion, then the population is assumed to be relocated to uncontaminated areas for the entire intermediate phase.

The long-term phase begins, at each successive downwind distance point, upon the conclusion of the intermediate phase. The exposure pathways considered during this period are groundshine, resuspension inhalation, and food and water ingestion.

The exposure pathways considered are those resulting from ground-deposited material. A number of protective measures can be modeled in the long-term phase to reduce doses to user-specified levels: decontamination, temporary interdiction, and condemnation. The decisions on mitigative action in the long-term phase are based on two sets of independent actions: decisions relating to whether land at a specific location and time is suitable for human habitation (habitability) and decisions relating to whether land at a specific location and time is suitable for agricultural production (farmability).

All of the calculations of MACCS2 are stored on the basis of a polar-coordinate spatial grid with a treatment that differs somewhat between calculations of the emergency phase and calculations of the intermediate and long-term phases. The region potentially affected by a release is represented with an (r,2) grid system centered on the location of the release. The radius, r, represents downwind distance. The angle, 2, is the angular offset from north, going clockwise.

The user specifies the number of radial divisions as well as their endpoint distances. The angular divisions used to define the spatial grid are fixed in the code and correspond to the 16 points of the compass, each being 22.5 degrees wide. The 16 points of the compass are used in the U.S. to express wind direction. The compass sectors are referred to as the coarse grid.

Since emergency phase calculations use dose-response models for early fatalities and early injuries that can be highly nonlinear, these calculations are performed on a finer grid basis than the calculations of the intermediate and long-term phases. For this reason, the calculations of the emergency phase are performed with the 16 compass sectors divided into three, five, or seven equal, angular subdivisions. The subdivided compass sectors are referred to as the fine grid.

The compass sectors are not subdivided into fine subdivisions for the intermediate and long-term phases because these calculations do not include estimation of the often highly nonlinear early fatality and early injury health effects, being limited to cancer and genetic effects. In contrast to the emergency phase, the calculations for these phases are performed using doses averaged over the full 22.5 degree compass sectors of the coarse grid.

Two types of doses may be calculated by the code: "acute" and "lifetime."

Acute doses are calculated to estimate deterministic health effects that can result from high doses delivered at high dose rates. Such conditions may occur in the immediate vicinity of a nuclear power plant following hypothetical severe accidents where containment failure has been assumed to occur. Examples of the health effects based on acute doses are early fatality, prodromal vomiting, and hypothyroidism.

Lifetime doses are the conventional measure of detriment used for radiological protection. These are 50-year dose commitments to either specific tissues (e.g., red marrow and lungs) or a weighted sum of tissue doses defined by the International Commission on Radiological Protection and referred to as "effective dose." Lifetime doses may be used to calculate the stochastic health effect risk resulting from exposure to radiation. MACCS2 uses the calculated lifetime dose in cancer risk calculations.

D.1.2.3 Data and General Assumptions

To assess the consequences of the accidents, with the exception of the beyond-design-basis accidents, data were collected and produced and assumptions made for incorporation in the GENII analyses. The source terms for the various accidents are described in Section D.1.1. The meteorological and population data are identical to those described in Appendix C. Ingestion parameters are based on Regulatory Guide 1.109 (NRC 1977).

To assess the consequences of beyond-design-basis accidents, the following data and assumptions were incorporated into the MACCS2 analysis.

- The **nuclide inventory** at accident initiation (e.g., reactor trip) of those radioactive nuclides important for the calculation of offsite consequences for each reactor is given in Section D.1.1.

- The **atmospheric source term** produced by the accident is described by the number of plume segments released, sensible heat content, timing, duration, height of release for each plume segment, time when offsite officials are warned that an emergency response should be initiated, and for each important radionuclide, the fraction of that radionuclide's inventory released with each plume segment. The source term(s) for each accident scenario is provided in Section D.1.1.

- **Meteorological data** characteristics of the site region are described by one year of hourly windspeed, atmospheric stability, and rainfall recorded at each site. Although one year of hourly readings contains 8,760 weather sequences, MACCS2 calculations examine only a representative subset of these sequences. The representative subset is selected by sampling the weather sequences after sorting them into weather bins defined by windspeed, atmospheric stability, and intensity and distance of the occurrence of rain.

- The **population distribution information** about each reactor site is based on the 1990 U.S. Census of Population and Housing (DOC 1992). State and county population estimates were examined to extrapolate the 1990 data to the year 2025. This data was fit to a polar coordinate grid having 16 angular sectors aligned with the 16 compass directions and 29 radial intervals that extend outward to 80 kilometers (50 miles).

- **Habitable land fractions** for the region around each reactor site were determined in a manner similar to the population distribution. The census block group boundary files include polygons that are classified as water features. The percentage of each sector that is covered by water is determined by fitting this data to the polar coordinate grid.

- **Farmland fractions** are the percentage of land devoted to farming (DOC 1993).

- **Emergency response assumptions** for evacuation, including delay time before evacuation, area evacuated, average evacuation speed, and travel distance, are provided in the Tennessee Multi-Jurisdictional Plans. Average evacuation speeds are based on the most conservative general population evacuation times.

- **Shielding and exposure data** must be input to MACCS2 code. The code requires shielding factors be specified for people evacuating in vehicles (cars, buses), taking shelter in structures (houses, offices, schools), and continuing normal activities either outdoors, in vehicles, or indoors. Because inhalation doses depend on breathing rate, breathing rates must be specified for people who are continuing normal activities, taking shelter, and evacuating. Since indoor concentrations of gas-borne radioactive materials are usually substantially less than outdoor concentrations, MACCS2 also requires that inhalation and skin protection shielding factors (indoor/outdoor concentration ratios) be provided.

  The protection factors presented in **Table D–15** were used in the analyses. The values in Table D–15 are for the Sequoyah Nuclear Plant as stated in NUREG/CR-4551 (NRC 1990c) and were used in the analysis for all three plants.

Table D–15 NUREG/CR–4551 Protection Factors

Protection Factor[a]	*Evacuees*	*Sheltering*	*Normal Activities*
Cloud Shielding Factor	1.0	0.65	0.75
Skin Protection Factor	1.0	0.33	0.41
Inhalation Protection Factor	1.0	0.33	0.41

[a] Protection factor of 1.0 indicates no protection, while a protection factor of 0.0 indicates 100% protection.

  For this analysis, the evacuation and sheltering region is defined as a 10 mile radial distance centered on the plant. A sheltering period is defined as the phase occurring before the initiation of the evacuation. During the sheltering phase, shielding factors appropriate for sheltered activity are used to calculate doses for the individuals in contaminated areas.

  At the end of the sheltering phase, the resident individuals begin their travel out of the region. Travel speeds and delay times were based on the Tennessee Multi-Jurisdictional Plans. The general population evacuation times for the various areas within the 10-mile radius were averaged to determine an overall evacuation delay time and evacuation speed for Sequoyah and Watts Bar Nuclear Plants. Bellefonte Nuclear Plant evacuation plans were unavailable, so the Bellefonte evacuation parameters were based on the Sequoyah Nuclear Plant data.

- Maximally Exposed Offsite Individual Dose is the total dose estimated to be incurred by a hypothetical individual assumed to reside at a particular location on the spatial grid. Population data, therefore, have no bearing on the generation of this consequence measure. Only direct exposure is considered in these results. Exposures from the ingestion of contaminated food and water are not included. Also, the generation of these results takes full account of any mitigative action models activated by accedence of dose thresholds. During evacuation, individuals have no protection from direct exposure. Therefore, in certain scenarios, it is possible that an evacuee may incur a larger direct exposure dose than an individual who does not evacuate.

- Long-term protective measures such as decontamination, temporary relocation, contaminated crops, milk condemnation, and farmland production prohibition are based on U.S. Environmental Protection Agency (EPA) Protective Action Guides.

- Mitigative actions (relocation, evacuation, interdiction, condemnation) are implemented for beyond-design-basis accidents (vessel breach with containment bypass, vessel breach with early containment failure, and vessel breach with late containment failure).

- Dose conversion factors required by MACCS2 for the calculation of committed effective dose equivalents are cloudshine dose-rate factor; groundshine dose-rate factor; "lifetime" 50-year committed inhalation dose, used for calculation of individual and societal doses and stochastic health effects; and 50-year committed ingestion dose, used for calculation of individual and societal doses and stochastic health effects from food and water ingestion.

The MACCS2 dose conversion factor preprocessor FGRDCF was used to create the dose factors. FGRDCF incorporates the data of Federal Guidance Reports 11 and 12 (EPA 1988, EPA 1993). The inhalation and ingestion dose conversion factors are for the most part identical to the values listed in International Commission on Radiological Protection 30 (ICRP 1980). Revised metabolic models for the following transuranic elements: niobium, plutonium, americium, curium, berkelium, californium, einsteinium, fermium, and mendelevium are used (ICRP 1986). In addition, Federal Guidance Report 11 provides inhalation and ingestion dose conversion factors for a few radionuclides (strontium 82, technetium 95, technetium 95m, antimony 116, plutonium 246, and curium 250) not considered in ICRP 30, but for which nuclear decay data were presented in ICRP 38 (ICRP 1983). Federal Guidance Report 12 provides external dose-rate factors for the 825 nuclides identified in ICRP 38.

The only change made to the dose conversion factors produced by FGRDCF was to the tritium inhalation factor. The 50-year committed inhalation dose for tritium was increased by 50 percent to account for skin absorption (PNL 1988).

D.1.2.4 Health Effects Calculations

The following sections describe the technical approach used to calculate potential consequences to human health from exposure to radionuclides.

The health consequences from exposure to radionuclides from accidental releases were calculated. Total effective dose equivalents were calculated and converted to estimates of cancer fatalities using dose conversion factors recommended by the International Commission on Radiological Protection. For populations, the number of estimated latent cancer fatalities is reported. For individuals, the estimated probability of a latent cancer fatality occurring is reported for the maximally exposed individual and a noninvolved worker.

The nominal values of lifetime cancer risk for low dose or low dose rate exposure (less than 20 rad) used in this environmental impact statement are 0.0005 per person-rem for a population of all ages and 0.0004 per person-rem for a working population. These dose-to-risk conversion factors are established by National Council on Radiation Protection and Measurement (NCRP 1993). See Appendix C for more detail regarding human health risk factors for nonfatal cancers and genetic disorders.

GENII uses a straight line plume method for calculating doses to receptors. The release/plume is assumed to disperse outward from the release point in one direction. Plume dispersion refers to the plume spreading out over a larger area and becoming less concentrated, which leads to lower doses. Certain weather conditions are better for plume dispersion than others. Therefore, it was necessary to analyze the doses to each receptor (e.g., maximally exposed individual population and non-involved worker) for the 16 compass sectors at each site to determine the maximum sector doses. This maximum receptor dose was presented in this EIS. This analysis conservatively assumes that after the accident, the wind would blow towards the sector which produces maximum dosage. In addition, the GENII analyses assume that the accident occurs in autumn which maximizes the estimated dose from contaminated food ingestion. Doses to each receptor were calculated using 50 percent meteorology. Fifty percent weather indicates a distribution with median weather conditions, (half of the weather conditions are worse and half are better). This meteorology is consistent with the guidance provided in NRC's Regulatory Guide 4.2 (NRC 1976).

The MACCS2 code was applied in a probabilistic manner using a weather bin sampling technique. The weather bin sampling method sorts weather sequences into categories and assigns a probability to each category according to the initial conditions (wind speed and stability class) and the occurrence of rain. Each of the sampled meteorological sequences was applied to each of the 16 sectors (accounting for the frequency of occurrence of the wind blowing in that direction). Individual doses as a function of distance and direction were calculated for each of the meteorological sequence samples. The mean dose values of the sequences were generated for each of the 16 sectors. The highest of these dose values was used for the maximally exposed individual and the noninvolved worker. Population doses are the sum of the individual doses in each sector.

D.1.2.5 Deterministic Calculations

D.1.2.5.1 Introduction

In addition to the GENII and MACCS2 calculations, deterministic analyses were performed for the reactor and nonreactor design-basis accidents (large break loss-of-coolant accident and waste gas decay tank rupture). The deterministic analyses were performed to provide a comparison of the effect of tritium on the doses calculated in the reactor Final Safety Analysis Reports. The Final Safety Analysis Reports present the thyroid inhalation, whole body beta, and whole body gamma doses at the exclusion area boundary and the low population zone. The deterministic analyses calculate the additional dose attributable to tritium using the same method as the Final Safety Analysis Reports.

D.1.2.5.2 Large Break Loss-of-Coolant Accident

To determine the effects of a tritium release following a postulated design-basis accident, a deterministic analysis, based on Regulatory Guide 1.4 (NRC 1974), was adopted. The Regulatory Guide 1.4 analysis was incorporated in the Safety Analysis Reports to calculate the environmental effects resulting from a design-basis large break loss-of-coolant accident event. The following paragraphs describe the release path(s) from containment to the environment, the conservatisms employed, and the dose calculation method.

The primary containment leak rate used in the Final Safety Analysis Report analyses for the first 24 hours is the design-basis leak rate (as specified in the technical specifications regarding containment leakage), and it is 50 percent of this value for the duration of the accident. The Watts Bar and Sequoyah Final Safety Analysis Reports assume the primary containment (known here as steel containment vessel) leak rates to be 0.25 percent of the containment atmosphere per day for the first 24 hours following the accident and 0.125 percent per day for the remainder of the 30-day period. The Bellefonte Final Safety Analysis Report assumes the leak rate to be 0.2 percent per day for the first 24 hours following the accident and 0.1 percent per day for the remainder of the 30-day period.

For the Watts Bar and Sequoyah Nuclear Plants, the leakage from the steel containment vessel can be grouped into two categories: leakage into the auxiliary building and leakage into the annulus (a space between the steel containment vessel and shield building where leakage from primary containment is collected before it is released). For the Bellefonte Nuclear Plant, the leakage from the primary containment can be grouped into three categories: leakage into the auxiliary building, leakage into the annulus (a space between primary and secondary containment), and leakage directly to the environment.

The Watts Bar and Sequoyah Nuclear Plant analyses assume that 25 percent of the total primary leakage goes to the auxiliary buildings. This value is an estimated upper bound of leakage to the auxiliary buildings based on 10 CFR 50, Appendix J testing of all containment penetrations. Selecting an upper bound is conservative because an increased leakage fraction to the auxiliary building would result in an increased offsite dose. The Bellefonte Nuclear Plant analysis assumes that 9.5 percent of the total primary leakage goes to the auxiliary building.

At the Watts Bar and Sequoyah Nuclear Plants, the auxiliary building is normally ventilated by the auxiliary building ventilation system. However, following a large break loss-of-coolant accident, the normal ventilation systems to all areas of the auxiliary building would be shut down and isolated. Upon auxiliary building isolation, the auxiliary building gas treatment system would be activated to ventilate the area and filter the exhaust to the atmosphere. At the Bellefonte Nuclear Plant, during both normal and emergency operation, the auxiliary building engineered safety feature environmental control system provides pressure control and cleanup.

At each plant, fission products that leak from the primary containment to areas of the auxiliary building would be diluted in the room atmosphere and would travel through ducts and other rooms to the areas where the suctions for the auxiliary building gas treatment system or environmental control system are located. The Final Safety Analysis Report analyses allow a holdup time for airborne activity after an initial period of direct release. However, for the tritium analysis, it is conservatively assumed that activity leaking to the auxiliary building would be released directly to the environment through the auxiliary building gas treatment system or environmental control system, neglecting any holdup time in the auxiliary building before being exhausted.

The Watts Bar and Sequoyah Nuclear Plant analyses assume that 75 percent of the primary containment leakage is to the annulus (TVA 1995a, TVA 1996). The Bellefonte Nuclear Plant analysis assumes that 90 percent of the primary containment leakage would be to the annulus (TVA 1991). The presence of the annulus between the primary containment (or steel containment vessel) and the secondary containment (or shield building) reduces the probability of direct leakage from the containment to the atmosphere and allows holdup and plateout of fission products in the shield building. For the tritium analysis, plateout in the annulus was neglected.

Transfer of activity from the annulus volume to the emergency gas treatment system suction for the Watts Bar and Sequoyah Nuclear Plants, or to the secondary containment cleanup system suction for the Bellefonte Nuclear Plant, is assumed to be a statistical process similar mathematically to the decay process (i.e., the rate of removal from the annulus is proportional to the activity in the annulus). This corresponds to an assumption that the activity is homogeneously distributed throughout the mixing volume. Because of the low emergency gas treatment system or secondary containment cleanup system flow rate compared to the annulus volume, the thermal convection due to heating of the containment structure, and the relative location of the emergency gas treatment system or secondary containment cleanup system suctions and the emergency gas treatment system or secondary containment cleanup system recirculation exhausts, a high degree of mixing can be expected. It is, however, conservatively assumed that only 50 percent of the annulus free volume is available for mixing of the activity.

The emergency gas treatment system and secondary containment cleanup system are essentially annulus recirculation systems with pressure-activated valves that allow part of the system flow to be exhausted to the atmosphere to maintain an adequate annulus pressure. It is conservatively assumed that, for the first hour following the accident, all of the available tritium is exhausted. The holdup time is a function of the emergency gas treatment system or secondary containment cleanup system flow and exhaust rates, as well as the annulus volume. The holdup time before release is defined as 50 percent of the annulus volume divided by the exhaust flow rate of the emergency gas treatment system or secondary containment cleanup system.

The annulus pressure would be maintained at less than the auxiliary building's internal pressure during normal operation, therefore, any leakage between the two volumes following a loss of coolant accident would be into the annulus. It is conservatively assumed that there is no leakage via this route.

The Bellefonte Nuclear Plant also has a leakage of 0.5 percent of the total primary containment leak rate directly to the environment. This leakage is assumed to pass directly to the environment without mixing or holdup.

In the Final Safety Analysis Reports, thyroid inhalation and external whole body gamma and beta doses are calculated at the exclusion area boundary and low population zone. The inhalation and beta doses for tritium are calculated; no gamma dose calculation is needed since tritium decays only by beta emission.

The exclusion area boundary is that area surrounding the reactor in which the reactor licensee has the authority to determine all activities, including exclusion or removal of personnel and property from the area. This area may be traversed by a highway, railroad, or waterway, provided these are not so close to the facility that they interfere with normal operations of the facility and appropriate and effective arrangements are made to control traffic and protect public health and safety on the highway, railroad, or waterway in an emergency. Residences within the exclusion area normally would be prohibited. In any event, residents would be subject to ready removal in case of necessity. Activities unrelated to operation of the reactor may be permitted in an exclusion area under appropriate limitations, provided that no significant hazards to the public health and safety would result.

The low population zone is the area immediately surrounding the exclusion area that contains residents whose total number and density indicate there is a reasonable probability that appropriate protective measures could be taken in their behalf in the event of a serious accident. These guides do not specify a permissible population density or total population within this zone because the situation may vary from case to case. Whether a specific number of people can, for example, be evacuated from a specific area or instructed to take shelter on a timely basis would depend on many factors such as location, number and size of highways, scope and extent of advance planning, and actual distribution of residents within the area.

Calculations are performed using hourly time steps. This time step size is appropriate because of the large primary containment volume and low leakage rate; the tritium concentration (activity per volume) decreases only a few tenths of a percent per hour. At each time step the activity per hour is calculated and placed in the thyroid inhalation and beta dose formulas shown below to determine the doses. Final Safety Analysis Report time-dependent atmospheric dispersion factors, breathing rates, and dose conversion factors are incorporated. The doses at each time step are summed for a total dose. Doses are calculated separately for each pathway (annulus, auxiliary building, bypass), and then summed.

Thyroid inhalation doses are calculated using the following equation (NRC 1974, AEC 1972).

$$\boldsymbol{Dose} \left(\frac{}{Q} \right)_t BR_t \, Q_t \, DCF$$

where:

$\left(\frac{}{Q} \right)_t$	is the average atmospheric dilution factor over a given time interval t
Br_t	is the breathing rate for time interval t
Q_t	is the activity of tritium released during a given time interval t
DCF	is the inhalation dose conversion factor for tritium

Whole body beta doses are calculated using the following equation (NRC 1974, AEC 1972).

$$Dose\ \ 0.23 \left(\frac{\ }{Q}\right)_t Q_t \overline{E}$$

where:

$\left(\frac{\ }{Q}\right)_t$	is the average atmospheric dilution factor over a given time interval t
Q_t	is the activity of tritium released during a given time interval t
$\overline{E}$	is the average beta radiation energy emitted by tritium per disintegration

D.1.2.5.3 Waste Gas Decay Tank Accident

The effects of a tritium release following a postulated waste gas decay tank rupture was also analyzed with a deterministic approach. As in the Final Safety Analysis Reports, the analysis was performed based on Regulatory Guide 1.24 (AEC 1972). The tritium source term available for release from the waste gas decay tank is described in Section D.1.1. The inventory of the waste gas decay tank is assumed to leak out at ground level over a two-hour time period. Thyroid inhalation and whole-body beta doses are calculated for the exclusion area boundary and the low population zone using the equations described in Section D.1.2.5.2. Final Safety Analysis Report time-dependent atmospheric dispersion factors, breathing rates, and dose conversion factors are incorporated.

D.1.2.6 Uncertainties

The sequence of analyses performed to generate the radiological and hazardous chemicals impacts estimates from normal operation of CLWR facilities, CLWR facility accidents and overland transportation include (1) selection of normal operational modes and accident scenarios and their probabilities, (2) estimation of source terms, (3) estimation of environmental transport and uptake of radionuclides and hazardous chemicals, (4) calculation of radiation and chemical doses to exposed individuals, and (5) estimation of health effects. Health effects are presented in terms of latent cancers and latent cancer fatalities. There are uncertainties associated with each of these steps. Uncertainties exist in the way the physical systems being analyzed are represented by the computational models and in the data required to exercise the models (due to measurement errors, sampling errors, or natural variability).

Of particular interest are the uncertainties in the estimate of cancer deaths from exposure to radioactive materials. The numerical values of the health risk estimates used in this EIS (refer to C.2.1.2) were obtained by the practice of linear extrapolation from the nominal risk estimate for lifetime total cancer mortality resulting from exposures at 10 rad. Other methods of extrapolation to the low-dose region could yield higher or lower estimates of cancer deaths. Studies of human populations exposed at low doses are inadequate to demonstrate the actual level of risk. There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiological observation, and the possibility of no risk or even health benefits (hormesis effects) cannot be excluded. Because the health risk estimators are multiplied by conservatively calculated radiological doses to predict fatal cancer risks, the fatal cancer values presented in this EIS are expected to be overestimates.

For the purposes of presentation in this EIS, the impacts calculated from the linear model are treated as an upper bound case, consistent with the widely used methodologies for quantifying radiogenic health impacts. This does not imply that health effects are expected. Moreover, in cases where the upper bound estimators predict a number of latent cancer deaths that is greater than 1, this does not imply that the latent cancer death(s) are identifiable to any individual.

Uncertainties are also introduced when accident analyses performed for similar existing facilities have been used as a major source of data. Although the radionuclide composition of source terms are reasonable estimates, there are uncertainties in the radionuclide inventory and release fractions that affect the estimated consequences. Accident frequencies for low probability sequences of events are always difficult to estimate, even for operating facilities, because there is little or no record of historical occurrences. For a new facility, such as Bellefonte 1 or 2, any use of accident frequencies that are estimated from similar exiting facilities would tend to further compound the effects of uncertainties.

In summary, the radiological and hazardous chemical impact estimates presented in this EIS were obtained by:

Using the latest available data;

Considering the processes, events, and accidents reasonably foreseeable for tritium production in a CLWR and overland transportation of irradiated TPBARs;

Making conservative assumptions when there is doubt about the exact nature of the processes and events taking place, such that the chance of underestimating health impacts is small.

D.1.3 Accident Consequences and Risks

D.1.3.1 Reactor Design-Basis Accident

The reactor design-basis accident source term and accident frequency data, presented in Tables D–2 and D–3, were evaluated using two different accident analysis approaches. The first analysis approach used the GENII accident analysis computer code (PNL 1988) to estimate the accident consequences and risks. The second analysis approach was based on published NRC guidance for the assessment of design-basis accident impacts. The NRC requires that the results of an analysis evaluating design-basis accident impacts on a different set of receptors be submitted for evaluation as part of the licensing basis for each reactor.

Analyses were performed in accordance with guidance provided in NRC Regulatory Guide 4.2 (NRC 1976). This guide recommends using an atmospheric diffusion value (

determined in Safety Guide No. 4. This safety guide has been revised and reissued as Revision 2, Regulatory Guide 1.4 (NRC 1974). NRC in 1983 issued Regulatory Guide 1.145, providing guidance in determining 95th percentile approach (NRC 1983). In this analyses, DOE assumes that the 95 percentile direction dependent

in Safety Guide No. 4 and Regulatory Guide 1.4. The GENII computer code which is based on the current NRC's acceptable directional dependent approach was used to determine 50 percentile and 95 percentile meteorological conditions for each site. The results indicated that the estimated doses using 50 percentile meteorological conditions were more than 0.1 times the 95 percentile meteorological doses. Therefore, the 50 percentile meteorological condition at each site was used to estimate the consequences of design-basis and TPBAR handling accidents.

Table D–16 summarizes the GENII-generated consequences of the reactor design-basis accident to the maximally exposed offsite individual, an average individual in the public within an 80 kilometer (50 mile) radius of the reactor site, a noninvolved worker at the Watts Bar and Bellefonte Nuclear Plant Sites located 640 meters (0.4

miles) from the release point, and a noninvolved worker at the Sequoyah Nuclear Plant located at the site boundary 556 meters (0.35 miles) from the release point. The risks associated with the reactor design-basis accident to the same receptors are summarized in **Table D–17**.

Table D–18 summarizes the consequences of the reactor design-basis accident (estimated using NRC guidance and 95th percentile
individual located at the reactor site low population zone. The zero TPBAR entries are total accident dose. The 1,000 and 3,400 TPBAR entries represent the incremental change to the dose due to the addition of TPBARs. The margin to site dose limits (i.e., the difference between the dose estimate and the site dose criteria) associated with the reactor design-basis accident to the same receptors are summarized in **Table D–19**.

Table D–16 GENII-Generated Reactor Design-Basis Accident Consequences

Reactor Site	*Tritium Production*	*Maximally Exposed Offsite Individual*		*Average Individual in Population to 80 km (50 mi)*		*Noninvolved Worker*	
		Dose (rem)	*Cancer Fatality [a]*	*Dose (rem)*	*Cancer Fatality[a]*	*Dose (rem)*	*Cancer Fatality [a]*
Watts Bar	1,000 TPBARs	0.0014	7.0×10^{-7}	0.000011	5.5×10^{-9}	0.000024	9.6×10^{-9}
	3,400 TPBARs	0.0047	2.4×10^{-6}	0.000038	1.9×10^{-8}	0.000081	3.2×10^{-8}
Sequoyah	1,000 TPBARs	0.0019	9.5×10^{-7}	0.000022	1.1×10^{-8}	8.1×10^{-6}	3.2×10^{-9}
	3,400 TPBARs	0.0065	3.3×10^{-6}	0.000075	3.8×10^{-8}	0.000028	1.1×10^{-8}
Bellefonte	1,000 TPBARs	0.000085	4.3×10^{-8}	1.7×10^{-6}	8.5×10^{-10}	2.9×10^{-8}	1.2×10^{-11}
	3,400 TPBARs	0.00029	1.5×10^{-7}	5.5×10^{-6}	2.8×10^{-9}	1.0×10^{-7}	4.0×10^{-11}

[a] Increased likelihood of cancer fatality.

Table D–17 Reactor Design-Basis Accident Annual Risks

Reactor Site	*Tritium Production*	*Maximally Exposed Offsite Individual [a]*	*Average Individual in Population to 80 km (50 mi) [a]*	*Noninvolved Worker [a]*
Watts Bar	1,000 TPBARs	1.4×10^{-10}	1.1×10^{-12}	1.9×10^{-12}
	3,400 TPBARs	4.8×10^{-10}	3.8×10^{-12}	6.4×10^{-12}
Sequoyah	1,000 TPBARs	1.9×10^{-10}	2.2×10^{-12}	6.4×10^{-13}
	3,400 TPBARs	6.6×10^{-10}	7.6×10^{-12}	2.2×10^{-12}
Bellefonte	1,000 TPBARs	8.6×10^{-12}	1.7×10^{-13}	2.4×10^{-15}
	3,400 TPBARs	3.0×10^{-11}	5.6×10^{-13}	8.0×10^{-15}

[a] Increased likelihood of cancer fatality per year.

Table D–18 Reactor Design-Basis Accident Consequences Using the NRC Analysis Approach

Reactor Site	Tritium Production	Dose Description	Individual at Area Exclusion Boundary Dose (rem)	Individual at Low Population Zone Dose (rem)
Watts Bar	0 TPBARs (No Action) [a]	Thyroid Inhalation Dose	34.1	11.0
		Beta + Gamma Whole Body Dose	3.5	3.4
	1,000 TPBARs [b]	Thyroid Inhalation Dose	0.0018	0.0022
		Beta + Gamma Whole Body Dose	0.00010	0.00018
	3,400 TPBARs [b]	Thyroid Inhalation Dose	0.0060	0.0075
		Beta + Gamma Whole Body Dose	0.00035	0.00061
Sequoyah	0 TPBARs (No Action) [a]	Thyroid Inhalation Dose	145	27
		Beta + Gamma Whole Body Dose	12.2	2.9
	1,000 TPBARs [b]	Thyroid Inhalation Dose	0.0044	0.0018
		Beta + Gamma Whole Body Dose	0.00026	0.0001
	3,400 TPBARs [b]	Thyroid Inhalation Dose	0.015	0.0060
		Beta + Gamma Whole Body Dose	0.00088	0.00047
Bellefonte	0 TPBARs [c, d]	Thyroid Inhalation Dose	5.8	2.7
		Beta + Gamma Whole Body Dose	0.031	0.18
	1,000 TPBARs [b]	Thyroid Inhalation Dose	0.0041	0.0028
		Beta + Gamma Whole Body Dose	0.00024	0.00021
	3,400 TPBARs [b]	Thyroid Inhalation Dose	0.011	0.0095
		Beta + Gamma Whole Body Dose	0.00082	0.00073

[a] TVA 1995a, TVA 1996.
[b] Only TPBAR contribution to dose.
[c] TVA 1991.
[d] The 0 TPBAR entry is included for consistency with the Watts Bar and Sequoyah analyses. The No Action alternative at the Bellefonte 1 implies the reactor is not brought into commercial service. The No Action radiological dose is 0.

Table D–19 Reactor Design-Basis Accident Consequence Margin to Site Dose Criteria

Reactor Site	Tritium Production	Dose Description [a]	Site Dose Criteria (rem) [b]	Individual at Area Exclusion Boundary		Individual at Low Population Zone	
				Dose (rem)	Margin (%) [c]	Dose (rem)	Margin (%) [c]
Watts Bar	0 TPBARs (No Action) [d]	Thyroid Inhalation Dose	300	34.1	88.6	11.0	96.3
		Beta + Gamma Whole Body Dose	25	3.5	86.1	3.4	86.2
	1,000 TPBARs	Thyroid Inhalation Dose	300	34.1	88.6	11.0	96.3
		Beta + Gamma Whole Body Dose	25	3.5	86.1	3.4	86.2
	3,400 TPBARs	Thyroid Inhalation Dose	300	34.1	88.6	11.0	96.3
Sequoyah	0 TPBARs (No Action) [d]	Beta + Gamma Whole Body Dose	25	3.5	86.1	3.4	86.2
		Thyroid Inhalation Dose	300	145	51.6	27	91.0
		Beta + Gamma Whole Body Dose	25	12.2	51.1	2.9	88.4
	1,000 TPBARs	Thyroid Inhalation Dose	300	145	51.6	27	91.0
		Beta + Gamma Whole Body Dose	25	12.2	51.1	2.9	88.4
Sequoyah	3,400 TPBARs	Thyroid Inhalation Dose	300	145	51.6	27	91.0
		Beta + Gamma Whole Body Dose	25	12.2	51.1	2.9	88.4
Bellefonte	0 TPBARs [e, f]	Thyroid Inhalation Dose	300	5.8	98.1	2.7	99.1
		Beta + Gamma Whole Body Dose	25	0.031	99.9	0.18	99.3
	1,000 TPBARs	Thyroid Inhalation Dose	300	5.8	98.1	2.7	99.1
		Beta + Gamma Whole Body Dose	25	0.031	99.9	0.18	99.3
	3,400 TPBARs	Thyroid Inhalation Dose	300	5.9	98.0	2.7	99.1
		Beta + Gamma Whole Body Dose	25	0.032	99.9	0.18	99.3

[a] Dose is the total dose from the reactor plus the contribution from the TPBARs.
[b] 10 CFR 100.11.
[c] Margin below the site dose criteria.
[d] TVA 1995a, TVA 1996.
[e] TVA 1991.
[f] The 0 TPBAR entry is included for consistency with the Watts Bar and Sequoyah or analyses. The No Action Alternative at the Bellefonte 1 implies the reactor is not brought into commercial service. The No Action Alternative radiological dose is 0.

Sequoyah	1,000 TPBARs	1.3×10^{-7}	1.0×10^{-8}	2.1×10^{-9}
	3,400 TPBARs	1.5×10^{-7}	1.2×10^{-8}	2.5×10^{-9}
Bellefonte	1,000 TPBARs	1.3×10^{-8}	3.6×10^{-9}	2.0×10^{-11}
	3,400 TPBARs	1.5×10^{-8}	4.1×10^{-9}	2.4×10^{-11}

[a] Increased likelihood of cancer fatality per year.

Table D–20 Nonreactor Design-Basis Accident Consequences Using the NRC Analysis Approach

Reactor Site	*Tritium Production*	*Dose Description*	*Individual at Area Exclusion Boundary Dose (rem)*	*Individual at Low Population Zone Dose (rem)*
Watts Bar	0 TPBARs (No Action) [a]	Thyroid Inhalation Dose	0.018	0.042
		Beta + Gamma Whole Body Dose	0.13	0.031
	1,000 TPBARs [b]	Thyroid Inhalation Dose	0.033	0.0079
		Beta + Gamma Whole Body Dose	0.0020	0.00047
	3,400 TPBARs [b]	Thyroid Inhalation Dose	0.038	0.0091
		Beta + Gamma Whole Body Dose	0.0023	0.00054
Sequoyah	0 TPBARs (No Action) [a]	Thyroid Inhalation Dose	0.000013	1.1×10^{-6}
		Beta + Gamma Whole Body Dose	0.0017	0.00014
	1,000 TPBARs [b]	Thyroid Inhalation Dose	0.090	0.011
	3,400 TPBARs [b]	Beta + Gamma Whole Body Dose	0.0053	0.00063
		Thyroid Inhalation Dose	0.10	0.012
		Beta + Gamma Whole Body Dose	0.0061	0.00073
Bellefonte	0 TPBARs [a, c]	Thyroid Inhalation Dose	0.0067	0.0019
		Beta + Gamma Whole Body Dose	0.71	0.14
	1,000 TPBARs [b]	Thyroid Inhalation Dose	0.11	0.022
		Beta + Gamma Whole Body Dose	0.0065	0.0013
	3,400 TPBARs [b]	Thyroid Inhalation Dose	0.13	0. 025
		Beta + Gamma Whole Body Dose	0.0074	0.0015

[a] TVA 1991, TVA 1995a, TVA 1996.
[b] Only TPBAR contribution to dose.
[c] The 0 TPBAR entry is included for consistency with the Watts Bar and Sequoyah Nuclear Plant analyses. The No Action Alternative at the Bellefonte Nuclear Plant implies the reactor is not brought into commercial service. The No Action Alternative radiological dose is 0.

Table D–21 Nonreactor Design-Basis Accident Consequence Margin to Site Dose Criteria

Reactor Site	*Tritium Production*	*Dose Description* [a]	*Site Dose Criteria (rem)* [b]	*Individual at Area Exclusion Boundary*		*Individual at Low Population Zone*	
				Dose (rem)	*Margin (%)* [c]	*Dose (rem)*	*Margin (%)* [c]
Watts Bar	0 TPBARs (No Action) [d]	Thyroid Inhalation Dose	300	0.018	99.99	0.0042	99.999
		Beta + Gamma Whole Body Dose	25	0.13	99.5	0.031	99.9
	1,000 TPBARs	Thyroid Inhalation Dose	300	0.051	99.98	0.012	99.996
		Beta + Gamma Whole Body Dose	25	0.13	99.5	0.032	99.9
	3,400 TPBARs	Thyroid Inhalation Dose	300	0.056	99.98	0.013	99.996
		Beta + Gamma Whole Body Dose	25	0.13	99.5	0.032	99.9
Sequoyah	0 TPBARs (No Action) [d]	Thyroid Inhalation Dose	300	0.000013	100	1.1×10^{-6}	100
		Beta + Gamma Whole Body Dose	25	0.0017	99.99	0.00014	99.999
	1,000 TPBARs	Thyroid Inhalation Dose	300	0.090	99.97	0.011	99.996
		Beta + Gamma Whole Body Dose	25	0.0070	99.97	0.00077	99.997
	3,400 TPBARs	Thyroid Inhalation Dose	300	0.10	99.97	0.012	99.996
		Beta + Gamma Whole Body Dose	25	0.0078	99.97	0.00087	99.997
Bellefonte	0 TPBARs [e, f]	Thyroid Inhalation Dose	300	0.0067	99.998	0.0019	99.99
		Beta + Gamma Whole Body Dose	25	0.71	97.2	0.14	99.4
	1,000 TPBARs	Thyroid Inhalation Dose	300	0.11	99.96	0.024	99.992
		Beta + Gamma Whole Body Dose	25	0.72	97.1	0.14	99.4
	3,400 TPBARs	Thyroid Inhalation Dose	300	0.13	99.96	0.027	99.991
		Beta + Gamma Whole Body Dose	25	0.72	97.1	0.14	99.4

[a] Dose is the total dose from the reactor plus the contribution from the TPBARs.
[b] 10 CFR 100.11.
[c] Margin below the site dose criteria.
[d] TVA 1995a, TVA 1996.
[e] Bellefonte Final Safety Analysis Report (TVA 1991), realistic analysis dose estimates. Design analysis dose estimates were also below the site dose limits.
[f] The 0 TPBAR entry is included for consistency with the Watts Bar and Sequoyah Nuclear Plant analyses. The No Action Alternative at the Bellefonte Nuclear Plant implies the reactor is not brought into commercial service. The No Action Alternative radiological dose is 0.

D.1.3.2 TPBAR Handling Accident

The TPBAR handling accident source term and accident frequency data presented in Section D.1.1.4 were evaluated using the GENII accident analysis computer code (PNL 1988). Analyses were performed in accordance with guidance provided in NRC Regulatory Guide 4.2 (NRC 1976). **Table D–24** summarizes the consequences of the TPBAR handling accident, with 50 percent meteorological conditions, to the maximally exposed offsite individual, an average individual in the public within an 80 kilometer (50 mile) radius of the reactor site, a noninvolved worker at the Watts Bar and Bellefonte Nuclear Plant Sites located 640 meters (0.4 mile) from the release point, and a noninvolved worker at the Sequoyah Nuclear Plant located at the site boundary 556 meters (0.35 mile) from the release point. The risks associated with the TPBAR handling accident to the same receptors are summarized in **Table D–25**.

Table D–22 TPBAR Handling Accident Consequences

Reactor Site	*Maximally Exposed Offsite Individual*		*Average Individual in Population to 80 kilometers (50 miles)*		*Noninvolved Worker*	
	Dose (rem)	*Cancer Fatality* [a]	*Dose (rem)*	*Cancer Fatality* [a]	*Dose (rem)*	*Cancer Fatality* [a]
Watts Bar	0.0010	5.0×10^{-7}	0.000012	6.0×10^{-9}	0.000016	6.4×10^{-9}
Sequoyah	0.00024	1.2×10^{-7}	0.000019	9.5×10^{-9}	5.0×10^{-6}	2.0×10^{-9}
Bellefonte	0.000024	1.2×10^{-8}	6.7×10^{-6}	3.4×10^{-9}	4.8×10^{-8}	1.9×10^{-11}

[a] Increased likelihood of cancer fatality.

Table D–23 TPBAR Handling Accident Annual Risks

Reactor Site	*Tritium Production*	*Maximally Exposed Offsite Individual* [a]	*Average Individual in Population to 80 km (50 mi)* [b]	*Noninvolved Worker* [a]
Watts Bar	1,000 TPBARs	8.5×10^{-10}	1.0×10^{-11}	1.1×10^{-11}
	3,400 TPBARs	2.9×10^{-9}	3.5×10^{-11}	3.7×10^{-11}
Sequoyah	1,000 TPBARs	2.0×10^{-10}	1.6×10^{-11}	3.4×10^{-12}
	3,400 TPBARs	7.0×10^{-10}	5.5×10^{-11}	1.2×10^{-11}
Bellefonte	1,000 TPBARs	2.0×10^{-11}	5.8×10^{-12}	3.2×10^{-14}
	3,400 TPBARs	7.0×10^{-11}	2.0×10^{-11}	1.1×10^{-13}

[a] Increased likelihood of cancer fatality per year.

D.1.3.3 Truck Transportation Cask Handling Accident

The truck transportation cask handling accident source term and accident frequency data presented in Section D.1.1.5 were evaluated using the GENII accident analysis computer code (PNL 1988). Analyses were performed in accordance with guidance provided in NRC Regulatory Guide 4.2 (NRC 1976). **Table D–26** summarizes the consequences of the truck transportation cask handling accident, with 50 percent meteorological conditions, to the maximally exposed offsite individual, an average individual in the public within an 80 kilometer (50 mile) radius of the reactor site, a noninvolved worker at the Watts Bar and Bellefonte Nuclear Plant Sites located 640 meters (0.4 miles) from the release point, and a noninvolved worker at the Sequoyah Nuclear Plant located at the site boundary 556 meters (0.35 miles) from the release point. The risks associated with the truck transportation cask handling accident to the same receptors are summarized in **Table D–27**.

Table D–24 Truck Transportation Cask Handling Accident Consequences

	Maximally Exposed Offsite Individual		*Average Individual in Population to 80 km (50 mi)*		*Noninvolved Worker*	
Reactor Site	***Dose (rem)***	***Cancer Fatality*** [a]	***Dose (rem)***	***Cancer Fatality*** [a]	***Dose (rem)***	***Cancer Fatality*** [a]
Watts Bar	0.00071	3.6×10^{-7}	8.5×10^{-6}	4.3×10^{-9}	0.000011	4.4×10^{-9}
Sequoyah	0.00017	8.5×10^{-8}	0.000013	6.5×10^{-9}	3.6×10^{-6}	1.4×10^{-9}
Bellefonte	0.000017	8.5×10^{-9}	4.8×10^{-6}	2.4×10^{-9}	3.4×10^{-8}	1.4×10^{-11}

[a] Increased likelihood of cancer fatality.

Table D–25 Truck Transportation Cask Handling Accident Annual Risks

Reactor Site	***Tritium Production***	***Maximally Exposed Offsite Individual*** [a]	***Average Individual in Population to 80 km (50 mi)*** [a]	***Noninvolved Worker*** [a]
Watts Bar	1,000 TPBARs	1.9×10^{-13}	2.3×10^{-15}	2.3×10^{-15}
	3,400 TPBARs	5.8×10^{-13}	6.9×10^{-15}	7.0×10^{-15}
Sequoyah	1,000 TPBARs	4.5×10^{-14}	3.4×10^{-15}	7.4×10^{-16}
	3,400 TPBARs	1.4×10^{-13}	1.0×10^{-14}	2.2×10^{-15}
Bellefonte	1,000 TPBARs	4.5×10^{-15}	1.3×10^{-15}	7.4×10^{-18}
	3,400 TPBARs	1.4×10^{-14}	3.8×10^{-15}	2.2×10^{-17}

[a] Increased likelihood of cancer fatality per year.

D.1.3.4 Rail Transportation Cask Handling Accident

The rail transportation cask handling accident source term and accident frequency data presented in Section D.1.1.7 were evaluated using the GENII accident analysis computer code (PNL 1988). Analyses were performed in accordance with guidance provided in NRC Regulatory Guide 4.2 (NRC 1976). **Table D–28** summarizes the consequences of the rail transportation cask handling accident, with 50 percent meteorological conditions, to the maximally exposed offsite individual, an average individual in the public within an 80 kilometer (50 mile) radius of the reactor site, a noninvolved worker at the Watts Bar and Bellefonte Nuclear Plant Sites located 640 meters (0.4 mile) from the release point, and a noninvolved worker at the Sequoyah Nuclear Plant located at the site boundary 556 meters (0.35 mile) from the release point. The risks associated with the rail transportation cask handling accident to the same receptors are summarized in **Table D–29**.

Table D–26 Rail Transportation Cask Handling Accident Consequences

	Maximally Exposed Offsite Individual		*Average Individual in Population to 80 kilometers (50 miles)*		*Noninvolved Worker*	
Reactor Site	***Dose (rem)***	***Cancer Fatality*** [a]	***Dose (rem)***	***Cancer Fatality*** [a]	***Dose (rem)***	***Cancer Fatality*** [a]
Watts Bar	0.00071	3.6×10^{-7}	8.5×10^{-6}	4.3×10^{-9}	0.000011	4.4×10^{-9}
Sequoyah	0.00017	8.5×10^{-8}	0.000013	6.5×10^{-9}	3.6×10^{-6}	1.4×10^{-9}
Bellefonte	0.000017	8.5×10^{-9}	4.8×10^{-6}	2.4×10^{-9}	3.4×10^{-8}	1.4×10^{-11}

[a] Increased likelihood of cancer fatality.

Table D–27 Rail Transportation Cask Handling Accident Annual Risks

Reactor Site	***Tritium Production Core Configuration***	***Maximally Exposed Offsite Individual*** [a]	***Average Individual in Population to 80 km (50 mi)*** [a]	***Noninvolved Worker*** [a]
Watts Bar	1,000 TPBARs	9.7×10^{-14}	1.2×10^{-15}	1.2×10^{-15}
	3,400 TPBARs	1.9×10^{-13}	2.3×10^{-15}	2.3×10^{-15}
Sequoyah	1,000 TPBARs	2.3×10^{-14}	1.8×10^{-15}	3.8×10^{-16}
	3,400 TPBARs	4.5×10^{-14}	3.4×10^{-15}	7.4×10^{-16}
Bellefonte	1,000 TPBARs	2.3×10^{-15}	6.5×10^{-16}	3.8×10^{-18}
	3,400 TPBARs	4.5×10^{-15}	1.3×10^{-15}	7.4×10^{-18}

[a] Increased likelihood of cancer fatality per year.

D.1.3.5 Beyond-Design-Basis Accident

The beyond-design-basis accident source term and accident frequency data, presented in Tables D–10, D–11, D–13, and D–14, were evaluated using the MACCS2 accident analysis computer code (SNL 1997). **Table D–30** summarizes the consequences of the beyond design-basis accident, with mean meteorological conditions, to the maximally exposed offsite individual and an average individual in the public within an 80 kilometer (50 mile) radius of the reactor site. The assessment of dose and the associated cancer risk to the noninvolved worker is not applicable for beyond design-basis accidents. A site emergency would have been declared early in the beyond design-basis accident sequence and all nonessential site personnel evacuate the site in accordance with site emergency procedures before any radiological releases to the environment. In addition, emergency action guidelines are implemented to evacuate the public within 16.1 kilometers (10 miles) of the plant. The location of the maximum exposed offsite individual may, or may not be at the site boundary for these accident sequences because emergency action guidelines have been implemented and the population is evacuating from the path of the radiological plume released by the accident. The MACCS2 computer code models the evacuation sequence to estimate the dose to the maximum exposed individual and the general population within 80 kilometers (50 miles) of the accident. The risks associated with the beyond design-basis accident to the same receptors are summarized in **Table D–31**.

Table D–28 Beyond Design-Basis Accident Consequences

Reactor Site	*Tritium Production*	*Maximally Exposed Offsite Individual*		*Average Individual in Population to 80 kilometers (50 miles)*		*Noninvolved Worker*	
		Dose (rem)	*Cancer Fatality* [a]	*Dose (rem)*	*Cancer Fatality* [a]	*Dose (rem)*	*Cancer Fatality* [a]
Release Category I - Vessel Breach with Early Containment Failure							
Watts Bar	0 TPBARs (No Action)	19.7	0.0099	0.25	0.00013	N/A	N/A
	1,000 TPBARs	19.7	0.0099	0.25	0.00013	N/A	N/A
	3,400 TPBARs	19.8	0.0099	0.25	0.00013	N/A	N/A
Sequoyah	0 TPBARs (No Action)	25.0	0.025	0.48	0.00024	N/A	N/A
	1,000 TPBARs	25.0	0.025	0.48	0.00024	N/A	N/A
	3,400 TPBARs	25.1	0.025	0.48	0.00024	N/A	N/A
Bellefonte	0 TPBARs [b]	2.3	0.0012	0.023	0.000012	N/A	N/A
	1,000 TPBARs	2.3	0.0012	0.023	0.000012	N/A	N/A
	3,400 TPBARs	2.4	0.0012	0.024	0.000012	N/A	N/A
Release Category II - Vessel Breach with Containment Bypass							
Watts Bar	0 TPBARs (No Action)	6.4	0.0032	0.35	0.00018	N/A	N/A
	1,000 TPBARs	6.4	0.0032	0.35	0.00018	N/A	N/A
	3,400 TPBARs	6.4	0.0032	0.35	0.00018	N/A	N/A
Sequoyah	0 TPBARs (No Action)	10.4	0.0052	0.72	0.00036	N/A	N/A
	1,000 TPBARs	10.4	0.0052	0.72	0.00036	N/A	N/A
	3,400 TPBARs	10.4	0.0052	0.73	0.00037	N/A	N/A
Bellefonte	0 TPBARs [b]	34	0.034	0.20	0.00010	N/A	N/A
	1,000 TPBARs	34	0.034	0.20	0.00010	N/A	N/A
	3,400 TPBARs	34	0.034	0.20	0.00010	N/A	N/A
Release Category III - Vessel Breach with Late Containment Failure							
Watts Bar	0 TPBARs (No Action)	0.51	0.00026	0.024	0.000012	N/A	N/A
	1,000 TPBARs	0.51	0.00026	0.025	0.000013	N/A	N/A
	3,400 TPBARs	0.53	0.00027	0.025	0.000013	N/A	N/A
Sequoyah	0 TPBARs (No Action)	0.84	0.00042	0.051	0.000026	N/A	N/A
	1,000 TPBARs	0.85	0.00042	0.052	0.000026	N/A	N/A
	3,400 TPBARs	0.87	0.00044	0.053	0.000027	N/A	N/A
Bellefonte	0 TPBARs [b]	0.37	0.00019	0.016	8.0×10^{-6}	N/A	N/A
	1,000 TPBARs	0.37	0.00019	0.016	8.0×10^{-6}	N/A	N/A
	3,400 TPBARs	0.38	0.00019	0.017	8.5×10^{-6}	N/A	N/A

N/A = not applicable

[a] Increased likelihood of cancer fatality.

[b] The 0 TPBAR entry is included for consistency with the Watts Bar and Sequoyah Nuclear Plant analyses. The No Action Alternative at the Bellefonte Nuclear Plant implies the reactor is not brought into commercial service. The No Action Alternative radiological dose is 0.

Table D–29 Beyond Design-Basis Accident Annual Risks

Reactor Site	*Tritium Production*	*Maximally Exposed Offsite Individual* [a]	*Average Individual in Population to 80 km (50 mi)* [a]	*Noninvolved Worker*
Release Category I - Vessel Breach with Early Containment Failure				
Watts Bar	0 TPBARs (No Action)	6.7×10^{-9}	8.8×10^{-11}	N/A
	1,000 TPBARs	6.7×10^{-9}	8.8×10^{-11}	N/A
	3,400 TPBARs	6.7×10^{-9}	8.8×10^{-11}	N/A
Sequoyah	0 TPBARs (No Action)	1.7×10^{-8}	1.6×10^{-10}	N/A
	1,000 TPBARs	1.7×10^{-8}	1.6×10^{-10}	N/A
	3,400 TPBARs	1.7×10^{-8}	1.6×10^{-10}	N/A
Bellefonte	0 TPBARs [b]	1.1×10^{-9}	1.1×10^{-11}	N/A
	1,000 TPBARs	1.1×10^{-9}	1.1×10^{-11}	N/A
	3,400 TPBARs	1.1×10^{-9}	1.1×10^{-11}	N/A
Release Category II - Vessel Breach with Containment Bypass				
Watts Bar	0 TPBARs (No Action)	2.2×10^{-8}	1.2×10^{-9}	N/A
	1,000 TPBARs	2.2×10^{-8}	1.2×10^{-9}	N/A
	3,400 TPBARs	2.2×10^{-8}	1.2×10^{-9}	N/A
Sequoyah	0 TPBARs (No Action)	2.1×10^{-8}	1.4×10^{-9}	N/A
	1,000 TPBARs	2.1×10^{-8}	1.4×10^{-9}	N/A
	3,400 TPBARs	2.1×10^{-8}	1.5×10^{-9}	N/A
Bellefonte	0 TPBARs [b]	3.1×10^{-8}	9.1×10^{-11}	N/A
	1,000 TPBARs	3.1×10^{-8}	9.1×10^{-11}	N/A
	3,400 TPBARs	3.1×10^{-8}	9.1×10^{-11}	N/A
Release Category III - Vessel Breach with Late Containment Failure				
Watts Bar	0 TPBARs (No Action)	2.4×10^{-9}	1.1×10^{-10}	N/A
	1,000 TPBARs	2.4×10^{-9}	1.2×10^{-10}	N/A
	3,400 TPBARs	2.5×10^{-9}	1.2×10^{-10}	N/A
Sequoyah	0 TPBARs (No Action)	3.9×10^{-9}	2.4×10^{-10}	N/A
	1,000 TPBARs	3.9×10^{-9}	2.4×10^{-10}	N/A
	3,400 TPBARs	4.0×10^{-9}	2.5×10^{-10}	N/A
Bellefonte	0 TPBARs [b]	6.3×10^{-10}	2.6×10^{-11}	N/A
	1,000 TPBARs	6.3×10^{-10}	2.6×10^{-11}	N/A
	3,400 TPBARs	6.3×10^{-10}	2.8×10^{-11}	N/A

N/A = not applicable

[a] Increased likelihood of cancer fatality per year

[b] The 0 TPBAR entry is included for consistency with the Watts Bar and Sequoyah Nuclear Plant analyses. The No Action Alternative at the Bellefonte Nuclear Plant implies the reactor is not brought into commercial service. The No Action Alternative radiological dose is 0.

D.2 HAZARDOUS CHEMICAL ACCIDENT IMPACTS ON HUMAN HEALTH

D.2.1 Accident Scenario Selection and Description

D.2.1.1 Accident Scenario Selection

Tritium production at the Watts Bar and Sequoyah Nuclear Plants will not introduce any additional operations that require the use of hazardous chemicals. No hazardous chemical accidents, attributable to tritium production, are postulated for the Watts Bar and Sequoyah Nuclear Plants.

The chemical inventory for Bellefonte was reviewed to identify potential accident scenarios. The chemical inventory at Bellefonte is given in **Table D–32** (TVA 1998):

Table D–30 Chemical Inventory at Bellefonte Site

Location	*Chemical*	*Storage*	*Quantity per Tank (gallons)*
Auxiliary Building	Boric Acid	1 Tank	2,340
		1 Tank	18,700
		2 Tanks	31,400
	Sodium Hydroxide	2 Tanks[a]	16,500
	Hydrazine (35%)	1 Tank	100
	Lithium Hydroxide	1 Tank	70
	Sodium Hydroxide	1 Tank	210
	Sulfuric Acid	batteries	5,000
Turbine Building	Ammonium Hydroxide	1 Tank	140
		1 Tank	175
		1 Tank	300
		1 Tank	500
		1 Tank	525
		1 Tank	4,000
	Hydrazine (35%)	2 Tanks	110
		1 Tank	250
		1 Tank	300
		1 Tank	525
	Sodium Hydroxide	1 Tank	250
	Sulfuric Acid	1 Tank	250
Chemical Storage Building	Sodium Hydroxide	1 Tank	13,000
	Sulfuric Acid	1 Tank	13,000

[a] One tank for each unit.

The largest quantity of material at risk that is likely to volatilize and be dispersed following accidental release from the tanks is in the turbine building. The hazardous chemicals stored in the turbine building were reviewed against the Emergency Planning and Community Right-to-Know Act Section 302 Extremely Hazardous Substances List Threshold Planning Quantity values published by the EPA (EPA 1996) to determine if the quantities of chemicals, stored in the turbine building, exceed the Threshold Planning Quantity threshold values. In the event that the inventory of a chemical exceeds the Threshold Planning Quantity value, EPA requires that emergency response planning actions, including evaluation of potential accident scenarios, be conducted. Only the chemical inventory in the Turbine Building was used for the purpose of this analysis. The physical properties of the other chemicals suggest that they would be of less concern with respect to widespread exposure upon accidental release from storage tanks. The inventory of two chemicals exceeded the Threshold Planning Quantity values. These Threshold Planning Quantity values are:

Ammonium Hydroxide Threshold Planning Quantity = 500 lbs for anhydrous ammonia
Hydrazine Threshold Planning Quantity = 1000 lbs

D.2.1.2 Accident Scenario Descriptions

Two hazardous chemical accident scenarios are postulated for this EIS, the accidental uncontrolled release of ammonium hydroxide and the accidental uncontrolled release of hydrazine.

Ammonium Hydroxide Release

EPA requires that the chemical accident analysis consider the release of the maximum inventory from the largest tank. The ammonium hydroxide release scenario was developed based on the following information:

The largest ammonium hydroxide storage tank volume is 4,000 gallons (TVA 1998).

The ammonium hydroxide storage tanks are located inside a room in the Turbine Building and are surrounded by a 828 ft^2 dike (TVA 1998).

The ammonium hydroxide concentration is 30% ammonia by weight (TVA 1998).

The scenario assumes that a break occurs in the largest ammonium hydroxide storage tank, releasing the entire contents of the tank (4,000 gallons) inside the confined area in the room formed by the dike. The released material forms a pool, with an effective pool area of 828 ft^2. Ammonia is then evaporated from the ammonium hydroxide liquid pool and forms a vapor cloud that fills the immediate area, leaks from the building, and moves downwind away from the building.

The rate of ammonia evaporation from a 30 percent concentration ammonium hydroxide pool is given in the Draft RMP Guidance–Wastewater Treatment Facilities, March 1998 (EPA 1998) as follows:

$$QR = 0.036A_p$$

where A_p is the diked area in square feet, and QR is the rate of evaporation in lb/min.

Based on a pool area of 828 ft^2, the rate of ammonia evaporation from the pool is:

$$QR = 0.036 \times 828 = 29.8 \text{ lb/min.}$$

Hydrazine Release

The hydrazine release scenarios were developed for conditions similar to those described for the ammonium hydroxide release scenarios. However, accident analysis computer code has the capability of modeling pool evaporation for pure chemicals such as hydrazine.

The scenario assumes the release of 525 gallons of hydrazine (35 percent concentration) inside the room of the Turbine Building. Although hydrazine is very reactive, the scenario does not assume any loss of the material by reactivity. The release is assumed to form a pool on the floor, with hydrazine vapor generated from pool evaporation. The vapor fills the immediate area, leaks from the building, and is dispersed downwind. The effective pool area is the same as that of the ammonium hydroxide release case (i.e., 828 ft^2) because the tank is located within the same dike. Since hydrazine has a relatively high boiling point, no ground effect is assumed in the release scenario.

D.2.2 Chemical Accident Analysis Methodology

The potential health impacts from accidental releases of hazardous chemicals were assessed by comparing estimated airborne concentrations of the chemicals to Emergency Response Planning Guidelines developed by the American Industrial Hygiene Association. The Emergency Response Planning Guidelines values are not regulatory exposure guidelines and do not incorporate the safety factors normally included in healthy worker exposure guidelines. ERPG-1 values are maximum airborne concentrations below which nearly all individuals could be exposed for up to one hour, resulting in only mild, transient, and reversible adverse health impacts. ERPG-2 values are protective of irreversible or serious health effects or impairment of an individual's ability to take protective action. ERPG-3 values are indicative of potentially life-threatening health effects.

Emergency Response Planning Guideline values have not been developed for ammonium hydroxide. Upon release of ammonium hydroxide from the storage tanks, ammonia will volatilize and be dispersed downwind to expose potential receptors. Therefore, the Emergency Response Planning Guideline values for ammonia were used to evaluate the potential health impacts of an ammonium hydroxide release. The Emergency Response Planning Guideline for ammonia and hydrazine are presented in **Table D–33**.

Table D–31 Emergency Response Planning Guide Values for Hydrazine and Ammonia

Chemicals	*ERPG-1 (ppm)*	*ERPG-2 (ppm)*	*ERPG-3 (ppm)*
Hydrazine [a]	0.03	8	80
Ammonia [b]	25	200	1000

ppm = concentration in parts per million
[a] AIHA 1994. Hydrazine ERPGs were removed by AIHA for further study in 1996 and have not be reinserted as of July 1998.
[b] AIHA 1995

D.2.2.1 Receptor Description

The potential health impacts of the accidental release of ammonium hydroxide and hydrazine were assessed for two types of receptors:

noninvolved workers - noninvolved workers were assumed to be located 640 meters from the point of release.

maximally exposed offsite individual - a member of the public located offsite at the site boundary, 914 meters from the point of release

Facility workers (i.e. those individuals in the building at the time of the accident) were assumed to be killed by the release. The analysis took no credit for mitigative actions (e.g., area atmosphere monitoring, area evacuation alarms, emergency operating procedures) or accident precursors (e.g., leak before break) to reduce the accident consequences to the facility worker.

D.2.2.2 Analysis Computer Code Selection

The computer code selected for estimation of airborne concentrations is the Computer Aided Management of Emergency Operations (CAMEO)/Areal Locations of Hazardous Atmospheres (ALOHA), developed by the National Safety Council, the U.S. Environmental Protection Agency, and the National Oceanic and Atmospheric Administration (NSC 1990).

D.2.2.3 Description of the Model

The atmospheric dispersion modeling for the above scenarios was conducted using the ALOHA 5.05 computer code (NSC 1990).

The ALOHA code was designed for use by first responders. The model is most useful for estimating plume extent and concentration downwind from the release source for short-duration chemical accidents. It uses a Gaussian dispersion model to describe the movement and spreading of a gas that is neutrally buoyant. For heavier-than-air vapor releases, the model uses the same calculations as those used in the DEGADIS model, an EPA heavy gas dispersion model (EPA 1989).

There are a number of limitations to the model, and these are summarized below:

ALOHA is not intended for use with accidents involving radioactive chemicals.

It is not intended for use with the permitting of stack gas or chronic, low-level (fugitive) emissions.

The ALOHA-DEGADIS heavy gas module is more conservative than the DEGADIS model which may result in a larger footprint than would actually be expected.

ALOHA does not consider the effects of thermal energy from fire scenarios or the by-products resulting from chemical reactions.

ALOHA does not include the process needed to model particulate dispersion

ALOHA does not consider the shape of the ground under the spill or that in the area affected by the plume.

ALOHA does not estimate concentrations under very low wind speeds (< 1 meters per second) since the wind direction may become inconsistent at these conditions.

Under very stable atmospheric conditions (usually late night or early morning), the model estimates will have large uncertainties due to shifting wind directions and virtually no mixing of the plume into the surrounding air. Thus, these processes may lead to high airborne concentrations for long periods of time or at large distances from the release source.

ALOHA does not accurately represent variations associated with near-field (close to the release source) patchiness. In the case of a neutrally buoyant gas, the plume will move downwind, but very near the source, the plume can be oriented in a different direction (such as going backward) due to the effect of drifting eddies in the wind.

D.2.2.4 Weather Condition Assumptions

The model results are presented for atmospheric Stability Classes D and F, with wind speeds of 5.3 meters per second and 1.5 meters per second, respectively. Atmospheric Stability Class D is considered to be representative of "average" weather conditions; Stability Class F is considered to be representative of "worst-case" weather conditions. These weather conditions were selected because they are recommended by the EPA in its *Technical Guidance for Hazards Analysis* (EPA 1987).

The model parameter values for these weather conditions are as follows:

1. Average Condition Stability Class D
   Ambient air temperature: 75
   Relative humidity: 50%
   Cloud cover: 50%
   Average wind speed: 5.3 meters per second

2. Worst-Case Condition Stability Class F
   Ambient air temperature: 60
   Relative humidity: 25%
   Cloud cover: 20%
   Average wind speed: 1.5 meters per second

D.2.3 Human Health Impacts

The potential health impacts from the accidental releases were assessed by comparing the modeled ambient concentrations of ammonia and hydrazine at each of the receptor locations identified previously to the Emergency Response Planning Guidelines. The estimated airborne concentrations of ammonia and hydrazine are presented in **Table D–34** and **Table D–35** respectively. **Table D–36** presents a summary of the impacts data.

D.2.3.1 Impacts to Noninvolved Workers

Noninvolved workers are assumed to be located at 640 meters from the point of release. The concentrations of ammonia at 640 meters range from 14 to 318 parts per million, based on the assumed meteorological conditions. The maximum estimated airborne concentration at 640 meters in the F stability class exceeds the ERPG-2 value of 200 parts per million for ammonia, which suggests that noninvolved workers may experience irreversible or serious, but not life-threatening, adverse health effects if the exposures are not mitigated.

For the hydrazine release scenarios, the concentrations at 640 meters range from 0.8 to 6.0 parts per million, based on the assumed meteorological conditions. As a result, the maximum estimated airborne concentration at 640 meters exceeds the ERPG-1 value of 0.03 parts per million for hydrazine, which suggests the potential for only mild, transient, and reversible adverse health impacts to noninvolved workers.

D.2.3.2 Offsite Impacts

The maximally exposed offsite individual is assumed to be located at a distance of 914 meters from the point of release. For the ammonium hydroxide release scenarios, the offsite receptor will be potentially exposed to an ammonia concentration of 7.7 parts per million under Stability Class D condition (see Table D–34), which is below the ERPG-1 value for ammonia of 25 parts per million. Exposures to concentrations below the ERPG-1 value are not expected to produce any adverse health effects for the offsite receptor. Under Stability Class F conditions, the offsite receptor may be exposed to an ammonia concentration of about 169 parts per million (see Table D–35), which is below the ERPG-2 value for ammonia of 200 parts per million. Exposure of the offsite receptor at concentrations greater than the ERPG-1 value but less than the ERPG-2 value may produce only mild, transient and reversible adverse health effects.

For the hydrazine release scenarios, the offsite receptor exposure concentrations range from 0.4 parts per million to 3.2 parts per million (see Table D–36; both stability classes). These concentrations exceed the ERPG-1 value for hydrazine of 0.03 parts per million, but are less than the ERPG-2 value of 8 parts per million. This suggests that the offsite receptor may experience only mild, transient and reversible adverse health effects as a result of the exposure.

Table D–32 Airborne Concentration Estimates for Ammonium Hydroxide Release Scenarios

Downwind Distance from Source (m)	*NH_3 Concentration under Stability Class D*		*NH_3 Concentration under Stability Class F*	
	mg/m^3	*(ppm)*	*mg/m^3*	*(ppm)*
30	3,233	(4,590)	83,900	(119,138)
100	306	(435)	7,730	(10,976)
500	15.5	(22)	352	(500)
640	9.9	(14)	224	(318)
914	5.4	(7.7)	119	(169)
1000	4.7	(6.7)	102	(145)
1500	2.5	(3.5)	51.6	(73)
2000	1.5	(2.2)	32.7	(46)

Table D–33 Airborne Concentration Estimates for Hydrazine Release Scenarios

Downwind Distance from Source(m)	*Concentration under Stability Class D*		*Concentration under Stability Class F*	
	mg/m^3	*(ppm)*	*mg/m^3*	*(ppm)*
30	168	(127)	730	(561)
100	30	(22.7)	194	(149)
500	1.6	(1.2)	12.2	(9.4)
640	1.1	(0.8)	7.81	(6.0)
914	0.5	(0.4)	4.17	(3.2)
1000	0.5	(0.4)	3.56	(2.7)
1500	0.3	(0.2)	1.7	(1.3)
2000	--	--	1.07	(0.8)

Table D–34 Summary of Impacts Data for Release Scenarios

	Guidelines	*Hydrazine (Stability Class D)*	*Hydrazine (Stability Class F)*	*Ammonia (Stability Class D)*	*Ammonia (Stability Class F)*
	ERPG-1 ERPG-2 ERPG-3	>2000 179 44	>2000 500 200	464 150 65	2250 825 425
Noninvolved worker (640 m)	Parts per million (ppm) Level of concern Potential health effects	0.8 ERPG-1 Mild, transient	6 ERPG-1 Mild, transient	16 ERPG-1 Mild, transient	318 ERPG-2 Serious

	Guidelines	Hydrazine (Stability Class D)	Hydrazine (Stability Class F)	Ammonia (Stability Class D)	Ammonia (Stability Class F)
Maximally exposed offsite individual (914 m)	Parts per million (ppm) Level of concern Potential health effects	0.4 ERPG-1 Mild, transient	3.2 ERPG-1 Mild, transient	7.7 ERPG-1 None (<ERPG-1)	169 ERPG-1 Mild, transient

D.2.3.3 Uncertainties in the Dispersion Analyses

The results of this screening level analysis contain a number of uncertainties in the atmospheric dispersion calculations, some of which are summarized below:

- The dispersion modeling has not taken into account the reduction in the predicted rate of evaporation because the spillage is inside the building, the dilution caused by the structures on the site or the potential for other mitigating actions. There are no accurate methods for predicting the extent of this dilution, but predicted concentrations at any point could well be too high by factors of 2 to 5 or more.

- The dispersion modeling does not take account of the deposition of highly reactive vapors such as (hydrazine) onto surfaces including equipment, the ground, water and vegetation. This means that the model overestimates airborne concentrations at longer distances.

- Overall, the uncertainties in predicted airborne concentrations may be as large as a factor of plus or minus two times the estimated concentration.

In view of these uncertainties, the results of this analysis should be considered only as screening level estimations. TVA will conduct analysis to comply with requirements specified in 40 CFR 68 prior to operation of the Bellefonte Nuclear Power Plant.

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APPENDIX E
EVALUATION OF HUMAN HEALTH EFFECTS OF OVERLAND TRANSPORTATION

E.1 INTRODUCTION

The overland transportation of any commodity involves a risk to both transportation crew members and members of the public. This risk results directly from transportation-related accidents and indirectly from the increased levels of pollution from vehicle emissions, regardless of the cargo. The transportation of certain materials, such as hazardous or radioactive waste, can pose an additional risk due to the unique nature of the material itself. To permit a complete appraisal of the environmental impacts of the proposed action and alternatives, the human health risks associated with the overland transportation of tritium-producing burnable absorber rods (TPBARs) and associated waste were assessed.

This appendix provides an overview of the approach used to assess the human health risks that may result from overland transportation. The appendix includes discussion of the scope of the assessment, analytical methods used for the risk assessment (i.e., computer models), important assessment assumptions, and determination of potential transportation routes. It also presents the results of the assessment. In addition, to aid in the understanding and interpretation of the results, specific areas of uncertainty are described with an emphasis on how the uncertainties may affect comparisons of the alternatives.

The risk assessment results are presented in this appendix in terms of "per-shipment" risk factors, as well as for the total risks for a given alternative. Per-shipment risk factors provide an estimate of the risk from a single TPBAR or waste shipment. The total risks for a given alternative are found by multiplying the expected number of shipments by the appropriate per-shipment risk factors.

E.2 SCOPE OF ASSESSMENT

The scope of the overland transportation human health risk assessment, including the alternatives and options, transportation activities, potential radiological and nonradiological impacts, and transportation modes considered, is described below. Additional details of the assessment are provided in the remaining sections of the appendix.

Proposed Action and Alternatives

The transportation risk assessment conducted for this EIS estimates the human health risks associated with the transportation of TPBARs and waste for a number of alternatives.

Transportation-Related Activities

The transportation risk assessment is limited to estimating the human health risks incurred during overland transportation for each alternative. The risks to workers or to the public during loading, unloading, and handling prior to or after shipment are not included in the overland transportation assessment, but are addressed in Appendix D of this EIS. Similarly, the transportation risk assessment does not address possible impacts from increased transportation levels on local traffic flow, noise levels, or infrastructure.

Radiological Impacts

For each alternative, radiological risks (i.e., those risks that result from the radioactive nature of the irradiated TPBARs and waste) are assessed for both incident-free (i.e., normal) and accident transportation conditions. The radiological risk associated with incident-free transportation conditions would result from the potential exposure of people to external radiation in the vicinity of a loaded shipment. The radiological risk from transportation accidents would come from the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of people.

All radiological impacts are calculated in terms of committed dose and associated health effects in the exposed populations. The radiation dose calculated is the total effective dose equivalent (see 10 CFR 20), which is the sum of the effective dose equivalent from external radiation exposure and the 50-year committed effective dose equivalent from internal radiation exposure. Radiation doses are presented in units of roentgen equivalent man (rem) for individuals and person-rem for collective populations. The impacts are further expressed as health risks in terms of latent cancer fatalities and cancer incidence in exposed populations using the dose-to-risk conversion factors established by the National Council on Radiation Protection and Measurement (NCRP 1993).

Nonradiological Impacts

In addition to the radiological risks posed by overland transportation activities, vehicle-related risks are also assessed for nonradiological causes (i.e., causes related to the transport vehicles and not the radioactive cargo) for the same transportation routes. The nonradiological transportation risks, which would be incurred for similar shipments of any commodity, assessed for both incident-free and accident conditions. The nonradiological risks during incident-free transportation conditions would be caused by potential exposure to increased vehicle exhaust emissions. The nonradiological accident risk refers to the potential occurrence of transportation accidents that directly result in fatalities unrelated to the shipment of cargo. State-specific transportation fatality rates are used in the assessment. Nonradiological risks are presented in terms of estimated fatalities.

Transportation Modes

All shipments to the reactors are assumed to take place by truck transportation modes. Additionally, dedicated rail shipments are considered from the commercial light water reactor (CLWR) sites to the DOE Savannah River Site.

Receptors

Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck or rail crew members involved in the actual overland transportation. The general public includes all persons who could be exposed to a shipment while it is moving or stopped en route. Potential risks are estimated for the collective populations of exposed people and for the hypothetical maximally exposed individual. For incident-free operation, the maximally exposed individual would be an individual stuck in traffic next to the shipment for 30 minutes. For accident conditions, the maximally exposed individual would be an individual located 33m (105 ft) directly downwind from the accident. The collective population risk is a measure of the radiological risk posed to society as a whole by the alternative being considered. As such, the collective population risk is used as the primary means of comparing various alternatives.

E.3 PACKAGING AND REPRESENTATIVE SHIPMENT CONFIGURATIONS

Regulations that govern the transportation of radioactive materials, are designed to protect the public from the potential loss or dispersal of radioactive materials, as well as from routine radiation doses during transit. The primary regulatory approach to promote safety is through the specification of standards for the packaging of radioactive materials. Because packaging represents the primary barrier between the radioactive material being transported and radiation exposure to the public and the environment, packaging requirements are an important consideration for transportation risk assessment. Regulatory packaging requirements are discussed briefly below and in Chapter 6. The representative packaging and shipment configurations assumed for this EIS also are described below.

E.3.1 Packaging Overview

Although several Federal and state organizations are involved in the regulation of radioactive waste transportation, primary regulatory responsibility resides with the U.S. Department of Transportation and the U.S. Nuclear Regulatory Commission (NRC). All transportation activities must take place in accordance with the applicable regulations of these agencies as specified in 49 Code of Federal Regulations (CFR) 173 and 10 CFR 71.

Transportation packaging for small quantities of radioactive materials must be designed, constructed, and maintained to contain and shield their contents during normal transport conditions. For large quantities and for more highly radioactive material, such as TPBARs or spent nuclear fuel, they must contain and shield their contents in the event of severe accident conditions. The type of packaging used is determined by the total radioactive hazard presented by the material within the packaging. Four basic types of packaging are used: Excepted, Industrial, Type A, and Type B. Another packaging option, "Strong, Tight," is still available for some domestic shipments.

Excepted packages are limited to transporting materials with extremely low-levels of radioactivity. Industrial packages are used to transport materials that, because of their low concentration of radioactive materials, present a limited hazard to the public and the environment. Type A packages are designed to protect and retain their contents under normal transport conditions and must maintain sufficient shielding to limit radiation exposure to handling personnel. These packages are used to transport radioactive materials with higher concentrations or amounts of radioactivity than Excepted, or Industrial packages. Strong, Tight packages are used in the United States for shipment of certain materials with low-levels of radioactivity, such as natural uranium and rubble from the decommissioning of nuclear reactors. Type B packages are used to transport material with the highest radioactivity levels and are described in more detail in the following sections.

E.3.2 Regulations Applicable to Type B Casks

Regulations for the transport of radioactive materials in the United States are issued by the U.S. Department of Transportation and are codified in 49 CFR 171–178. The regulation authority for radioactive materials transport is jointly shared by the U.S. Department of Transportation and the NRC. As outlined in a 1979 Memorandum of Understanding with the NRC, the U.S. Department of Transportation specifically regulates the carriers of spent nuclear fuel and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. The U.S. Department of Transportation also regulates the labeling, classification, and marking of all spent nuclear fuel packages. The NRC regulates the packaging and transport of spent nuclear fuel for its licensees, which include commercial shippers of spent nuclear fuel. In addition, NRC sets the standards for packages containing fissile materials and spent nuclear fuel.

DOE policy requires compliance with applicable Federal regulations regarding domestic shipments of spent nuclear fuel. Accordingly, DOE has adopted the requirements of 10 CFR 71, "Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions," and 49 CFR 171–178, "Hazardous Material Regulations." DOE Headquarters can issue a certificate of compliance for a package to be used by DOE and DOE contractors only.

E.3.2.1 Cask Design Regulations

Spent nuclear fuel is transported in robust "Type B" transportation casks that are certified for transporting radioactive materials. Casks designed and certified for spent nuclear fuel transportation within the U.S. must meet the applicable requirements of NRC for design, fabrication, operation, and maintenance as contained in 10 CFR 71.

Cask design and fabrication can only be done by approved vendors with established quality assurance programs (10 CFR 71.101). Cask and component suppliers or vendors are required to obtain and maintain documents that prove the materials, processes, tests, instrumentation, measurements, final dimensions, and cask operating characteristics meet the design-basis established in the Safety Analysis Report for Packaging for the cask and that the cask will function as designed.

Regardless of where a transportation cask is designed, fabricated, or certified for use, it must meet certain minimum performance requirements (10 CFR 71.71–71.77). The primary function of a transportation cask is to provide containment and shielding. Casks similar to the designs being considered or TPBARs have been used to transport spent nuclear fuel for many years. Regulations require that casks must be operated, inspected, and maintained to high standards to ensure their ability to contain their contents in the event of a transportation accident (10 CFR 71.87). There are no documented cases of a release of radioactive materials from spent nuclear fuel shipments, even though thousands of shipments have been made by road, rail, and water transport. Further, a number of obsolete casks have been tested under severe accident conditions to demonstrate their adherence to design criteria without failure. Such tests have demonstrated that transportation casks are not only fabricated to a very high factor of safety; they are even sturdier than required.

Transportation casks are built out of heavy, durable structural materials such as stainless steel. These materials must ensure cask performance under a wide range of temperatures (10 CFR 71.43). In addition to the structural materials, shielding is provided to limit radiation levels at the surface and at prescribed distances from the surface of transportation casks (10 CFR 71.47). Shielding typically consists of dense material such as lead or depleted uranium. The design for a TPBAR cask is less challenging than the design for a spent nuclear fuel cask because the spent nuclear fuel cask must address additional requirements of criticality control and neutron shielding. Additionally, spent fuel rods are more radioactive, and the effect of the radioactivity is significantly greater for spent fuel rods than tritium rods. The cask cavity can be configured to hold various contents, including irradiated TPBARs or irradiated hardware. The assemblies are supported by internal structures, called baskets, that provide shock and vibration resistance and establish minimum spacing and heat transfer to maintain the temperature of the contents within the limits specified in the Safety Analysis Report for Packaging.

DOE is currently evaluating its approach to procuring transportation packages and/or services. DOE will specify the requirements for packages in great detail. As of publication of this document, it has not been determined whether an existing Type B package will be modified to handle TPBARs or a new package will be designed. The level of safety will be the same in either case. The choice will be based on the ability to economically meet the CLWR program requirements. Typical Type B packages are shown in **Figures E–1** and **E–2**.

Finally, to limit impact forces and minimize damage to the structural components of a cask in the event of a transportation accident, impact-absorbing structures may be attached to the exterior of the cask. These are usually composed of balsa wood, foam, or aluminum honeycomb that is designed to readily deform upon

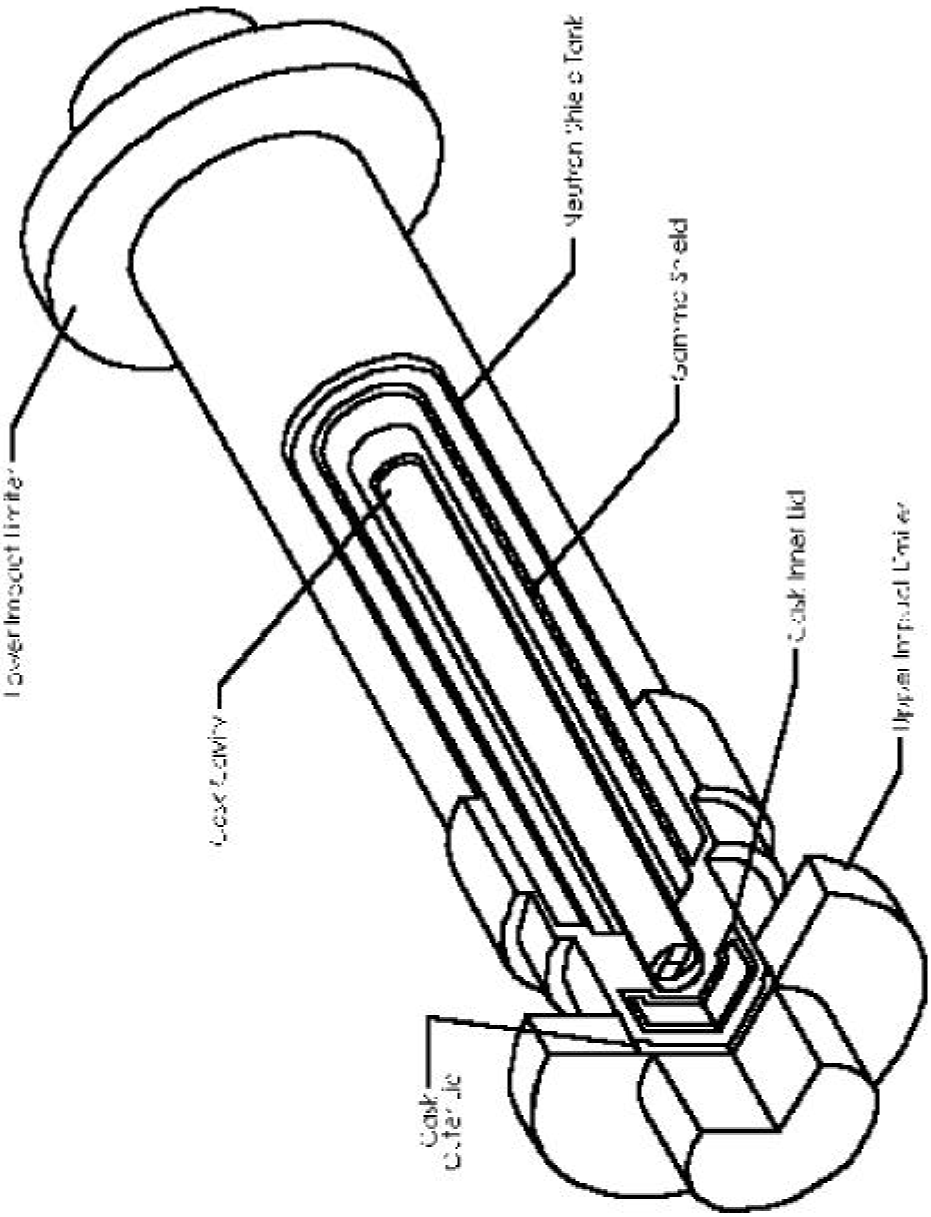

Figure E–1 Typical Type B Legal Weight Track Shipping Cask

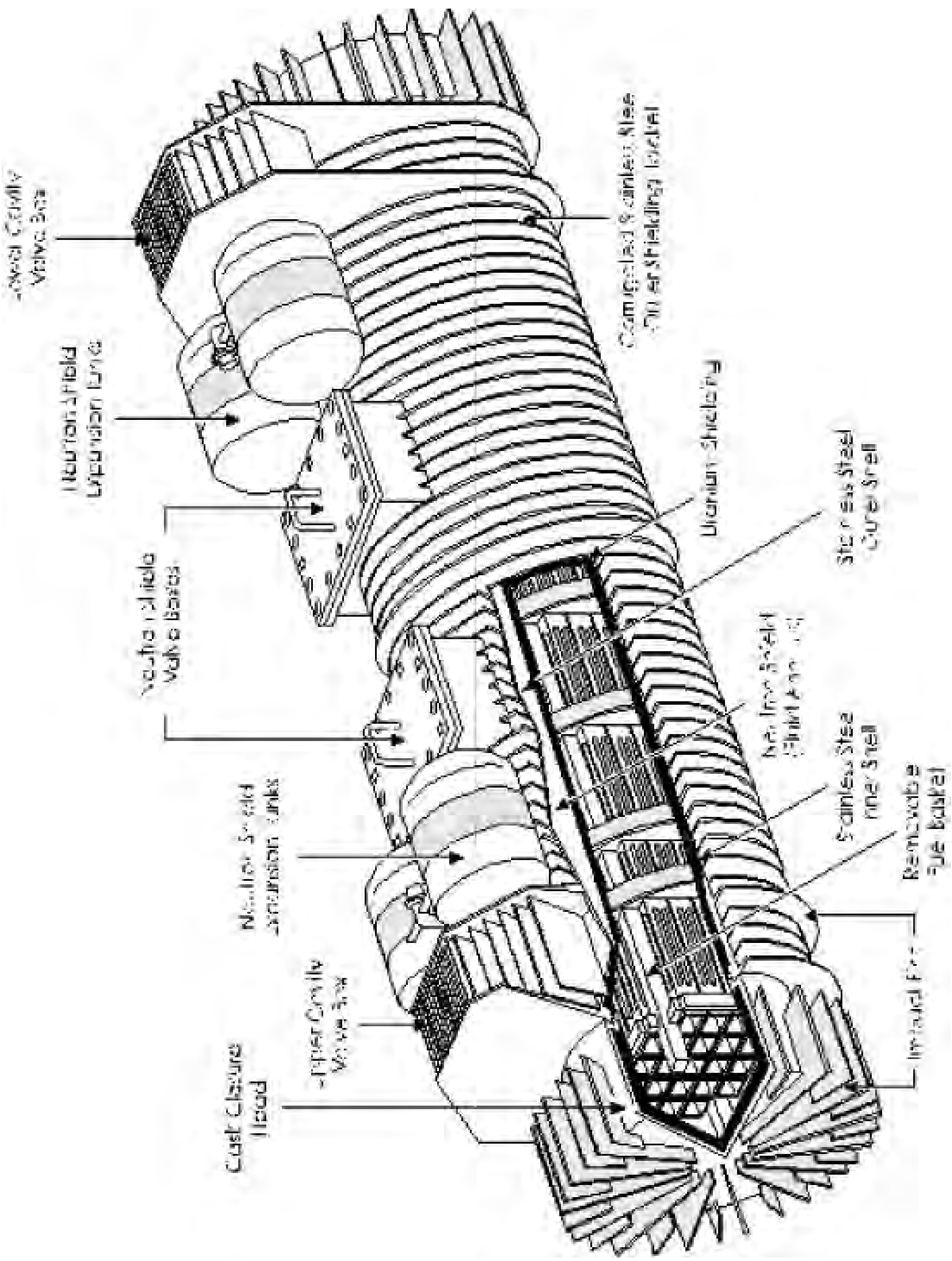

Figure E–2 Typical Type B Rail Shipping Cask

impact to absorb impact energy. All of these components are designed to work together in order to satisfy the regulatory requirements for a cask to operate under normal conditions of transportation and maintain its integrity in an accident.

E.3.2.2 Design Certification

For certification, transportation casks must be shown by analysis and/or test to withstand a series of hypothetical accident conditions. These conditions have been internationally accepted as simulating damage to transportation casks that could occur in most reasonably foreseeable accidents. The impact, fire, and water-immersion tests are considered in sequence to determine their cumulative effects on one package. These accident conditions are described in **Figure E–3**. The NRC issues regulations, 10 CFR 71, governing the transportation of radioactive materials. In addition to the tests shown in Figure E–3, the regulations affecting Type B casks require that a transportation cask with activity greater than 10^6 curies (which is applicable to irradiated TPBARs) be designed and constructed so that its undamaged containment system would withstand an external water pressure of 290 pounds per square inch, or immersion in 200 meters (656 feet) of water, for a period of not less than one hour without collapse, buckling, or allowing water to leak into the cask.

Under the Federal certification program, a Type B packaging design must be supported by a Safety Analysis Report for Packaging, which demonstrates that the design meets Federal packaging standards. The Safety Analysis Report for Packaging must include a description of the proposed packaging in sufficient detail to identify the packaging accurately and provide the basis for evaluating its design. The Safety Analysis Report for Packaging must provide the evaluation of the structural design, materials properties, containment boundary, shielding capabilities, and criticality control, and present the operating procedures, acceptance testing, maintenance program, and the quality assurance program to be used for design and fabrication. Upon completion of a satisfactory review of the Safety Analysis Report for Packaging to verify compliance to the regulations, a Certificate of Compliance is issued.

E.3.2.3 Transportation Regulations

To ensure that the transportation cask is properly prepared for transportation, trained technicians perform numerous inspections and tests (10 CFR 71.87). These tests are designed to ensure that the cask components are properly assembled and meet leak-tightness, thermal, radiation, and contamination limits before shipping radioactive material. The tests and inspections are clearly identified in the Safety Analysis Report for Packaging and/or the Certificate of Compliance for each cask. Casks can only be operated by registered users who conduct operations in accordance with documented and approved quality assurance programs meeting the requirements of the regulatory authorities. Records must be maintained that document proper cask operations in accordance with the quality requirements of 10 CFR 71.91. Reports of defects or accidental mishandling must be submitted to the NRC. DOE will be the Shipper-of-Record for the TPBAR and waste shipments.

External radiation from a package must be below specified limits that minimize the exposure of handling personnel and the general public. For these types of shipments, the external radiation dose rate during normal transportation conditions must be maintained below the following limits of 49 CFR 173:

- 10 mrem/hr at any point 2 meters (6.6 feet) from the vertical planes projected by the outer lateral surfaces of the transport vehicle (referred to as the regulatory limit throughout this document)

- 2 mrem/hr in any normally occupied position in the transport vehicle

Additional restrictions apply to package surface contamination levels, but these restrictions are not important for the transportation radiological risk assessment. For risk assessment purposes, it is important to note that

Standards for Type B Casks

For certification by the NRC, a cask must be shown by test or analysis to withstand a series of accident conditions without releasing its contents. These conditions have been internationally accepted as simulating damage to spent fuel casks that could occur in most severe credible accidents. The impact, fire, and water-immersion tests are considered in sequence to determine their cumulative effects on one package. A separate cask is subjected to a deep water-immersion test. The details of the tests are as follows:

Impact

Free Drop (a) – The cask drops 30 feet onto a flat, horizontal, unyielding surface so that it strikes at its weakest point.

Puncture (b) – The cask drops 40 inches onto a 6-inch-diameter steel bar at least 8 inches long; the bar strikes the cask at its most vulnerable spot.

Fire (c)

After the impact tests, the cask is totally engulfed in a 1475 °F thermal environment for 30 minutes.

Water Immersion (d)

The cask is completely submerged under at least 3 feet of water for 8 hours. A separate cask is completely immersed under 50 feet of water for 8 hours.

Figure E–3 Standards for Transportation Casks

all packaging of a given type is designed to meet the same performance criteria. Therefore, two different Type B designs would be expected to perform similarly during incident-free and accident transportation conditions. The specific containers selected or designed, however, will determine the total number of shipments necessary to transport a given quantity of irradiated TPBARs.

E.3.2.4 Communications

Proper communication assists in ensuring safe preparation and handling of transportation casks. Communication is provided by labels, markings, placarding, shipping papers, or other documents. Labels (49 CFR 172.403) applied to the cask document the contents and the amount of radiation emanating from the cask exterior (transport index). The transport index lists the ionizing radiation level (in mrem/yr) at a distance of 1 meter (3.3 feet) from the cask surface.

In addition to the label requirements, markings (49 CFR 173.471) should be placed on the exterior of the cask to show the proper shipping name and the consignor and consignee in case the cask is separated from its original shipping documents (49 CFR 172.203). Transportation casks are required to be permanently marked with the designation “Type B,” the owner's (or fabricator's) name and address, the Certificate of Compliance number, and the gross weight (10 CFR 71.83).

Placards (49 CFR 172.500) are applied to the transport vehicle or freight container holding the transportation cask. The placards indicate the radioactive nature of the contents. Irradiated TPBARs will constitute a Highway Route-Controlled Quantity (HRCQ) must be placarded according to 49 CFR 172.507. Placards provide the first responders to a traffic or transportation accident with initial information about the nature of the contents.

Shipping papers for the irradiated TPBARs should contain the notation “HRCQ” and have entries identifying the following: the name of the shipper, emergency response telephone number, description of contents, and the shipper's certificate as described in 49 CFR 172 Subpart C. Since the shipment is a Highway Route- Controlled Quantity, the shipping papers must contain the notation “HRCQ.”

In addition, drivers of motor vehicles transporting radioactive material must have training in accordance with the requirements of 49 CFR 172.700. The training requirements include familiarization with the regulations, emergency response information, and the communication programs required by the Occupational Safety and Health Administration. Drivers are also required to have training on the procedures necessary for safe operation of the vehicle used to transport the irradiated TPBARs or hardware.

E.3.3 Ground Transportation Route Selection Process

According to DOE guidelines, TPBAR and waste shipments must comply with both NRC and U.S. Department of Transportation regulatory requirements. NRC regulations cover the packaging and transport of irradiated TPBARs and waste, whereas the U.S. Department of Transportation specifically regulates the carriers and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. The highway routing of nuclear material is systematically determined according to U.S. Department of Transportation regulations 49 CFR 171–179 and 49 CFR 397 for commercial shipments. Specific routes cannot be publicly identified in advance for DOE’s Transportation Safeguards Division’s shipments because they are classified to protect national security interests.

The U.S. Department of Transportation routing regulations require that shipment of a “highway route controlled quantity” of radioactive material be transported over a preferred highway network, including interstate highways, with preference toward interstate system bypasses and beltways around cities and state-designated preferred routes. A state or Tribe may designate a preferred route to replace or supplement the interstate highway system in accordance with U.S. Department of Transportation guidelines (DOT 1992).

Carriers of Highway Route-controlled Quantities are required to use the preferred network unless they are moving from their origin to the nearest interstate highway or from the interstate highway to their destination, they are making necessary repair or rest stops, or emergency conditions render the interstate highway unsafe or impassable. The primary criterion for selecting the preferred route for a shipment is travel time. Preferred routing takes into consideration accident rate, transit time population density, activities, time of day, and day of week.

The HIGHWAY computer code (ORNL 1993a) is used for selecting highway routes in the U.S. The HIGHWAY database is a computerized road atlas that currently describes about 386,400 kilometers (240,000 miles) of roads. The Interstate System and all U.S. (US-designated) highways are completely described in the database. In addition, most of the principal state highways and many local and community roads are also identified. The code is updated periodically to reflect current road conditions and has been benchmarked against reported mileages and observations of commercial truck firms. Features in the HIGHWAY code allow the user to select routes that conform to U.S. Department of Transportation regulations. Additionally, the HIGHWAY code contains data on the population densities along the routes. The distances and populations from the HIGHWAY code are part of the information used for the transportation impact analysis in this EIS.

The INTERLINE (ORNL 1993b) computer program, designed to simulate routing of the U.S. rail system, is used for selecting railway routes for the purpose of analysis. The INTERLINE database consists of 94 separate subnetworks and represents various competing rail companies in the United States. The database used by INTERLINE was originally based on Federal Railroad Administration data and reflected the U.S. railroad system in 1974. The database has since been expanded and modified over the past two decades. The code is updated periodically to reflect current track conditions and has been benchmarked against reported mileages and observations of commercial rail firms. The INTERLINE model uses a shortest-route algorithm that finds the minimum impedance path within an individual subnetwork. A separate routine is used to find paths along the subnetworks. The routes selected for this study used the standard assumptions in the INTERLINE model that simulate the selection process that railroads use to direct shipments.

E.4 Methods for Calculating Transportation Risks

The overland transportation risk assessment method is summarized in **Figure E–4**. After the EIS alternatives were identified and the goals of the shipping campaign were understood, data was collected on material characteristics and accident parameters. Accident parameters were largely based on the DOE-funded study of transportation accidents (ANL 1994).

Representative routes that may be used for the shipment of TPBARs and waste were selected for risk assessment purposes using the HIGHWAY code. They do not necessarily represent the actual routes that would be used to transport nuclear materials. Specific routes cannot be identified in advance because the routes cannot be finalized until they had been reviewed and approved by the NRC. The selection of the actual route would be responsive to environmental and other conditions that would be in effect or could be predicted at the time of shipment. Such conditions could include adverse weather conditions, road conditions, bridge closures, and local traffic problems. For security reasons, details about a route would not be publicized before the shipment.

The first analytic step in the ground transportation analysis was to determine the incident-free and accident risk factors, on a per-shipment basis. Risk factors, as with any risk estimate, are the product of the probability of exposure and the magnitude of the exposure. Accident risk factors were calculated for radiological and

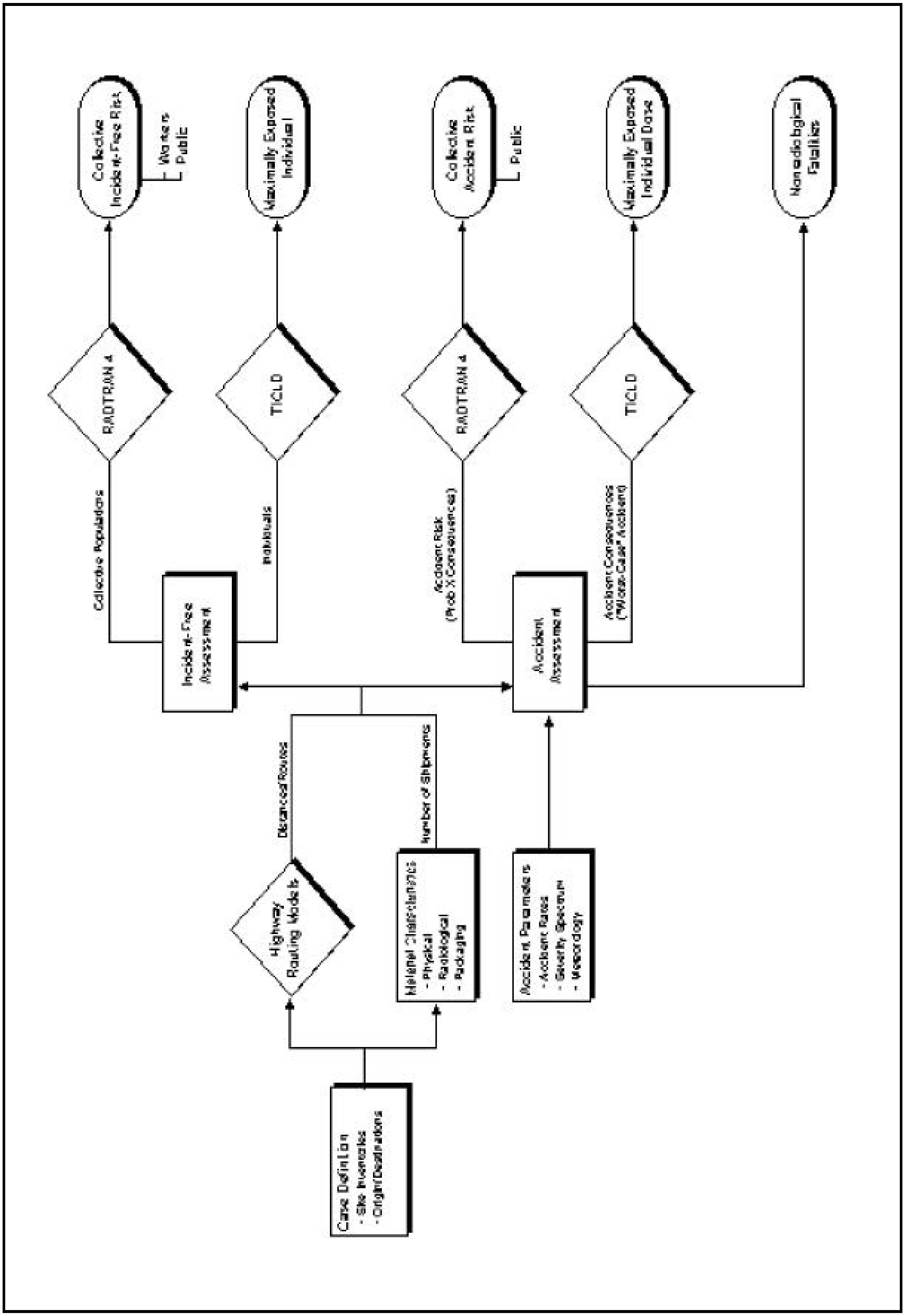

Figure E–4 Overland Transportation Risk Assessment

nonradiological traffic accidents. The probabilities, which are much lower than one, and the magnitudes of exposure were multiplied, yielding very low risk numbers. Incident-free risk factors were calculated for crew and public exposure to radiation emanating from the shipping container (cask) and public exposure to the chemical toxicity of the transportation vehicle exhaust. The probability of incident-free exposure is unity (one).

For each alternative, risks were assessed for both incident-free transportation and accident conditions. For the incident-free assessment, risks are calculated for both collective populations of potentially exposed individuals and for maximally exposed individuals. The accident assessment consists of two components: (1) a probabilistic accident risk assessment that considers the probabilities and consequences of a range of possible transportation accident environments, including low-probability accidents that have high consequences and high-probability accidents that have low consequences, and (2) an accident consequence assessment that considers only the consequences of the most severe postulated transportation accidents.

The RADTRAN 4 computer code (SNL 1993a) is used for incident-free and accident risk assessments to estimate the impacts on population. RADTRAN 4 was developed by Sandia National Laboratories to calculate population risks associated with the transportation of radioactive materials by a variety of modes, including truck, rail, air, ship, and barge. The Transportation Incident Center Line Dose (TICLD) code, run in conjunction with RADTRAN 4, was used to calculate the doses to the maximally exposed individuals.

The RADTRAN 4 population risk calculations take into account both the consequences and probabilities of potential exposure events. The RADTRAN 4 and TICLD codes consequence analyses include the cloud shine, ground shine, inhalation, and resuspension exposures. The collective population risk is a measure of the total radiological risk posed to society as a whole by the alternative being considered. As such, the collective population risk is used as the primary means of comparing the various alternatives.

E.5 ALTERNATIVES, PARAMETERS AND ASSUMPTIONS

E.5.1 Description of Alternatives

Four transportation segments were evaluated in this EIS: (1) shipment of fabricated TPBARs to assembly facilities, (2) shipment of TPBAR assemblies to each of the CLWRs, (3) shipment of irradiated TPBARs to the Savannah River Site, and (4) shipment of irradiated hardware to a waste disposal site.

Transportation segment (1) involves shipment of nonhazardous, nonradioactive TPBAR material in secure commercial containers from TPBAR fabricators to fuel assembly facilities. Candidate sites for fabrication of the TPBARs include Wilmington, North Carolina (General Electric) and Columbia, South Carolina (Westinghouse Electric Corporation).

Transportation segment (2) involves shipment of nonhazardous, nonradioactive TPBAR material in secure commercial containers, along with new (fresh, unirradiated) reactor fuel. The impacts of shipping fresh reactor fuel are outside the scope of this EIS and are covered in NUREG-0170 (NRC 1977). Candidate sites for assembly of the TPBARs include Richland, Washington (Siemens Power Corporation); Lynchburg, Virginia (Framatome-Cogema Fuels or BWX Technologies, Inc.); and Columbia, South Carolina (Westinghouse Electric Corporation). The transportation impacts of all possible combinations of these facilities have been evaluated. The choice of facilities will be made by DOE using normal commercial practices.

Transportation segment (3) involves shipment of irradiated TPBARs from the CLWRs to the Tritium Extraction Facility at the Savannah River Site. The metallic components of the TPBARs will have been activated by the reactor flux, and they will contain the radioactive tritium. Therefore, these TPBARs will be shipped in a Type B cask. This EIS has evaluated the shipment of TPBARs by three distinct methods. First, truck-sized casks, which hold a single consolidated assembly, could be transported using legal-weight trucks (one cask per truck) on public roads. Second, two truck-sized casks could be shipped by dedicated train on rail lines. Third, rail-sized casks, which hold between 2 and 24 consolidated TPBAR containers, could be shipped by dedicated train on rail lines. For the purpose of conservative analysis, this EIS assumes that only two consolidated containers will be loaded in a rail-size cask. This assumption is conservative because putting more than two consolidated assemblies into a cask would decrease the number of shipments, which decreases the incident-free and traffic accident risks. These risks are dominant contributors of the transportation risk.

The transportation analysis looked at likely implementation approaches for each of the three reactor options. The approaches quantitatively addressed minimum production at a single unit (1,000 TPBARs per 18-month fuel cycle) and maximum production at a single unit (3,400 TPBARs per 18-month fuel cycle).

Transportation segment (4) involves shipment of irradiated hardware from the CLWRs to either the Savannah River Site or the Barnwell disposal facility in South Carolina for disposal as low-level radioactive waste. Irradiated hardware includes base plates and thimble plugs removed from the TPBARs at the CLWR site.

E.5.2 Representative Routes

Representative overland truck routes were selected for the shipments to the CLWRs, Savannah River Site, and the Barnwell disposal facility. The routes were selected consistent with current routing practices and all applicable routing regulations and guidelines (DOT 1992). However, the routes were determined for risk assessment purposes. They do not necessarily represent the actual routes that would be used to transport TPBARs and waste in the future. Specific routes cannot be identified in advance. The representative truck routes are shown in **Figure E–5**. Rail routes, determined by commercial as well as safety considerations, are not shown on Figure E–5 for brevity.

Route characteristics that are important to the radiological risk assessment include the total shipment distance and the population distribution along the route. The specific route selected determines both the total potentially exposed population and the expected frequency of transportation-related accidents. Route characteristics are summarized in **Table E–1**. The population densities along each route are derived from 1990 U.S. Bureau of Census data. Rural, suburban, and urban areas are characterized according to the following breakdown: rural population densities range from 0 to 54 persons per square kilometer (0 to 139 person per square mile); the suburban range is from 55 to 1,284 persons per square kilometer (140 to 3,326 persons per square mile); and the urban range includes all population densities greater than 1,284 persons per square kilometer (3,326 persons per square mile). The exposed population includes all persons living within 800 meters (0.5 mile) of each side of the road. The exposed population, for the purpose of route characterization and incident-free dose calculation, includes all persons living within 800 meters (0.5 mile) of each side of the road.

The preferred route for truck shipments entering the Savannah River Site is to enter the site from Jackson, South Carolina, on Route 125 at barricade 7; take road 3 over to road 5; go south on road 5 until reaching road 6; go east on road 6 until reaching F road; go north on F road until reaching E road; go north on E road until reaching road 4; go north on road 4 into H-area; and then approach the Tritium Extraction Facility via the local H-area roads. DOE has identified two alternate routes (WSRC 1996):

- Assuming that the newly completed bridge modification on road F is adequate to handle trucks, enter the site from Jackson, South Carolina, on Route 125 at barricade 7. Take road 3 over to road 5. Go northeast on road 5 until reaching C road. Go north on C road until reaching road 4. Go northeast on road 4 into H area, and approach the Tritium Extraction Facility via the local H-area roads.

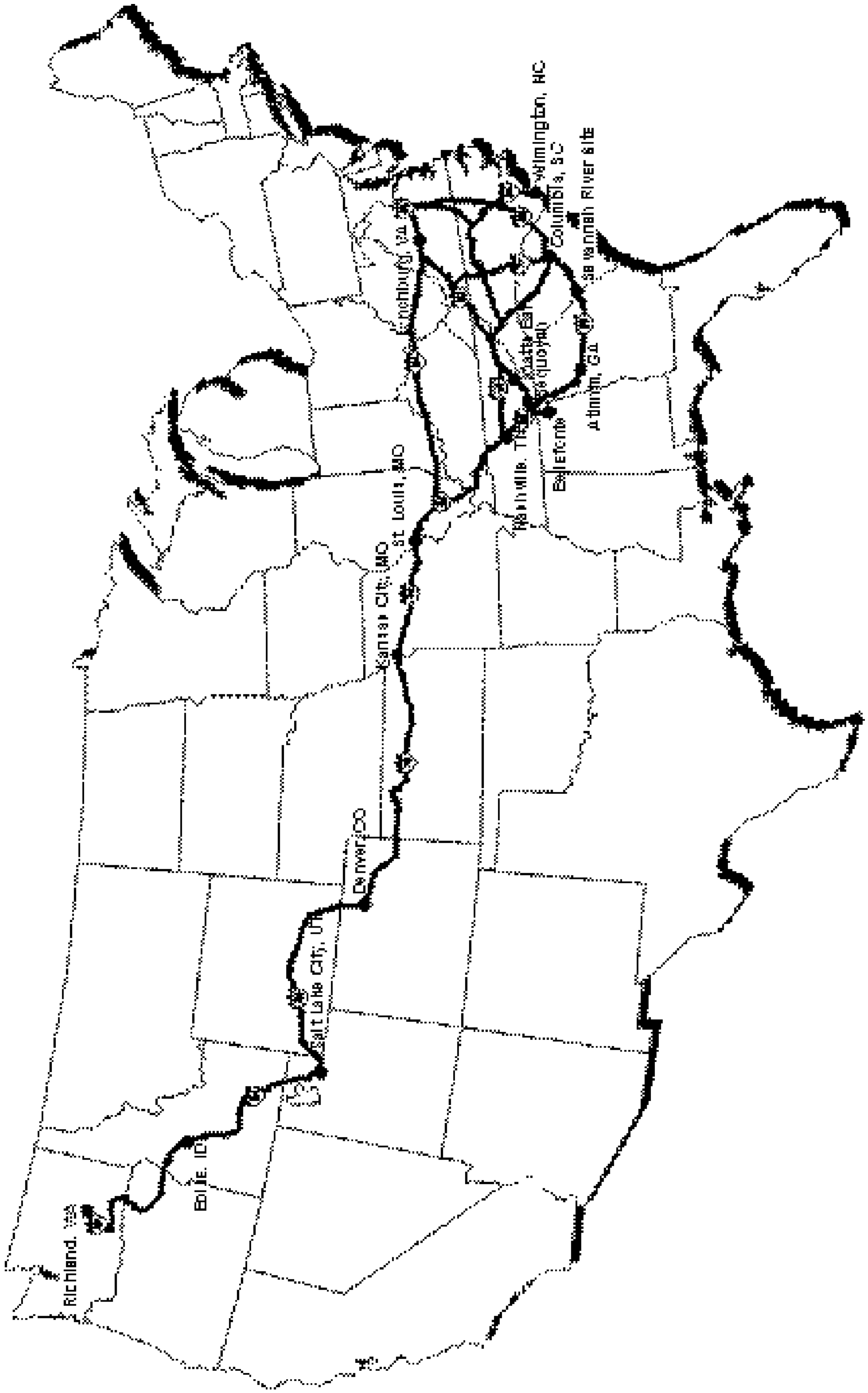

Figure E–5 Representative Overland Truck Routes

Table E–1 Potential Shipping Routes Evaluated for the CLWR Tritium EIS

From	To	Distance (km)	Percentages in Zones			Population Density in Zone ($1/km^2$)			Number of Affected Persons
			Rural	Suburban	Urban	Rural	Suburban	Urban	
Truck Routes									
WBN	SRS	574.5	61.7	34.9	3.4	18.1	349.7	2,195.3	191,000
SQN	SRS	498.9	55.0	40.6	4.4	16.8	373.0	2,157.4	204,000
BLN	SRS	560.0	61.7	34.5	3.8	16.7	358.4	2,158.0	193,000
Wilmington, NC	Columbia, SC	513.4	72.3	27.2	0.4	19.9	229.3	1,764.7	69,000
Wilmington, NC	Lynchburg, VA	577.7	83.0	16.1	0.7	14.4	188.7	2,276.9	54,000
Wilmington, NC	Richland, WA	4,787.7	82.7	16.1	1.2	7.4	329.5	2,169.9	653,000
Columbia, SC	Lynchburg, VA	595.4	70.0	28.7	1.3	16.9	296.5	2,037.7	118,000
Columbia, SC	Richland, WA	4,451.3	85.7	13.1	1.2	6.7	336.5	2,146.8	538,000
Lynchburg, VA	WBN	614.8	69.6	29.6	0.8	18.7	276.3	2,028.9	109,000
Columbia, SC	WBN	552.0	70.0	29.1	0.9	14.2	297.0	1,856.0	100,000
Richland, WA	WBN	4,031.3	87.7	11.0	1.2	6.2	340.7	2,174.7	445,000
Lynchburg, VA	SQN	729.0	64.7	34.2	1.1	19.3	302.4	1,967.3	160,000
Columbia, SC	SQN	597.1	57.1	39.5	3.4	16.0	348.2	2,110.6	209,000
Richland, WA	SQN	3,950.8	87.0	11.7	1.3	6.2	347.2	2,173.3	469,000
Lynchburg, VA	BLN	790.2	68.8	30.3	0.9	18.9	287.8	1,950.5	149,000
Columbia, SC	BLN	658.2	62.6	34.4	3.0	16.0	334.7	2,109.6	198,000
Richland, WA	BLN	3,925.1	87.6	11.1	1.3	6.2	347.0	2,173.8	453,000
WBN	Barnwell, SC	632.5	62.9	34.3	2.8	16.5	342.3	2,145.2	190,000
SQN	Barnwell, SC	556.8	57.0	39.3	3.7	14.9	364.0	2,110.7	205,000
BLN	Barnwell, SC	618.0	62.9	33.9	3.2	15.2	350.1	2,109.8	194,000
Rail Routes									
WBN	SRS	668.2	62.4	36.2	1.3	14.1	269.0	2,091.1	143,000
SQN	SRS	611.9	60.5	38.0	1.4	14.3	271.4	2,091.1	138,000
BLN	SRS	675.9	63.3	35.4	1.2	14.0	268.8	2,091.1	140,000

BLN = Bellefonte Nuclear Plant SQN = Sequoyah Nuclear Plant SRS = Savannah River Site WBN = Watts Bar Nuclear Plant

- Assuming that the newly completed bridge on road F is adequate to handle trucks, enter the site from the North on Route 19 through barricade 2. Take road 2 to F road. Go south on F road until reaching road 4. Go southeast on road 4 into H-area, and approach the Tritium Extraction Facility via the local H-area roads.

The differences in the risk of the three possible routes was evaluated to be much less than the significant figures shown on the risk estimates. Final determination of route details is an operational decision to be made at the time of shipment.

If rail transportation is the chosen mode, the preferred rail system is to use existing Savannah River Site rails and railspurs. The Savannah River Site would use an existing 300-ton Manitowoc portable crane at the end of the rail spur to transfer the casks from the rail car to trucks. The trucks would travel the quarter mile to the Tritium

Extraction Facility. A railspur terminal support facility may be required to support this crane. Construction impact estimates (if construction is required) are not available at this time (WSRC 1996).

The Bellefonte, Watts Bar, and Sequoyah nuclear power plants currently have cranes that could handle 125-ton casks, although Sequoyah is currently downgraded to 80 tons and load testing would be required to restore the rating to the design capacity of 125 tons. Large cask handling has not been addressed in detail at any of the sites, so regulatory, structural, and spacial issues must be evaluated before rail transportation could be implemented.

E.5.3 Material Inventory

The amount of hazardous material in a package is called the inventory. It refers to the material available for release in an accident scenario. Inventory estimates for the materials shipped are given below.

Low-Level Radioactive Waste

DOE assumes 24 TPBARs per production assembly. Irradiation of 3,400 TPBARs per 18-month fuel cycle would generate 141 holddown assemblies (see Appendix, **Figure A–12**). These holddown assemblies would be discarded as low-level radioactive waste. The low-level radioactive waste volume is estimated to be about 0.43 cubic meter (15 cubic feet) per year (WEC 1998).

Use of a “generic legal weight truck waste cask” with a usable cavity measuring 18 inches in diameter by 144 inches long would result in about two shipments per year. However, achieving perfect packing efficiency of these wastes is not realistic, and this estimate must be expanded. DOE estimates that the annual waste shipments will be a minimum of two and a maximum of eight.

Pacific Northwest National Laboratory provided source terms for 16 thimble plugs, which is about 1,500 grams of irradiated hardware (PNNL 1998a). Using the above information, which was chosen to conservatively estimate the amount of irradiated hardware, each shipment will carry about 56 kilograms of irradiated hardware. The thimble plugs are more highly irradiated than other hardware, so use of the data from thimble plugs is conservative. **Table E–2** lists the derived source term used for the purpose of analyzing low-level radioactive waste transportation risks. Further analysis, using final design information and actual irradiation schedules, will be used to verify that the concentration of radionuclides does not exceed the Class C limits of 10 CFR 61. The regulatory limit dose rates were assumed for low-level radioactive waste shipments.

TPBARs

Pacific Northwest National Laboratory determined the radionuclide inventory, and decay heat for the Lead Test Assembly TPBARs at reactor discharge and for decay times ranging from 7 days to 10 years following reactor discharge (PNNL 1998a). Table E–2 shows the TPBAR radionuclide inventory, with a decay time of 30 days used for the analysis. The inventory includes tritium and other irradiated components associated with the cladding, liner, getter and other structures within a TPBAR. The latter is collectively called non-target-bearing components (NTBC).

Crud

The crud inventory assumed to be available for release from TPBARs is shown in Table E–2 with a 30-day decay time following reactor discharge in units of Ci/TPBAR. The crud inventory has been very conservatively bounded using worst-case measurements of crud from pressurized water reactor spent nuclear fuel (SNL 1991a).

Table E–2 Irradiated Hardware and TPBAR Inventory

Nuclide	*Low-Level Radioactive Waste (Ci per shipment)*	*TPBAR (Ci per TPBAR)*	*TPBAR Crud (Ci per TPBAR)*
Tritium		9,600[a]	
Carbon-14	0.0000042	0.0095	NA
Chromium-51	30,000	300	0.21
Manganese-54	2,700	23	0.4
Iron-55	14,000	120	NA
Iron-59	890	7.5	0.21
Cobalt-58	3,400	66	1.2
Cobalt-60	3,500	33	0.15
Zinc-65	0.000038	0.0015	NA
Zirconium-89	0.000029	0.0000022	NA
Zirconium-95	0.04	31	0.029
Niobium-95	8.1	.39	NA
Molybdenum-99	2.6	0.19	NA
Ruthenium-103	0.014	0.0010	NA

[a] For failed TPBAR a value of 1.15×10^4 Ci of tritium (1.2 g of tritium) per TPBAR is used for analytic consistency.
NA = Not available

E.5.4 External Dose Rates

Cask design for irradiated TPBARs and cask selection for low-level radioactive waste are not complete. However, even though the hardware is highly irradiated, the container external dose rate is not as high as the regulatory limits. For the purposes of analysis, it is conservative to assume that TPBAR and low-level radioactive waste container external dose rates are equal to regulatory limits.

E.5.5 Health Risk Conversion Factors

The health risk conversion factors used to estimate expected cancer fatalities were: 0.0005 and 0.0004 fatal cancer cases per person-rem for members of the public and workers, respectively (NCRP 1993). Both cancer fatalities and incidence occur during the lifetimes of the exposed populations and, thus, are called latent cancer fatalities.

E.5.6 Accident Involvement Rates

For the calculation of accident risks, vehicle accident and fatality rates are taken from data provided in other reports (ANL 1994). Accident rates are generically defined as the number of accident involvements (or fatalities) in a given year per unit of travel in that same year. Therefore, the rate is a fractional value, with accident-involvement count as the numerator of the fraction and vehicular activity (total travel distance in truck-kilometers or railcar-kilometers) as its denominator. Accident rates are generally determined for a multi-year period. For assessment purposes, the total number of expected accidents or fatalities is calculated by multiplying the total shipment distance for a specific case by the appropriate accident or fatality rate.

For truck transportation, the rates presented are specifically for heavy combination trucks involved in interstate commerce (ANL 1994). Heavy combination trucks are rigs composed of a separable tractor unit containing the engine and one to three freight trailers connected to each other. Heavy combination trucks are typically used for radioactive waste shipments. The truck accident rates are computed for each state based on statistics compiled by the U.S. Department of Transportation Office of Motor Carriers from 1986 to 1988. Saricks and Kvitek present accident involvement and fatality counts; estimated kilometers of travel by state; and the corresponding average accident involvement, fatality, and injury rates for the three years investigated. Fatalities are public deaths that are attributable to the accident or that occurred at any time within 30 days after.

Rail accidents are computed and presented similarly to truck accident rates (ANL 1994). The state-specific rail accident involvement and fatality rates are based on statistics compiled by the Federal Railroad Administration from 1985 to1988. Rail accident rates include both main line accidents and those occurring in railyards. It is important to note that the accident rates used in this assessment were computed using the universe of all interstate heavy combination truck shipments, independent of shipment cargo. The cited report points out that shippers and carriers of radioactive material generally have a higher than average awareness of transport risk and prepare cargoes and drivers for such shipments accordingly (ANL 1994). This preparation should have a twofold effect of reducing component/equipment failure and mitigating the human error contribution to accident causation. These effects were not given credit in the accident assessment.

E.5.7 Container Accident Response Characteristics and Release Fractions

E.5.7.1 Development of Conditional Probabilities

The Modal Study was the result of an initiative taken by the NRC (NRC 1987) to refine more precisely the analysis presented in NUREG-0170 (NRC 1977) for spent nuclear fuel shipping casks. Whereas the NUREG-0170 analysis was primarily performed using best engineering judgments and presumptions concerning cask response, the Modal Study relies on sophisticated structural and thermal engineering analysis and a probabilistic assessment of the conditions that could be experienced in severe transportation accidents. The Modal Study results are based on representative spent nuclear fuel casks that were assumed to have been designed, manufactured, operated, and maintained in accordance with national codes and standards. Design parameters of the representative casks were chosen to meet the minimum test criteria specified in 10 CFR 71. The study is believed to provide realistic, yet conservative, results for radiological releases under transport accident conditions.

In the Modal Study, potential accident damage to a cask is categorized according to the magnitude of the mechanical forces (impact) and thermal forces (fire) to which a cask may be subjected during an accident. Because all accidents can be described in these terms, severity is independent of the specific accident sequence. In other words, any sequence of events that results in an accident in which a cask is subjected to forces within a certain range of values is assigned to the accident severity region associated with that range. The accident severity scheme is designed to take into account all potential foreseeable transportation accidents, including accidents with low probability but high consequences and those with high probability but low consequences.

Each severity region actually represents a set of accidents defined by a combination of mechanical and thermal forces. A conditional probability of occurrence—that is, the probability that if an accident occurs, it is of a particular severity—is assigned to each region. The Modal Study conditional probability matrices for truck and train accidents (see **Figures E–6** and **E–7**) each contain 20 accident regions. In the Modal Study, these regions are collapsed to form six severity categories, where a severity category represents a set of accidents defined by a combination of mechanical and thermal forces that are expected to produce accident source terms that have similar magnitudes. The fraction of all accidents that fall into each severity category is developed by summing the values for the fractions of all accidents presented in the Modal Study for the set of regions combined to form one severity category. Figure E–6 indicates the regions that were combined to generate each of the six accident categories specified in DOE/EIS-0203-F (DOE 1995) and DOE/EA-1210 (DOE 1997). The y-axis break-points on the accident matrix (S_1 = 0.2%, S_2 = 2%, S_3 = 30%) specify the maximum strain in percent on the inner shell of the Type B truck cask. The x-axis break-points (T_1 = 260 $_2$ = 316 $_3$ = 343 $_4$ = 565 specify the lead mid-wall temperature. Thus, each of the 20 regions in the matrix specifies both an impact load and a thermal load. Figure E–7 presents the Modal Study matrix for rail accidents and gives the conditional probability for each of the 20 accident regions. The y-axis and x-axis break-points are the same as those developed for the Modal Study truck accident matrix. The regions have not been grouped into categories for TPBAR performance in train accidents, so none are presented.

Accidents in Region (1,1) are the least severe but most frequent, whereas accidents in Region (4,5) are very severe but very infrequent. To determine the expected frequency of an accident of a given severity, the conditional probability in the category is multiplied by the baseline accident rate. The entire spectrum of accident severities is considered in the accident risk assessment.

As discussed above, the accident consequence assessment only considers the potential impacts from the most severe transportation accidents. In terms of risk, the severity of an accident must be viewed in terms of potential radiological consequences, which are directly proportional to the fraction of the radioactive material within a cask that is released to the environment during the accident. Although regions span the entire range of mechanical and thermal accident loads, they are grouped into accident categories that can be characterized by a single set of release fractions and are, therefore, considered together in the accident consequence assessment. The accident category severity fraction is the sum of all conditional probabilities in that accident category.

To use the conditional probabilities developed in the Modal Study for Rail Casks Transported by Rail for the case of truck casks transported by rail, a comparison of the effect of rail accidents on truck casks was made. The response of truck and rail casks to rail accident impacts is essentially identical; therefore, no adjustment was required. However, these casks would respond differently to a rail accident involving fire. For the same design-basis fire environment, the truck cask will reach a given temperature in a shorter duration than the rail cask. The Modal Study provides graphs that relate the fire duration with lead mid-wall temperature for both truck and rail casks. Using the graph for rail casks, the durations of engulfing fires required to reach each of the x-axis break-points were determined. From these durations the graph for truck casks was used to develop new x-axis break-points. An exponential function was fitted to the resulting cumulative probability versus mid-wall temperature data, and it was then applied to determine the cumulative probability for the original Modal Study x-axis break-points. The resulting conditional probabilities for truck casks transported by rail are given in **Figure E–8**.

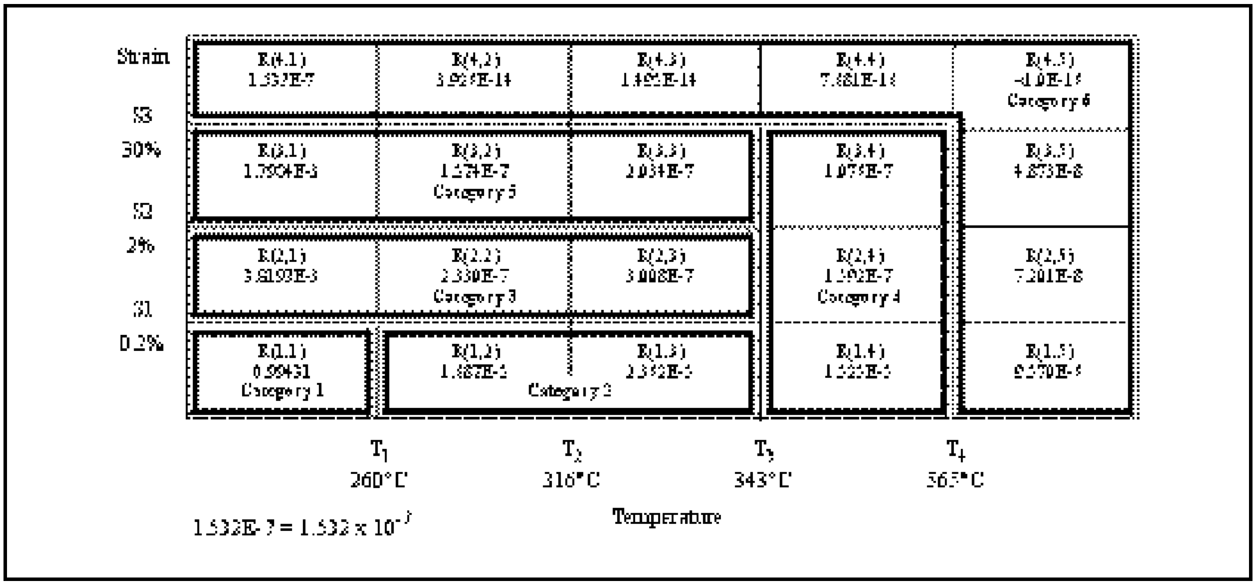

Figure E–6 Conditional Probability Matrix for Modal Study Truck Cask

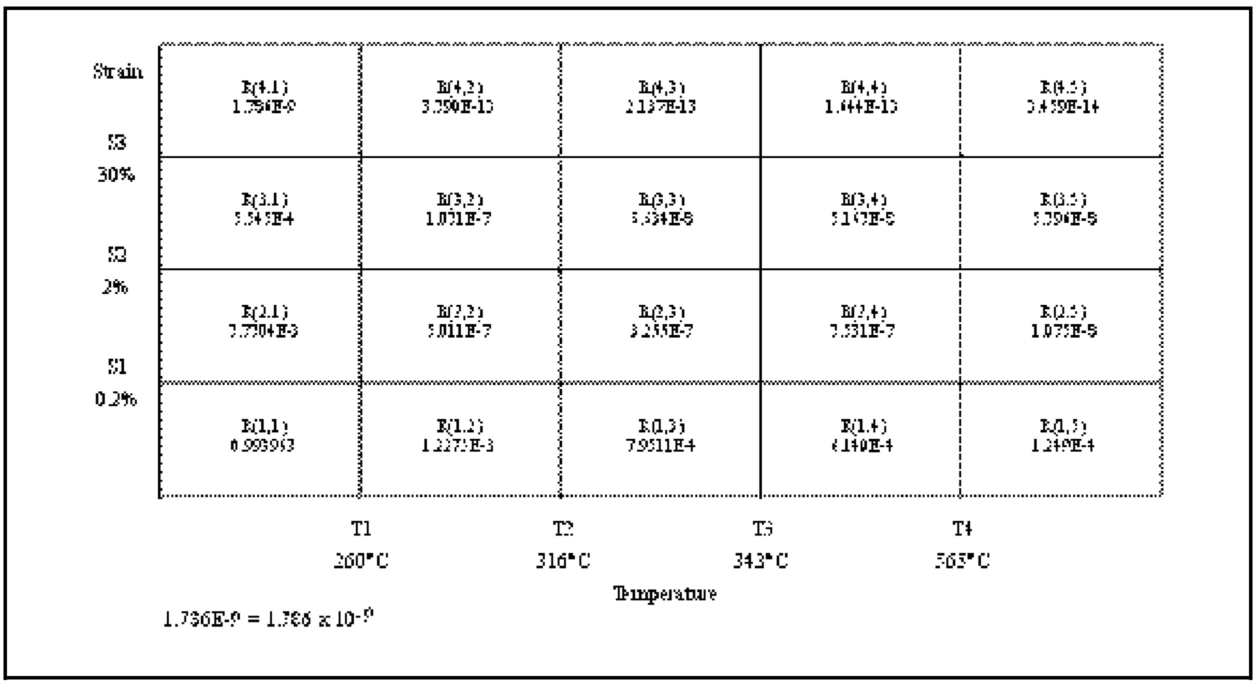

Figure E–7 Conditional Probability Matrix for Modal Study Rail Cask

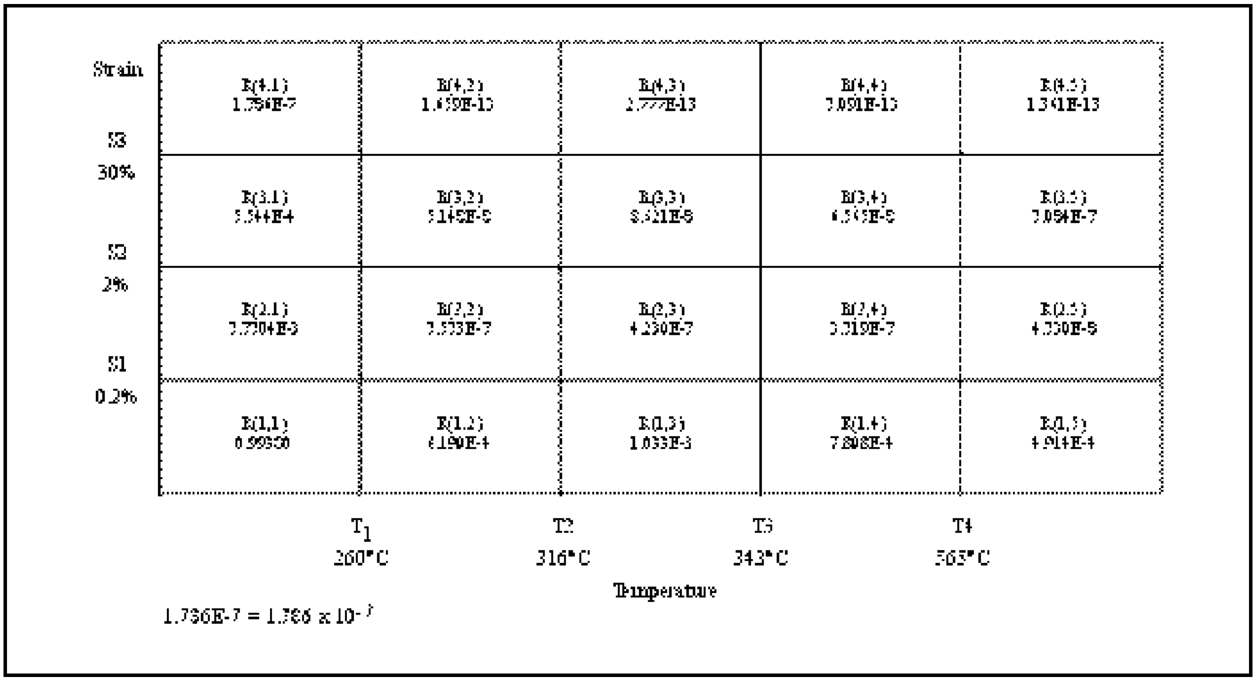

Figure E–8 Conditional Probability Matrix for Truck Cask Transported by Rail

E.5.7.2 Transportation Risk Analyses Assumptions

E.5.7.2.1 Cask Response to Impact and Thermal Loads

This section provides separate analyses for casks with elastomeric seals and metallic seals since they perform differently in accidents. In general, elastomeric seals will perform better (i.e., fail at a higher strain) than metallic seals in accidents involving impacts without fires. Metallic seals will perform better (i.e., fail at a higher temperature) than elastomeric seals in accidents involving fires.

The regulatory design-basis accident defined by 10 CFR 71 and 49 CFR 173 is encompassed within a region bounded by a maximum impact load of S_1 (0.2 percent maximum strain on the inner shell) and a maximum thermal load of T_1 (260

The cask containment boundary for a truck or rail cask using elastomeric seals was assumed not to fail for impact loads less than S_2 (2 percent strain) and temperatures less than T_1. Radioactive material packages are designed to a very rigorous set of standards. This design philosophy results in a large margin of safety against accidents more severe than the Design Basis Accident. For the EIS analyses the conditional probabilities were taken directly from the Modal Study, and those conditional probabilities were based on the response of the representative truck and rail casks described in the Modal Study. These generic casks were chosen such that the regulatory Design Basis Accident would result in a 0.2 percent strain in the inner shell of the cask. Recent tests and analyses performed at Sandia National Laboratory using packages with elastomeric seals have shown that this level of strain is reasonable for the Design Basis Accident and that the cask containment boundary does not fail for accidents resulting in inner shell strains of up to 20 percent (Ammerman 1995). Based on these results, the EIS transportation risk analyses assumed that the cask containment boundary will not fail for packages using elastomeric seals for inner shell strains less than S_2.

Packages using metallic seals cannot tolerate the slight amounts of closure movements that may occur during extra regulatory impacts. Therefore, the EIS analyses assume that any impact load above S_1 for a cask using metallic seals results in failure of the cask containment boundary. The probability of failure of the cask containment boundary as a result of failure of the metallic seal below T_4 (565
probability of seal failure for normal operating conditions. The American Society for Testing and Materials Type 304 stainless steel structural materials and metallic seal materials typically used in radioactive material packages are also used in high-temperature industrial applications. To avoid creep, the American Society of Mechanical Engineers Code, Section III, rates the American Society for Testing and Materials Type 304 material commonly used for radioactive material packages at 122 MPa (17.7 ksi) for a 10-hour exposure to temperatures of 565
With only internal pressure as a source of primary stresses and secondary thermal stresses, stress levels in the seal area are anticipated to be well below this material rating. However, bolt materials for package closures must be carefully selected. The American Society of Mechanical Engineers Codes, Sections VIII and III, rate common high-strength carbon steel bolt materials only to temperatures near 370
however, are rated to temperatures as high as 620
bolts will be utilized (SNL 1998).

E.5.7.2.2 TPBARs Response to Impact and Thermal Loads

The EIS transportation risk analyses assumed a TPBAR failure rate, consistent with the assumptions used for reactor operations, of two TPBARs per core (maximum of 3,400 TPBARs per core). Since the possibility exists that the two assumed failed TPBARs could be transported in the same cask shipment following consolidation at the reactor, the EIS transportation risk analyses assumed that there could be a maximum of two prefailed (failed prior to transportation) TPBARs in a truck cask (at least 289 TPBARs per shipment) or a given rail cask (at least 578 TPBARs per shipment).

Following Design Basis Accident impacts, spent fuel rods with precracking due to pellet-clad-interactions at the pellet boundaries experience very few failures (SNL 1992). Therefore, the analysis assumes that the regulatory impact (S_1 = 0.2 percent) will not cause any TPBAR cladding failures. Moreover, the design conservatism in the impact limiters for spent fuel casks result in only relatively small increases in acceleration loads to the contents for extraregulatory impacts up to a point where the strain in the wall is equal to 2 percent. Therefore, it is assumed that there are no failures of the TPBAR cladding for impact loads resulting in strains below S_2 (2 percent). To achieve strains higher than 2 percent the impact limiter must be completely locked-up (can no longer absorb energy) and the acceleration levels increase significantly. At this point there is a possibility that some of the TPBARs could experience cladding failure due to the mechanical loads placed upon them. The probability of this failure is relatively small due to the high ductility of the 316 stainless steel cladding and the small diameter of the TPBARs. Small-diameter tubing is able to undergo large deformations without high strains. For tubing the size of TPBARs (0.97-cm [0.381-in] diameter) (PNNL 1997) and an assumed failure strain of only 2 percent (much less than the ductility of 20 percent cold-worked 316 stainless steel), the cladding can be bent into an arc with a radius of up to 24.1 cm (9.5 inches) before reaching the failure strain. Within the confines of a truck cask it is impossible to get large enough lateral deflections to achieve this level of curvature. Therefore, the only TPBARs that can fail during impact loads are those with pre-existing part-wall cracks (SNL 1998). These analyses conservatively assumed that this is equal to 1 percent of the TPBARs, based on the frequency of spent fuel rods with pre-existing part-wall cracks (SNL 1992).

As noted earlier, the temperatures that define the regions for the conditional probabilities in the Modal Study truck and rail cask accident matrices are the temperatures at the mid-wall of the lead shield that result from thermal loads during the fire accident. The temperature of the TPBAR cladding is conservatively assumed to be equal to lead shield mid-wall temperature. For temperatures below T_3 (343
0.12 mCi/TPBAR/hour of tritium in the form of molecular tritium gas (T_2 and HT) are released from all intact TPBARs into the cask cavity (PNNL 1998b). For the purposes of determining the quantity of molecular tritium

gas that is released from intact TPBARs into the cask cavity, the EIS analyses conservatively assume that the TPBARs are in the transport cask for a period of two weeks. For the purpose of analysis, each TPBAR is designed to contain an average of 1.0 grams of tritium, or approximately 9,640 Ci (PNNL 1997). For temperatures between T_3 and T_4 (343
tritium/TPBAR in the form of molecular tritium gas are released from all intact TPBARs into the cask cavity (PNNL 1998b).

For temperatures below T_4, the EIS analyses assume that 0.015 grams of tritium/TPBAR in the form of tritiated water (T_2O and HTO) are instantaneously released into the cask cavity from all TPBARs that have failed due to impact and thermal loads (PNNL 1998b). The potential for TPBAR rupture was assessed at T_4, and it was determined that TPBARs are unlikely to rupture at temperatures less than T_4. However, TPBARs may rupture at temperatures higher than T_4. Therefore, the analyses conservatively assume that all TPBARs fail during a transportation cask fire accident when TPBAR temperatures are above T_4. For TPBARs with temperatures above T_4, the analyses assume that 100 percent of the tritium inventory of the TPBARs is instantaneously released in the form of tritiated water into the cask cavity (PNNL 1998b).

Finally, the EIS analyses assume that 100 percent of the tritium inventory of prefailed (failed prior to transportation) TPBARs will be released into the cask cavity in the form of tritiated water (PNNL 1998b) and that tritiated water does not permeate through the elastomeric seals comprising the cask containment boundary for temperatures less than T_1 (260
for temperatures less than T_4.

E.5.7.3 Accident Matrix Category Descriptions

The six accident categories specified in DOE/EA-1210 (DOE 1997) and shown in Figure E–6 were based on the performance of spent nuclear fuel. The analysis described in Section E.5.7.2 has been used to refine the category descriptions to better fit the characteristic behavior of TPBARs. Retaining the basic structure of the Modal Study matrices allows the use of the conditional probabilities given in the Modal Study for accident matrix regions.

The 20 regions described by the 4 × 5 conditional probability matrix were combined to give seven accident severity categories for the truck and rail casks used to transport the irradiated TPBARs from the production reactor to the Tritium Extraction Facility. The regions of the conditional probability matrix that are encompassed by a specific accident category will differ between a cask using elastomeric seals and one using metallic seals due to the varying response of each cask to the impact and thermal loads.

E.5.7.3.1 Elastomeric Seal

Figure E–9 gives the accident matrix for both truck and rail casks using an elastomeric seal. The regions that were combined to generate the seven accident categories are also shown in Figure E–9.

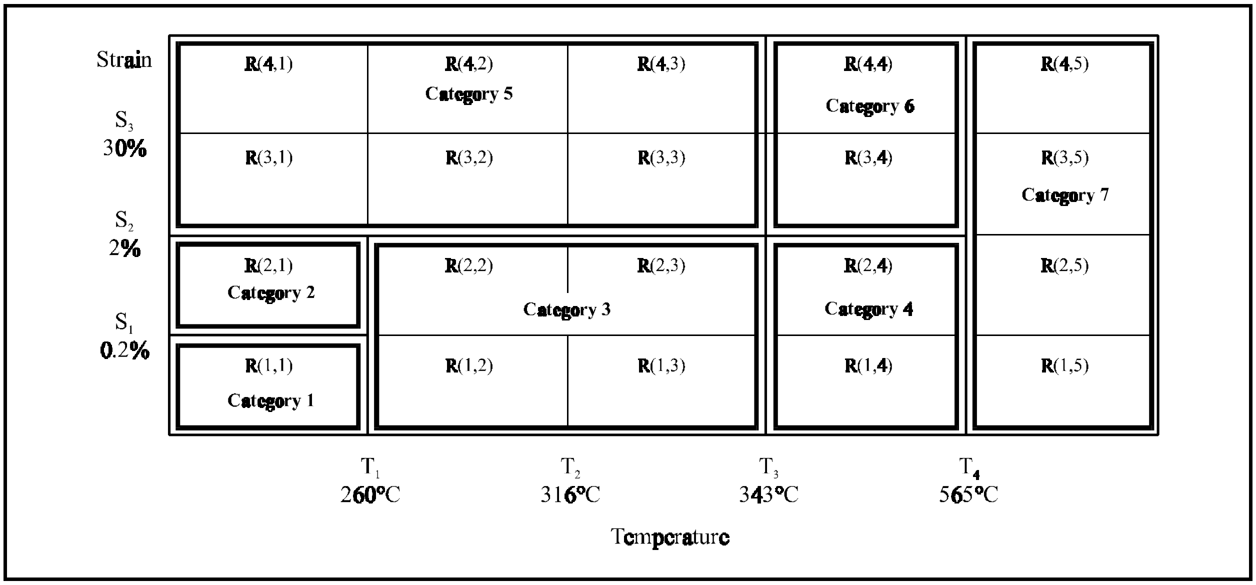

Figure E–9 Accident Matrix for Truck and Rail Casks Using Elastomeric Seals

E.5.7.3.2 Metallic Seals

Figure E–10 gives the accident matrix for both truck and rail casks using a metallic seal. The regions that were combined to generate each of the seven accident categories are also shown in Figure E–10.

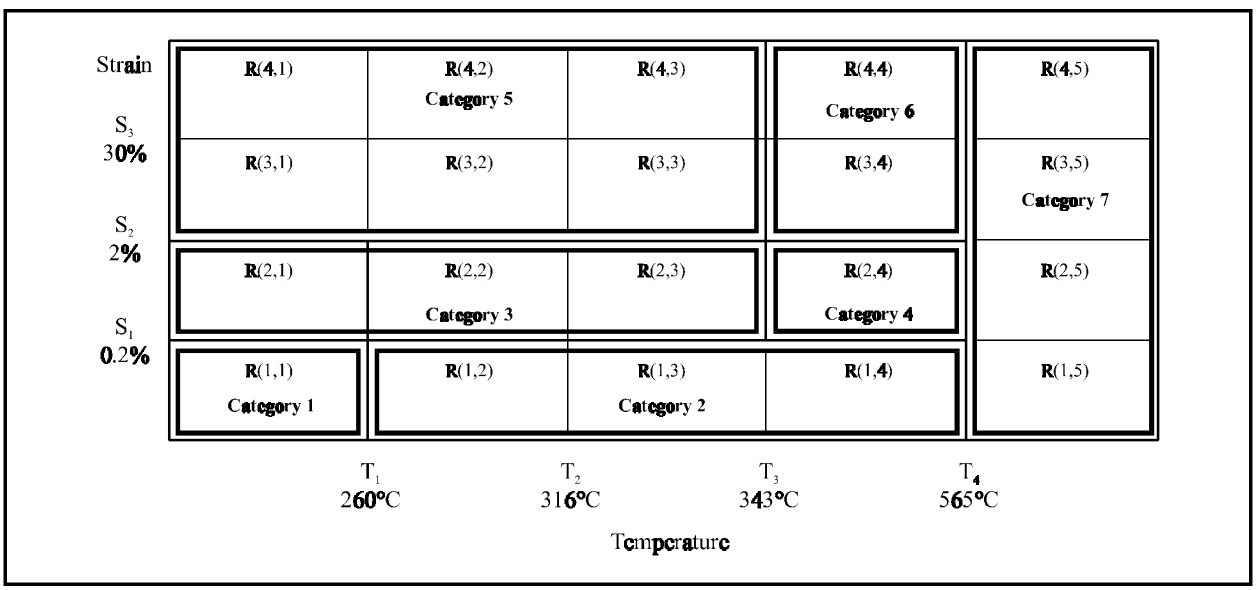

Figure E–10 Accident Matrix for Truck and Rail Casks Using Metallic Seal

E.5.7.3.3 Accident Category Release Fractions for Tritium, Non-Target-Bearing Components, and Crud

Release fractions for tritium, both as molecular tritium gas (T_2 or HT) and as tritiated water (T_2O or HTO), non-target-bearing components, and crud for truck casks transported by road, truck casks transported by rail, and rail casks transported by rail with no prefailed TPBARs are given in **Table E–3** for each of the seven accident categories. For both regulatory and extra regulatory transport conditions, 100 percent of the crud is assumed to spall. The average crud concentration in a cask cavity can be expressed as the concentration immediately after spallation and initial mixing, multiplied by a release reduction factor that incorporates all geometrical information on the cask volume, settling, and collection areas, and the aerosols time-varying size distribution (SNL 1993a). A bounding maximum release fraction for crud based on 100-percent spallation

Table E–3 Release Fractions for Truck and Rail Casks with No Pre-Failed TPBARs

Category	***1***	***2***	***3***	***4***	***5***	***6***	***7***
T_2 / HT	0	0	4.18E-6	1.50E-2	4.18E-6	1.49E-2	0
T_2O / HTO	0	0	0	0	1.50E-4	1.50E-4	1.0
NTBC	0	0	3.1E-10	1.0E-8	1.0E-8	1.0E-8	1.0E-7
Crud	0	0	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3

NTBC = Non-target-bearing components.
4.18 E-6 = 4.18×10^{-6}

and typical release reduction factors is 2×10^{-3} (SNL 1991b). Release fractions for non-target-bearing components are equivalent to those used in DOE/EA-1210 (DOE 1997) for the Lead Test Assembly, with adjustments made for the accident categories that are defined by different regions of the matrix. The crud and non-target-bearing components release fractions are independent of whether the cask uses an elastomeric seal or a metallic seal.

Release fractions for tritium, non-target-bearing components, and crud for truck casks transported by road and truck casks transported by rail with two prefailed out of 289 are given in **Table E–4** for each of the seven accident categories. The release fractions are independent of whether the cask uses an elastomeric seal or a metallic seal.

Release fractions for tritium, non-target-bearing components, and crud for rail casks transported by rail with two prefailed TPBARs out of 578 TPBARs in two consolidated containers in the rail cask) are given in **Table E–5** for each of the seven accident categories. The release fractions are independent of whether the cask uses an elastomeric seal or a metallic seal.

Table E–4 Release Fractions for Truck Casks with Two Pre-Failed TPBARs

Category	***1***	***2***	***3***	***4***	***5***	***6***	***7***
T_2 / HT	0	0	4.15E-6	1.49E-2	4.15E-6	1.48E-2	0
T_2O / HTO	0	0	8.29E-3	8.29E-3	8.44E-3	8.44E-3	1.0
NTBC	0	0	3.1E-10	1.0E-8	1.0E-8	1.0E-8	1.0E-7
Crud	0	0	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3

NTBC = Non-target-bearing components.

4.15E-6 = 4.15×10^{-6}

Table E–5 Release Fractions for Rail Casks with Two Pre-Failed TPBARs

Category	*1*	*2*	*3*	*4*	*5*	*6*	*7*
T_2 / HT	0	0	4.17E-6	1.50E-2	4.17E-6	1.48E-2	0
T_2O / HTO	0	0	4.14E-3	4.14E-3	4.29E-3	4.29E-3	1.0
NTBC	0	0	3.1E-10	1.0E-8	1.0E-8	1.0E-8	1.0E-7
Crud	0	0	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3

NTBC = Non-target-bearing components.
4.17E-6 = 4.17×10^{-6}

E.5.7.3.4 Accident Category Severity Fractions

The conditional probabilities given in Figure E–6, Figure E–7, and Figure E–8 were combined using the accident categories depicted in Figures E–9 and E–10 to develop the accident category severity fractions given in **Table E–6**. The severity fractions are independent of whether there are any prefailed TPBARs since the conditional probability accident matrix category descriptions are the same whether there are no prefailed TPBARs or there are two prefailed TPBARs in the transport cask.

Table E–6 Accident Category Severity Fractions

	Category						
	1	*2*	*3*	*4*	*5*	*6*	*7*
Truck cask transported by road using elastomeric seals	0.99432	3.819E-3	4.102E-5	1.541E-5	1.799E-3	1.076E-7	9.641E-6
Truck cask transported by rail using elastomeric seals	0.99380	2.720E-3	1.653E-3	9.812E-4	5.546E-4	6.565E-8	4.917E-4
Rail cask transported by rail using elastomeric seals	0.99396	2.720E-3	2.023E-3	6.143E-4	5.547E-4	5.162E-8	1.250E-4
Truck cask transported by road using metallic seals	0.99432	5.574E-5	3.828E-3	1.542E-7	1.799E-3	1.076E-7	9.641E-6
Truck cask transported by rail using metallic seals	0.99380	2.433E-3	2.721E-3	3.219E-7	5.546E-4	6.565E-8	4.917E-4
Rail cask transported by rail using metallic seals	0.99396	2.637E-3	2.721E-3	2.531E-7	5.547E-4	5.162E-8	1.250E-4

3.819E-3 = 3.819×10^{-3}

E.5.8 Nonradiological Risk (Vehicle Related)

Vehicle-related health risks resulting from incident-free transport may be associated with the generation of air pollutants by transport vehicles during shipment and are independent of the radioactive nature of the shipment. The health end-point assessed under incident-free transport conditions is the excess latent mortality due to inhalation of vehicle exhaust emissions. Risk factors for pollutant inhalation in terms of latent mortality have been generated (SNL 1982). These risks are 1×10^{-7} mortality per kilometer (1.6×10^{-7} per mile) and 1.3×10^{-7} mortality per kilometer (2.1×10^{-7} per mile) of truck and rail travel in urban areas, respectively. The risk factors are based on regression analyses of the effects of sulfur dioxide and particulate releases from diesel exhaust on mortality rates. Excess latent mortalities are assumed to be equivalent to latent cancer fatalities. Vehicle-related risks from incident-free transportation are calculated for each case by multiplying the total distance traveled in urban areas by the appropriate risk factor. Similar data are not available for rural and suburban areas.

Risks are summed over the entire route and over all shipments for each case. This method has been used in several EISs to calculate risks from incident-free transport. Lack of information for rural and suburban areas is an obvious data gap, although the risk factor would presumably be lower than for urban areas because of lower total emissions from all sources and lower population densities in rural and suburban areas.

E.6 RISK ANALYSIS RESULTS

Per-shipment risk factors have been calculated for the collective populations of exposed persons and for the crew for all anticipated routes and shipment configurations. The radiological risks are presented in doses per shipment for each unique route, material, and container combination. The radiological dose per shipment factors for incident-free transportation are presented in **Table E–7**. Doses are calculated for the crew, off-link public (i.e., people living along the route), on-link public (i.e., pedestrians and drivers along the route), and public at rest and fueling stops (i.e., stopped cars, buses and trucks, workers, and other bystanders). Accident impacts were calculated under the conservative assumption that all tritium gas released is quickly oxidized to form tritiated water.

The radiological dose risk factors for accident transportation conditions are also presented in Table E–7. The accident risk factors are called "dose risk" because the values incorporate the spectrum of accident severity probabilities and associated consequences.

The nonradiological risk factors are presented in fatalities per shipment in **Table E–8**. Separate risk factors are provided for fatalities resulting from exhaust emissions (caused by hydrocarbon emissions known to be carcinogens) and transportation accidents (fatalities resulting from impact).

The performance of both elastomeric and metallic cask seals was evaluated. Elastomeric seals perform better in accidents that involve impact because they are more flexible. Metallic seals perform better in accidents that

Table E–7 Radiological Risk Factors for Single Shipments

From	To	Material & Package	Incident-Free Dose (Person-rem)					Accident Dose (Person-rem)
				Public				
			Crew	Off-link	On-link	Stops	Total	
No Failed TPBARs								
Truck Routes								
WBN	SRS	Irradiated TPBARs	1.4×10^{-2}	2.4×10^{-3}	1.3×10^{-2}	6.8×10^{-2}	8.4×10^{-2}	2.3×10^{-5}
SQN	SRS	Irradiated TPBARs	1.3×10^{-2}	2.9×10^{-3}	1.7×10^{-2}	5.9×10^{-2}	7.9×10^{-2}	2.8×10^{-5}
BLN	SRS	Irradiated TPBARs	1.4×10^{-2}	2.3×10^{-3}	1.4×10^{-2}	6.6×10^{-2}	8.2×10^{-2}	2.4×10^{-5}
Rail Routes								
WBN	SRS	Irradiated TPBARs - Rail Cask	1.2×10^{-3}	7.5×10^{-4}	1.6×10^{-4}	4.8×10^{-3}	5.7×10^{-3}	1.9×10^{-5}
WBN	SRS	Irradiated TPBARs - 2 Truck Casks	1.2×10^{-3}	7.5×10^{-4}	1.6×10^{-4}	4.9×10^{-3}	5.8×10^{-3}	7.0×10^{-5}
SQN	SRS	Irradiated TPBARs - Rail Cask	1.1×10^{-3}	6.9×10^{-4}	1.5×10^{-4}	4.7×10^{-3}	5.6×10^{-3}	1.8×10^{-5}
SQN	SRS	Irradiated TPBARs - 2 Truck Casks	1.1×10^{-3}	6.9×10^{-4}	1.5×10^{-4}	4.8×10^{-3}	5.6×10^{-3}	6.4×10^{-5}
BLN	SRS	Irradiated TPBARs - Rail Cask	1.2×10^{-3}	7.5×10^{-4}	1.6×10^{-4}	4.8×10^{-3}	5.7×10^{-3}	1.9×10^{-5}
BLN	SRS	Irradiated TPBARs - 2 Truck Casks	1.2×10^{-3}	7.6×10^{-4}	1.6×10^{-4}	4.9×10^{-3}	5.8×10^{-3}	7.0×10^{-5}
2 Failed TPBARs								
Truck Routes								
WBN	SRS	Irradiated TPBARs	1.4×10^{-2}	2.4×10^{-3}	1.3×10^{-2}	6.8×10^{-2}	8.4×10^{-2}	4.0×10^{-5}
SQN	SRS	Irradiated TPBARs	1.3×10^{-2}	2.9×10^{-3}	1.7×10^{-2}	5.9×10^{-2}	7.9×10^{-2}	5.7×10^{-5}
BLN	SRS	Irradiated TPBARs	1.4×10^{-2}	2.3×10^{-3}	1.4×10^{-2}	6.6×10^{-2}	8.2×10^{-2}	4.2×10^{-5}

From	To	Material & Package	Incident-Free Dose (Person-rem)						Accident Dose (Person-rem)
			Crew	Public					
				Off-link	On-link	Stops	Total		
All Metallic Seals									
Rail Routes									
WBN	SRS	Irradiated TPBARs - Rail Cask	1.2×10^{-3}	7.5×10^{-4}	1.6×10^{-4}	4.8×10^{-3}	5.7×10^{-3}		1.9×10^{-5}
WBN	SRS	Irradiated TPBARs - 2 Truck Casks	1.2×10^{-3}	7.5×10^{-4}	1.6×10^{-4}	4.9×10^{-3}	5.8×10^{-3}		7.1×10^{-5}
SQN	SRS	Irradiated TPBARs - Rail Cask	1.1×10^{-3}	6.9×10^{-4}	1.5×10^{-4}	4.7×10^{-3}	5.6×10^{-3}		1.8×10^{-5}
SQN	SRS	Irradiated TPBARs - 2 Truck Casks	1.1×10^{-3}	6.9×10^{-4}	1.5×10^{-4}	4.8×10^{-3}	5.6×10^{-3}		6.5×10^{-5}
BLN	SRS	Irradiated TPBARs - Rail Casks	1.2×10^{-3}	7.5×10^{-4}	1.6×10^{-4}	4.8×10^{-3}	5.7×10^{-3}		2.0×10^{-5}
BLN	SRS	Irradiated TPBARs - 2 Truck Casks	1.2×10^{-3}	7.6×10^{-4}	1.6×10^{-4}	4.9×10^{-3}	5.8×10^{-3}		7.1×10^{-5}
Waste Transport									
Truck Routes									
WBN	SRS	Low-Level Radioactive Waste	1.9×10^{-2}	1.7×10^{-3}	6.2×10^{-3}	6.8×10^{-2}	7.6×10^{-2}		$<1.0 \times 10^{-8}$
SQN	SRS	Low-Level Radioactive Waste	1.7×10^{-2}	1.7×10^{-3}	5.9×10^{-3}	5.9×10^{-2}	6.7×10^{-2}		$<1.0 \times 10^{-8}$
BLN	SRS	Low-Level Radioactive Waste	1.2×10^{-2}	1.0×10^{-3}	3.9×10^{-3}	4.3×10^{-2}	4.7×10^{-2}		$<1.0 \times 10^{-8}$
WBN	Barnwell	Low-Level Radioactive Waste	2.0×10^{-2}	1.7×10^{-3}	6.6×10^{-3}	7.5×10^{-2}	8.3×10^{-2}		$<1.0 \times 10^{-8}$
SQN	Barnwell	Low-Level Radioactive Waste	1.9×10^{-2}	1.8×10^{-3}	6.3×10^{-3}	6.6×10^{-2}	7.4×10^{-2}		$<1.0 \times 10^{-8}$
BLN	Barnwell	Low-Level Radioactive Waste	2.0×10^{-2}	1.7×10^{-3}	6.5×10^{-3}	7.3×10^{-2}	8.1×10^{-2}		$<1.0 \times 10^{-8}$

BLN = Bellefonte Nuclear Plant SQN = Sequoyah Nuclear Plant SRS = Savannah River Site WBN = Watts Bar Nuclear Plant involve fire because they are less susceptible to heat damage. Overall, metallic seals exhibit a slightly higher risk and, therefore, are used to evaluate EIS alternatives.

Table E–9 shows the risks of transporting each of the hazardous materials. The risks are calculated by multiplying the previously given per-shipment factors by the number of shipments over 40 years duration of the program and, in the case of the radiological doses, by the health risk conversion factors. The accident risk from TPBAR shipments includes the irradiated metal and the crud deposited onto the TPBARs. Over 90 percent of the accident risk comes from the tritium. Based on the results of the transportation risk analysis, it is unlikely that shipping TPBARs and waste will result in a fatality. The risk estimates include the highest conceivable impacts of shipping unirradiated TPBARs and assemblies.

Table E–8 Nonradiological Risk Factors per Shipment

Nonradiological Risk Estimates (Fatalities/Shipment)			
From	***To***	***Exhaust Emission***	***Accident***
Truck Routes			
WBN	SRS	1.95×10^{-6}	1.13×10^{-5}
SQN	SRS	2.20×10^{-6}	9.87×10^{-6}
BLN	SRS	2.13×10^{-6}	1.10×10^{-5}
Wilmington, NC	Columbia, SC	2.05×10^{-7}	9.97×10^{-6}
Wilmington, NC	Lynchburg, VA	4.04×10^{-7}	1.11×10^{-5}
Wilmington, NC	Richland, WA	5.75×10^{-6}	9.26×10^{-5}
Columbia, SC	Lynchburg, VA	7.74×10^{-7}	1.16×10^{-5}
Columbia, SC	Richland, WA	5.34×10^{-6}	8.60×10^{-5}
Lynchburg, VA	WBN	4.92×10^{-7}	1.20×10^{-5}
Columbia, SC	WBN	4.97×10^{-7}	1.08×10^{-5}
Richland, WA	WBN	4.84×10^{-6}	7.77×10^{-5}
Lynchburg, VA	SQN	8.02×10^{-7}	1.43×10^{-5}
Columbia, SC	SQN	2.03×10^{-6}	1.18×10^{-5}
Richland, WA	SQN	5.14×10^{-6}	7.63×10^{-5}
Lynchburg, VA	BLN	7.11×10^{-7}	1.54×10^{-5}
Columbia, SC	BLN	1.97×10^{-6}	1.29×10^{-5}
Richland, WA	BLN	5.10×10^{-6}	7.57×10^{-5}
WBN	Barnwell, SC	1.77×10^{-6}	1.24×10^{-5}
SQN	Barnwell, SC	2.06×10^{-6}	1.10×10^{-5}
BLN	Barnwell, SC	1.98×10^{-6}	1.21×10^{-5}
Rail Routes			
WBN	SRS	1.13×10^{-6}	1.57×10^{-5}
SQN	SRS	1.11×10^{-6}	1.44×10^{-5}
BLN	SRS	1.05×10^{-6}	1.59×10^{-5}

BLN = Bellefonte Nuclear Plant SQN = Sequoyah Nuclear Plant SRS = Savannah River Site WBN = Watts Bar Nuclear Plant

Table E–9 Risks of Transporting the Hazardous Materials

Reactor Site (No. of TPBARs)	TPBAR Transportation Mode	*Incident-Free*			*Accident*	
		Radiological		*Nonradiological*		
		Crew	*Public*	*Emission*	*Traffic*	*Radiological*
Watts Bar (3,400 TPBARs/cycle)	Truck Cask via Truck	0.0033	0.021	0.0032	0.031	4.0×10^{-6}
	Truck Cask via Rail	0.0016	0.008	0.0023	0.029	5.7×10^{-6}
	Rail Cask via Rail	0.0016	0.008	0.0023	0.029	1.6×10^{-6}
Sequoyah (3,400 TPBARs/cycle)	Truck Cask via Truck	0.0030	0.019	0.0035	0.029	4.9×10^{-6}
	Truck Cask via Rail	0.0014	0.007	0.0024	0.028	5.2×10^{-6}
	Rail Cask via Rail	0.0014	0.007	0.0024	0.028	1.4×10^{-6}
Bellefonte (3,400 TPBARs/cycle)	Truck Cask via Truck	0.0026	0.018	0.0034	0.030	4.2×10^{-6}
	Truck Cask via Rail	0.0010	0.005	0.0024	0.028	5.7×10^{-6}
	Rail Cask via Rail	0.0010	0.005	0.0024	0.028	1.6×10^{-6}
Watts Bar (1,000 TPBARs/cycle)	Truck Cask via Truck	0.0010	0.007	0.0010	0.009	1.5×10^{-6}
	Truck Cask via Rail	0.0005	0.002	0.0007	0.009	1.9×10^{-6}
	Rail Cask via Rail	0.0005	0.002	0.0007	0.009	5.2×10^{-7}
Sequoyah (1,000 TPBARs/cycle)	Truck Cask via Truck	0.0009	0.006	0.0011	0.009	1.9×10^{-6}
	Truck Cask via Rail	0.0004	0.002	0.0007	0.008	1.7×10^{-6}
	Rail Cask via Rail	0.0004	0.002	0.0007	0.008	4.8×10^{-7}
Bellefonte (1,000 TPBARs/cycle)	Truck Cask via Truck	0.0008	0.006	0.0010	0.009	1.6×10^{-6}
	Truck Cask via Rail	0.0003	0.001	0.0007	0.009	1.9×10^{-6}
	Rail Cask via Rail	0.0003	0.001	0.0007	0.009	5.3×10^{-7}

*Maximum impacts are assumed for fabrication, assembly and waste transportation, and are included in these totals.
All risks are expressed in latent cancer fatalities, except for the Accidental-Traffic column, which is a number of fatalities.

The risks to various exposed individuals under incident-free transportation conditions have been estimated for hypothetical exposure scenarios. The estimated dose to inspectors and the public is presented in **Table E–10** on a per-event basis (person-rem per event). Note that the potential exists for larger individual exposures if multiple exposure events occur. For example, the dose to a person stuck in traffic next to a shipment for 30 minutes is calculated to be 11 mrem. If the exposure duration was longer, the dose would rise proportionally. In addition, a person working at a truck service station could receive a significant dose if trucks were to use the same stops repeatedly. The dose to a person fueling a truck could be as much as 1 mrem. Administrative controls could be instituted to control the location and duration of truck stops if multiple exposures were to happen routinely.

Table E–10 Estimated Dose to Exposed Individuals During Incident-Free Transportation Conditions

Receptor		***Dose to Maximally Exposed Individual***[a]
Workers	Crew member (truck driver)	0.1 rem/yr[b]
	Inspector	0.0029 rem/event
Public	Resident	4.0×10^{-7} rem/event
	Person in traffic congestion	0.011 rem/event
	Person at service station	0.001 rem/event

[a] Doses are calculated assuming that the shipment external dose rate is equal to the maximum expected dose 10 mrem/hr at 2 m (6.6 ft) from the package.

[b] This is a dose limit for a non-radiation worker (10 CFR 20). The truck driver dose could exceed this limit in the absence of administrative controls.

The cumulative dose to a resident was calculated assuming all shipments passed his or her home. The cumulative doses assume that the resident is present for every shipment and is unshielded at a distance of 30 meters (66 feet) from the route. Therefore, the cumulative dose is only a function of the number of shipments passing a particular point and is independent of the actual route being considered. The maximum dose to this resident, if all the material were to be shipped via this route, would be less than 0.1 mrem.

The estimated dose to transportation crew members is presented for a commercial crew. No credit is taken for the shielding associated with the tractor or trailer.

The accident consequence assessment is intended to provide an estimate of the maximum potential impacts posed by the most severe potential transportation accidents involving a shipment. The maximum foreseeable (frequency greater than 1×10^{-7} per year) offsite transportation accident involves a shipment of irradiated TPBARs under neutral (average) weather conditions. The accident has a probability of occurrence of about 1 every 10 million years and could result in 5.9 rem to a person 33 meters from the vehicle. The probability of an accident occurring is smaller with failed TPBARs, or under stable atmospheric conditions. This accident would fall into Category 5 of the previously described accident matrix shown in Figure E–9. In this hypothetical accident, the impact would cause the cask to fail, and the deformation of the cask would be assumed to fail one percent of the TPBARs. In the event of a fire, it would not be hot enough or would be too short in duration to damage the TPBARs. To incur this level of damage, the cask would have to collide with an immovable object at a speed much greater than 55 miles per hour. The probability of an accident with a more energetic collision or fire, and higher consequences, is lower.

E.7 CONCLUSIONS AND LONG-TERM IMPACTS OF TRANSPORTATION

E.7.1 Conclusions

It is unlikely that the transportation of radioactive materials will cause an additional fatality.

E.7.2 Long-Term Impacts of Transportation

The *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DOE 1995) analyzed the cumulative impacts of all transportation of radioactive materials, including impacts from reasonably foreseeable actions that include transportation of radioactive material for a specific purpose and general radioactive materials transportation that is not related to a particular action. The total worker and general population collective doses are summarized in **Table E–11**. The table shows that the impacts of this program are quite small compared with overall transportation impacts. Total collective worker doses from all types of shipments (historical, the alternatives, reasonably foreseeable actions, and general transportation) were estimated to be 320,000 person-rem (130 latent cancer fatalities) for the period 1943 through 2035 (93 years). Total general population collective doses were also estimated to be 320,000 person-rem (160 latent cancer fatalities). The majority of the collective dose for workers and the general population was due to the general transportation of radioactive material. Examples of these activities are shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial low-level radioactive waste to commercial disposal facilities. The total number of latent cancer fatalities estimated to result from radioactive materials transportation over the period between 1943 and 2035 was 290. Over this same period (93 years), approximately 28 million people would die from cancer, based on 300,000 cancer fatalities per year (10 CFR 71). It should be noted that the estimated number of transportation-related latent cancer fatalities would be indistinguishable from other latent cancer fatalities, and the transportation-related latent cancer fatalities are 0.0010 percent of the total number of latent cancer fatalities.

Table E–11 Cumulative Transportation-Related Radiological Collective Doses and Latent Cancer Fatalities (1943 to 2035)

Category	*Collective Worker Dose (person-rem)*	*Collective General Population Dose (person-rem)*
CLWR Impacts		
Shipment of TPBARs and LLW	< 100	< 100
Latent cancer fatalities from TPBARs and LLW	<1	<1
Other Nuclear Material Shipments		
Reasonably foreseeable actions[a]		
Truck	11,000	50,000
Rail	820	1,700
General transportation (1943–2035)	310,000	270,000
Total collective dose	320,000	320,000
Total Latent Cancer Fatalities	**130**	**160**

[a] LLW=Low-Level Radioactive Waste.
[b] DOE 1995.

E.8 UNCERTAINTY AND CONSERVATISM IN ESTIMATED IMPACTS

The sequence of analyses performed to generate the estimates of radiological risk for transportation includes: (1) determination of the inventory and characteristics, (2) estimation of shipment requirements, (3) determination of route characteristics, (4) calculation of radiation doses to exposed individuals (including estimation of environmental transport and uptake of radionuclides), and (5) estimation of health effects. Uncertainties are associated with each of these steps. Uncertainties exist in the way that the physical systems being analyzed are represented by the computational models; in the data required to exercise the models (due to measurement errors, sampling errors, natural variability, or unknowns simply caused by the future nature of the actions being analyzed); and in the calculations themselves (e.g., approximate algorithms used by the computers).

In principle, one can estimate the uncertainty associated with each input or computational source and predict the resultant uncertainty in each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final, or absolute, result; however, conducting such a full-scale quantitative uncertainty analysis is often impractical and sometimes impossible, especially for actions to be initiated at an unspecified time in the future. Instead, the risk analysis is designed to ensure, through uniform and judicious selection of scenarios, models, and input parameters, that relative comparisons of risk among the various alternatives are meaningful. In the transportation risk assessment, this design is accomplished by uniformly applying common input parameters and assumptions to each alternative. Therefore, although considerable uncertainty is inherent in the absolute magnitude of the transportation risk for each alternative, much less uncertainty is associated with the relative differences among the alternatives in a given measure of risk.

In the following sections, areas of uncertainty are discussed for the assessment steps enumerated above. Special emphasis is placed on identifying whether the uncertainties affect relative or absolute measures of risk. The degree of reality conservatism of the assumption is addressed. Where practical, the parameters that most significantly affect the risk assessment results are identified.

E.8.1 Uncertainties in TPBAR and Radioactive Waste Inventory and Characterization

The inventories and the physical and radiological characteristics are important input parameters to the transportation risk assessment. The potential amount of transportation for any alternative is determined primarily by the projected dimensions of package contents and, in the case of irradiated TPBARs, the strength of the radiation field and assumptions concerning shipment capacities. The physical and radiological characteristics are important in determining the amount of material released during accidents and the subsequent doses to exposed individuals through multiple environmental exposure pathways.

Uncertainties in the inventory and characterization will be reflected to some degree in the transportation risk results. If the inventory is overestimated (or underestimated), the resulting transportation risk estimates also will be overestimated (or underestimated) by roughly the same factor. However, the same inventory estimates are used to analyze the transportation impacts of each of the EIS alternatives. Therefore, for comparative purposes, the observed differences in transportation risks among the proposed reactor sites as given in Table E-9 are believed to represent unbiased, reasonably accurate estimates from current information in terms of relative risk comparisons.

If DOE should enter into the final design and implementation phase of the project, the amount of tritium in the TPBARs could change. The incident-free risk estimate would not change unless the number of shipments changes because the maximum regulatory limit dose rate was used. However, since over 90 percent of the accident impact comes from the tritium in the TPBARs, the accident impact would increase or decrease in proportion to the amount of tritium in the TPBARs.

E.8.2 Uncertainties in Containers, Shipment Capacities, and Number of Shipments

The amount of transportation required for each alternative is based in part on assumptions concerning the packaging characteristics and shipment capacities for commercial trucks and safe secure transports. Representative shipment capacities have been defined for assessment purposes based on probable future shipment capacities. In reality, the actual shipment capacities may differ from the predicted capacities, so that the projected number of shipments and, consequently, the total transportation risk would change. However, although the predicted transportation risks would increase or decrease accordingly, the relative differences in risks among alternatives would remain about the same. The maximum amount of material allowed in Type B containers is set by conservative safety analyses.

E.8.3 Uncertainties in Route Determination

Representative routes have been determined between all origin and destination sites considered in the EIS. The routes have been determined consistent with current guidelines, regulations, and practices, but may not be the actual routes that would be used in the future. In reality, the actual routes could differ from the representative ones in terms of distances and total population along the routes. Moreover, since TPBARs and waste could be transported over an extended period of time starting at some time in the future, the highway infrastructures and the demographics along routes could change. These effects have not been accounted for in the transportation assessment; however, it is not anticipated that these changes would significantly affect relative comparisons of risk among the alternatives considered in the EIS. Specific routes cannot be identified in advance because the routes are classified to protect national security interests.

E.8.4 Uncertainties in the Calculation of Radiation Doses

The models used to calculate radiation doses from transportation activities introduce a further uncertainty in the risk assessment process. It is generally difficult to estimate the accuracy or absolute uncertainty of the risk assessment results. The accuracy of the calculated results is closely related to the limitations of the computational models and to the uncertainties in each of the input parameters that the model requires. The single greatest limitation facing users of RADTRAN, or any computer code of this type, is the scarcity of data for certain input parameters.

Uncertainties associated with the computational models are minimized by using state-of-the-art computer codes that have undergone extensive review. Because there are numerous uncertainties that are recognized but difficult to quantify, assumptions are made at each step of the risk assessment process that are intended to produce conservative results (i.e., overestimate the calculated dose and radiological risk). Because parameters and assumptions are applied to all alternatives, this model bias is not expected to affect the meaningfulness of relative comparisons of risk; however, the results may not represent risks in an absolute sense.

To understand the most important uncertainties and conservatism in the transportation risk assessment, the results for all cases were examined to identify the largest contributors to the collective population risk. The results of this examination are discussed briefly in the following paragraph.

For truck shipments, the largest contributors to the collective population dose, in decreasing order of importance, were found to be: (1) incident-free dose to members of the public at stops, (2) incident-free dose to transportation crew members, (3) incident-free dose to members of the public sharing the route (on-link dose), (4) incident-free dose to members of the public residing along the route (off-link dose), and (5) accident dose risk to members of the public. Approximately 80 percent of the estimated public dose was incurred at stops; 15 percent was received by the on-link population and 5 percent by the off-link population. In general, the accident contribution to the total risk was negligible compared with the incident-free risks.

As shown above, incident-free transportation risks are the dominant component of the total transportation risk. The most important parameter in calculating incident-free doses is the shipment external dose rate (incident-free doses are directly proportional to the shipment external dose rate). For this assessment, it was assumed that all shipments would have an external dose rate at the regulatory limit of 10 mrem/hour at 2 meters. In practice, the external dose rates would vary from shipment to shipment, but would not exceed the regulatory limit.

Finally, the single largest contributor to the collective population doses calculated with RADTRAN was found to be the dose to members of the public at truck stops. Currently, RADTRAN uses a simple point-source approximation for truck-stop exposures and assumes that the total stop time for a shipment is proportional to the shipment distance. The parameters used in the stop model were based on a survey of a very limited number of radioactive material shipments that examined a variety of shipment types in different areas of the country. It was assumed that stops occur as a function of distance, with a stop rate of 0.011 hour per kilometer (0.018 hour per mile). It was further assumed that an average of 50 people at each stop are exposed at a distance of 20 meters (66 feet). In RADTRAN, the population dose is directly proportional to the external shipment dose rate and the number of people exposed and inversely proportional to the square of the distance. The stop rate assumed results in an hour of stop time per 100 kilometers (62 miles) of travel.

Based upon the qualitative discussion with shippers, the parameter values used in the assessment appear to be conservative. However, data do not exist to quantitatively assess the degree of control and the location, frequency, and duration of truck stops. However, based on the regulatory requirements for continuous escort of the material (10 CFR 73) and the requirement for two drivers, it is clear that the trucks would be on the move much of the time until arrival at the destination. Therefore, the calculated impacts are extremely conservative. By using these conservative parameters, the calculations in this EIS are consistent with the RADTRAN default values.

Shielding of exposed populations was not considered. For all incident-free exposure scenarios, no credit was taken for shielding of exposed individuals. In reality, shielding would be afforded by trucks and cars sharing the transport routes, rural topography, and the houses and buildings in which people reside. Incident-free exposure to external radiation could be reduced significantly depending on the type of shielding present. For residential houses, shielding factors (i.e., the ratio of shielded to unshielded exposure rates) have been estimated to range from 0.02 to 0.7, with a recommended value of 0.33. If shielding were to be considered for the maximally exposed resident living near a transport route, the calculated doses and risks would be reduced by approximately 70 percent. Similar levels of shielding may be provided to individuals exposed in vehicles. However, consideration of shielding does not significantly affect the overall incident-free risks to the general public.

Post accident mitigative actions are not considered for dispersal accidents. For severe accidents involving the release and dispersal of radioactive materials in the environment, no post accident mitigative actions, such as interdiction of crops or evacuation of the accident vicinity, have been considered in this risk assessment. In reality, mitigative actions would take place following an accident in accordance with U.S. Environmental Protection Agency (EPA) radiation protection guides for nuclear incidents (EPA 1991). The effects of mitigative actions on population accident doses are highly dependent upon the severity, location, and timing of the accident. For this risk assessment, ingestion doses are only calculated for accidents occurring in rural areas (the calculated ingestion doses, however, assume all food grown on contaminated ground is consumed and is not limited to the rural population). Examination of the severe accident consequence assessment results has shown that ingestion of contaminated foodstuffs contributes on the order of 50 percent of the total population dose for rural accidents. Interdiction of foodstuffs would act to reduce, but not eliminate, this contribution.

E.9 REFERENCES

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APPENDIX F
THE PUBLIC SCOPING PROCESS

F.1 SCOPING PROCESS DESCRIPTION

As a preliminary step in the development of an environmental impact statement (EIS), regulations established by the Council on Environmental Quality (40 CFR 1501.7) and the U.S. Department of Energy (DOE) require "an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action." The purpose of this scoping process is: (1) to inform the public about a proposed action and the alternatives being considered and (2) to identify and/or clarify issues that are relevant to the EIS by soliciting public comments.

On January 16, 1998, DOE published a Notice of Intent in the *Federal Register* concerning its proposal to produce tritium in one or more nuclear power plants owned and operated by the Tennessee Valley Authority (TVA). During the NEPA process, there are opportunities for public involvement (**Figure F–1**). The Notice of Intent listed the issues initially identified by DOE for evaluation in the EIS. Public citizens, civic leaders, and other interested parties were invited to comment on these issues and to suggest additional issues that should be considered in the EIS. The Notice of Intent informed the public that comments on the proposed action could be communicated via U.S. mail, a special DOE web site on the Internet, a toll-free phone line, a toll-free fax line, or in person at public meetings to be held near the TVA plant sites.

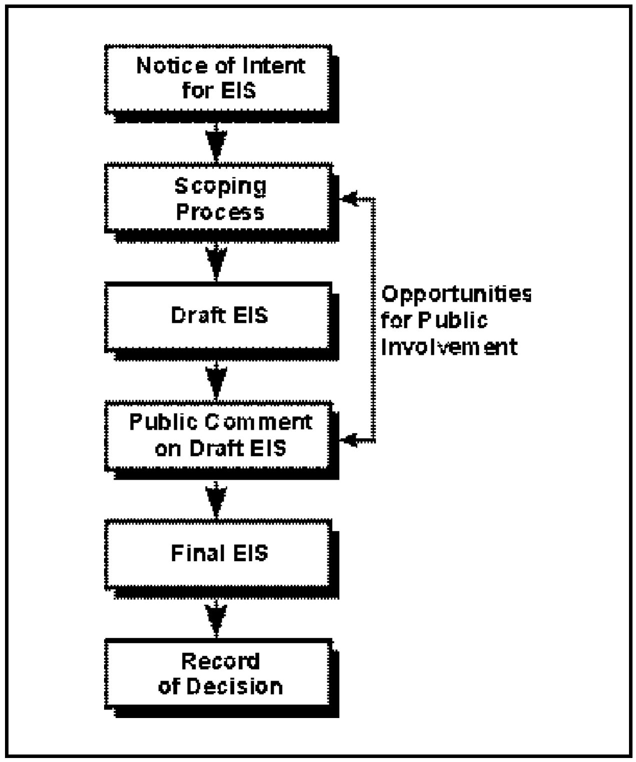

Figure F–1 NEPA Process

Two public meetings were held near the TVA nuclear power plants proposed for tritium production (**Figure F–2**). The first was held on February 24, 1998, in Rainsville, Alabama, near the partially completed Bellefonte nuclear power plant site. More than 800 persons, mostly from regional communities, attended the Rainsville meeting. The second meeting was held in Evensville, Tennessee, near the Watts Bar and Sequoyah nuclear power plants on February 26, 1998. An estimated 400 persons attended this meeting. A majority of the attendees were residents of communities located near the two TVA plants and several attendees were from cities such as Nashville and Knoxville, Tennessee.

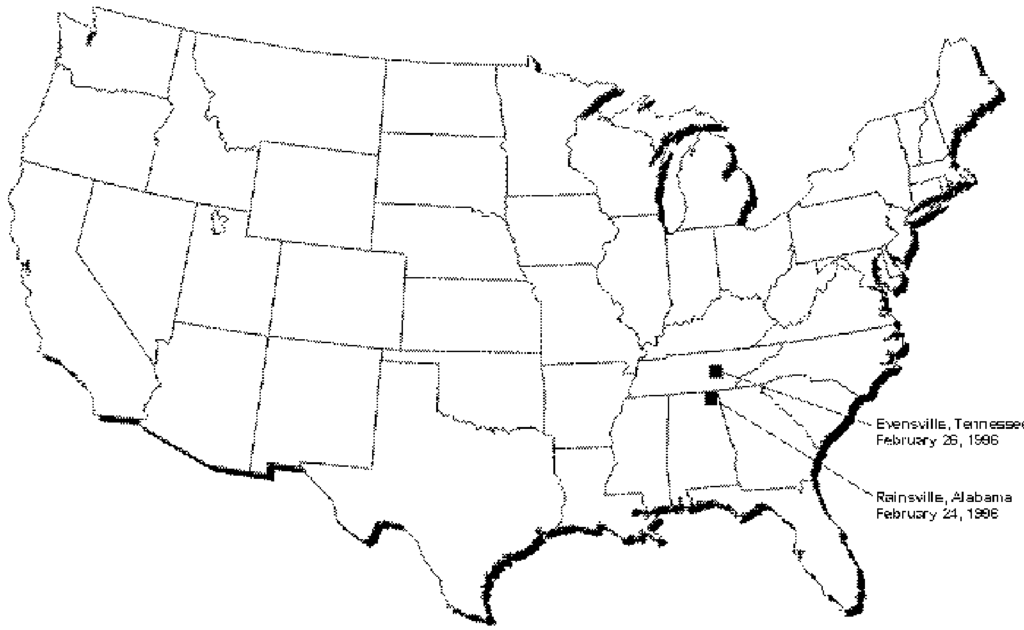

Figure F–2 Public Scoping Meeting Locations and Dates (1998)

As a result of previous experience and positive responses from attendees of other DOE/National Environmental Policy Act (NEPA) public meetings and hearings, DOE chose an interactive format for the scoping meetings. Each meeting began with a presentation by a DOE representative who explained the proposed tritium production plan. Afterwards, an impartial facilitator opened the floor to questions, comments, and concerns from the audience. DOE and TVA personnel were available to respond to the questions and comments as needed. While verbatim recordings or transcripts of the meetings were not produced, trained note-takers recorded the substance of each public comment. In addition, the public was encouraged to submit written or verbal comments either during the meetings or via letters, the DOE Internet web site, the toll-free phone line, or the toll-free fax line until the end of the scoping period on March 20, 1998.

It should be noted that, for EIS public scoping purposes, a comment is defined as a single statement or opinion concerning a specific issue. Any statement may contain many separate comments. Most of the verbal and written public statements submitted during the EIS scoping period contained multiple comments on various individual issues.

F.2 SCOPING PROCESS RESULTS

Approximately 700 comments were received from citizens, interested groups, and Federal, state, and local officials during the public scoping period, including 156 verbal comments made during the public meetings. The remainder of the comments (513) were submitted at the public meetings in written form, or via mail, Internet, fax, or phone over the entire scoping period. Commentors who spoke at the public meetings often read from written statements that were later submitted during or after the meetings. Where this occurred, each comment provided by an individual commentor in both verbal and written form was counted as a single comment. In addition to the comments, four petitions totaling 1,586 signatures were submitted in support of completing the Bellefonte plant for tritium production purposes.

The majority of the verbal and written comments received during the public scoping period favored producing tritium at one or more of TVA's nuclear power plants. Comments from residents of northern Alabama were particularly supportive of completing the Bellefonte plant for tritium production. Reasons given for this support mostly involved potential socioeconomic benefits such as job creation, a greater abundance of inexpensive electricity, attraction of new businesses to the area, and increased local revenues.

Many of the comments received from residents of the local areas near the TVA plants also communicated an understanding that the U.S. will begin producing tritium in the near future–either at the Savannah River Site (the accelerator option) or at one of TVA's nuclear power plants. These commentors expressed confidence in the safety of the TVA plants and the capabilities of area workers to provide the skills needed for tritium production. They also said they believe nuclear power plants are a more sensible choice for tritium production because reactors are a proven technology and the total project cost would be less than the cost of building an accelerator.

A significant number of other comments received during the scoping period opposed tritium production in general and the use of a nuclear power plant for this purpose in particular. This group disagreed with the Presidential and Congressional decision to produce tritium and denied there is any real defense-related need for new tritium production because they believe other options are available. Among the options cited were unilateral disarmament, commercial purchases, recycling the material from deactivated nuclear weapons, and/or extending the half-life of tritium.

Several commentors voiced concerns about the environmental, health, and safety risks they believe are inherent to tritium production. DOE representatives were urged to thoroughly evaluate the potential consequences of the proposed action on local water resources and the health and safety of area residents and wildlife. Concerns also were raised about the safety of TVA's nuclear power plants and how the security of the plants would be managed if tritium production were to begin.

Waste production and disposal was another issue. Some commentors correctly stated that tritium production in a nuclear reactor would increase the amount of spent fuel wastes generated. Questions were posed as to how this additional waste would be dealt with, both onsite and in the long term.

Many commentors also viewed the U.S. Government's decision to produce tritium as a violation of its own policies and commitments under the international Nonproliferation and Strategic Arms Limitation Treaties. They accused the government of hypocrisy and asserted that tritium production in a commercial light water reactor would blur the historical line between U.S. civilian and military nuclear programs. This action, they warned, would encourage other countries to use their own commercial plants to produce weapons materials and to increase their weapons stockpiles.

The public comments and materials submitted during the scoping period were carefully logged as they were received and placed in the Administrative Record of this EIS. Their disposition is described in the next section.

F.3 COMMENT DISPOSITION AND ISSUE IDENTIFICATION

Comments received during the scoping period were systematically reviewed by the EIS preparers. Where possible, comments on similar or related topics were grouped under comment categories as a means of summarizing the comments. An attempt was made to avoid duplication in counting the number of comments received, however, comments submitted in both written and verbal form may have been counted twice in some cases. The comment categories were used to identify specific issues of public concern. After the issues were identified, they were evaluated to determine whether they fell within or outside the scope of the EIS. Some issues were found to be already "in scope," i.e., they were among the EIS issues already identified by DOE for inclusion in the EIS. **Table F–1** lists these issues along with their EIS references.

Table F–1 Issues Already Included in the EIS (In Scope)

Issues	*No. of Comments*	*EIS References*
Use of commercial nuclear power reactors to produce tritium will blur the line between civilian and military programs and will impact U.S. nuclear nonproliferation efforts	93	Section 1.5.4
Socioeconomic benefits such as job creation, new business growth, and increased TVA payments in-lieu-of-taxes to Jackson County as a result of using any of the TVA plants for tritium production	142	Section 5.2.3.8
Tritium's importance to national security	24	Chapter 1 Chapter 2
Environmental, safety, and health impacts of tritium production, including potential for increased rates of breast cancer, childhood leukemia, and birth defects	52	Sections 5.2.1.9 5.2.2.9 5.2.3.9 Appendix C
Section 7 Consultation with the National Wildlife Service	1	Sections 5.2.1.6 5.2.2.6 5.2.3.6
Frequency and public notification of water/soil testing near Bellefonte plant	1	Chapter 6
Handling and shipping (transportation) of TPBARs and radioactive waste and associated escort requirements	8	Section 5.2.8 Appendix E
Safety record of TVA's nuclear power plants	22	Chapter 6
Reactor accident analyses	18	Sections 5.2.1.9 5.2.2.9 5.2.3.9 Appendix D
Impacts of spent fuel production and interim storage	13	Section 5.2.6
Final, long-term disposition of spent fuel rods if no deep geologic repository is available and the fuel pools are filled	2	Section 3.2.1
Additional plant security requirements	15	Section 5.2.10
Potential safety impacts of shortening the refueling schedule	2	Section 5.2.9
Processing tritium-producing burnable absorber rods	1	Appendix A
Impacts of tritium production on reactor decommissioning plans	1	Section 5.2.5
Need for separate EISs for the Bellefonte Plant, one for tritium production and one for completion	4	Section 1.5.1.3
Support for conversion of Bellefonte plant to a natural gas facility	2	Section 1.5.2.3
Use of excess electricity produced by tritium production at the Bellefonte plant	2	Section 5.4.2
Rationale for making the accelerator option the "no action" alternative	4	Section 3.2.4

One additional issue, the avoidance of greenhouse gases as a result of tritium production in a reactor instead of an accelerator, was added to the scope of the EIS as a result of the public scoping process. (**See Table F–2.**)

Table F–2 Issues Added to the Scope of the EIS

Issues	*No. of Comments*	*EIS References*
Avoidance of greenhouse gases as a result of tritium production in a reactor instead of an accelerator	8	Section 5.2.11

Many of the public issues were not analyzed for a specific reason or were determined to be outside the scope of the EIS. These issues are listed in **Table F–3**. Corresponding responses from DOE also are provided in Table F–3 to explain why each issue was not analyzed.

Table F–3 Issues Considered to be Out of Scope or Raised But Not Analyzed

Issues	*No. of Comments*	*DOE Responses*
Tritium Production		
Tritium production is not needed because: (1) there are reserve stockpiles, (2) it can be recycled from deactivated nuclear weapons and/or purchased, or (3) the half-life can be extended.	33	As stated in Section 1.3.3 of the CLWR EIS, reductions in the size of the nuclear weapons stockpile, brought on by international arms control agreements have enabled DOE to fulfill its tritium requirements by recycling tritium removed from dismantled weapons. This source of tritium is presently being utilized and has already been factored into the tritium requirement projections, which indicate a need for new supply tritium by approximately 2005. DOE has considered the purchase of tritium from other sources, including foreign nations, and has determined that the uncertainties associated with obtaining tritium from foreign sources render this alternative unreasonable for an assured long-term supply. Accordingly, as discussed in Section 3.1.3 of the Tritium Supply and Recycling Programmatic Environmental Impact Statement (DOE 1995), the Department considered this alternative but eliminated it from detailed study. DOE is aware of and has reviewed laboratory research on extending the half-life of isotopes similar to tritium. To date, such a process does not exist and the likelihood of developing such a process in sufficient time to reduce the need for tritium is too low to render this as a credible alternative. DOE will however, continue to monitor results from such research. As discussed in Chapter 2 of the CLWR EIS, DOE presently maintains a strategic reserve of tritium. This reserve contains a quantity of tritium maintained for emergencies and contingencies, and similar to tritium available from dismantled weapons, has been factored into the tritium requirement projections which indicate a need for new supply tritium by approximately 2005.
Tritium production is not needed because nuclear arms reduction treaties will allow the U.S. to deactivate and dismantle its nuclear weapons as their tritium load decays.	4	The need for tritium is explained in Chapter 2 of the CLWR EIS. As explained in Chapter 2, the 1996 Nuclear Weapons Stockpile Plan and an accompanying Presidential Decision Directive mandate that new tritium must be available by approximately 2005 if a CLWR is the selected option for tritium production. While it is true that recent international arms control agreements have caused the nuclear weapons stockpile to be reduced in size, these reductions are accounted for in the Presidential requirements. While future arms control reductions may change the requirements, DOE is responsible for meeting the current requirements set forth by the President.

Issues	***No. of Comments***	***DOE Responses***
Reactor tritium production relies on a proven technology and is more sensible and economical than the accelerator option.	21	The purpose of the CLWR EIS is to assess the environmental impacts associated with tritium production in one or more CLWRs. Relative comparisons between the CLWR option and the accelerator option have previously been documented in the Record of Decision for the Tritium Supply and Recycling Programmatic Environmental Impact Statement (DOE 1995). As a tiered document from that Programmatic Environmental Impact Statement, the CLWR EIS does not purport to compare the CLWR and the accelerator for tritium production.
An international agreement is needed to halt tritium production as a means of using tritium's decay rate to pace a reciprocal build-down of nuclear weapons.	1	There are currently no international agreements that prohibit tritium production. In accordance with national security requirements set forth by the President, DOE is responsible for producing the tritium required to support the nation's nuclear deterrent. Future international agreements related to tritium production are speculative and beyond the scope of the CLWR EIS.
DOE should: (1) develop a list of no more than three commercial reactors that could be used for tritium production only as a contingency source in case of congressionally declared war or another national emergency [ref. Section 108 of the Atomic Energy Act], (2) obtain tritium only by purchasing irradiation services at one of these reactors under such emergency circumstances, and (3) use the reactor only under defined conditions that preserve the principle of separating civilian and military nuclear activities (i.e., the reactor should not generate electricity for sale while being used for tritium production).	1	The need for tritium is explained in Chapter 2 of the CLWR EIS. As explained in Chapter 2, the 1996 Nuclear Weapons Stockpile Plan and an accompanying Presidential Decision Directive mandate that new tritium must be available by approximately 2005 if a CLWR is the selected option for tritium production. The CLWR EIS is being prepared in accordance with the national security requirements set forth by the President.
DOE should more clearly articulate the policy options for tritium production to the public, e.g., use of reactors as either a primary or contingency source, purchasing a commercial reactor or merely purchasing irradiation services from a commercial reactor, etc., [comment refers to information found in programmatic EIS].	1	The policy options for tritium production are explained in the Tritium Supply and Recycling Programmatic Environmental Impact Statement (DOE 1995). The purpose of the CLWR EIS is to assess the environmental impacts associated with tritium production in one or more CLWRs, not debate policy options.
Couldn't nuclear weapons be maintained without tritium?	2	All weapons in the existing stockpile require tritium to function as designed. Section 1.3.2, of the CLWR EIS, describes how tritium is used in the modern nuclear weapon. Section 3.1.3 of the Tritium Supply and Recycling Programmatic Environmental Impact Statement (DOE 1995) provides a thorough discussion of why redesigning weapons with less or no tritium is not a reasonable alternative.
How many weapons does the U.S. really need?	2	The number of U.S. nuclear weapons is set forth by the Nuclear Weapons Stockpile Plan and an accompanying Presidential Decision Directive.

Issues	***No. of Comments***	***DOE Responses***
The U.S. has called for a negotiated ban on production of fissile materials for weapons. While not covered under this ban, operation of tritium production facilities would complicate treaty verification because the facilities could be used for clandestine production of plutonium but will not be subject to intrusive verification measures because of their military significance. How would appropriate safeguards be employed at a commercial tritium production reactor?	1	Safeguard and security provisions of TVA and of DOE have been reviewed and found to be sufficiently protective of both Federal property and employees and the general public. Section 5.2.10, of the CLWR EIS provides additional information related to safeguards and security issues.
Could the K-Reactor at DOE's Savannah River Site in South Carolina be refurbished and used for tritium production if the serious safety issues were corrected?	2	The option of utilizing the K-Reactor, located at the Savannah River Site in South Carolina, along with other existing DOE reactors or accelerators, was evaluated but dismissed from further consideration in the Tritium Supply and Recycling Programmatic Environmental Impact Statement (Section 3.1.3) (DOE 1995). In the early 1990s, when tritium supply needs were much greater, DOE not only considered putting the K-Reactor back-on line, but had an extensive and costly effort underway to restart the K-Reactor. Unfortunately, the age of this facility and the magnitude of the environmental and safety upgrades required for this task proved too great, and in 1994, the K-Reactor was placed in a "cold stand-by" status with no provisions for restart. The reduced tritium needs of today make the K-Reactor alternative even less attractive.
Why is new reactor-produced tritium needed in 2005, but accelerator-produced tritium is not needed until 2007?	5	The Presidential Decision Directive that accompanies the 1996 Nuclear Weapons Stockpile Plan mandates that new tritium must be available by approximately 2005 if a CLWR is the selected option for tritium production, and approximately 2007 if the accelerator is the selected option. The reason why the year 2007 is mandated for the accelerator is because that is the earliest date by which the accelerator could be built and begin operation. In such a case, tritium requirements from 2005 until 2007 would have to be met by dipping into the tritium reserve shown on Figure 2-1 of this CLWR EIS. The tritium reserve would then be replenished by producing tritium quantities greater than the decay requirements.
Why doesn't the government just purchase a commercial reactor for tritium production?	5	Concurrent with the preparation of the CLWR EIS, DOE is evaluating the feasibility of various CLWR alternatives through a procurement process. Through that process, DOE expects to enter into a contract/interagency agreement with the owner/operator of one or more commercial reactors for the purpose of producing tritium. Such a contract/interagency agreement could result in DOE purchasing CLWR irradiation services and/or purchasing a CLWR. In response to the procurement request, none of the CLWR owners/operators proposed selling a CLWR to DOE. Instead, only irradiation services have been proposed. Thus, it now appears likely that DOE will purchase irradiation services only.
Would hydrogen ignitors be used in a tritium production plant?	1	Hydrogen ignitors are currently used in Watts Bar and Sequoyah. The use of hydrogen ignitors at a reactor facility is independent of tritium production.

Issues	*No. of Comments*	*DOE Responses*
If a second major use for tritium is identified, now or in the future, the safest course would be construction of a new tritium production facility at the DOE's Savannah River Site in South Carolina.	1	The DOE is addressing only that amount of tritium necessary to support the U.S. nuclear weapons stockpile. Based on the analysis of the Tritium Supply and Recycle Programmatic Environmental Impact Statement, the DOE in the December 1995, Record of Decision, decided to pursue a dual-track approach on the two most promising tritium-supply alternatives: 1) to initiate purchase of an existing commercial reactor (operating or partially complete) or irradiation services with an option to purchase the reactor for conversion to a defense facility; and 2) to design, build, and test critical components of an accelerator for tritium production. DOE will select one of these alternatives as the primary source for tritium. The other alternative, if feasible, would continue to be developed as a backup tritium source.
The EIS should address the additional complications of loading and unloading the boron isotope or lithium aluminate cores, their subsequent unloading, and the final tritium separation processes.	2	The environmental impacts associated with the fabrication of the TPBARS is addressed in Section 5.2.7 of the CLWR EIS. The DOE has already analyzed the environmental impacts associated with the unloading and the final tritium extraction process in the draft Tritium Extraction Facility EIS (DOE 1998). A summary of the environmental impacts associated with the preferred alternative in the Tritium Extraction Facility EIS may be found in Section 5.3, of the CLWR EIS.
DOE should not be doing this EIS because they are overcommitted to other activities, their management is inadequate, their staffing and technical expertise are insufficient, and they have contaminated every site they have managed.	11	DOE is fully committed to carrying out all of its responsibilities in full compliance with all Federal, state, and local laws and requirements.
Tritium should not be produced by anyone who thinks about the future of humanity. Everyone involved in creating these weapons of mass destruction should quit their jobs.	1	The issue of an individual's employment choice is beyond the scope of the EIS.
Environment, Safety, and Health		
The EIS should evaluate global environmental impacts resulting from U.S. tritium production. The EIS should evaluate the environmental impacts of tritium production in other countries with similar programs.	8 3	The CLWR EIS evaluates the direct, indirect, and cumulative environmental impacts associated with producing tritium at one or more CLWRs. The only reasonable foreseeable global environmental impacts that are assessed concern impacts to global warming. DOE is unaware of any other global environmental impacts associated with tritium production. The CLWR EIS evaluates the direct, indirect, and cumulative environmental impacts associated with producing tritium at one or more CLWRs. Environmental impacts associated with tritium production in other countries is beyond the scope of the CLWR EIS.
The EIS should address the environmental impacts of the full life cycle of the tritium-producing fuel rods, from mining through final disposal.	3	DOE has focused the analysis in the CLWR EIS on the proposed action in accordance with the requirements of the NEPA, Council on Environmental Quality requirements, and the DOE NEPA Regulations. From a life cycle cost perspective, the analysis of costs are not part of the EIS process, and accordingly, are not included in the CLWR EIS. DOE does, however consider costs in its final decision, and in this instance, has determined that sufficient quantities of the materials required for the fabrication of the TPBARS are openly available and that the cost of mining and finishing of such products is already reflected in their cost. Since sufficient source material is available already, the provision of source materials (e.g., mining) is not analyzed. The disposition of TPBARs is addressed in the EIS for the construction and operation of a Tritium Extraction Facility at the Savannah River Site. (See Section 1.5.2.2.)
Waste		

Issues	No. of Comments	DOE Responses
The wastes generated by tritium production should be placed in the backyards of those who make the decisions and the Congress.	1	Any wastes generated as a result of activities addressed by the CLWR EIS will be managed in accordance with all applicable Federal and state regulations and DOE Orders.
Plutonium should not be brought for disposal to northern Alabama.	1	DOE has no plans to utilize plutonium in the CLWR Tritium Program. The CLWR Tritium program would utilize non-radioactive lithium targets to be placed into the normal reactor cycle, with no change normal operations. No plutonium would be generated in these targets. Although the normal operation of a commercial reactor does generate small quantities of plutonium as an integral part of the spent nuclear fuel, such spent nuclear fuel is presently being stored at commercial reactor sites for ultimate disposal at a national repository. DOE is presently considering only one site for the location of such a repository, Yucca Mountain, Nevada. The DOE has no plans to site such a repository in the State of Alabama.
Socioeconomics		
The EIS should evaluate the socioeconomic benefits of completing the Bellefonte plant such as abundant electricity and reduced power rates.	8	The CLWR EIS evaluates the environmental impacts associated with completing construction of one or both of the Bellefonte plants and operating them for tritium production. Socioeconomic impacts are assessed including impacts associated with population and employment, housing, schools, and tax revenues. The environmental impacts associated with electricity production are also assessed.
The EIS should evaluate the potential economic consequences to ratepayers from extended outages.	2	There are no extended outages expected from tritium production at any of the reactor plant alternatives. Consequently, no economic consequences are expected. As a matter of contract law, the contract/interagency agreement between the DOE and the TVA would be expected to provide a mechanism for addressing any cost issues associated with unexpected extended outages. The CLWR EIS does provide a sensitivity analysis of shortening a reactor's fuel cycle from 18 to 12 months, but no socioeconomic consequences are envisioned.
It is unfair for the government to subsidize TVA; this proposal is just an attempt to help TVA resolve its debts.	6	Concurrent with the preparation of the CLWR EIS, DOE is evaluating the feasibility of various CLWR alternatives through a procurement process. That process, which was based on the policy of full and open competition, has been conducted in accordance with all applicable laws, and was open to all owners/operators of pressurized CLWRs. The proposals from the TVA for producing tritium using existing and partially completed reactors were the only bids determined to be responsive to the requirements contained in the request for proposals.
Area utilities will oppose using government funding to help TVA complete a competitive nuclear power plant at Bellefonte.	1	The opposition or support of area utilities to the alternatives in the CLWR EIS is beyond the scope of the EIS.
Ratepayers who are against nuclear weapons should not be forced to pay for tritium production.	6	DOE does not anticipate costs being passed onto rate payers since DOE will be paying for services.
Will tritium production at a TVA power plant require any hydro-pumped storage?	1	No.
Costs		
How cost-effective is tritium production in a commercial nuclear power plant for U.S. taxpayers? How do the costs compare with the accelerator option?	38	Costs are beyond the scope of the EIS. Relative cost comparisons between a CLWR and an accelerator have previously been documented in the Record of Decision for the Tritium Supply and Recycling Programmatic Environmental Impact Statement (DOE 1995).

Issues	No. of Comments	DOE Responses
Who will cover the costs of power outages or identification of safety problems resulting from the shorter refueling cycle?	5	Costs are beyond the scope of the EIS. Additionally, there is no proposal to shorten the fuel cycle of any reactor that would produce tritium. For completeness, the CLWR EIS does provide a sensitivity analysis of shortening a reactor's fuel cycle from 18 to 12 months. That sensitivity analysis is provided as a contingency to address the situation of maximizing tritium production in a reactor. Such a situation is not currently expected or proposed. As a matter of contract law, the contract/interagency agreement between the DOE and the TVA would be expected to provide a mechanism for addressing any cost issues associated with shortening a reactor's fuel cycle from 18 to 12 months.
If Bellefonte is completed for tritium production, who will pay for hazardous materials training and equipment?	3	Costs are beyond the scope of the EIS. However, DOE does not expect tritium production to change the requirements for hazardous material training or equipment.
The EIS should include cost analyses for tritium production at each TVA reactor plant.	3	Costs are beyond the scope of the EIS. However, concurrent with the preparation of the CLWR EIS, DOE is evaluating the feasibility of the various CLWR alternatives through a procurement process. Through that process, DOE expects to enter into a contract/interagency agreement with the TVA for the purpose of producing tritium. Once a contract/interagency agreement is reached, the terms would be made public as appropriate.
DOE should release the report from the accounting firm of Putnam, Hayes, & Bartlett, which assessed the costs of various options for tritium production.	1	The Putnam, Hayes, and Bartlett report is available to anyone who wishes to request that report from DOE, DP-62.
The EIS should explain the total cost of completing Bellefonte and the difficulty of obtaining Congressional appropriations for this purpose.	3	The cost to complete the Bellefonte plant is beyond the scope of the CLWR EIS. Through the procurement process, DOE expects to enter into a contract/interagency agreement with the TVA for the purpose of producing tritium. Once a contract/interagency agreement is reached, the terms would be made public as appropriate. The issue of obtaining Congressional appropriations is beyond the scope of the EIS. While it is true that Congressional appropriations will have to be made for any of the CLWR EIS alternatives, DOE will pursue such appropriations independent of the EIS process.
Nuclear Weapons		
The EIS should explain whether new [nuclear weapons] designs or prototypes are being considered and whether international nonproliferation treaties prohibit the manufacture of new nuclear weapons.	2	As stated in Section 1.3.1 of the CLWR EIS, the U.S. is no longer producing new-design nuclear weapons. Since the end of the Cold War, the U.S. has significantly reduced the size of its nuclear weapons stockpile and the DOE has dismantled more than 8,000 nuclear weapons. At the present time, the U.S. is further downsizing the nuclear weapons stockpile consistent with the terms of the START I Treaty, and DOE is continuing dismantlement. The U.S. has ratified the START II Treaty and is hopeful that Russia will likewise ratify this treaty. DOE acknowledges that further multilateral reductions in the U.S. nuclear weapons stockpile could occur. However, the negotiations required for such reductions are likely to stretch well into the next century. Therefore, a new supply source of tritium is required to assure the reliability of the stockpile. Such a program is consistent with, and fully supportive of, the commitments of the U.S. under the terms of the START I Treaty, the START II Treaty, and Article VI of the Nonproliferation Treaty.

Issues	***No. of Comments***	***DOE Responses***
EIS Process		
The EIS process is inadequate; it does not address all the risks.	16	The EIS process is performed in accordance with all applicable laws and regulations. The purpose of the CLWR EIS is to assess the direct, indirect, and cumulative environmental impacts associated with tritium production in one or more CLWRs.
Why were additional scoping meetings not held in other areas?	11	Scoping meetings were held at all locations where DOE determined that there was significant interest to warrant public input related to the potential for environmental impacts from CLWR tritium production. This resulted in scoping meetings near each of the reactor sites that were determined to be reasonable alternative in the CLWR EIS. The scoping process allows for comments from anyone at any location.
Other Federal agencies such as the Environmental Protection Agency and the Department of Defense should be involved in preparing this EIS.	2	In accordance with the Council on Environmental Quality Guidelines and DOE's NEPA regulations for the preparation of a NEPA document, the Department of Defense as well as other major Federal agencies were notified of the opportunity to participate as a cooperating agency in the preparation of the CLWR EIS. TVA was the only Federal agency that requested, and was granted, designation as a cooperating agency. The Department of Defense has a vested interest in DOE activities in assuring the long term supply of tritium and is briefed as to the status of the Tritium Project Office, including the analysis being conducted for the CLWR EIS, on a regular basis. Although EPA did not choose to participate as a cooperating agency in the preparation of the CLWR EIS, EPA will review the adequacy of the EIS and provide DOE with its comments as to the adequacy of the EIS in accordance with the Council on Environmental Quality guidelines.
The Nuclear Regulatory Commission should be fully involved in this EIS process from the beginning.	3	In accordance with the Council on Environmental Quality Guidelines and the DOE NEPA regulations for the preparation of a NEPA document, the NRC was notified of its opportunity to participate as a cooperating agency in the preparation of the CLWR EIS, and did not elect to participate. The CLWR EIS addresses DOE activities for the production of tritium in a commercial reactor. Any commercial reactors participating in the CLWR tritium program would be required to obtain a license amendment from the NRC. Prior to the production of any tritium in a commercial reactor, the NRC would be the responsible agency for conducting any NEPA analysis required on the part of specific commercial reactors participating in the CLWR tritium program.
The EIS process should be delayed until completion of the tests of the tritium-producing rods at Watts Bar in 1999.	9	DOE has sufficient experience and confidence in the production of tritium using TPBARs to initiate the CLWR Tritium Program prior to the completion of the Watts Bar Demonstration Project. That project, referred to by DOE as the Lead Test Assembly test, has a stated purpose to provide confidence to regulators and the public that tritium production in a commercial light water reactor is straightforward and safe. Preliminary data from the Lead Test Assembly test supports DOE's preliminary conclusion that tritium production in a CLWR is straightforward and safe.
Miscellaneous		
Tritium should be redesignated as a special nuclear material to ensure that it is treated the same as all other materials that are critical for nuclear weapons production.	1	The issue of reclassifying tritium as a special nuclear material is beyond the scope of the EIS. However, Section 51 of the Atomic Energy Act authorizes the NRC to determine whether a material should be classified as "special nuclear material." To date, neither the NRC, nor any of its predecessor agencies have ever determined that tritium should be classified as a special nuclear material in accordance with the criteria spelled out in Section 51 of the Atomic Energy Act.
What is the possibility of burning mixed oxide fuel at Bellefonte?	8	TVA officials stated publicly at the public scoping meeting in Evensville, Tennessee, on February 26, 1998, that TVA has no intention of pursuing mixed oxide fuel at any TVA reactor that would be utilized for tritium production. Consequently, the potential impacts associated with producing tritium while also burning mixed oxide fuel are not reasonably foreseeable.

Issues	***No. of Comments***	***DOE Responses***
The fairness and adequacy of the procurement process for tritium production appears questionable.	6	The CLWR procurement process was based on the policy of full and open competition and has been conducted in accordance with all applicable laws. The procurement process was open to all owners/operators of pressurized CLWRs. The proposals from the TVA for producing tritium using existing and partially completed reactors were the only bids determined to be responsive to the requirements contained in the request for proposals.
The contractors hired to work on this project should be U.S. citizens, and the public should have oversight responsibilities for their qualifications and experience.	1	The nationality and qualifications of contractors, as well as their oversight, are issues beyond the scope of the EIS. However, all work associated with the CLWR Program will comply with all applicable laws and regulations.
The information materials used to prepare this EIS are inadequate and are not conveniently available to the public.	4	The analysis, dissemination of information, and the inclusion of public participation for the CLWR EIS is conducted in accordance with Council on Environmental Quality regulations (40 CFR 1500-1508), and DOE's NEPA regulations (10 CFR 1021) and procedures. DOE has acted in accordance with these requirements, making a good faith effort to disseminate factsheets explaining the issues associated with tritium production, holding meetings with community groups and the media, holding more than the required number of public scoping meetings, and in addressing all questions put to DOE on such issues.
The following information should be declassified because it is relevant to this EIS and the public should have access to it: (1) the amount of tritium currently in the U.S. arsenal, (2) the size of current reserve stockpiles of tritium, (3) the total number of nuclear weapons assumed to be in the U.S. arsenal between 2011and 2015, and (4) projected amounts that must be produced annually to maintain the nuclear arsenal after 2015.	1	The CLWR EIS has been prepared based on unclassified information. To the extent possible, the EIS provides unclassified information as a substitute for classified information that cannot be disseminated. The classification of information and the potential for the declassification of information within the control of DOE is outside of the scope of the CLWR EIS. Information such as the existing amount of tritium in the national stockpile of nuclear weapons, the exact number and make-up of nuclear weapons in the stockpile, and the exact number of nuclear weapons which are expected to be in the U.S. arsenal in future years is critical to U.S. national security and cannot be disclosed.
The EIS should evaluate the dangers and impacts of maintaining a nuclear weapons stockpile and the possible explosion of a nuclear warhead.	5	The environmental impacts associated with maintaining a nuclear weapons stockpile are assessed in the DOE's Stockpile Stewardship and Management Programmatic Environmental Impact Statement (DOE 1996). The environmental impacts associated with the possible explosion of a nuclear warhead are speculative and beyond the scope of the CLWR EIS.
In addition to evaluating the physical and social environments, the EIS should look at the moral and ethical issues related to continuing the production of nuclear weapons.	6	Moral and ethical issues are beyond the scope of the EIS.

F.4 REFERENCES

DOE (U.S. Department of Energy), 1995, *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling*, DOE/EIS-0161, Office of Reconfiguration, Washington, DC, October 19.

DOE (U.S. Department of Energy), 1996, *Final Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*, DOE/EIS-0236, September.

DOE (U.S. Department of Energy), 1998, *Production of Tritium for Defense Purposes in a Commercial Light Water Reactor*, Office of Commercial Light Water Reactor Production, CLWR/RM/SSO5-06, March 17.

APPENDIX G
ENVIRONMENTAL JUSTICE ANALYSIS

G.1 INTRODUCTION

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs Federal agencies to identify and address, as appropriate, the disproportionately high and adverse health or environmental effects of their programs, policies, and activities on minority populations and low-income populations.

The Council on Environmental Quality has oversight responsibility for documentation prepared in compliance with the National Environmental Policy Act. In May 1996, the Council released draft guidance on environmental justice (CEQ 1997). The Council's guidance was adopted as the basis for the analysis of environmental justice contained in this environmental impact statement (EIS).

This section provides an assessment of the potential for disproportionately high and adverse human health or environmental effects due to production of tritium in a commercial light water reactor (CLWR) on minority and low-income populations that live within areas surrounding the candidate facilities. The potential for adverse impacts from onsite activities during commercial tritium production and transportation is determined in this EIS.

G.2 DEFINITIONS AND APPROACH

The following definitions of minority individuals and population were used in this analysis of environmental justice:

Minority Individuals—Persons who are members of any of the following population groups: Hispanic, Native American, Asian or Pacific Islander, or African American.

Minority Population—The total number of minority individuals residing within a potentially affected area. In the discussions of environmental justice in this document, persons self-designated as Hispanic are included in the Hispanic population regardless of race. The Asian or Pacific Islander population is comprised of persons self-designated as Asian or Pacific Islander and not of Hispanic origin. Asian or Pacific Islanders who designate themselves as having Hispanic origins are included in the Hispanic population. Data for the analysis of minorities and racial population were extracted for year 2025 from the U.S. Census Bureau's worldwide web site (http://www.census.gov/population/www/projections/stproj.html).

Executive Order 12898 specifically addresses "disproportionately high and adverse effects" on "low-income" populations. The Council recommends that poverty thresholds be used to identify "low-income" individuals.

The following definitions of low-income individuals and population were used in this analysis:

Low-Income Individuals—All persons whose self-reported incomes are less than the poverty threshold.

Low-Income Population—The total number of poverty-level individuals residing within a potentially affected area.

Data for the analysis of low-income populations were extracted from Table P121 of Standard Tape File 3 (DOC 1992).

Disproportionately High and Adverse Human Health Effects

Adverse health effects are measured in risks and rates that could result in latent cancer fatalities, as well as other fatal or nonfatal adverse impacts to human health. Disproportionately high and adverse human health effects occur when the risk or rate from exposure to an environmental hazard to a minority population or low-income population is significant and exceeds the risk from exposure rate to the general population or, where available, to another appropriate comparison group (CEQ 1997).

Disproportionately High and Adverse Environmental Impacts

A disproportionately high environmental impact refers to an impact (or risk of an impact) in a low-income or minority community that is significant and exceeds the environmental impact on the larger community. An adverse environmental impact is a deleterious environmental impact determined to be significant. In assessing cultural and aesthetic environmental impacts, impacts that uniquely affect geographically dislocated or dispersed low-income or minority populations were considered (CEQ 1997).

Potentially affected areas examined in this EIS include areas defined by an 80-kilometer (50-mile) radius centered on candidate facilities for CLWR production of tritium located at the Watts Bar, Sequoyah, and Bellefonte Nuclear Plants. Minority and low-income populations residing within a 1.6 kilometer (1 mile) corridor centered on representative transportation routes were also included in the evaluation of environmental justice.

G.3 METHODOLOGY

G.3.1 Spatial Resolution

For the purposes of enumeration and analysis, the U.S. Census Bureau has defined a variety of areal units (DOC 1992). Areal units of concern in this document include (in order of increasing spatial resolution) states, counties, census tracts, block groups, and blocks. The block is generally the smallest of these entities and offers the finest spatial resolution. This term refers to a relatively small geographical area bounded on all sides by visible features such as streets and streams or by invisible boundaries such as city limits and property lines. During the 1990 census, the U.S. Census Bureau subdivided the United States and its territories into 7,017,425 A blocks. For comparison, the number of counties, census tracts, and block groups used in the 1990 census were 3,248; 62,276; and 229,192; respectively. While blocks offer the finest spatial resolution, economic data required for identification of low-income populations are not available at the block-level of spatial resolution. In the analysis below, block groups are used throughout as the areal unit. Block groups generally contain between 250 and 500 housing units (DOC 1992).

During the decennial census, the U.S. Census Bureau collects data from individuals and aggregates the data according to residence in a geographical area such as a county or block group. Boundaries of the areal units are selected to coincide with features such as streams and roads or political boundaries such as county and city borders. Boundaries used for aggregation of the census data usually do not coincide with boundaries used in the calculation of health effects. As discussed in Chapter 4 of this EIS, radiological health effects due to an accident at one of the sites for commercial production of tritium are evaluated for persons residing within a distance of 80 kilometers (50 miles) of the accident site. In general, the boundary of the circle with an 80-kilometer (50-mile) radius centered at the accident site will not coincide with boundaries used by the U.S. Census Bureau for enumeration of the population in the potentially affected area. Some block groups lie completely inside or outside of the radius for health effects calculation. However, other block groups are only partially included. As a result of these partial inclusions, uncertainties are introduced into the estimate of the population at risk from the accident.

In order to estimate the populations at risk in partially included block groups, it was assumed that populations are uniformly distributed throughout the area of each block group. For example, if 30 percent of the area of a block group lies within 80 kilometers (50 miles) of the accident site, then it was assumed that 30 percent of the population residing in that block group would be at risk. An upper bound for the population at risk is obtained by including the total population of partially included block groups in the population at risk. Similarly, a lower bound for the population at risk is obtained by excluding the population of partially included blocks from the population at risk. As a general rule, if the areas of geographic units defined by the U.S. Census Bureau are small in comparison with the potentially affected area, then the uncertainties due to partial inclusions will be relatively small.

G.3.2 Population Projections

Health effects were calculated for populations projected to reside in potentially affected areas during the year 2025. Extrapolations of the total population for individual states are available from both the U.S. Census Bureau and various state agencies (DOC 1996). The U.S. Census Bureau also projects populations by ethnic and racial classification in one year intervals for the years from 1995 to 2025 at the state level. State agencies project total populations for individual counties. No Federal or state agency projects block groups or low-income populations. Data used to project minority populations were extracted from the U.S. Census Bureau's web site (http://www.census.gov/population/www/projections/stproj.html). In order to project minority populations in potentially affected areas, minority populations determined from the 1990 census data were taken as a baseline for each block group. Then it was assumed that percentage changes in the minority population of each block group for a given year (compared to the 1990 baseline data) will be the same as percentage changes in the state minority population projected for the same year. An advantage to this assumption is that the projected populations are obtained with consistent method regardless of the state and associated block group involved in the calculation. A disadvantage is that the method is insensitive to localized demographic changes that could alter the projection in a specific area.

The U.S. Census Bureau uses the cohort-component method to estimate future populations for each state (DOC 1996). The set of cohorts is comprised of: (1) age groups from 1 year or less to 85 years or more, (2) male and female populations in each age group, and (3) the following racial and ethnic groups in each age group (Hispanic, non-Hispanic Asian, non-Hispanic African American, non-Hispanic Native American, and non-Hispanic White). Components of the population change used in the demographic accounting system are births, deaths, net state-to-state migration, and net international migration. If P(t) denotes the number of individuals in a given cohort at time "t", then:

$$P(t) = P(t_0) + B - D + DIM - DOM + IIM - IOM \qquad (1)$$

where:

$P(t_0)$	=	Cohort population at time $t_0 \leq t$. For this analysis, t_0 denotes the year 1990.
B	=	Births expected during the period from t_0 to t.
D	=	Deaths expected during the period from t_0 to t.
DIM	=	Domestic migration expected into the state during the period from t_0 to t.
DOM	=	Domestic migration expected out of the state during the period from t_0 to t.
IIM	=	International migration expected into the state during the period from t_0 to t.
IOM	=	International migration expected out of the state during the period from t_0 to t.

Estimated values for the components shown on the right side of equation 1 are based on past data and various assumptions regarding changes in the rates for birth, mortality, and migration (DOC 1996). Persons of Hispanic origin are included in the Hispanic population regardless of race. It should be noted that the U.S. Census Bureau does not project populations of individuals who identified themselves as "other race" during the 1990 Census. This population group is less than 2 percent of the total population in each of the states. However, in order to project total populations in the environmental justice analysis, population projections for the "other race" group were made under the assumption that the growth rate for the "other race" population will be identical to the growth rate for the combined minority and White populations.

G.4 Environmental Justice Assessment

The analysis of environmental justice concerns was based on an assessment of the impacts reported in Section 4 of this EIS. This analysis was performed to identify any disproportionately high and adverse human health or environmental impacts on minority populations or low-income populations surrounding the three potential sites. Demographic information obtained from the U.S. Census Bureau was used to identify the minority populations and low-income communities in the zone of potential impact surrounding the sites. The outer zone is within the region of influence, a circle that has an 80-kilometer (50-mile) radius around the potential sites. This radius is consistent with that used to evaluate the collective dose for human health effects, air impact modeling, and socioeconomic impacts and is judged to encompass all of the impacts that may occur.

G.5 Results for the Sites

Table G–1 shows projected total populations, minority populations, and percentage minority populations that resided within 80 kilometers (50 miles) of the potential sites for the year 2025. The 80-kilometer (50-mile) distance defines the radius of potential radiological effects for calculations of radiation dose to the general population (see Chapter 4 of this EIS). **Table G–2** shows projected populations in the year 2025 for various racial and ethnic populations. Projections of the total population shown in Table G–2 differ from the projected total populations used in the health effects calculations described in Chapter 4. This is because the projections used in the analysis of environmental justice are based on projections for the states provided by the U.S. Bureau of the Census (DOC 1996). Projections used in the analysis of health effects are based on county-wide projections provided by state agencies. As discussed in Section G.3.2, the county projections are more sensitive to localized demographic changes. However, the states do not provide projections for minority populations. Therefore, the U.S. Census Bureau's projections were used in the analysis of environmental justice. Population projections obtained with the two approaches differ by 4 percent or less and will have essentially no effect on the results of the analyses. The low-income population characteristics within the 80-kilometer (50-mile) region of influence are shown in **Table G–3**. **Figures G–1 through G–6** show the locations of minority and low-income populations at risk in the vicinity of the potential sites. The racial and ethnic composition of minority populations is predominantly African-American and Hispanic at all three potential sites.

G.6 Results for Transportation Routes

Overland transportation of tritium involves radiological and nonradiological risks to the public. **Tables G–4 through G–6** show minority and low-income populations residing along highway routes from Watts Bar, Bellefonte, and Sequoyah Nuclear Plants to the Savannah River Site in South Carolina. These tables show populations residing within the 1.6-kilometer (1-mile) corridor centered along highway routes from all three potential sites to the Savannah River Site. Data presented in the tables were resolved at the block-group level. Data for minority populations are projected for year 2025 and data for low-income populations are taken from the 1990 Census. The distances along highway routes connecting the Savannah River Site with other sites are as follows: 349 miles, Bellefonte; 311 miles, Sequoyah; 360 miles, Watts Bar.

Table G–1 Minority Populations (2025) Residing Within 80 Kilometers (50 Miles) of Potentially Affected Areas

Site	*Total Population*	*Minority Population*	*% Minority Population*
Watts Bar	1,161,912	134,678	11.6
Bellefonte	1,265,628	222,559	17.6
Sequoyah	1,298,051	323,447	25.0

Table G–2 Racial and Ethnic Composition of Minority Populations (2025) Residing Within 80 Kilometers (50 Miles) of Potential Sites

Site	*Total Pop.*	*Total Minority Pop.*	*% Minority Pop.*	*American Indian, Eskimo, or Aleut Pop.*	*% American Indian, Eskimo, or Aleut Pop.*	*Asian or Pacific Islander Pop.*	*% Asian or Pacific Islander Pop.*	*Black Pop.*	*% Black Pop.*	*Hispanic Origin Pop.*	*% Hispanic Origin Pop.*
Watts Bar	1,161,912	134,678	11.6	4,303	0.4	15,453	1.3	97,814	8.4	17,108	1.5
Bellefonte	1,265,628	222,559	17.6	7,070	0.5	18,620	1.5	79,815	14.0	17,054	1.3
Sequoyah	1,298,051	323,447	25.0	4,138	0.3	10,577	0.8	108,828	8.0	199,904	15.5

Table G–3 Poverty Populations (1990) Residing Within and 80 Kilometers (50 Miles) of Affected Areas

Site	*Total Population*	*Low-Income Population*	*% Low-Income Population*	*Population in Counties Surrounding Site*	*Low-Income Population in Counties Surrounding Site*	*% Low-Income Population in Counties Surrounding Site*
Watts Bar	872,755	115,827	13.3	1,546,174	233,480	15.1
Bellefonte	957,641	137,740	14.0	1,558,154	210,995	13.5
Sequoyah	832,464	117,451	14.0	1,284,258	186,727	14.5

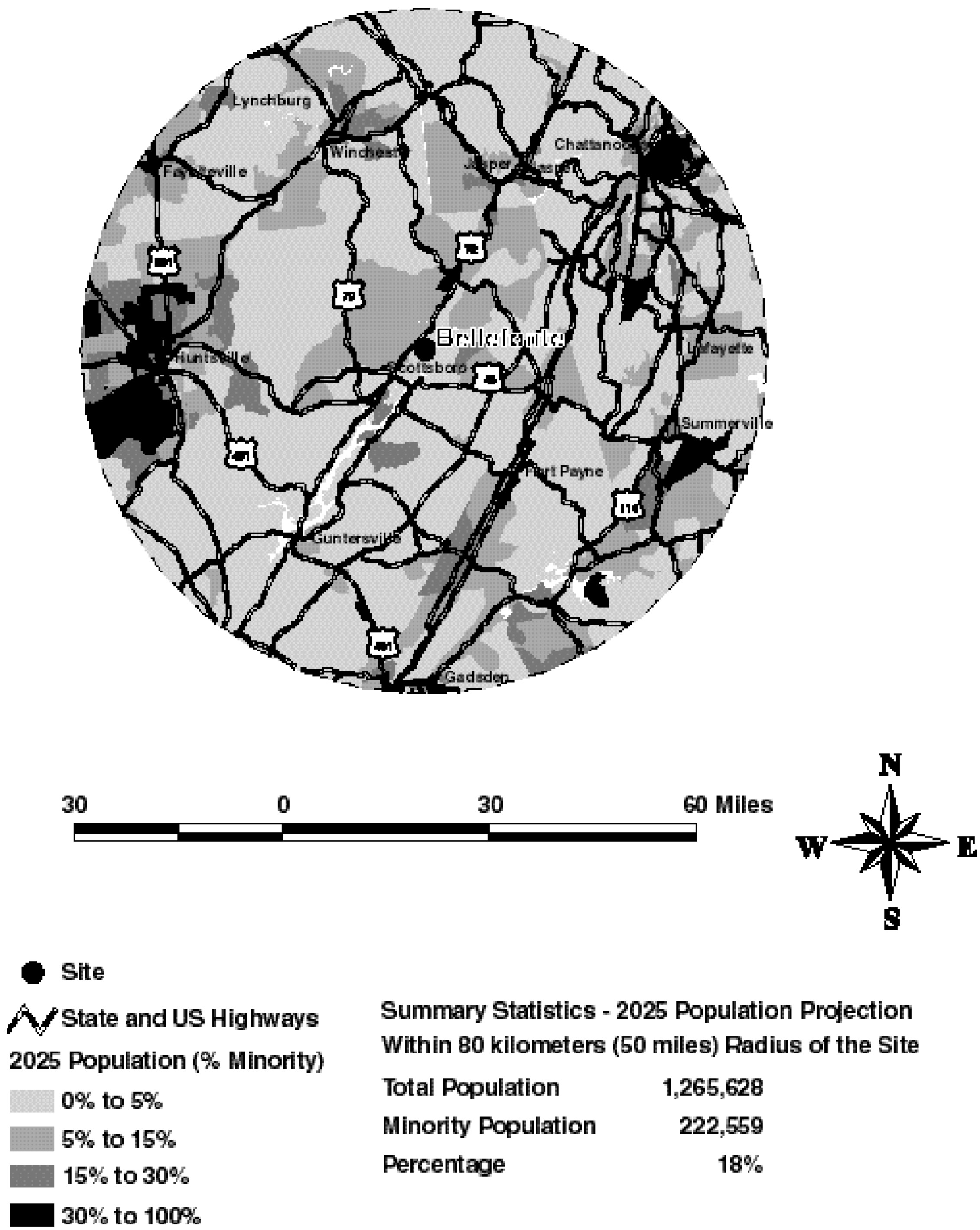

Figure G–1 Minority Populations Residing Within 80 Kilometers (50 Miles) of the Bellefonte Site

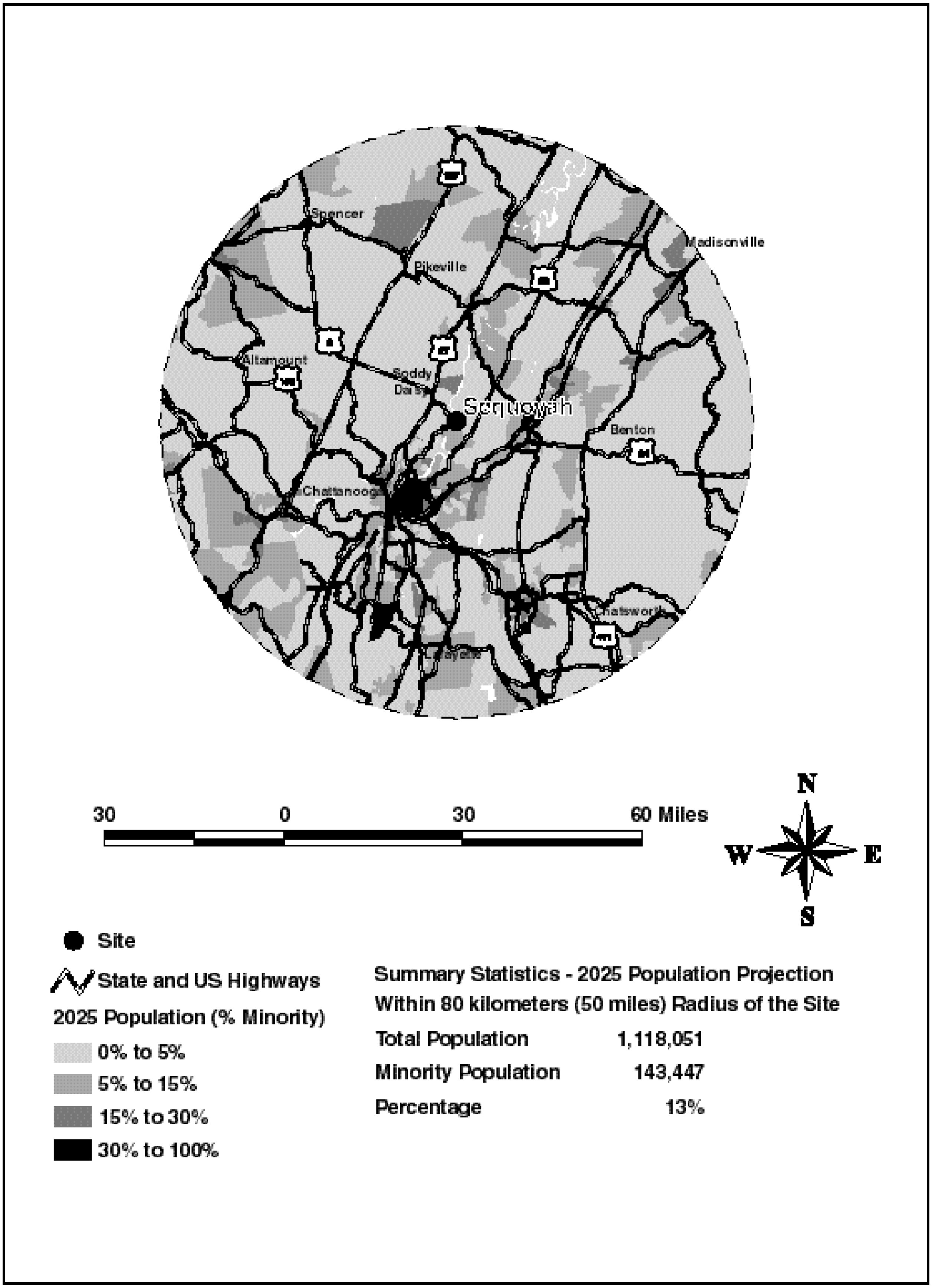

Figure G–2 Minority Populations Residing Within 80 Kilometers (50 Miles) of the Sequoyah Site

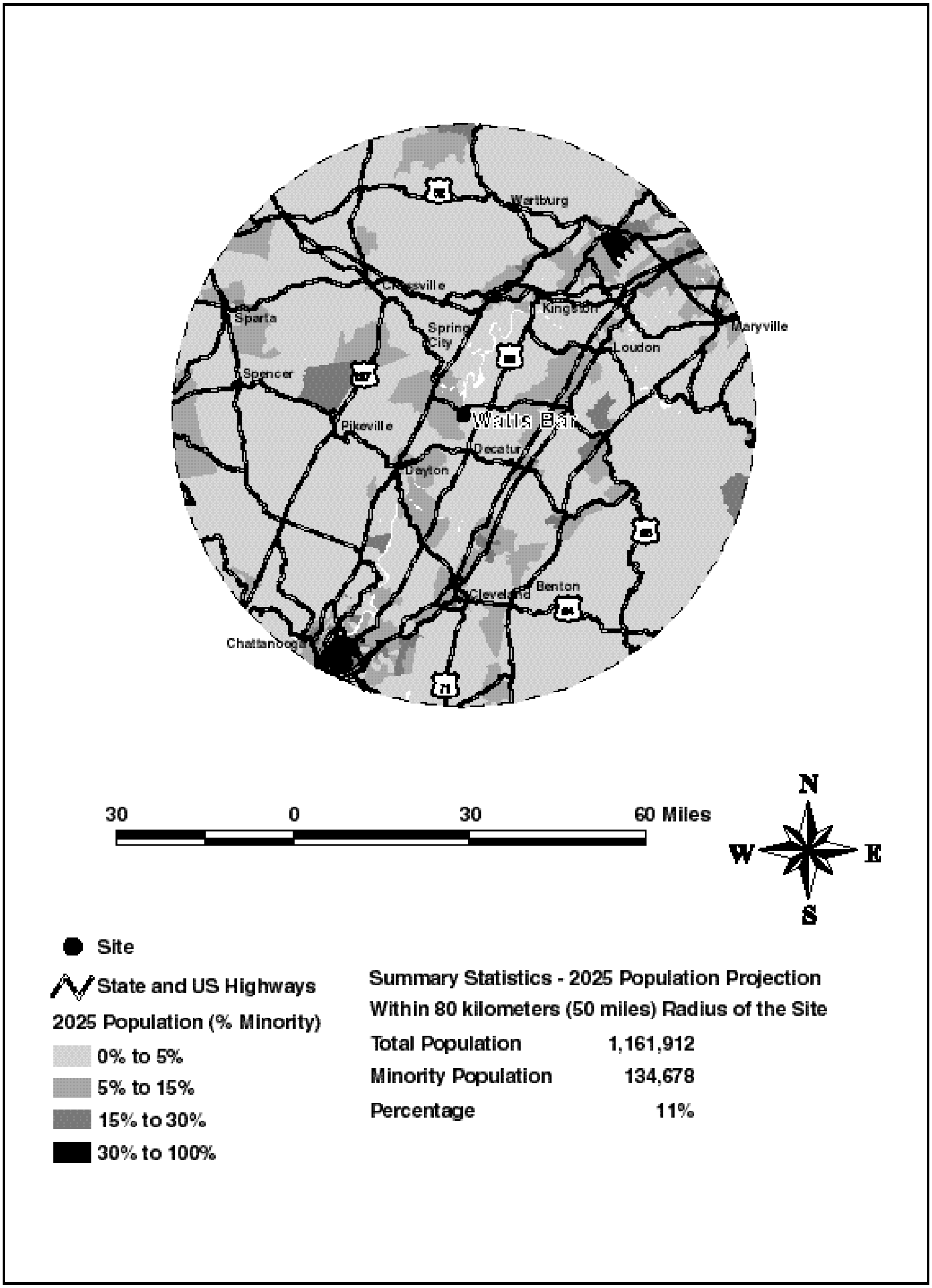

Figure G–3 Minority Populations Residing Within 80 Kilometers (50 Miles) of the Watts Bar Site

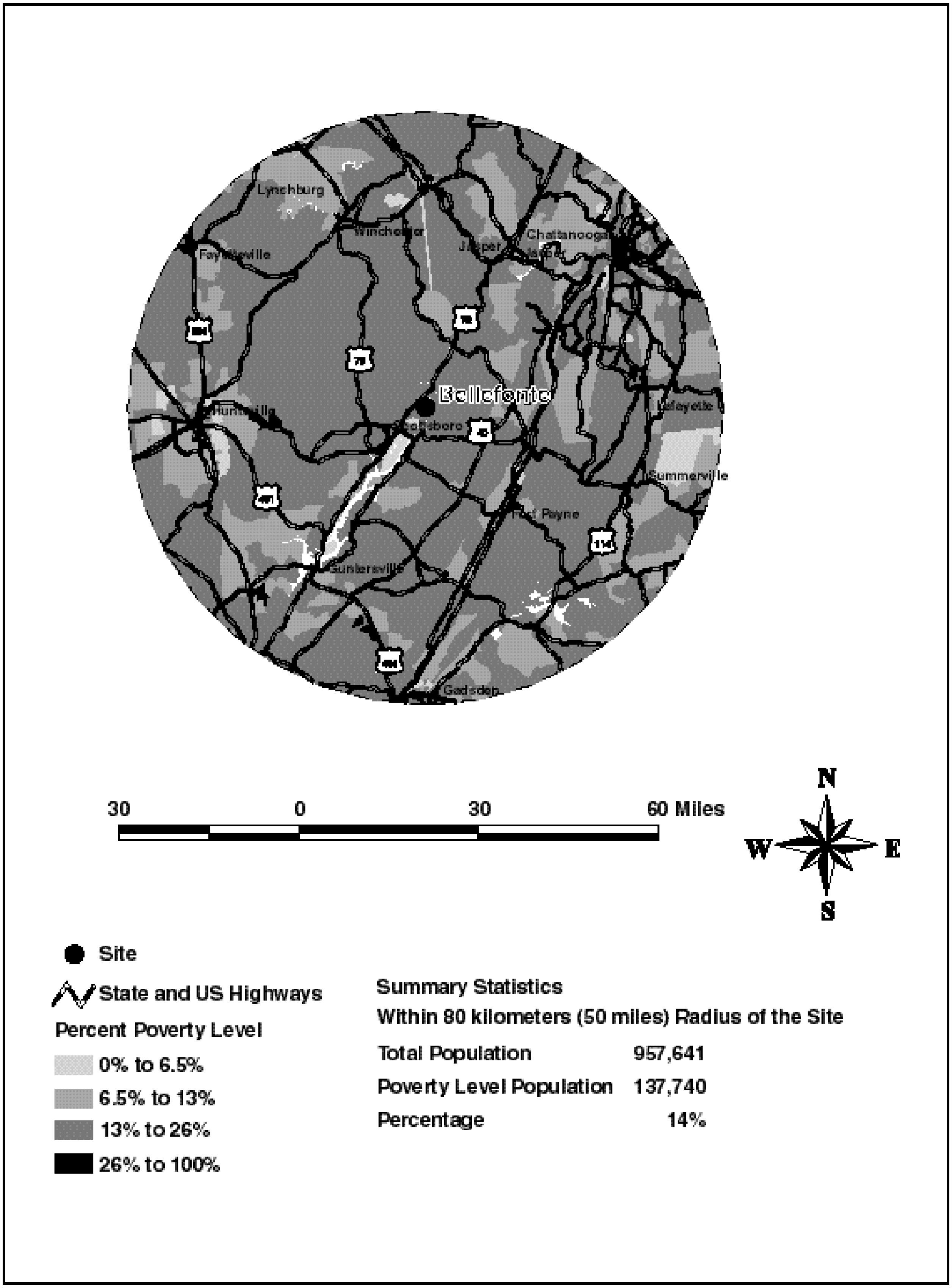

Figure G–4 Low-Income Populations Residing Within 80 Kilometers (50 Miles) of the Bellefonte Site

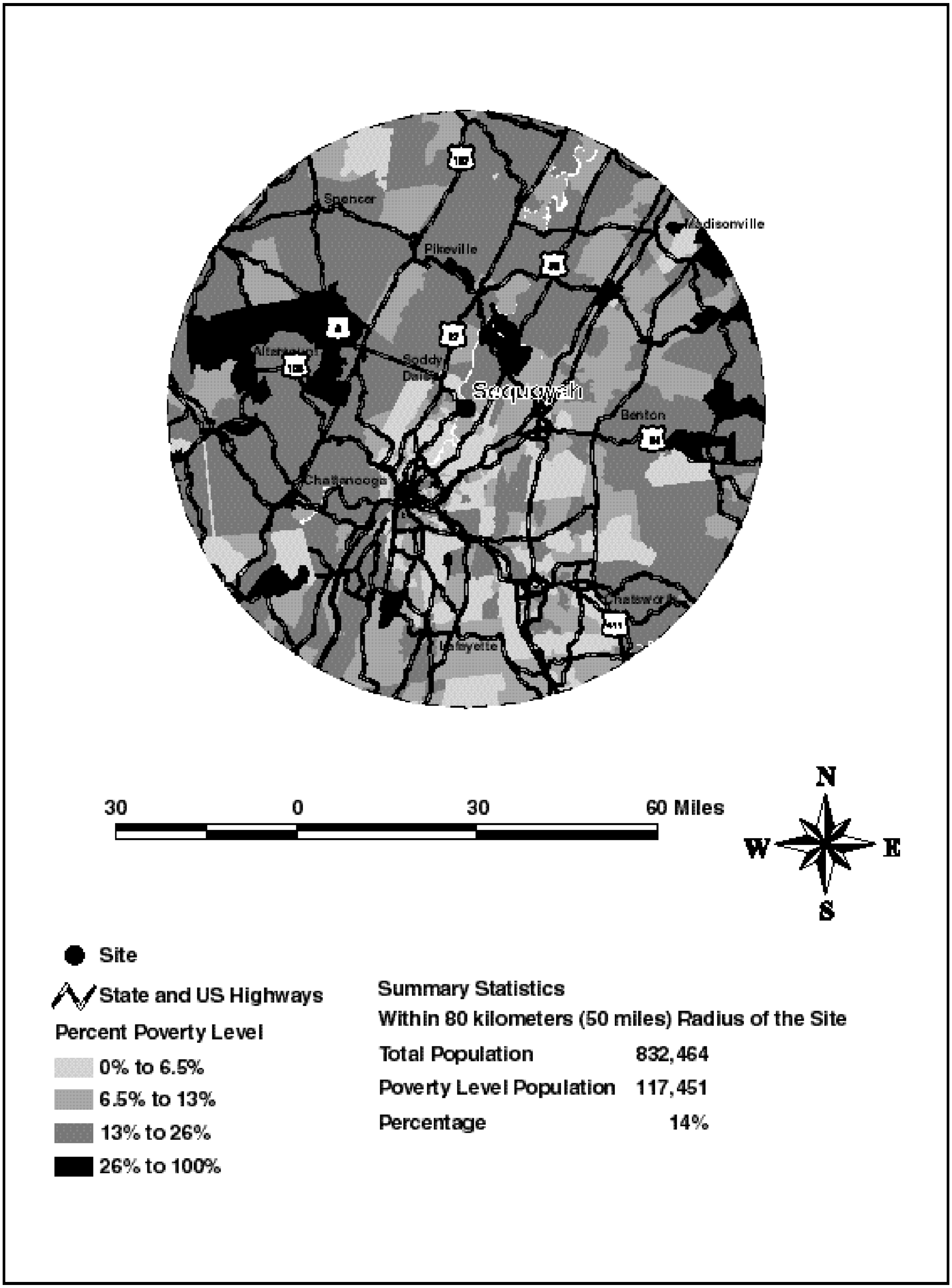

Figure G–5 Low-Income Populations Residing Within 80 Kilometers (50 Miles) of the Sequoyah Site

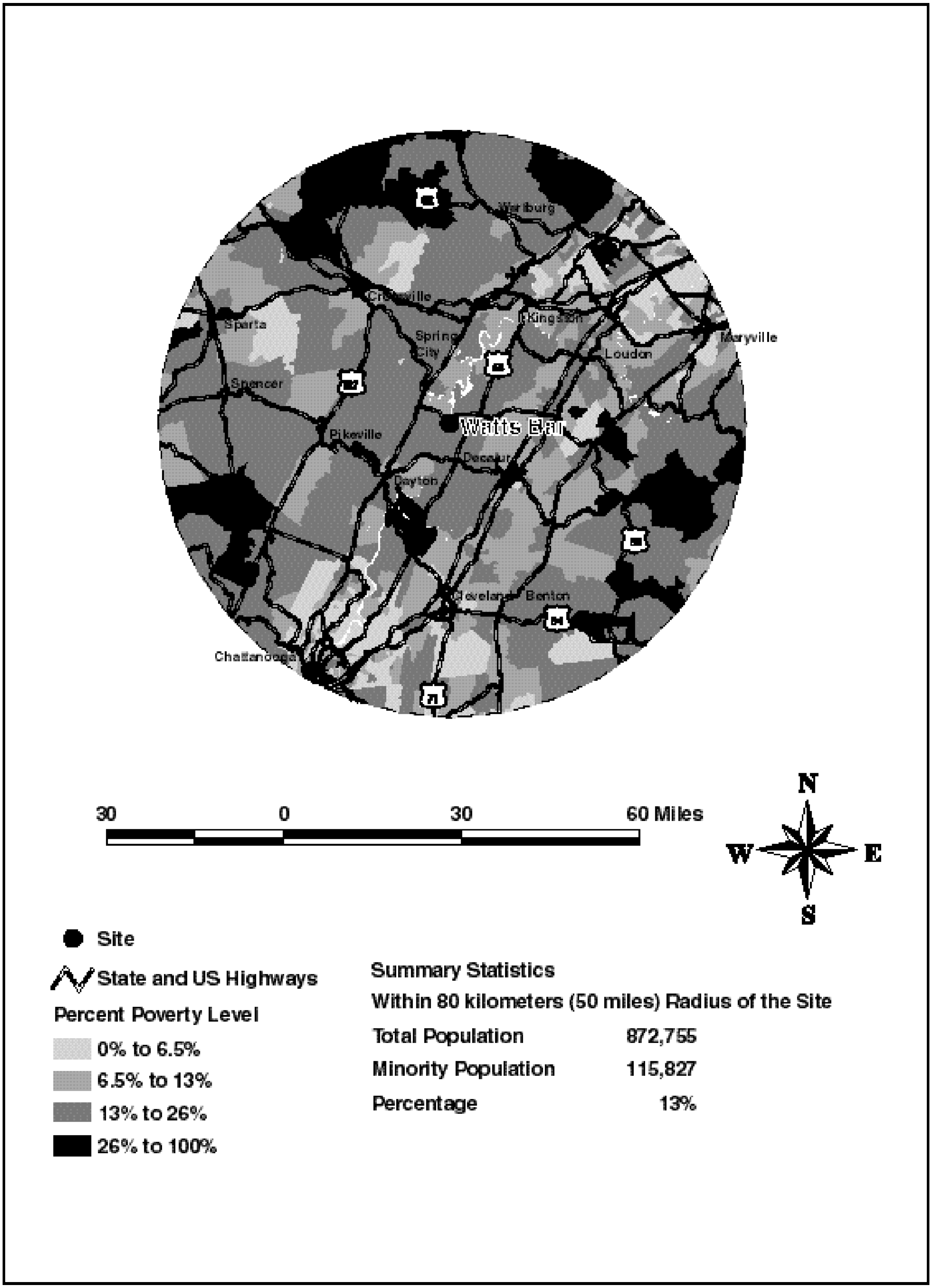

Figure G–6 Low-Income Populations Residing Within 80 Kilometers (50 Miles) of the Watts Bar Site

Table G–4 Minority Populations Residing Near Highway Routes from Potential Sites to the Savannah River Site

Site	*Population Along Route*	*Minority Population Along Route*	*% Minority Population Along Route*
Bellefonte	303,417	129,701	43.0
Sequoyah	298,364	123,694	41.5
Watts Bar	296,423	122,972	41.5

Table G–5 Racial and Ethnic Composition of Minority Populations (2025) Residing Within 1.6 Kilometers (1 Mile) Along Highway from Potential Sites to the Savannah River Site

Site	*Total Pop.*	*Total Minority Pop.*	*% Minority Pop.*	*American Indian Eskimo, or Aleut Pop.*	*% American Indian, Eskimo, or Aleut Pop.*	*Asian or Pacific Islander Pop.*	*% Asian or Pacific Islander Pop.*	*Black Pop.*	*% Black Pop.*	*Hispanic Origin Pop.*	*% Hispanic Origin Pop.*
Watts Bar	296,423	122,972	41.5	739	0.24	12,108	4	97,594	33	12,531	4
Bellefonte	303,417	129,701	43.0	821	0.30	12,303	4	104,289	34	12,288	4
Sequoyah	298,364	123,694	41.5	720	0.24	12,368	4	98,146	33	12,460	4

As discussed in Appendix E, it is unlikely that radiological and nonradiological harm to the general population, including low-income populations and minority populations, would result from highway transportation of tritium.

Table G–6 Low-Income Populations Residing Near Highway Routes from Potential Sites to the Savannah River Site

Site	*Population Along Route*	*Low-Income Population Along Route*	*% Low-Income Population Along Route*
Bellefonte	303,417	24,731	8
Sequoyah	298,364	21,489	7
Watts Bar	296,423	21,415	7

G.7 Other Environmental Impacts

No significant adverse impacts to biotic resources, air resources, socioeconomics, land use, or cultural resources were identified in Chapter 4. Therefore, no disproportionately high or adverse impacts were identified for any segment of the population. None of the alternatives would have a significant adverse impact on the previously mentioned resources because under all of the alternatives a limited amount of previously undisturbed land would be used onsite and offsite.

G.8 Cumulative Impacts

Based on the analysis of the environmental impacts evaluated in this EIS, along with the impacts of other past, present, and reasonably foreseeable future activities, no reasonably foreseeable cumulative adverse impacts are expected to affect the surrounding minority and low-income populations.

G.9 REFERENCES

CEQ (Council on Environmental Quality), 1997, *Guidance for Addressing Environmental Justice under the National Environmental Policy Act*, Executive Office of the President, Washington, DC, December.

DOC (U.S. Department of Commerce), 1992, *1990 Census of Population and Housing, Summary Tape File 3 on CD-ROM*, Bureau of the Census, Washington, DC, May.

DOC (U.S. Department of Commerce), 1996, "Population Projections for States by Age, Sex, Race, and Hispanic Origin: 1995 to 2025" (available at http://www.census.gov/population/www/projections/ppl47.html), Population Division, October.