EXHIBIT 2

Environmental Assessment for Renewal of Special Nuclear Material License No. SNM-124

Nuclear Fuel Services, Inc.
Erwin, Tennessee

Docket 70-143

U.S. Nuclear Regulatory Commission
Division of Fuel Cycle Safety and Safeguards, NMSS

January 1999

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ABBREVIATIONS AND ACRONYMS

Am	americium
AOC	area of concern
BTP	Branch Technical Position
C	carbon
°C	degrees Centigrade
CEDE	committed effective dose equivalent
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
Ci	curie
cm	centimeter
CO	carbon monoxide
COD	chemical oxygen demand
D&D	decontamination and decommissioning
DOE	United States Department of Energy
EA	environmental assessment
EDE	effective dose equivalent
EPA	Environmental Protection Agency
°F	degrees Fahrenheit
gpd	gallons per day
gpm	gallons per minute
HEPA	high-efficiency particulate air (filter)
HEU	highly enriched uranium
HF	hydrogen fluoride or hydrofluoric acid
HNO_3	nitric acid
H_2SO_4	sulfuric acid
HSWA	Hazardous and Solid Waste Amendments
ICRP	International Commission on Radiological Protection
KAST	KAST Fuel Manufacturing Process
kg	kilogram
km	kilometer
L	liter
LD	leak detection
LEU	low enriched uranium
LLW	low-level waste
m^2	square meter
m^3	cubic meter
mi	mile
μCi/g	microcurie per gram
μCi/yr	microcurie per year
μg/L	microgram per liter
$\mu g/m^3$	microgram per cubic meter
μg/mL	microgram per milliliter
mg/L	milligram per liter
mL	milliliter
MMI	Modified Mercalli Intensity
MW	monitoring well
mrem	millirem
m/s	meters per second

NAAQS	National Ambient Air Quality Standards
NDA	non-detectable activity
NEPA	National Environmental Policy Act
NFS	Nuclear Fuels Services, Inc.
NO_x	nitrogen oxides
NPDES	National Pollution Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
O_3	ozone
Pb	lead
PCB	poly-chlorinated biphenyl
pCi/g	picocurie per gram
pCi/L	picocurie per liter
PM-10	particulate matter less than 10 microns in diameter
POTW	publicly owned treatment works
ppm	parts per million
Pu	plutonium
R&D	research and development
Ra	radium
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
s	second
SER	*safety evaluation report*
s/ft^3	second per cubic foot
s/m^3	second per cubic meter
SO_2	sulfur dioxide
Sv	sievert
SWMU	solid waste management unit
Tc	technetium
TEDE	total effective dose equivalent
Th	thorium
U	uranium
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UNH	uranyl nitrate hexahydrate
UO_2	uranium dioxide
UST	underground storage tank
U_3O_8	triuranium octoxide
wt%	weight percent
yr	year

1. PURPOSE AND NEED FOR ACTION

1.1 Introduction

On July 24, 1996, Nuclear Fuel Services (NFS), Inc., requested renewal of its Special Nuclear Material (SNM) License No. SNM-124 (Ref. 1). The requested renewal is for a period of 10 years. The U.S. Nuclear Regulatory Commission (NRC) has prepared this environmental assessment (EA) pursuant to the Council on Environmental Quality regulations [40 CFR Parts 1500-1508 (Ref. 2)] and NRC regulations [10 CFR Part 51 (Ref. 3)], which implement the requirements of the National Environmental Policy Act (NEPA) of 1969 (Ref. 4). The purpose of this document is to assess the environmental consequences of the proposed license renewal.

1.2 Site History

The NFS plant, located in Erwin, Tennessee, produces nuclear fuel for the [redacted]. The principal operations include: (1) the processing of highly enriched uranium [greater than 90 weight percent ^{235}U] into a classified fuel product; and (2) the processing of scrap materials containing highly enriched uranium (HEU) to recover uranium. The major facilities that are used for SNM processing are in the Building [redacted] and Building [redacted] complex, shown on Figure 1.1. The key to the facilities identified on Figure 1.1 is given in Table 1.1.

The NFS Erwin Plant has been engaged in various decommissioning activities, some of which will continue during the 10-year license renewal period. The decommissioning actions are mainly limited to an area referred to as the North Site, which includes all NFS property north of the manufacturing facilities and covers approximately 10 hectares (24 acres). Figure 1.1 shows the area encompassed by the North Site.

As shown in Figure 1.1, the North Site includes ponds and burial areas. Ponds 1, 2, and 3 received liquid waste from onsite processing operations from 1957 until 1978, and Pond 4 (partially enclosed by Building 410) was used for solid waste disposal. About 25 burial trenches were used for the disposal of low-level radioactive waste in the North Site Radiological Burial Ground from 1966 until 1977, as authorized under former 10 CFR 20.304. In addition to the burial areas in the North Site, there are two former waste disposal trenches at the southwestern edge of the plant site which are believed to contain low-level uranium- and thorium-contaminated scrap metals and equipment (Ref. 5). These trenches are referred to as the Southwest Burial Trenches and are also shown on Figure 1.1.

NFS proposes to complete excavation, processing, and disposal of radioactive waste materials, debris and contaminated soils from the Radiological Burial Ground and the Southwest Burial Trenches during the license renewal period. In addition, NFS proposes to complete decommissioning of the entire North Site during the license renewal period to levels which would allow release of the area for unrestricted use. This will involve the following actions: removal of Building 400 and surrounding tanks, utilities, and structures; decommissioning of the area north of Banner Spring between Banner Spring and the security zone; relocation or temporarily rerouting of Banner Spring Branch and the plant drainage system; decontamination and decommissioning (D&D) of the Banner Spring Branch stream bed and Ponds 1 and 2 outside the protected area; D&D of the security zone in the northwest areas; removal of substation 205

Figure 1.1 Redacted

and the guard tower, and D&D of the area; and removal of Building 410 and D&D of the area (Ref. 6). The detail of these areas is shown in Figure 2.1.

1.3 Description of the Proposed Action

The proposed action is to renew License No. SNM-124, so as to continue operations and to perform certain decommissioning activities at the NFS Erwin Plant. The principal operations expected during the renewal period include the processing of HEU into a classified fuel product and processing HEU scrap to recover uranium, as well as support operations. The principal decommissioning activities expected during the renewal period include excavation, sampling, segregation, packaging, and offsite disposal of radioactive materials from the North Site Radiological Burial Ground and the Southwest Burial Trenches. Although the analysis of the impacts from final decommissioning of the North Site to meet unrestricted release criteria are included in this assessment, NRC approval of these activities will be considered as a separate licensing action. Therefore, these activities are not included in the proposed action.

1.4 Need for Action

The NFS Erwin Plant is the sole fabricator of classified fuel material for the [redacted] In addition, NFS is involved in a number of U.S. Department of Energy (DOE) uranium recovery projects due to its unique ability to perform complex chemical processing of HEU materials. Demand for these services by the DOE is expected to continue. Therefore, denial of the license renewal would require similar activities to be undertaken at an alternative site.

1.5 References for Section 1

1. Nuclear Fuel Services, Inc., U.S. Nuclear Regulatory Commission SNM License No. 124, (NRC Docket No. 70-143), License Application dated July 24, 1996.

2. U.S. Code of Federal Regulations, "Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act," Parts 1500-1508, Chapter 5, Title 40, *Protection of Environment.*

3. U.S. Code of Federal Regulations, "Environmental Protection Regulations for Domestic Licensing and Regulatory Functions," Part 51, Chapter 1, Title 10, *Energy.*

4. National Environmental Policy Act, as amended, 42 U.S.C. §4321, et seq., 1970.

5. U.S. Nuclear Regulatory Commission, "Amendment of License SNM-124 Concerning the North Site Burial Ground Remediation (TAC No. L30886), and the SWMU II Remediation (TAC No. L30808), and Acknowledgment of Changes to Revision 2 of Pond 4 Work Plan (TAC No. 30897)," March 27, 1997.

6. Nuclear Fuel Services, "North Site Decommissioning Plan," Vols. 1 and 2, Erwin, Tennessee, NRC Docket No. 70-143, November 20, 1997.

2. THE PROPOSED ACTION AND ALTERNATIVES

Alternatives being considered for the NFS Erwin Plant include (1) the proposed action (renewing the license to authorize processing operations and decommissioning activities), (2) renewing the license to authorize decommissioning activities only, and (3) a No-Action alternative (not renewing the license). This section describes the alternatives, as well as the waste management operations and effluents associated with each alternative.

2.1 The Proposed Action: Renewal of the License to Authorize Both Processing Operations and Decommissioning Activities

The proposed alternative would involve renewing the license to authorize the production of HEU fuel for the [redacted]; uranium recovery processes, including small uranium hexafluoride cylinder cleaning and enriched material downblending and conversion; and decommissioning/remediation activities. The processing operations are discussed in Section 2.1.1, and the decommissioning/remediation activities are discussed in Section 2.1.2. The processing and decommissioning activities would require utilities and support operations, such as waste treatment, which are discussed in Section 2.1.3. The operations at the site result in gaseous and liquid effluents and solid waste, which are discussed in Section 2.1.4.

2.1.1 Description of the Proposed Processing Operations

2.1.1.1 High-Enriched Uranium Production

Beginning in September 1957, NFS produced HEU fuel for the [redacted] using a classified process. NFS terminated fuel production in early 1993 and has replaced this earlier process with a modified process that would be authorized under the proposed alternative. The modified process, referred to as the [redacted] involves the production of HEU fuel using a classified process. Production will occur in the Building [redacted] complex, specifically in Buildings [redacted] and [redacted] (see Figure 1.1).

HEU production operations will be supported by uranium scrap recovery systems, laboratory operations, off-gas treatment systems, waste water treatment systems, process development operations, and a cooling water system, which includes a cooling tower located outside the 300 complex and water supply tanks located in Building 304.

The scrap materials generated during fuel production and laboratory operations are processed through the uranium recovery process systems or are disposed of if uranium recovery is not economically justified. The recovery process for scrap uranium solutions begins with precipitation of the uranium from solution and then dissolution of the precipitate in nitric acid. Uranium in phosphate based solutions, generated by the laboratories during uranium analysis, is separated from solution as uranium tetrafluoride (UF_4) before dissolution as uranyl nitrate. Dilute solutions that do not contain organic materials are concentrated by boiling before precipitation and dissolution as uranyl nitrate.

Solid scrap materials that contain uranium may be calcined to permit separation of the uranium from the solids. These materials may include reject semi-finished fuel, finished fuel, UF_4 from the phosphate precipitation process, and combustible materials. The calcined uranium is then processed through dissolution to convert the uranium to a uranyl nitrate solution.

Impure uranyl nitrate solutions generated by uranium separation and fuel production are processed by two cycles of solvent extraction. Solvent extraction selectively separates the uranium from other impurities in the solution with a tributyl phosphate/NORPAR solvent. The purified uranyl nitrate solution is concentrated by evaporation and recycled to the fuel production process.

2.1.1.2 High-Enriched Uranium Scrap Recovery

Under the proposed action, NFS would be authorized to apply uranium scrap recovery processes to commercial work for the private sector, as well as to material generated at the site. This HEU scrap recovery process is housed in the [redacted] complex (i.e., Buildings [redacted]) (see Figure 1.1). Scrap may be prepared by calcination, screening, grinding, blending, and sulfate roasting. The prepared scrap is dissolved in acid, either nitric acid (HNO_3) or a combination of HNO_3 and hydrofluoric acid (HF), producing a uranyl nitrate hexahydrate (UNH) solution. The UNH solution is processed through two cycles of solvent extraction to produce a purified UNH solution and is then boiled in an evaporator to concentrate the liquid. Solid uranium is produced by either a peroxide or oxalate precipitation process. The precipitated uranium is calcined and dried in a furnace to form U_3O_8, which is then packaged as a product.

2.1.1.3 Downblending Operations

Under the proposed action, downblending operations would also be conducted in the Building [redacted] complex. In this process, HEU material of an enrichment up to 100 weight percent (wt%) ^{235}U is blended with natural or depleted uranium to produce a final low-enriched uranium product (approximately 5 wt% ^{235}U) that could be used for commercial nuclear fuel. The HEU is received as impure uranium in various physical forms and is converted to purified uranyl nitrate solution in the HEU uranium recovery areas of the facility (as discussed in Section 2.1.1.2). The natural/depleted uranium blendstock is received as liquid uranyl nitrate or uranium oxide, which is dissolved and subsequently blended with the HEU to produce a low-enriched product. The low-enriched solution is evaporated, and subsequently converted to a solid oxide product in a conversion furnace.

2.1.1.4 UF_6 Cylinder Washing

Also under the proposed action, NFS would be authorized to perform washing of nominally empty model 5A or 5B uranium hexafluoride (UF_6) cylinders to recover uranium. Cylinder washing is performed in a ventilated glovebox in the 200 complex using water or steam. Removed wash solution is then transferred for further processing to recover the uranium, as described in Section 2.1.1.2.

2.1.2 Description of the Proposed Decommissioning Activities

Under the proposed action, NFS would be authorized to conduct decommissioning activities including excavation, processing, and disposal of radioactive waste materials, debris and contaminated soils from the Radioactive Burial Ground and the Southwest Burial Trenches.

These activities are discussed in Section 2.1.2.1. In addition, NFS would be authorized to remove equipment that is no longer needed and to decontaminate buildings, as discussed in Section 2.1.2.2.

By letter dated November 20, 1997, NFS submitted a document entitled "North Site Decommissioning Plan" [Ref. 3]. This submittal describes NFS' plans for remediation of the northern portion of the site to reduce residual radioactivity to levels which would permit release of the property for unrestricted use. This Plan is currently under review by the NRC staff to determine if it meets the requirements of 10 CFR 70.38(g). The review is not expected to be completed by the time of renewal of the license, and therefore, activities specified in the Plan are not included in the proposed action. However, impacts associated with implementation of the Plan have been included in this environmental assessment to facilitate a timely environmental review of the Plan, in the event the staff determines that it does meet the requirements of §70.38(g).

The Plan is subject to revision. If it is revised, the impacts associated with implementation of the Plan will be reviewed again to ensure that the impacts are enveloped by this assessment. If impacts have been underestimated in this assessment, the staff will perform further environmental review in accordance with 10 CFR Part 51. The North Site Decommissioning Plan is discussed in Section 2.1.2.3.

2.1.2.1 Decommissioning of Burial Areas

NFS is currently engaged in excavation, processing, and disposal of radioactive waste materials, debris and contaminated soils from the Radiological Burial Ground. The Radiological Burial Ground comprises four acres and includes 23 burial trenches containing contaminated equipment, construction debris, laboratory waste, and process waste (e.g., filter press cake) buried between 1966 and 1977 under the provisions of former 10 CFR 20.304. NFS burial records and several characterization studies indicate that the waste includes thorium-232 and uranium, with enrichments ranging from depleted to 97%, as well as small amounts of plutonium-239/240, uranium-233, and americium-242. The total radioactivity of the burial trenches is estimated at slightly less than 1 Ci. Excavation activities are expected to be completed in the first quarter of the year 2000.

In addition, NFS is planning to conduct similar activities for the Southwest Burial Trenches. Decommissioning of the Southwest Burial Trenches is expected to begin in May 1999 and to be completed within three months. The Southwest Burial Trenches include two former waste disposal trenches at the southwestern edge of the plant site which are believed to contain low-level uranium- and thorium-contaminated scrap metals and equipment.

NFS is conducting these decommissioning activities in these areas in accordance with "Addendum 1 to the Pond 4 Decommissioning/Interim Measures Work plan for Excavation of the North Site Burial Ground" in addition to applicable sections of "Decommissioning/Interim Measures Work Plan for the Pond 4 Area, Solid Waste Management Units 2, 4, and 6." In addition, NFS committed to monthly monitoring of the wells down-gradient of the Southwest Trenches in a letter dated March 4, 1997. These decommissioning plans include NFS' commitments for effluent control and effluent and environmental monitoring during these activities and were approved by the NRC by a Confirmatory Order dated June 23, 1994 and a License Amendment dated March 27, 1997 (Ref. 2)..

The NRC's March 27, 1997 Safety Evaluation Report includes an analysis of environmental impacts associated with these activities, which is not repeated in this EA. However, the combined impacts from Decommissioning of the Burial Ground and the Southwest Trenches, along with impacts expected from operational activities and final decommissioning of the North Site are assessed in the analysis of cumulative impacts in Section 5.1.3 of this document

2.1.2.2 Building Decontamination

Under the proposed license renewal, NFS would be authorized to dismantle contaminated buildings and equipment; to clean the surfaces of structures of equipment by washing, spraying, stripping, or vacuuming; and to decontaminate structural and equipment surfaces by scabbling or scaling. However, prior to initiating these actions, NFS will be required to determine if the procedures could result in significantly greater releases of radioactive material to the environment than those associated with operation. If so, NFS will be required to submit a decommissioning plan for NRC review and approval prior to initiating such actions, in accordance with 10 CFR 70.38(g)(1).

2.1.2.3 *Proposed Decommissioning Activities in the North Site Area*

Previous remediation activities in the northern portion of the plant, referred to as the North Site area, have included removal of sediments from Ponds 1, 2, and 3; removal of waste and debris from the Pond 4 area; and removal of the contaminated soil stockpile (see Figures 1.1 and 2.1). All activities have been conducted in accordance with NRC-approved decommissioning plans. Currently, NFS is exhuming waste, debris, and contaminated soil from the North Site Radiological Burial Ground as discussed in Section 2.1.2.1. The North Site Decommissioning Plan which was submitted for NRC review, discusses the removal of an additional 39,100 cubic meters (1,380,000 cubic feet) of contaminated soil and sediment from the North Site area. Although the decommissioning of the northern portion of the plant has been ongoing, the North Site Decommissioning Plan addresses final decommissioning activities which are necessary to meet unrestricted release criteria. The nature and extent of contamination in the North Site area are described in Section 3.9.

Decommissioning activities in the North Site area will include excavation, sampling, segregation, packaging, and transporting radioactive materials offsite. The main decommissioning activities in the North Site area will be:

- Removal of contaminated soils and sediments north and west of Banner Spring Branch;
- Removal of contaminated sediments from the Banner Spring Branch stream bed and Ponds 1 and 2;
- Removal of the plant drainage lines that empty into Banner Spring Branch;
- Removal of contaminated soil from the security zone;
- Removal of temporary Buildings 400 (sediment treatment facility) and 410 (Pond 4 containment facility), which will be used to support remediation activities, as well as surrounding tanks, equipment, utilities, and structures to access contaminated soil adjacent to and underneath the foundations.

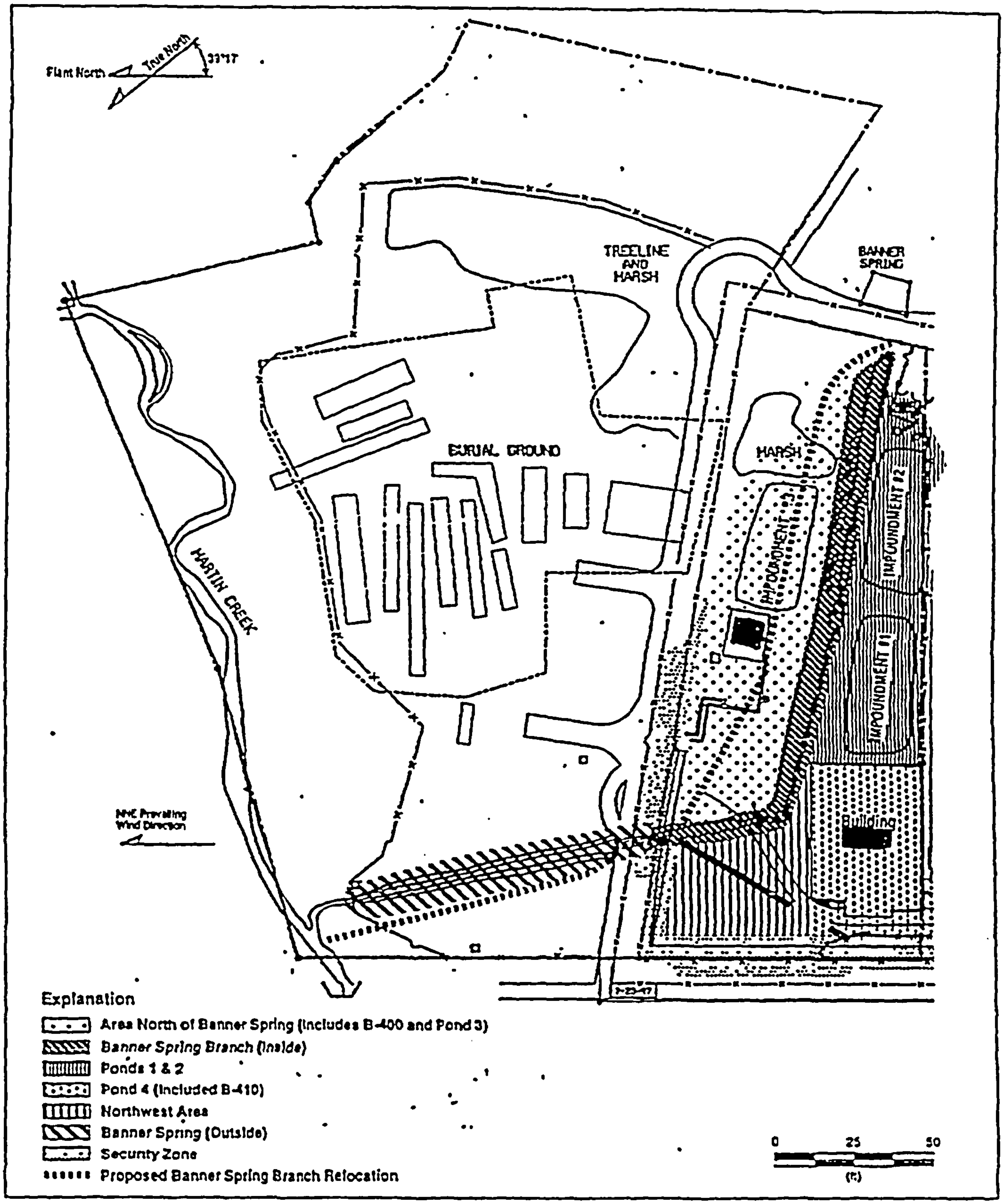

Figure 2.1 Areas to be excavated in the North Site area (modified from Ref. 3)

Contaminated soil is expected to constitute the majority of the waste stream; significant quantities of waste and debris are not expected to be encountered. Contaminated soil will be excavated, taken to Building [redacted] for sorting and separating waste and debris, and dried. Building 410 will also be used for blending waste, storage, and packaging of waste. Excavated soil will be temporarily stockpiled before shipment for offsite disposal. Finally, excavated areas will be backfilled with clean soil or other suitable fill material.

NFS has indicated that specific controls will be implemented to protect the environment during decommissioning actions. These controls will include:

- Using straw bales and silt fences to reduce and contain surface water runoff;
- Wetting dry soil to reduce dust;
- Defining areas of operation (controlled areas) ;
- Covering stockpiled soil during periods of inactivity, if necessary, to prevent the spread of contamination;
- Using clean equipment to move and spread backfill;
- Maintaining onsite transportation routes as clean areas;
- Conducting routine radiological surveys of the transportation routes and transport equipment;
- Removing groundwater and rain water that has accumulated in excavations;
- Using holding tanks for storing decontamination wash water and water pumped from excavation areas and pumping water to the Waste Water Treatment Facility or the Groundwater Treatment Facility;
- Performing continual monitoring of air and water and periodic monitoring of sediment.

Excavation activities are expected to take about 5 years, from 1998 to 2003, with the final surveys being completed in 2004.

2.1.3 Utilities or Support Operations

Utilities and other operations will support the processing and decommissioning activities. These utilities and support operations include water use, the incinerator, the heating plant, the Waste Water Treatment Facility, the Groundwater Treatment Facility, and mixed waste treatment.

2.1.3.1 Water Use

The NFS Erwin Plant obtains most of its water from the municipal water supply. Municipal water is used for processing operations, decommissioning, mixed waste treatment, utilities, and sanitary use. Liquid effluents generated by processing and decommissioning are treated in the Waste Water Treatment Facility (Building [redacted]) and then discharged to the Nolichucky River.

Liquid effluents from utilities and sanitation are pumped to the sewer [i.e., to the Erwin Utilities Publicly Owned Treatment Works (POTW)]. Groundwater pumped from specific site areas to lower the water table for dry excavation is treated in the Groundwater Treatment Facility. The treated water is then combined with sanitary effluents and discharged to the Erwin Utilities POTW. Non-contact cooling water is obtained from and discharged to Banner Spring Branch. Stormwater run-off at the site also drains into Banner Spring Branch. Liquid effluents from the Waste Water Treatment Facility, non-contact cooling water, and stormwater run-off are discharged in accordance with a National Pollutant Discharge Elimination System (NPDES) permit (Ref. 4).

Figure 2.2 presents the water balance for the NFS Erwin Plant, based on information provided by NFS (Ref. 9). The average discharge from the Waste Water Treatment Facility during the license renewal period is estimated to be about 61,000 liters (16,000 gallons) per day. The throughput is dominated by decommissioning/site remediation activities [46,000 liters (12,150 gallons) per day], which is five times greater than from production operations. The average discharge to the municipal sewer is estimated to be about 102,000 liters (27,000 gallons) per day. About 235,000 liters (62,000 gallons) per day are withdrawn from Banner Spring Branch, used as non-contact cooling water, and then returned to Banner Spring Branch. Quantitative information on the water balance at the NFS Erwin Plant is presented in Table 2.1.

Table 2.1 Summary of water usage at the NFS Erwin Plant

Use	Consumption (gallons per day)[a]	Discharge (gallons per day)[a]/Evaporation	Discharge Location
Processing, decommissioning activities, and mixed-waste treatment[b]	17,440	16,490	Nolichucky River (Outfall 001)
		950	Evaporation
Non-contact cooling	62,340	62,240	Banner Spring Branch (Outfall 002)
		100	Evaporation
Utilities and sanitation	21,200	17,600	Erwin Utilities POTW[c]
		3,150	Evaporation
Groundwater treatment	10,800	9,400	Erwin Utilities POTW
		1,400	Evaporation

a. To convert gallons to liters, multiply by 3.785.
b Decommissioning activities and mixed-waste treatment use 12,150 gallons per day, while processing uses only 3,850.
c. POTW - Publicly Owned Treatment Works.

Source: Nuclear Fuel Services, Inc., "Response to NRC Request for Additional Information to Complete Environmental Review for License SNM-124 (TAC No. L30873), Dated 11/26/97," Docket No. 70-143, February 4, 1998 (Ref. 9).

2.1.3.2 Incinerator

Building [redacted] houses an incinerator used for reducing the volume of combustible process and laboratory waste before uranium recovery. The incinerator is gas-fired and consists of a pyrolitic

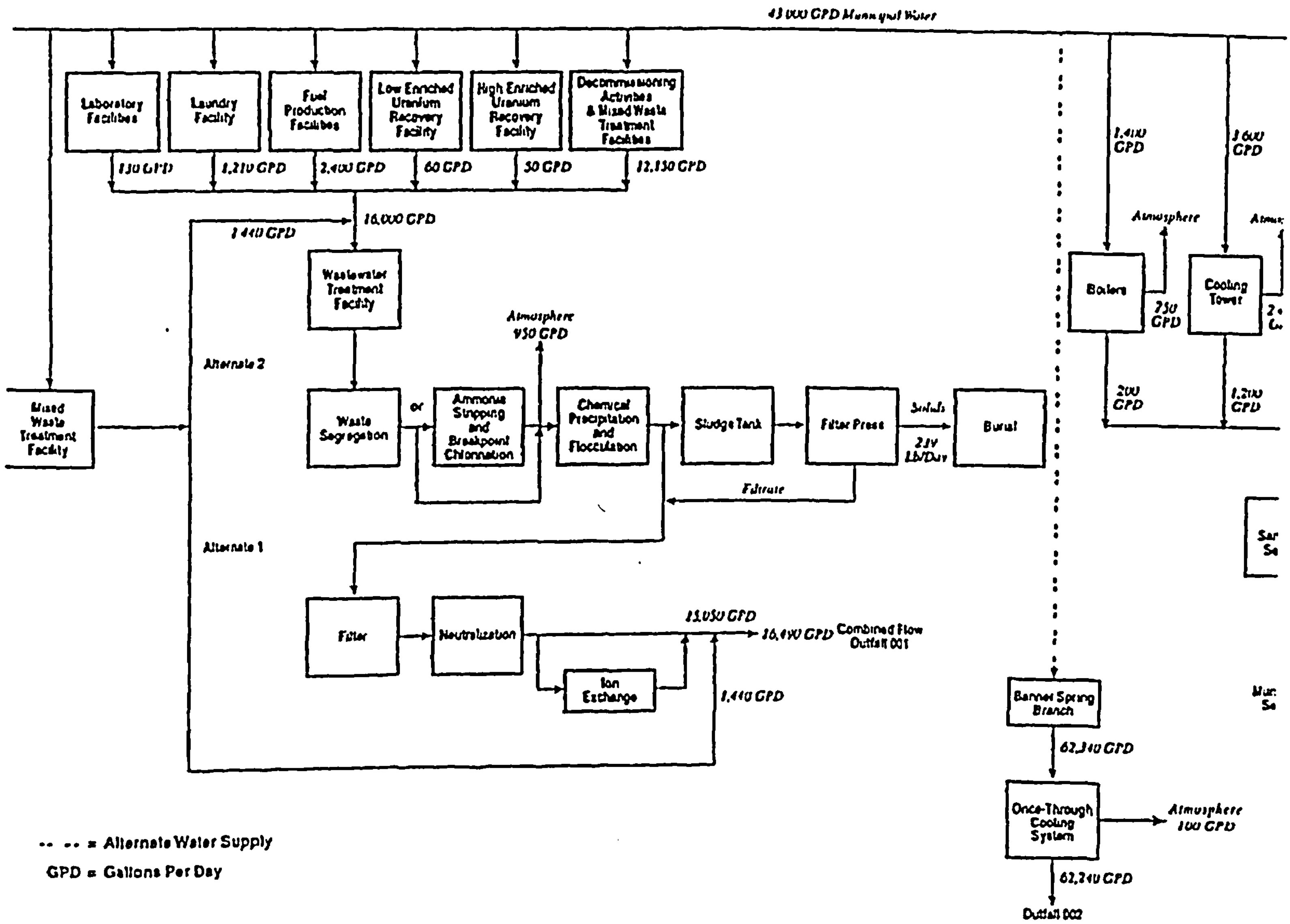

Figure 2.2 Process flow schematic for the wastewater treatment facility and groundwater tre
(modified from Ref. 7)

combustion chamber and an afterburner (Ref. 5). Air exhausted from the incinerator is routed to the Building 300 complex ventilation system and exhausted through the main stack (Ref. 6). However, at this time, the incinerator is shut down with no current schedule for restart (Ref. 7). Operation of the incinerator is not authorized under the renewal and therefore neither the operation nor the potential impacts from operation were considered in this environmental assessment.

2.1.3.3 Heating Plant

The heating plant (Building [redacted]) is the primary emissions source of nonradiological criteria pollutants [i.e., sulfur dioxide (SO_2), ozone (O_3), nitrogen oxides (NO_x) carbon monoxide (CO), lead (Pb), and particulate matter] (Ref. 8). The heating plant uses natural gas; however, No. 2 diesel fuel oil can also be used.

2.1.3.4 Waste Water Treatment Facility

The Waste Water Treatment Facility (located in Building [redacted]) treats liquid effluents generated by the various site operations, including fuel production, low-enriched and high-enriched uranium recovery, mixed-waste treatment, laboratory operations, laundry, building decommissioning, and site remediation. These liquid waste streams are pH adjusted and ammonia is removed by a stripping tower or by breakpoint chlorination, as appropriate. Waste water is treated by lime precipitation, to remove fluoride, uranium, and other metals. After the lime is precipitated, the waste water is filtered, neutralized, and discharged into the Nolichucky River through outfall 001, under the NPDES permit. The precipitate is dewatered in a filter press, and the filter press cake is packaged for offsite disposal at a low-level waste (LLW) disposal facility (Ref. 7).

2.1.3.5 Groundwater Treatment Facility

The Groundwater Treatment Facility (located in Building 335) is used to treat groundwater pumped from onsite wells. Volatile organics are removed by air stripping, and radionuclides and semi-volatile organics are removed by lime precipitation. Settled solids are removed and pumped to the filter press located in the Waste Water Treatment Facility (Building 330). Carbon adsorption is used to remove semi-volatiles, heavier fractions of hydrocarbons, and various inorganic matter from the filtered water. The pH is adjusted to approximately 7 and the treated groundwater is discharged to the sanitary sewer, in compliance with a POTW pre-treatment permit.

2.1.3.6 Mixed-Waste Treatment

Mixed waste (sludges and sediments) contaminated by radionuclides and mercury undergo stabilization and amalgamation in Building [redacted], using a proprietary process. The waste is shredded and treated in a tank; the waste slurry is pumped to a filter press, and the filter press cake is packaged for LLW disposal. The liquid filtrate is recycled for subsequent reuse. Sampled filtrate within an acceptable range is transferred to the Waste Water Treatment Facility.

2.1.3.7 Chemical Usage

Approximately 25 major chemicals are used for processing and waste treatment operations at the NFS Erwin Plant. These chemicals, the amount stored, and the storage locations are listed in Table 1-3 of the 1997 Emergency Plan (Ref. 10).

2.1.4 Gaseous and Liquid Effluents and Solid Waste

Gaseous, liquid, and solid wastes are generated at the NFS Erwin Plant. This section describes the nature of these streams, describes current waste management practices, and estimates release rates of effluents to the environment.

2.1.4.1 Gaseous Effluent Management

Gaseous effluents are generated from two types of activities: emissions from process stacks and fugitive dust from remediation activities. Gaseous effluents are discharged from process stacks in accordance with operating permits issued from the Tennessee Air Pollution Control Board (Ref. 11) and NRC regulations.

Radiological Constituent Discharges

During the renewal period, the majority of the radioactive air emissions are expected to be from the Building [redacted] complex, Building 200 complex, and Building [redacted] complex, which house the HEU production process, HEU scrap recovery operations, and laboratories, respectively. Emissions from these processing areas are combined in the main process ventilation system. The combined effluent is cleaned by venturi and demisting scrubbers and high efficiency particulate air (HEPA) filters and then exhausted through the 33-meter (108-feet) main plant stack (Figure 2.3, stack no. 416) (Ref. 8).

Air is exhausted from a number of other stacks and vents at buildings that house the laboratories, laundry dryers, furnace, boilers, diesel generator, the Waste Water Treatment Facility, and the Groundwater Treatment Facility. Table 2.2 presents the diameter, height, velocity, constituents released, and pollution control device for each process stack. Figure 2.3 shows the locations of the stacks.

Uranium is the primary radiological constituent expected to be released through the stacks during the renewal period. Smaller amounts of thorium and plutonium, and trace amounts of americium are also expected to be released. Based on data from a pilot study which was performed during development of the KAST process, NFS estimates that 360 µCi/yr of uranium (U-234, U-235, U-236, U-238) will be released from the main stack [Ref. 17]. This is significantly less than annual releases during the former fuel production process. However, because of the preliminary nature of this data, historic information on radionuclide releases to the environment was relied on to develop a more conservative estimate of releases during future production operations.

Because major operations ceased in 1993 and decommissioning activities were being conducted, historical data from 1990 through 1993 was considered representative of historic production operations and data from 1994 through 1996 was considered representative of facility decommissioning operations. Table 2.3 summarizes the estimated quantities (curies) of

Figure 2.3 Redacted

Table 2.2 Physical characteristics of exhaust stacks at the NFS Erwin Plant

Building	Stack No.	Effective Diameter (m)*	Stack Height (m)	Gas Exit Velocity (m/s)*	Potential Contaminants Exhausted	Pollution Control Devices
Main Stack:						
300/200/105 Complex	416	1.52	33	11 57	U	Scrubber, HEPA filter, activated carbon filter
Other Stacks*:						
[redacted] Laundry Dryer	421	0 30	Horiz. Vent	15 3	U	None
[redacted] Laundry Dryer	547	0 43	4*	5.75	Th, Pu	None
[redacted] R&D Lab	600	0.61	18.9	15.0	U	Scrubber
[redacted] R&D	554	0.15	4*	18.1	Pu	HEPA filter
[redacted] ND*	646	ND	ND	ND	ND	ND
[redacted] ND	333	ND	ND	ND	ND	ND
[redacted] Welding Hood	332	0.20	6.0	13.2	U	HEPA filter
[redacted] Boiler Exhaust	[618]*	ND	ND	ND	ND	ND
[redacted] Lab. Hood	185	0.20	10 36	5 35	U	None
[redacted] Mech. Equip. Room	[-]*	ND	ND	ND	ND	ND
[redacted] Furnace Drybox	27	0.41	12	5.23	Pu	HEPA filter
[redacted] Room Air & Cell Atmos.	28	0.45	12	6.21	Pu	HEPA filter
[redacted] Wet Process in Scrap Recovery	224	0.17	14	4 96	Pu	HEPA filter
[redacted] Lab	583	0.10	8*	18 0	Pu	HEPA filter
[redacted] --	376	0 61	15	8 26	U	HEPA filter

Table 2.2 Physical characteristics of exhaust stacks at the NFS Erwin Plant (continued)

Building	Stack No.	Effective Diameter (m)	Stack Height (m)	Gas Exit Velocity (m/s)	Potential Contaminants Exhausted	Pollution Control Devices
Other Stacks[b] (continued):						
[redacted] Hydrogen Vent	[573]	0.31	7[c]	7.08	U	High efficiency filter
[redacted] Room Air Exhaust	615	0.30	7[c]	12.0	U	HEPA filter
[redacted] Mech. Equip Room	[--]	ND	ND	ND	ND	ND
[redacted] Diesel Generator	[--]	ND	ND	ND	ND	ND
[redacted] Waste Water Treatment Facility	[327]	ND	ND	ND	ND	ND
[redacted] Groundwater Treatment Facility	649	0.25	15.24	11.5	U	Carbon absorption filter
[redacted] 400/Decommissioning Facility	[643]	ND	17	ND	ND	HEPA filter
[redacted] Pond 4	667	1.40	12[c]	6.17	U	None
[redacted] (West Side)/Pond Compactor	[594]	ND	3	ND	ND	ND

a. To convert meters to feet and from meters per second to feet per second, multiply by 3.28.
b. For purposes of the impact assessment, all "other stacks" were conservatively assumed to result in ground level releases.
c. The heights given are building heights.
d. ND = no data provided.
e. [stack #] = No data provided for stack in the semi-annual effluent monitoring reports.
f. Stack name or number unknown.
U = uranium
Th = thorium
Pu = plutonium
R&D = research and development
HEPA = high efficiency particulate air

Source: Nuclear Fuel Services, Inc., "Environmental Report, Erwin Plant, Erwin, Tennessee," July 1984 (Ref. 14); Nuclear Fuel Services, Inc., "Response to request by NRC for additional information concerning NFS's 1996 license renewal request," Docket No. 70-143, June 17, 1997 (Ref. 7); and Nuclear Fuel Services, Inc., "Emergency Plan," May 23, 1997 (Ref. 10).

radionuclide releases from both the main stack and from all other stacks and vents. Separate estimates are presented for production and decommissioning operations.

Because process offgases from the [redacted] complex (HEU production) and 200 complex (HEU recovery) are filtered to remove radionuclides, very small quantities of radionuclides are released to the environment. Historical data (1979 to 1996) from stack effluent monitoring (Refs. 6 and 8) indicate that the main process stack discharges about 1000 microcuries of uranium per year and about 3 microcuries of thorium per year during HEU production operations. Based on review of stack monitoring data (Refs. 8 and 13), the quantities of radionuclides released from the main stack during decommissioning and site remediation activities (no HEU production operations) are about one order of magnitude lower than when HEU production operations are occurring.

Lower quantities of radionuclides are released from the remaining stacks or building vents other than the main stack. Historical data from stack effluent monitoring indicate that less than 1000 microcuries of uranium, 0.3 microcurie of thorium, and 0.2 microcurie of plutonium per year are discharged during HEU production operations (see Table 2.3). These same historical data indicate that during decommissioning and remediation activities (no HEU production) thorium discharges are expected to be about the same as during HEU production operations, whereas uranium discharges would be about one order of magnitude lower and plutonium discharges would be about two orders of magnitude higher.

Table 2.3 Estimated annual releases of radiological constituents from process stacks

Discharge Source/ Constituent Released	During Production Operations (μCi/year)	During Decommissioning/ Remediation Activities (μCi/year)	Total[a] (μCi/year)
Main Stack:			
Uranium	1,000[b]	100[b]	1,100[b]
Thorium	3[c]	0.3[c]	3.3[c]
Other Stacks:			
Uranium	1,000[b]	100[b]	1,100[b]
Thorium	0.3[c]	0.3[c]	0.6[c]
Plutonium	0.02[d]	2[d]	2.02[d]

a. Total is the sum of releases from both production operations and decommissioning/remediation activities.
b. Estimated composition is 95% U-234, 2% U-235, and 3% U-238.
c. Estimated composition is 40% Th-228, 20% Th-230, and 40% Th-232.
d. Estimated composition is 30% Pu-239, 10% Pu-240, and 60% Pu-241.

Source: U.S. NRC, "Environmental Assessment for Renewal of Special Nuclear Material License No. SNM-124, Nuclear Fuel Services, Inc., Erwin Plant, Erwin, Tennessee," Docket No. 70-143, August 1991 (Ref. 6); Nuclear Fuel Services, Inc., "Applicant's Environmental Report for Renewal of Special Nuclear Material License No. SNM-124," December 1996 (Ref. 8); and Nuclear Fuel Services, Inc., "Bi-Annual Effluent Monitoring Reports, Docket No 70-143/SNM-124," 1990-1996 (Ref. 13).

Fugitive Dust Emissions

Decommissioning activities in the North Site area will involve excavating and moving contaminated soil and sediment that can generate fugitive dust containing radionuclides. Fugitive dust emission estimates are based on the correlation between actual measurements of fugitive dust generated and the amount of material moved. It was assumed that fugitive dust emissions would occur from decommissioning activities such as scraping off topsoil, loading excavated material into trucks, and adding or removing material from a storage pile.

The schedule for excavation activities in the North Site area (Ref. 3) indicates that approximately 39,100 cubic meters (1,380,000 cubic feet) of contaminated soil/sediment will be moved over approximately 4.75 years, yielding an average annual material movement rate of 13,200 metric tons per year (14,500 tons per year). Using the method prescribed in reference 15 for calculating aggregate handling and storage pile emission factors, it was estimated that less than 4×10^{-4} kilogram per metric ton (8×10^{-4} pound per ton) of inhalable fugitive dust would be generated. The annual material movement rate was multiplied by the above emission factor to yield an annual fugitive dust generation rate of 5.4 kilograms per year (12 pounds per year). The fugitive dust generation rate was multiplied by the median radionuclide concentrations in contaminated soil from the North Site area, as reported in reference 16, to yield the annual estimated radionuclide release rates presented in Table 2.4.

Table 2.4 Estimated annual radiological air emissions in fugitive dust generated from site remediation activities

Nuclide	Estimated Emission Rate (μCi/year)
Uranium Isotopes[a]	
Uranium-234	0.068
Uranium-235	0.001
Uranium-238	0.002
Thorium Isotopes	
Thorium-230	0.006
Thorium-232	0.009
Plutonium-241	0.002
Americium-241	0.0005
Technetium-99	0.01

a. Total uranium was assumed to consist of 95% U-234, 2% U-235, and 3% U-238.

Nonradiological Constituent Discharges in Stack Emissions

The heating plant is the primary nonradiological emissions source of criteria pollutants (see Section 3.2.4 for a discussion of criteria pollutants). Other emission sources include chemical processes, vehicles, diesel-powered emergency generators, and, when operational, the incinerator. NFS estimates of annual nonradiological emissions from process stacks are presented in Table 2.5. (Note that there are a few contaminants in air effluents that are classified as confidential restricted information and are therefore not included in Table 2.5.) Because the main source of the criteria pollutants is from the heating plant, the majority of the emissions are expected to occur regardless of the type of activities (i.e., production operations, decommissioning/site remediation activities, or both).

Table 2.5 Estimated annual releases of nonradiological constituents from process stacks

Pollutant	Total Annual Emissions* (tons/year)
Particulates	0.61
Sulfur dioxide	0.27
Carbon monoxide	0.94
Volatile organic compounds	21.27
Nitrogen oxides	15 87
Hydrogen fluoride	0 48
Hydrogen chloride	1 42
Vinyl chloride	0.01
Tetrachloroethylene	0.21
Trichloroethylene	0.06
Bis-2-ethylhexylphthalate	0.01
Mercury	0.72E-2
Methanol	0 06
Isopropyl Alcohol	0.18
NORPAR 12	0.13
Tri-butyl Phosphate	0 02
Hydrogen	18.13

Source: Nuclear Fuel Services, "Applicant's Environmental Report for Renewal of Special Nuclear Material License No. SNM-124," December 1996 (Ref 8) and Nuclear Fuel Services, "KAST Fuel Manufacturing Process - Revised Response to NRC Questions," October 1, 1998 (Ref. 17).

2.1.4.2 Liquid Waste Management

Radiological Effluents

As discussed in Section 2.1.3.1, liquid waste streams are generated from process facilities, decommissioning activities, utilities, and various support operations (see Figure 2.2). NFS has estimated that the radioactivity in liquid effluents will be more than a factor of four lower during operation of the KAST process than during operation of the former fuel production process (Ref. 17). However, as with airborne effluents, historic operations were used to develop a more conservative estimate of radiological releases during future production operations. The historical data from 1990 through 1993 was considered representative of production operations and the data from 1994 through 1996 was considered representative of facility decommissioning operations. Table 2.6 summarizes the estimated quantities of radionuclide releases from each of the three discharge points. No sampling data of radionuclide concentrations in stormwater run-off was available for inclusion in this table. Separate estimates are presented for production operations and decommissioning actions.

The thorium activity is expected to be the same during production operations and decommissioning activities in discharges from the Waste Water Treatment Facility; however, the uranium and technetium-99 activity are expected to be about one order of magnitude higher during production operations than during decommissioning activities (Table 2.6).

Table 2.6 Annual releases of radionuclides in liquid effluents

Discharge Source/ Constituent Released	During Production Operations (Ci)	During Decommissioning/ Site Remediation Activities (Ci)	Total[a] (Ci)
Waste-Water Treatment Facility:			
Uranium Isotopes	0.02[b]	0.005[b]	0.025[b]
Thorium Isotopes	0.005[c]	0.005[c]	0.010[c]
Technetium-99	0.01	0.001	0.011
Banner Spring Branch:			
Uranium Isotopes	0.05[b]	0.05[b]	0.10[b]
Thorium Isotopes	0.002[c]	0.002[c]	0.004[c]
Plutonium Isotopes	0.001[d]	0.001[d]	0.002[d]
Sewer:			
Uranium Isotopes	0.01[b]	0.01[b]	0.02[b]
Thorium Isotopes	0.0001[c]	0.0001[c]	0.0002[c]
Plutonium Isotopes	0.0001[d]	0.0001[d]	0.0002[d]

a. Total releases are the sum of the releases during production operations and during decommissioning/site remediation activities
b. Estimated composition is 95% U-234, 2% U-235, and 3% U-238.
c. Estimated composition is 40% Th-228, 20% Th-230, and 40% Th-232.
d Estimated composition is 30% Pu-239, 10% Pu-240, and 60% Pu-241.

Source: U.S. NRC, "Environmental Assessment for Renewal of Special Nuclear Material License No. SNM-124, Nuclear Fuel Services, Inc., Erwin Plant, Erwin, Tennessee," Docket No. 70-143, August 1991 (Ref 6), Nuclear Fuel Services, Inc., "Applicant's Environmental Report for Renewal of Special Nuclear Material License No SNM-124," December 1996 (Ref 8); and Nuclear Fuel Services, Inc., "Bi-Annual Effluent Monitoring Reports, Docket No. 70-143/SNM-124," 1990-1996 (Ref 13).

Nonradiological Effluents

Nonradiological characteristics of the waste water treatment effluent discharged through outfall 001 during historic production operations and decommissioning activities are summarized in Table 2.7. Concentrations of nonradiological contaminants in liquid effluent releases during operation of the KAST process are not expected to exceed concentrations released during operation of the former fuel manufacturing process (Ref. 18).

2.1.4.3 Solid Waste Management

Solid wastes generated at the NFS Erwin Plant include radioactive waste (from both processing operations and decommissioning/site remediation activities), mixed waste, hazardous waste, and non-contaminated solid waste. A combination of processing, offsite disposal, and recycling are used to manage these wastes.

Radioactive waste is compacted to the extent practical and disposed of offsite at a licenced low-level waste disposal facility. The total annual volume of solid waste expected to be generated during both production operations and decommissioning activities is about 8500 cubic meters (300,000 cubic feet). About 99 percent of this waste is generated from decommissioning activities. The average activity of this waste is expected to be less than 100 pCi/g.

Table 2.7 Average nonradiological characteristics of effluent from outfall 001

Parameter	Production Operations[a]	Decommissioning/ Site Remediation Activities[b]	Total[c]
Discharged volume (gallons/day)	22,000	16,000	38,000
Total Suspended Solids (mg/L)	22	13	18
Ammonia (as Nitrogen) (kg/day)	1.3	6.4	3.4
Nitrates (as Nitrogen) (kg/day)	290	15	175
Fluoride (mg/L)	26	14	21
Chlorine (mg/L)	1.1	<0.04	0.65
Cadmium (mg/L)	<0.006	0.0153	0.010
Mercury (mg/L)	0.002	0.0002	0.0012
pH	8.6	7.6[d]	8.2

a. Based primarily on data from 1984 - 1988, and also on data from 1979 - 1983 (Ref. 6).
b. *Based on data from 1994, assumed to be representative of the period from 1993 - 1995 (Ref. 8).*
c. Total is the average values based on a total combined flow of 38,000 gallons/day.
d. *An average value was not reported, so the midpoint of the reported range (6.4 to 8.7) was used.*

Mixed waste (because of mercury contamination) is generated at a rate of about 0.4 cubic meter (14 cubic feet) per year (Ref. 7). Mixed waste is either treated onsite to remove its hazardous characteristic or shipped offsite for treatment and/or disposal. Poly-chlorinated biphenyl-contaminated mixed waste (such as concrete and demolition debris) is stored onsite (Ref. 8). Small amounts of other mixed waste, including waste code F002 (solvents) and D038 (pyridine), are also stored onsite (Ref. 8). There is also some mercury contaminated soils onsite. Hazardous waste may either be treated onsite or shipped offsite for treatment and/or disposal. Treatment and/or storage of mixed waste at the site is authorized by the Tennessee Department of Environment and Conservation and by the EPA pursuant to the Hazardous and Solid Waste Amendments of 1984.

Non-contaminated solid wastes generated at the NFS Erwin Plant include waste oil, paper, cafeteria waste, industrial materials, metals, and construction/demolition debris. These types of non-contaminated solid wastes are generated at a rate of about 61 metric tons (67 tons) per year and are disposed of offsite at a local landfill (Ref. 7).

2.2 Alternative 1: Renewal of the License to Authorize Decommissioning Only

Under the alternative to the proposed action, HEU production and scrap recovery operations would not be authorized. Instead, the license for the NFS Erwin Plant would be renewed to only allow ongoing decommissioning activities, including decommissioning of the North Site Radiological Burial Ground and Southwestern Burial Trenches and final decommissioning of the North Site area. If only decommissioning/remediation activities were authorized, actions like those described in Sections 2.1.2 and 2.1.3 would occur. In addition there would be a transition to site-wide decommissioning activities which have not been identified or assessed at this time, but would be assessed when NFS submits a site-wide decommissioning plan. The characteristics of gaseous and liquid effluents produced from limited decommissioning/site remediation activities being performed were presented in Tables 2.3, 2.4, 2.6, and 2.7.

2.3 Alternative 2: The No-Action Alternative

Under this alternative to the proposed action, neither HEU production and scrap recovery operations nor ongoing decommissioning activities would be authorized, and all activities at the site would cease. However, as in alternative 1, it is expected that site-wide decommissioning activities would be initiated in the future, in accordance with NRC regulations in 10 CFR 70.38. Site-wide decommissioning activities have not been identified or assessed at this time.

2.4 References for Section 2

1. Nuclear Fuel Services, "Special Nuclear Material License SNM-124, Part II, Safety Demonstration, Renewal," June 1996.

2. U.S. Nuclear Regulatory Commission, "Amendment of License SNM-124 Concerning the North Site Burial Ground Remediation (TAC No. L30886), and the SMWU II Remediation (TAC No. L30808); and Acknowledgment of Changes to Revision 2 of Pond 4 Workplan (TAC No. 30897)," March 27, 1997.

3. Nuclear Fuel Services, "North Site Decommissioning Plan for Nuclear Fuel Services, Inc., Erwin, Tennessee," November 1997.

4. State of Tennessee Department of Environment and Conservation Division of Water Pollution Control, "NPDES Permit No. TN0002038, Nuclear Fuel Services, Erwin, Unicoi County, Tennessee," April 3, 1996.

5. Nuclear Fuel Services, "1997 Annual Update to Special Nuclear Material License SNM-124," June 30, 1997.

6. U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, "Environmental Assessment for Renewal of Special Nuclear Material License No. SNM-124, Nuclear Fuel Services, Inc., Erwin Plant, Erwin, Tennessee," Docket No. 70-143, August 1991.

7. Nuclear Fuel Services, Inc., "Response to a request by NRC for additional information concerning NFS's 1996 license renewal request," Docket No. 70-143, June 17, 1997.

8. Nuclear Fuel Services, "Applicant's Environmental Report for Renewal of Special Nuclear Material License No. SNM-124," December 1996.

9. Nuclear Fuel Services, Inc., "Response to NRC Request for Additional Information to Complete Environmental Review for License SNM-124 (TAC No. L30873), Dated 11/26/97," Docket No. 70-143, February 4, 1998.

10. NFS, "Emergency Plan," Revision 1, Erwin, Tennessee, May 23, 1997.

11. Tennessee Air Pollution Control Board, Department of Environment and Conservation, "Operating Permit No. 037723F, issued to Nuclear Fuel Services, Inc., Erwin, Tennessee," March 15, 1994.

12. U.S. Nuclear Regulatory Commission, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," Regulatory Guide 1.111.

13. Nuclear Fuel Services, Inc., "Bi-Annual Effluent Monitoring Reports, Docket No. 70-143/SNM-124," 1990 - 1996.

14. Nuclear Fuel Services, Inc., "Environmental Report, Erwin Plant, Erwin, Tennessee," July 1984.

15. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, "Supplement B to Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources," AP-42, Fifth Ed., November 1996.

16. Nuclear Fuel Service, Inc., "North Site Characterization Report for Nuclear Fuel Services, Inc., Erwin, Tennessee," November 1997.

17. Nuclear Fuel Services, "KAST Fuel Manufacturing Process - Revised Response to NRC Questions," October 1, 1998.

18. Nuclear Fuel Services, "KAST Fuel Manufacturing Process - S-7 Evaluation," August 20, 1998.

3. AFFECTED ENVIRONMENT

3.1 Site Description

The NFS Erwin Plant is located approximately in the center of Unicoi County in northeastern Tennessee, about 32 kilometers (20 miles) southwest of Johnson City, Tennessee. Asheville, North Carolina, is located 80 kilometers (50 miles) to the southwest. The plant is about 0.8 kilometer (0.5 miles) southwest of the Erwin city limits and lies on the southeastern edge of the Nolichucky River (see Figure 3.1). The developed portion of the site is at a distance of about 0.3 kilometer (0.2 miles) from the river. The plant elevation is about 9 meters (30 feet) above the nearest point on the Nolichucky River.

The site occupies about 26 hectares (65 acres) of land and is located in a southwest-to-northeast-oriented valley, bounded by the Appalachian Mountains. The mountains to the immediate north and south of the valley have a maximum elevation of about 756 meters (2480 feet) above sea level. The site elevation is about 511 meters (1675 feet) above sea level.

3.2 Climatology and Meteorology

3.2.1 Climatology

Data collected at the Bristol, Johnson City, and Kingsport, Tennessee, tri-city area, about 32 kilometers (20 miles) northeast of the NFS Erwin Plant, is considered representative of meteorological conditions at the NFS site. Table 3.1 gives the mean monthly temperatures from 1986 to 1995 for the tri-city area of Bristol, Johnson City, and Kingsport, Tennessee. As the table demonstrates, the climate of the area is characterized by warm, humid summers and relatively mild winters.

The area has a relatively high annual precipitation rate. Precipitation at the site is relatively evenly distributed throughout the year, as shown in Table 3.2. October is the driest month and February the wettest. The annual mean precipitation measured from 1986 through 1995 was 102.6 centimeters (40.4 inches) in the tri-city area. The annual average precipitation in the Erwin area is 103.4 centimeters (40.7 inches) (Ref. 2). The maximum monthly total recorded over the past 10 years [19.7 centimeters (7.75 inches)] was in February 1994 (Ref. 1). The maximum daily precipitation recorded over the past 50 years was 9.27 centimeters (3.65 inches) in October 1964 (Ref. 1). The daily precipitation is greater than 0.03 centimeters (0.01 inch) about 11 days per month (Ref. 1).

3.2.2 Winds, Tornadoes, and Storms

Prevailing winds at the site tend to follow the orientation of the valley, southwest to northeast. Based on data collected from the NFS meteorological tower, the winds are predominantly from the southwest/south-southwest, with an average annual speed of 3.4 meters per second (7.6 miles per hour) over a 5-year period (Ref. 2).

The NFS Erwin Plant is located east of the center of tornado activity. Only one tornado has been recorded in Unicoi County since 1950 (Ref. 3). The average number of thunderstorm days per year near Erwin is 42.8.

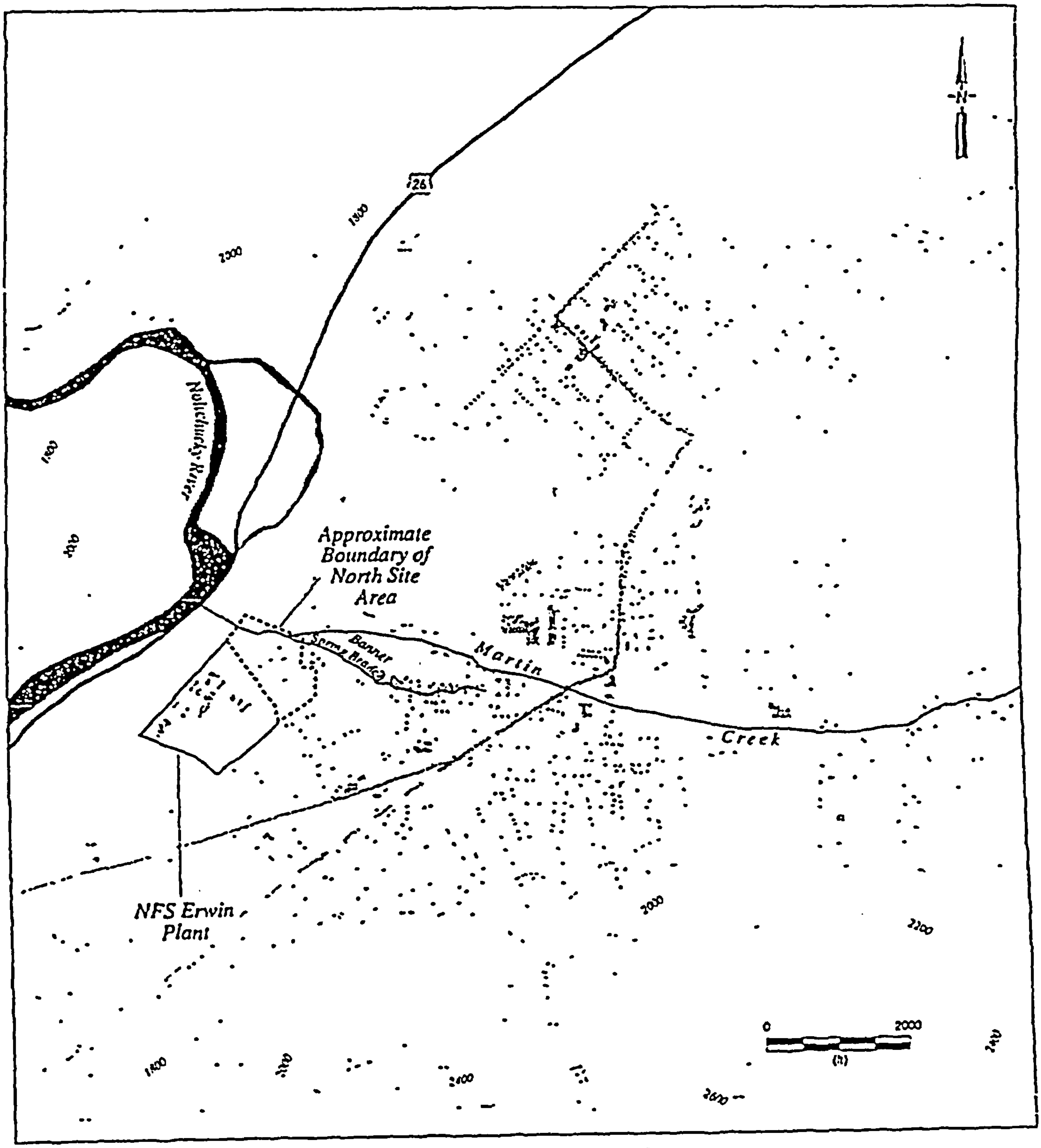

Figure 3.1 NFS Plant Site near Erwin, Tennessee (modified from U.S. Geological Survey, Erwin, Tennessee and Chestoa, Tennessee-NC Quadrangles, 1971 and 1978)

Table 3.1 Means and extremes of monthly temperature in the Tri-City Area of Bristol, Johnson City, and Kingsport, Tennessee (°F)[a]

Month	Monthly Mean[b]	Normal Daily Maximum[c]	Normal Daily Minimum[c]
January	35.7	43.7	24.3
February	38.9	48 0	26.8
March	46.6	58.9	35.4
April	55.5	67.4	43.0
May	64.3	75.2	51.6
June	71.9	82.2	59.9
July	75.0	84.6	64.1
August	74.0	84.1	63.1
September	68.0	79.1	56.6
October	56.2	69.1	44.2
November	46.3	58.2	35.9
December	38.3	48.1	28.2

a. *To convert from °F to °C, subtract 32 and divide the difference by 1.8.*
b. The period of record is 1937-1996.
c. The period of record is 1966-1996.

Source: National Oceanic and Atmospheric Administration, "1996 Local Climatological Data, Annual Summary with Comparative Data, Bristol, Johnson City, Kingsport, Tennessee (TRI)," ISSN0198-4764 (Ref. 1).

3.2.3 Meteorology

Wind speed and wind direction data collected at the NFS meteorological tower from 1991 through 1995 are summarized in Table 3.3. The winds are from the south, south-southwest, and southwest directions approximately 43 percent of the time and out of the north and north-northwest about 20 percent of the time, reflecting the orientation of the valley. The annual average wind speed, based on the data in Table 3.3, is 2.7 meters per second (6.0 miles per hour).

The NFS onsite meteorological data collection program does not include measurement of stability class. Estimates of stability class, based on data collected in 1982 and 1983, indicate that stability classes A, B, C, D, E, and F occur approximately 31, 24, 27, 20, 1, and 0 percent of the time, respectively (Ref. 4). Given the absence of a complete set of current data for the stability class distribution, atmospheric dispersion estimates based on class A stability, for elevated releases, and class F stability, for ground-level releases, give conservative estimates of possible conditions.

For normal operational releases to the atmosphere, the location of the maximally exposed individual is defined as the point of highest concentration per unit source (χ/Q) determined by the atmospheric dispersion analysis. The location of the maximally exposed individual is influenced by the frequency of occurrence of meteorological conditions and the distance from the source to actual residences surrounding the site. The results of this analysis are summarized in Table 3.4 for both ground-level and elevated releases.

Table 3.2 Climatological data for the Tri-City Area of Bristol, Johnson City, and Kingsport, Tennessee

	Precipitation (inches)[a]			Relative Humidity (%)	
Month	Monthly Mean[b]	Monthly Maximum[c]	Daily Maximum[c]	Morning (7 a.m.)	Afternoon (1 p.m.)
January	3.48	9.18	2.34	86	69
February	3.58	7.75	2.48	78	58
March	3.88	9.56	3.35	79	53
April	3.13	5.85	2.66	86	53
May	3.75	9.71	3.26	93	61
June	3.53	6.97	3.10	90	59
July	4.72	9.73	2.90	91	65
August	3.40	7.07	3.07	96	62
September	2.92	7.09	3.61	95	65
October	2.18	5.65	3.65	89	53
November	2.93	5.90	2.55	85	64
December	3.41	6.75	2.95	86	63
Annual	40.42	--	--	88	60

a. To convert inches to centimeters, multiply by 2.54.
b. The period of record is 1937-1996.
c. The period of record is 1945-1996.

Source: National Oceanic and Atmospheric Administration, "1995 Local Climatological Data, Annual Summary with Comparative Data, Bristol, Johnson City, Kingsport, Tennessee (TRI)," ISSN0198-4764 (Ref. 1).

The results indicate that the maximally exposed individual is located 200 meters (655 feet) south of the site with a concentration per unit source (χ/Q) of 3.5×10^{-6} and 6.1×10^{-5} seconds per cubic meter (9.9×10^{-8} and 1.7×10^{-6} seconds per cubic foot) for elevated and ground-level releases, respectively. Estimates of χ/Q for 16 sectors and 10 distances surrounding the site are presented in Appendix A.

3.2.4 Air Quality

Air quality is measured against the National Ambient Air Quality Standards (NAAQS) established by the U.S. Environmental Protection Agency (EPA) to protect human health and welfare (primary standards) and to protect against damage to the environment and property (secondary standards). The pollutants regulated under the NAAQS are total suspended particulates (inhalable particulate matter with aerodynamic diameter less than 10 microns, referred to as PM-10), ozone (O_3), nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), and lead (Pb). Tennessee has adopted air quality standards comparable to those of the EPA. These standards are summarized in Table 3.5. In addition, Tennessee monitors gaseous fluorides, such as hydrogen fluoride (HF). Unicoi County is presently in attainment with regard to the eight criteria pollutants monitored by the State of Tennessee (Ref. 5).

Table 3.3 Frequency of occurrence of wind speed and direction at the NFS Site (percent)

Direction	Maximum Wind Speed (m/s)[a]			
	1.64	2.30	2.95	3.61
N	0.0	4.12	2.86	0.0
NNE	0.0	4.20	0.0	0.0
NE	1.78	1.26	0.0	0.0
ENE	2.18	0.0	0.0	0.0
E	1.74	0.0	0.0	0.0
ESE	0.76	1.10	0.0	0.0
SE	0.0	0.58	2.86	0.0
SSE	0.0	0.0	2.6	3.98
S	0.0	0.0	0.0	11.39
SSW	0.0	0.0	3.29	14.79
SW	0.0	0.0	0.0	13.07
WSW	0.0	0.0	3.48	2.02
W	0.0	2.12	0.42	0.0
WNW	0.0	2.46	0.0	0.0
NW	0.0	0.0	4.68	0.0
NNW	0.0	0.0	0.0	12.31

a. To convert meters per second to miles per hour, divide by 0.447.

Table 3.4 Normal operations dispersion factors for NFS facility nearest residents

Direction	Distance (m)[a]	χ/Q (s/m^3)	
		Ground level	Elevated
N	357	2.4×10^{-5}	1.4×10^{-6}
NE	381	2.5×10^{-5}	1.4×10^{-6}
E	262	1.3×10^{-5}	6.5×10^{-7}
SE	226	2.4×10^{-5}	1.3×10^{-6}
SSE	202	6.1×10^{-5}	3.5×10^{-6}
S	214	4.5×10^{-5}	2.0×10^{-6}

a. To convert meters to feet, multiply by 3.2803.

Table 3.5 Tennessee primary and secondary ambient air quality standards

Pollutant	Averaging Time	Primary ($\mu g/m^3$)	Secondary ($\mu g/m^3$)
SO_2	Annual Arith. Mean	80	
	24 hour[a]	365	
	3 hour[a]		1,300
O_3	1 hour[b]	235	235
NO_x (NO_2)	Annual Arith Mean	100	100
CO	8 hour[a]	10,000	10,000
	1 hour[a]	40,000	40,000
Pb	Calendar quarter	1.5	1.5
PM-10[c]	Annual Geom. Mean	50	50
	24 hour	150	150
Total suspended particulates	Annual Geom. Mean	75	60[d]
	24 hour	260	150
Gaseous fluorides (HF)[e]	30 days[a]	1 2	1.2
	7 days[a]	1 6	1.6
	24 hour[a]	2.9	2.9
	12 hour[a]	3 7	3.7

a. Maximum concentration not to be exceeded more than once per year.
b. Maximum 1-hour concentration not to be exceeded more than one day per year.
c. Federal standard for PM-10, 40 CFR Part 50, Appendix K.
d. Guide to be used in addressing implementation plans to achieve the 24-hour standard.
e. All conditions relate to air at standard conditions of 25 °C temperature and 760 millimeters of mercury pressure.

Source: Tennessee Air Pollution Control Regulations, Rules of Tennessee Department of Health and Environment, Division of Air Pollution Control, Chapter 1200-3-3—Ambient Air Quality Standards (Ref. 5).

3.3 Demography, Socioeconomics, and Environmental Justice

The NFS Erwin Plant is located in Unicoi County, which has a population of about 16,900 (Ref. 6), and has shown about 3 percent growth since the 1980 census. The nearest population center is the City of Erwin, which has a 1996 population of about 5,400 people (Ref. 6). The population of the City of Erwin has increased by about 2 percent since 1980. Estimates of the incremental population within 80 kilometers (50 miles) of the site are given in Table 3.6. The data are provided as a function of direction and distance for a combination of 16 directional sectors and 10 radial distances. The 1990 population within an 80-kilometer (50-mile) radius of the facility is approximately 949,797 people. The NFS Erwin Plant is the major industrial employer in the area, with a labor force of 350 people or about 17 percent of the local industry (Ref. 6).

On February 11, 1994, President Clinton signed Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," which directs all Federal agencies to develop strategies for considering environmental justice in their programs, policies, and activities. Environmental justice assessment is described in the Executive Order as "identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." The NMSS Policy & Procedure Letter 1-50 (April 1995) provides the guidance used for addressing the issue of environmental justice in NEPA review for the United States Nuclear Regulatory Commission. The agency is committed

Table 3.6 1990 incremental population data within 80 kilometers (50 miles) of the NFS Erwin Plant

Direction	Distance in miles										
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50	Total
N	20	62	106	148	190	1,701	17,947	29,404	14,925	6,723	71,226
NNE	21	64	110	154	199	3,548	39,665	14,348	36,297	7,850	102,256
NE	24	73	121	170	214	1,762	19,153	20,426	29,099	17,695	88,737
ENE	28	85	142	198	238	1,154	6,206	5,404	8,597	12,787	34,839
E	30	91	152	213	206	1,008	3,938	7,510	11,530	30,250	54,928
ESE	28	85	142	195	121	693	2,729	8,818	15,385	23,532	51,728
SE	24	73	121	135	65	455	2,502	8,000	13,188	16,310	40,873
SSE	21	63	106	145	101	439	2,745	4,975	8,313	9,510	26,418
S	20	60	100	141	181	843	2,867	6,165	37,948	37,744	86,069
SSW	21	63	106	148	190	1,512	3,114	8,009	47,196	41,411	101,770
SW	24	73	121	170	218	1,049	2,203	3,048	4,951	13,162	25,019
WSW	28	85	142	198	255	1,713	4,587	7,648	4,912	18,716	38,284
W	30	91	152	213	274	1,573	6,797	11,942	10,414	39,457	70,943
WNW	28	85	142	204	267	1,347	5,236	10,648	13,182	10,726	41,865
NW	24	73	126	178	229	1,649	5,499	10,017	12,246	4,970	35,011
NNW	21	65	111	156	200	1,657	7,389	40,741	23,532	5,257	79,129
Total	392	1,192	2,002	2,769	3,739	22,108	132,587	197,123	291,745	296,140	949,797

a. To convert from miles to kilometers, multiply by 1.609.

Source: CACI Marketing Systems, "1993 Updates/1998 Forecasts Edition: Demographic Sourcebooks on CD-ROM," (Ref. 8) to following the Council on Environmental Quality guidance on environmental justice once it is issued; in the interim, the NMSS Policy & Procedures Letter 1-50 provides interim instructions for handling the topic in NEPA documents.

Demographic data used in this environmental justice evaluation consists of minority breakdown and income levels. For this section, minority is defined as individuals classified by the U.S. Bureau of the Census as of (1) Black, (2) American Indian, (3) Asian, or (4) Hispanic origin (persons of Hispanic origin may be of any race). Low-income is defined as being below the poverty level as defined by the U.S. Bureau of the Census. Currently, the poverty level is considered to be $15,000 per year or less. The guidelines for determining the area of assessment indicate that a 0.56-mile (0.9-km) radius from the center of the site is to be used if the facility is within the city limits, or a 4-mile (6.4-km) radius is to be used if the facility is outside the city limits or in a rural area. NRC guidance (NMSS Policy & Procedures Letter 1-50) indicates that if the site area percentage is greater than the state or county percentage (or the comparison base used) for either minority population or economically stressed households by 20 percentage points or more, the site has an environmental justice potential, and environmental justice will have to be considered in greater detail. For example, if the immediate area surrounding the site is 30% Asian, and the county is 10% Asian, there is a 20 percentage point difference between the two which indicates a higher minority population and, therefore, a potential for environmental justice issues around the site

NFS' facility is located in the City of Erwin, which is in the northeastern portion of the State of Tennessee. The facility is located in Unicoi County, which is bordered by Washington County and Carter County. The facility consists of approximately 65 acres located in a valley in the Appalachian Mountains. The site is bounded to the northwest by CSX railroad line property and the Nolichucky River and to the northeast by Martin Creek. The highest density of residents are to the northeast toward Erwin. The site is located approximately 50 miles northeast of Asheville, North Carolina and about 20 miles south of Johnson City.

Blocks, the smallest census geographic area, are not appropriate for environmental justice studies because there is no income information available at this level. Therefore the next largest geographic level, census block group, was used for this analysis. There were 3 block groups located within the 1 mile area of the NFS site. All are in Unicoi County. The 1990 estimates (no new numbers are available) of median income and racial characteristics for these census blocks in the 1-mile radius of the site are shown in Table 3.7.

Table 3.7 1990 Population and Income estimates by the Bureau of Census based on racial income characteristics

Political Unit	Median Income	Total Person Number	Black	American Indian	Asian	Hispanic	Other
Tennessee	24,807	4,877,185	16.0 %	0.2 %	0.7 %	0.7 %	0 2 %
Unicoi County, TN	20,536	16,791	0 0 %	0.1 %	0 1 %	0 6 %	0 2 %
1-mile radius around NFS site	22,234	2,418	0 0 %	0.1 %	0.0 %	0 5 %	0 0 %

Source: Landview geographic information system software developed by EPA/Census/NOAA

The table indicates that the area around the site does not contain a significantly larger minority population or lower income population than for the rest of the surrounding counties or the entire State of Tennessee. Therefore, based on this information, environmental justice does not appear to be a concern, and no minority population will be disproportionally impacted by the actions proposed for this site.

3.4 Land

As noted in Section 3.1, the NFS Erwin Plant occupies about 26 hectares (65 acres) on the southeastern side of the Nolichucky River (Figure 3.1). The site is generally flat and slopes west toward the Nolichucky River. About 60 percent of the site is used for activities licensed by the NRC. The restricted area covers about 9.7 hectares (24 acres) and includes office, process and laboratory buildings, outdoor storage areas and waste-handling areas (Figure 1.1). The northern Radiological Burial Ground covers about 1.6 hectares (4 acres). The remainder of the site includes woods, brushland, shrub swamp and open fields.

Banner Spring, a natural spring, originates on NFS property, and forms Banner Spring Branch, which flows across the site into Martin Creek. This creek then discharges into the Nolichucky River, about 1.6 kilometer (1 mile) from the site boundary. The adjacent area and historically significant sites are discussed in subsections 3.4.1 and 3.4.2, respectively.

3.4.1 Adjacent Area

The NFS Erwin Plant is located about 0.8 kilometer (0.5 mile) southwest of the Erwin city limits and is immediately northwest of the unincorporated community of Banner Hill. The area adjacent to the NFS Erwin Plant consists primarily of residential, industrial, and commercial areas, with a small amount of agricultural land to the northwest. The site is situated in a mountain valley, as discussed in Section 3.1; developed areas predominate to the northeast and agricultural lands predominate to the northwest. The site is bounded on the east and south by Banner Hill Road and privately owned residences. The housing density is relatively low to the south, since the houses occupy approximately 12,000 to 20,000 m^2 (3 to 5 acre) tracts (Ref. 7). The CSX Railroad right-of-way parallels the site boundary on the west. A light industrial park is located opposite the site on the other side of the railroad. Martin Creek bounds the site on the north, with privately owned, vacant, and low-density residential land on the opposite side (Ref. 7). Land use in Unicoi County is given in Table 3.8.

Table 3.8 Land use in Unicoi County, Tennessee

Land Use	Acreage[a]	Percent
Forest land	44,100	66.3
Grass land	7,822	11.8
Crop land	6,890	10.3
Urban and built-up areas (includes residential and industrial)	6,250	9.4
Other land	1,449	2.2
TOTAL	66,511	100

a. To convert acres to hectares, multiply by 0.407.

Source: Natural Resources Conservation, Erwin, Tennessee, "Unicoi County Land Use," Information sent from Russell Kaiser, Conservationist, to Deborah Raja, Science Applications International Corporation (SAIC), November, 1996 (Ref. 9)

3.4.2 Historic Significance

There are three sites in Unicoi County that are listed on the National Register of Historic Places. Table 3.9 lists these facilities, their location, and the date of listing. The Clarksville Iron Furnace is in the Cherokee National Forest about 9.9 miles (16 kilometers) west of the facility. The Clinchfield Depot is located in the town of Erwin.

Table 3.9 Places In Unicoi County listed on the National Register of Historic Places

Site Name	Location	Date Listed
Clarksville Iron Furnace	Southwest of Erwin off TN 107 in Cherokee National Forest	6/4/73
Carolina, Clinchfield, and Ohio Railway Depot at Erwin	Junction of Nolichucky Avenue and Union Street, Erwin	6/22/93
Tilson Farm: Gunn Farm: Brown Farm	242 Little Branch Road, Flag Pond	6/17/94

Source: Tennessee Historical Commission, "Properties Listed in the National Register by County," information sent from Rebecca Parker, Tennessee Historical Commission, to Deborah Raja, SAIC, November 1, 1996 (Ref. 10).

3.4.3 Floodplains and Wetlands

The northern portion of the NFS Erwin Plant is located within the 100-year floodplain of the Nolichucky River and Martin Creek, according to current Flood Insurance Rate Maps (Ref. 11). However, site development and related activities over the past 30 years have modified the topography so that the site would be protected in the event of a 100-year flood (Ref. 2). For example, a significant flood of the Nolichucky River (92 percent of greatest recorded flow) in 1977 did not result in flooding of buildings on the NFS site (Ref. 2). There are plans to revise the 100-year base flood elevation to reflect the current engineering at the site (Ref. 2).

Based on the review of the National Wetlands Inventory (Ref. 12), no natural wetlands have been mapped in the area, although a site-specific wetlands assessment has not been conducted.

3.5 Geology, Mineral Resources, and Seismicity

The NFS Erwin Plant is located in an elongated valley near the boundary of two physiographic provinces. Both of these physiographic provinces consist of northeast trending ridges of varying lithography separated by valleys covered by residual clays and bouldery wash from adjacent ridges. The subsurface stratigraphy is characterized by an alternating sequence of sedimentary rocks comprised of limestone, dolomite, shale, and sandstone.

3.5.1 Geology and Soils

The bedrock beneath the plant is a section of the Rome Formation. This section contains areas of sandstone, siltstone, shale, dolomite, and limestone, with silty to sandy shale being the dominant rock type. The maximum relief of the bedrock surface is about 20 meters (67 feet) from a point that is north-northeast in the Burial Ground area to a point south near Banner Hill Road. The overall slope of the bedrock surface is from the valley edge (southeast) toward the Nolichucky River (northwest).

The bedrock of the Rome Formation is overlain by unconsolidated alluvial material. Alluvial deposits range in thickness from less than 0.3 meters (1 foot) to approximately 6.4 meters (21 feet) and consist of clay, silt, sand, gravel, and cobbles. The sand and gravel have the greatest permeability and their thickness exceeds 5.5 meters (18 feet) in the area of Martin Creek.

Less permeable silts and clays ranging in thickness from 0.15 to 5.6 meters (0.5 to 18.5 feet) are interbedded with and overlie the sand and gravel deposits. Construction fill materials are widely distributed throughout the facility and consist of clay, silt, sand, and gravel mixtures. Figure 3.2 shows the stratigraphic relationships at the site.

The regional geologic structure of the area is dominated by four major fault systems. All the faults are oriented in a northeast direction. The local geologic structures in the Rome Formation were determined from observations made on the condition of cuttings and cores collected during drilling and on two surface manifestations. The presence of faults or fractures from drilling was determined from strongly oxidized zones in shale and sandstone, from quartz fracture fillings in sandstone, from calcite fracture fillings in limestone, and from pulverized shale. The fluctuation of the water level in Pond 1, which reacts differently than that observed for Ponds 2 and 3, and the observation that Banner Spring is similar to other fault-controlled springs in the area, may be interpreted as indicating fault- or fracture-controlled discharge (Ref. 7). Figure 3.3 shows the bedrock surface expressions of two faults and five fracture zones interpreted from the above information.

The natural soils at the site consist of well-drained loamy and stony soils that can range from gently sloping to steep. The soils are more than 1.5-meters (5-feet) deep over shale or quartzite bedrock on foot slopes, terraces, benches, and fans (Ref. 13).

3.5.2 Mineral Resources

The principal mineral resources in the area are sand and gravel used by the construction industry and metallurgical grade manganese and iron ore (Ref. 2). Sand and gravel were extracted from the bed and floodplain of the Nolichucky River until large operations ceased in the mid-1970s. Manganese is mined from bedrock formations in the area. Iron ore is no longer mined in the area (Ref. 2).

3.5.3 Seismicity

The NFS Erwin Plant is located in the Appalachian Tectonic Belt, an area of moderate seismic risk. The site is in an area classified by the 1994 Uniform Building Code as seismic hazard zone 2, which means moderate damage could occur to the buildings if there were an earthquake.

The number of earthquakes within 80, 160, and 320 kilometers (50, 100, and 200 miles) of the site of Modified Mercalli Intensity (MMI) IV (i.e., felt by nearly everyone), or greater, is given in Table 3.10. Almost 700 earthquakes of intensity greater than MMI IV have occurred within 320 kilometers (200 miles) of the site, since 1774. The earthquake of May 31, 1897, was the largest earthquake (MMI VIII, magnitude 5.8) recorded in an 80-kilometer (50-mile) radius of the site. The most recent earthquake above MMI IV (magnitude 3.9) occurred October 26, 1995, at a distance of about 80 kilometers (50 miles) from the site. A plot of earthquake epicenters within 320 kilometers (200 miles) of the site is shown in Figure 3.4.

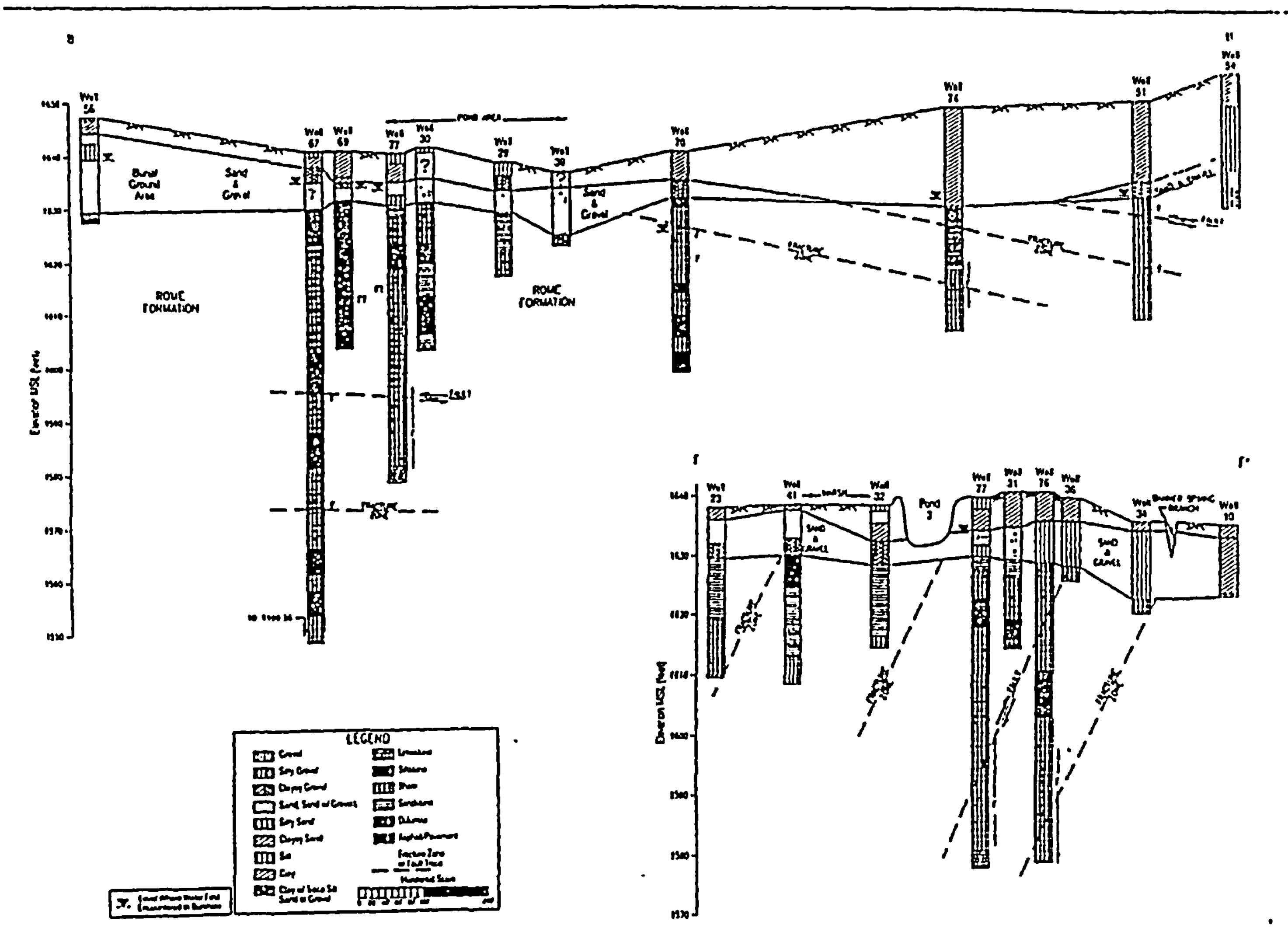

Figure 3.2 Geologic cross sections showing the stratigraphy underlying the NFS Erwin Plant [illegible] 1989 (Ref. 7)] Refer to Figure 3.3 for cross section locations.

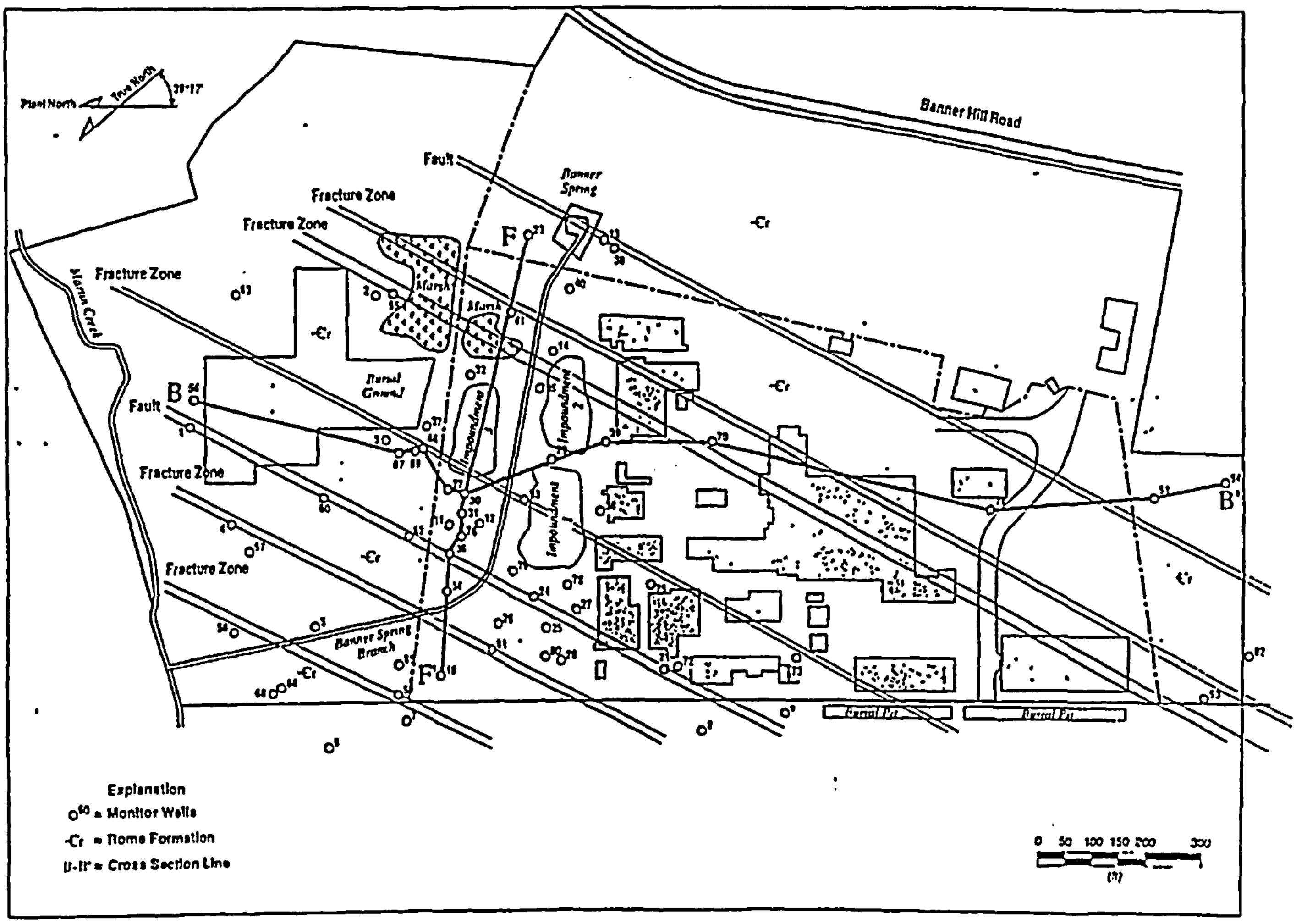

Figure 3.3 Bedrock features underlying the NFS Erwin Plant [modified from Ecotek, 1989 (Ref. 7)]

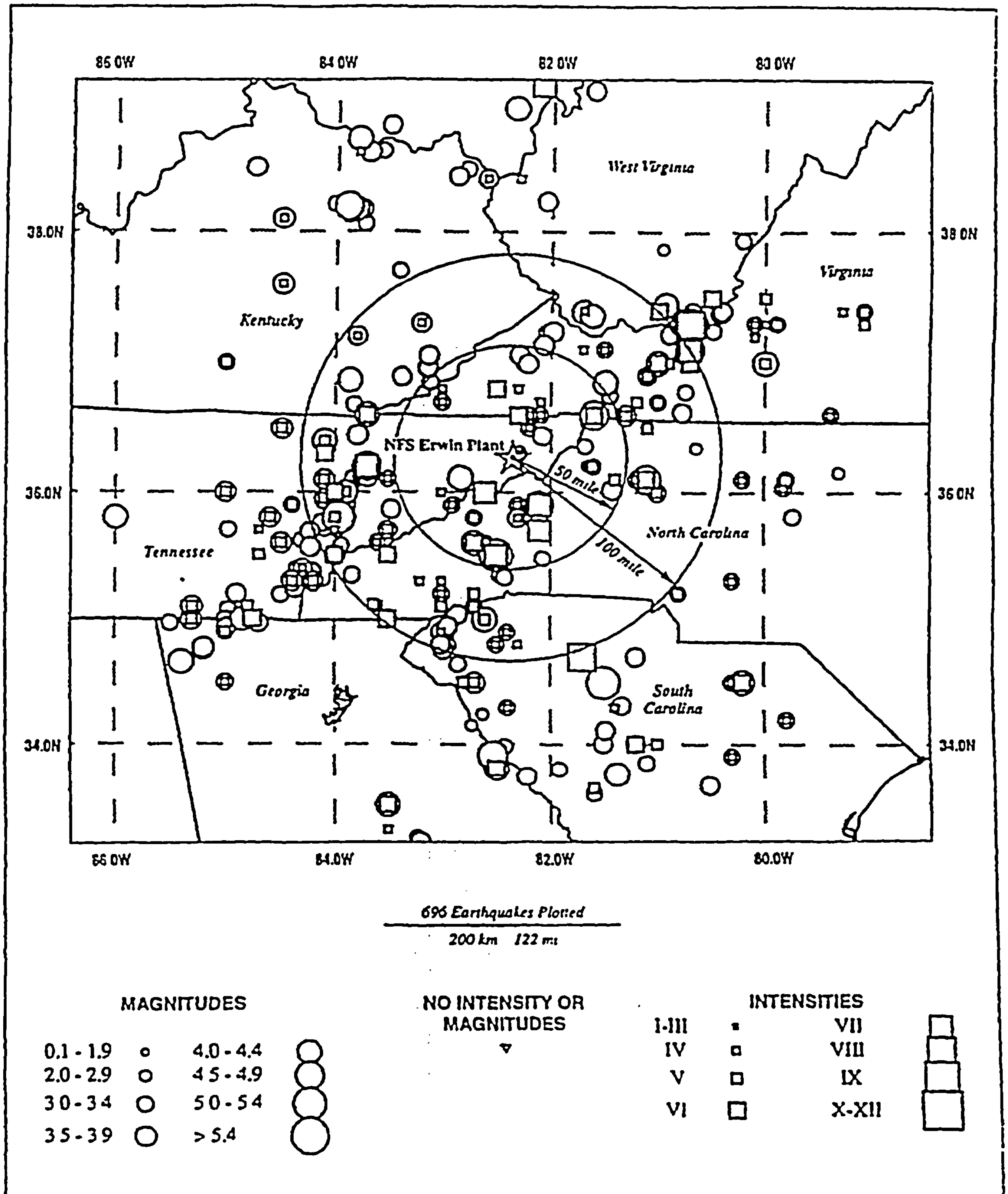

Figure 3.4 Earthquake epicenters located within 320 kilometers (200 miles) of the NFS Erwin Plant [modified from National Geophysical Data Center (Ref. 14)]

Table 3.10 Earthquakes of Modified Mercalli Intensity IV or greater from 1774 - 1996

Radius around site (miles)	Number of earthquakes	Range of magnitudes	Largest earthquake (date, magnitude, intensity)
50	110	3.0 - 5.5	02/21/1916, 5.5, VII
100	385	2.29 - 5.5	02/21/1916, 5.5, VII
200	696	1.9 - 5.8	05/31/1897, 5.8, VIII

a To convert miles to kilometers, multiply by 1.61.

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center, Boulder, Colorado, (Ref. 14).

3.6 Hydrology

3.6.1 Surface Water

The Nolichucky River flows along the western side of the NFS Erwin Plant at an average rate of 38 cubic meters per second (1347 cubic feet per second). The channel of Banner Spring Branch is completely man-made and stream flows have been measured to determine if there are gains or losses in flows between Banner Spring and Martin Creek. Based on 16 stream flow measurements made at four different locations on Banner Spring Branch in May/June 1988, the average flow rate is 0.019 cubic meters per second (302 gallons per minute) (Ref. 7).

Martin Creek flows parallel to the northern property line; the flow rate varies seasonally from 0.063 to 0.32 cubic meters per second (1,000 to 5,000 gallons per minute) (Ref. 15). The nearest public water intake is 13 kilometers (8 miles) downstream from the NFS Erwin Plant.

Two outfalls are used to discharge liquid effluents in accordance with Tennessee Department of *Environment and Conservation National Pollutant Discharge Elimination System Permit No.* TN0002038. Treated liquid effluents from the Waste Water Treatment Facility are discharged offsite into the Nolichucky River via outfall 001, and non-contact cooling water is discharged onsite into Banner Spring Branch. Figure 4.1 shows the outfall locations.

3.6.2 Groundwater

Municipal water supplies are from groundwater. Erwin Utilities uses a combination of wells and springs for its water supply (Ref. 15). Domestic water supplies generally obtain water from the alluvium and shallowest bedrock. Seven public groundwater supply wells exist within an 8-km (5-mile) radius of the site. The nearest withdrawal well, the Railroad Well, is about one-half mile north of the NFS Erwin Plant boundary (Ref. 15). Groundwater modeling for the site predicts that this well is not directly downstream of the site and therefore would not be affected by site operations at NFS (Ref. 15). Erwin Utilities averages daily usage of 7.6 million liters (2 million gallons) per day (Ref. 6). Other groundwater users in Unicoi County consume approximately 11 million liters (3 million gallons) per day (Ref. 16).

A hydrogeologic investigation was performed by NFS to determine soil and rock characteristics, variations in groundwater levels, groundwater occurrence, and groundwater/surface-water relationships (Ref. 7). Approximately 84 active groundwater monitoring wells are completed on and around the NFS site to depths ranging from about 2.7 to 10 meters (9 to 119 feet). Three monitoring zones have been defined at the site to gain a better understanding of groundwater flow at three depths: zone 1 monitors the alluvial materials (unconsolidated aquifer); zone 2 monitors the deep alluvial material and shallow bedrock; and zone 3 refers to wells that monitor intermediate-depth bedrock from 15 to 37 meters (50 to 120 feet) below the land surface. Table 3.11 identifies the wells in each zone.

Table 3.11 Monitoring wells by zone at the NFS Erwin Plant

Zone 1		Zone 2	Zone 3
Well 5	Well 68	Well 30	Well 67
Well 10	Well 72	Well 41	Well 82
Well 24	Well 75	Well 60B	SC-1
Well 25	Well 78	Well 63B	SC-3
Well 26	Well 80	Well 65	SC-4
Well 27	Well 91	Well 67B	
Well 28	Well 92	Well 66	
Well 29	Well 93	Well 71	
Well 31	Well 94	Well 76	
Well 32	Well 95A	Well 77	
Well 33	Well 96A	Well 79	
Well 34	Well 97A	Well 81	
Well 35	Well 98A	Well 100B	
Well 36	Well 99A	Well 107B	
Well 38	Well 100A		
Well 39	Well 101A		
Well 40	Well 102A		
Well 52	Well 103A		
Well 55	Well 104A		
Well 55A	Well 105A		
Well 56	Well 106A		
Well 57	Well 107A		
Well 58	Well LD-1A		
Well 59	Well LD-2A		
Well 60	Well 234-2		
Well 62	Well 234-3		
Well 63	SC-6		
Well 63A	SC-7		
Well 70A	SC-8		
Well 64			

Source: Geraghty & Miller, Inc., "Final Project Report Groundwater Flow and Constituent Modeling at the Nuclear Fuel Services Facility," Erwin, Tennessee, April 25, 1996 (Ref. 15).

The shallow groundwater occurs in the unconsolidated alluvial materials (unconsolidated aquifer) overlying bedrock. Primary recharge to this aquifer is from rainfall infiltration from the ground surface and upward seepage from the underlying bedrock. A secondary local source of groundwater recharge is seepage from the floors of ponds, marshes, and streambeds (Ref. 7). The thicknesses of the alluvial materials in the unconsolidated deposits range from about 1.5 to 5.8 meters (5 to 19 feet) across the facility. The sand and gravel thicknesses range from about 0.3 to 5.2 meters (1 to 17 feet) within the unconsolidated deposits, with the maximum thickness located along the northern edge of the burial ground near Martin Creek. The saturated thickness of this unit ranges up to 4 meters (13 feet) in the vicinity of the burial ground (Ref. 7). The depth to water ranges from about 2.7 to 4.3 meters (9 to 14 feet). A groundwater contour map for zone 1 is shown in Figure 3.5. The influence of the ponds in recharging the water table can be seen from this map by the radial contours in the vicinity of the ponds.

The overall direction of groundwater flow is toward the western plant boundary, toward the river. Groundwater flow to the northwest is influenced by the topography that slopes to the northwest

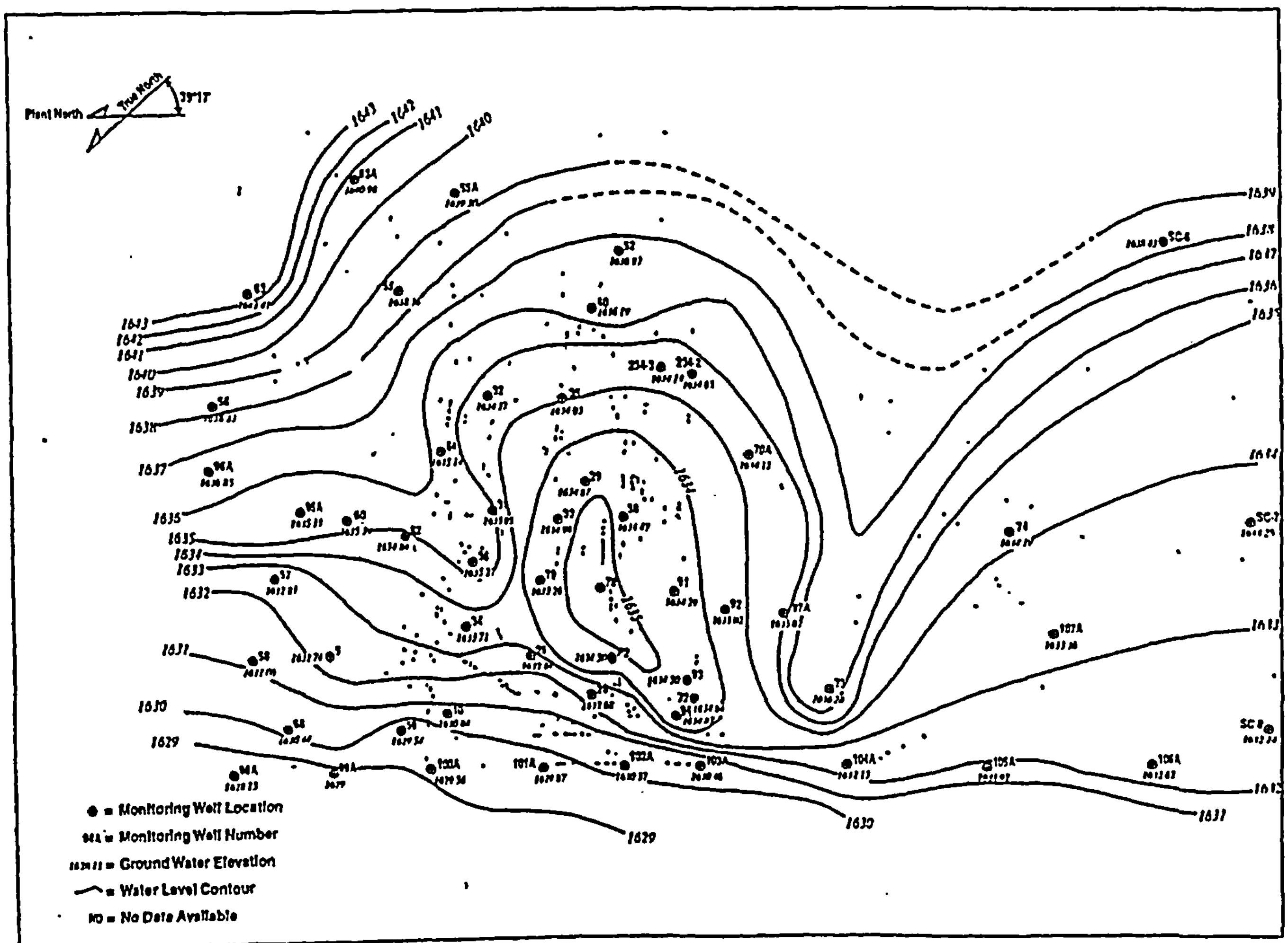

Figure 3.5 Groundwater monitoring and direction of groundwater flow in the shallow aquifer [modified from Gerahty & Miller, (Ref. 15)]

and by localized recharge to the overlying alluvial layer at upgradient locations along the valley wall. The overall slope of the water table is disrupted by Banner Spring Branch, near Ponds 1-3, and beneath the central portion of the plant (Ref. 7). The hydraulic gradient of the water table ranges from 0.007 to 0.06, with an average gradient of 0.015 in the area of the ponds and the facility. The vertical hydraulic gradient has been determined from water levels measured in clustered wells completed in different zones. Based on these data, a transition from downward to upward hydraulic gradient occurs at a depth of 12 to 15 meters (40 to 50 feet) beneath most of the facility (Ref. 7).

The deep groundwater system is in the Rome Formation. The uppermost 3 meters (10 feet) of the Rome aquifer has been defined as belonging to the alluvial (unconsolidated) aquifer, based on physical and hydraulic conditions. Where the surface of the Rome Formation is in direct contact with the alluvial aquifer, water table conditions may prevail. Recharge to the Rome aquifer is primarily from subsurface flow of water from adjacent hill slopes via fractures; a secondary recharge source is downward infiltration from the overlying alluvial (unconsolidated aquifer), as indicated from pump tests conducted at the site. The occurrence and yield of groundwater from the Rome aquifer is primarily a function of fracture occurrence. Yields from wells completed in the Rome aquifer have varied from 0.32 liters per second (5 gallons per minute) (well 30) up to 19 liters per second (300 gallons per minute) (well 67), when a well has intersected a water-bearing fracture.

3.7 Biota

3.7.1 Terrestrial

Plant communities in Unicoi County in the site vicinity are characteristic of the intermountain regions of central and southern Appalachia. Major forest types include oak-hickory, oak-pine, and white pine. Near the NFS Erwin Plant, the natural vegetation is a forest community dominated by red oak, white oak, yellow poplar, hickory, other oaks, and some pine. Plant communities consist of second-growth forests and open grassy areas (Ref. 3). No site-specific plant surveys have been conducted and most of the site is covered by plant facilities. However, a limited area of the site consists of woods, shrub, swamp, and brush.

The nearby mountainous areas are largely undisturbed and support extensive forest and wildlife resources. Common wildlife in the site vicinity include the European starling, northern cardinal, mourning dove, Carolina chickadee, opossum, and eastern cottontail house mouse. Important game species of the region include the whitetail deer, eastern gray squirrel, ruffed grouse, and wild turkey.

3.7.2 Aquatic

The Nolichucky River in the vicinity of Erwin contains a substrate of rocks, sand, boulders, and aquatic moss. This habitat supports smallmouth bass, olive darters, catfish, largemouth and spotted bass, central stonerollers, and white crapple.

3.7.3 Threatened and Endangered Species

The U.S. Fish and Wildlife Service has identified three protected animal species -- the peregrine falcon, Appalachian elktoe, and osprey -- in Unicoi County, as summarized in Table 3.12. The

Table 3.12 Threatened and endangered species in Unicoi County

Common Name	Scientific Name	Status
Animals:		
Peregrine falcon	*Falco peregrinus*	Endangered (F, S)
Appalachian elktoe	*Alasmidonta raveneliana*	Endangered (F, S)
Osprey	*Pandion Haliaetus*	Threatened (S)
Plants:		
Virginia spiraea	*Spiraea virginiana*	Threatened (F) Endangered (S)
Climbing fumitory	*Adlumia fungosa*	Threatened (S)
White heath aster	*Aster ericoides*	Threatened (S)
Piratebush	*Buckleya distichophylla*	Threatened (S)
Mountain bittercress	*Cardamine clematitus*	Threatened (S)
Round-leaf watercress	*Cardamine rotundifolia*	Threatened (S)
Wretched sedge	*Carex misera*	Threatened (S)
Roan mountain sedge	*Carex roanensis*	Endangered (S)
Giant blue cohosh	*Caulophyllum giganteum*	Threatened (S)
Long-bracted green orchis	*Coeloglossum viride var virescens*	Endangered (S)
Spotted coralroot	*Corallorhiza maculata*	Threatened (S)
Fraser's sedge	*Cymophyllus fraserianus*	Threatened (S)
Pink lady's-slipper	*Cypripedium acaule*	Endangered (S)
Mountain bush-honeysuckle	*Diervilla sessilifolia var rivulari*	Threatened (S)
Spinulose shield fern	*Dryopteris carthusiana*	Threatened (S)
Appalachian gentian	*Gentiana austromontana*	Threatened (S)
White-leaved sunflower	*Helianthus glaucophyllus*	Threatened (S)
John's cabbage	*Hydrophyllum virginianum*	Threatened (S)
Mountain St. John's-wort	*Hypericum graveolens*	Threatened (S)
Blue Ridge St. John's-wort	*Hypericum mitchellianum*	Threatened (S)
Naked-fruited rush	*Juncus gymnocarpus*	Threatened (S)
Kidney-leaf twayblade	*Listera smallii*	Threatened (S)
Swamp loosestrife	*Lysimachia terrestris*	Endangered (S)
American ginseng	*Panax quinquefolius*	Threatened (S)
Silverling	*Paronychia argrocoma*	Threatened (S)
Large round-leaved orchid	*Platanthera orbiculata*	Endangered (S)
Small purple fringed orchid	*Platanthera psycodes*	Threatened (S)
Fringed black bindweed	*Polygonum cilinode*	Threatened (S)
Mountain rattlesnake-root	*Prenanthes roanensis*	Threatened (S)

Table 3.12 Threatened and endangered species in Unicoi County cont.

Common Name	Scientific Name[a]	Status
Plants:		
Rock skullcap	*Scutellaria saxatilis*	Threatened (S)
Robbins' ragwort	*Senecio schweinitzianus*	Threatened (S)
Ovate catchfly	*Silene ovata*	Threatened (S)
Clingman's hedge-nettle	*Stachys clingmanii*	Threatened (S)
Southern nodding trillium	*Trillium rugelii*	Endangered (S)

(F) = Federal status.
(S) = State status.

Source: State of Tennessee Department of Environment and Conservation, "List of Rare and Endangered Species by Tennessee County," fax from William M. Christie, Division of Natural Heritage, to Deborah Raja, SAIC, November 25, 1996 (Ref. 18).

osprey is protected under State laws. Of these threatened and endangered animals, none are known to occur at the NFS site (Ref. 2). There are 34 plant species, in Unicoi County, that the State of Tennessee considers threatened or endangered. The Virginia spiraea (*Spiraea virginiana*) is Federally listed as threatened, but the State of Tennessee considers it endangered. Although a detailed site-specific survey of plants onsite has not been performed, NFS' 1996 Environmental Report stated that no Federally threatened or endangered species are known to occur onsite.

3.8 Background Radiological Characteristics

Naturally occurring background radiation in the Erwin area is from cosmic and terrestrial sources. These sources produce both external and internal doses, as described below. The data are derived from National Council on Radiation Protection and Measurement reports for the U.S. and Canada (Ref. 17).

3.8.1 External Background Radiation

Particles entering the atmosphere from space interact with the atmospheric gases, producing gamma- and X-radiation. Radionuclides in the earth also decay, producing gamma- and X-radiation (terrestrial sources). The total body doses from cosmic and terrestrial sources are approximately 2.6×10^{-4} and 2.8×10^{-4} Sv/yr (26 and 28 mrem/yr), respectively.

3.8.2 Internal Radiation

Cosmic radiation interacts with gases in the upper atmosphere to produce radionuclides, primarily carbon-14, which contribute to internal doses. Radionuclides in soil are also incorporated into the body, introducing a second source of internal radiation. The total body doses from cosmic and terrestrial sources are 1.0×10^{-5} and 4.0×10^{-4} Sv/yr (1.0 and 40.0 mrem/yr), respectively. Radon is an additional highly variable terrestrial source. Average dose rates of 2.4×10^{-2} Sv/yr (2.4 rem/yr) to the bronchial epithelium, or about 3.0×10^{-3} Sv/yr (300 mrem/yr) effective may occur (Ref. 17).

3.9 Nature and Extent of Contamination

Operations at the NFS Erwin Plant have resulted in radiological and nonradiological contamination of the environment. Characterization data are available from Resource Conservation and Recovery Act (RCRA) investigations, from routine monitoring programs, and from radiological surveys of waste disposal areas. In accordance with the Hazardous and Solid Waste Amendment permit issued to NFS by EPA in 1993, NFS has been conducting RCRA Facility Investigations (RFIs) to define the nature and extent of releases from solid-waste-management units (SWMUs) and areas of concern (AOCs) at the site. The SWMUs and AOCs that EPA is investigating under RCRA are summarized in Table 3.13 and shown in Figure 3.6. In addition, data is available from characterization of the northern portion of the site which was performed to satisfy Condition 1 of the Confirmatory Order Modifying License (Docket 70-143, License SNM-124) issued by the NRC to NFS dated June 23, 1994. This characterization effort was conducted from 1995 through 1997, and the results were submitted to the NRC in November 1997 (Ref. 30).

NFS began to partially remediate specific areas where radioactive wastes were known to exist in 1991. These actions have been referred to as "Interim Measures," with the goal being to remove sources of contamination from the environment. Table 3.14 summarizes interim measures that have been conducted to date. The following section describes the nature and extent of contamination which has been identified at the site. NFS' plans to remediate areas of contamination are discussed in Section 5.

3.9.1 Soil Contamination

Soil sampling was conducted for the North Site area, to determine the nature and extent of radiological contamination at the site (Ref. 30). The background radiological concentration in soil was determined by sampling from one onsite and two offsite reference areas. Samples collected from the NFS Training Center were chosen to be representative of background at the site. Table 3.15 summarizes radionuclide concentrations in background soil samples. Release criteria for soils in the North Site area were proposed for determining radiological cleanup levels, as summarized in Table 3.16. These radiological cleanup criteria are currently under review by NRC and will be considered as part of a separate licensing action from renewal.

Table 3.13 Summary of U.S. Environmental Protection Agency AOCs and SWMUs

AOC No.	SWMU No.	Location	Potentially Affected Media
1		Plant scrubbers	[b]
2		Building 111 boiler blowdown and backwash water	Soil
3		Building 130 cooling tower	Soil, surface water
4		Storm sewer system	Soil, surface water, groundwater
5		Banner Spring Branch present channel[a]	[b]
	1	Ponds 1, 2, and 3[a]	Air, soil, surface water, groundwater
	2	Pond 4[a]	Soil, surface water, groundwater
	3	Building 110 underground storage tank[a]	Soil, groundwater
	4	Yard incinerator	Air, soil, surface water
	5	Deleted before EPA permit issued	
	6	Abandoned Banner Spring Branch Channel[a]	Soil, groundwater
	7	CSX soil stockpile[a]	Soil, surface water
	8	Soil excavation site on CSX property	Groundwater
	9	Radioactive waste burial ground[a]	Soil, groundwater
	10	Demolition landfill[a]	Soil, groundwater
	11	Burial trenches on CSX property	Groundwater
	12	Building 130 warehouse	[c]
	13	Building 111 bulk chemical storage area	Soil, surface water, groundwater
	14	Well 72 (LNAPL Plume)	Groundwater
	15	Wastewater treatment facility	[b]
	16	Radioactive waste incinerator	Air, soil
	17	Scrap recovery calcine furnace	[b]
	18	Building 105 underground storage tank	Soil, groundwater
	19	Building 100 underground storage tank	[b]
	20	Building 130 scale pit (new SWMU)	

a. The facility or area is part of the North Site decommissioning.
b. The AOC or SWMU has no known unregulated releases.
c. The facility is regulated by the State RCRA permit.

Source W E Cline, U S Nuclear Regulatory Commission, NRC Inspection Report No. 70-143/94-02, to D. Ferguson, Nuclear Fuel Services, Inc., March 18, 1994 (Ref. 19) and Nuclear Fuel Services, Inc., Appendix A, Solid Waste Management Unit Summary, undated (Ref. 20).

Figure 3.6 Redacted

Table 3.14 Summary of Interim measures

Activity	Date	Reference
Former stream bed of Banner Spring Branch released for unrestricted use	1987	(Ref. 22)
Ponds 1, 2, and 3 partial remediation to remove the source term	1993-1994	(Ref. 23)
Pond 4 Area, SWMUs 2, 4, 6	1994-1996	(Ref. 24)
Excavation of contaminated soil stockpile (SWMU 7)[a]	1996-1997	
Excavation of North Site Burial Ground (SWMU 9)	1997-1999	License Amendment 33 to License No. SNM-124 (Ref 25)

a. SWMU - Solid Waste Management Unit

Source: *Nuclear Fuel Services, Inc., "North Site Characterization Reports" in North Site Decommissioning Plan*, Erwin, Tennessee, November 1997 (Ref. 21).

Table 3.15 Radionuclide concentrations in background soil samples from the NFS training center

Parameter	Average (pCi/g)	95% UCL (pCi/g)
Am-241	0	≈ 0
Pu-238	0	0
Pu-239/240	0	0
Pu-241	0	0
Pu-242	0	0
Tc-99	0	0
Th-230	1.82	2.13
Th-232	1.58	1.66
U-234	1.35	1.47
U-235	0.078	0.086
U-238	1.36	1.45

Source. Nuclear Fuel Services, Inc., "North Site Characterization Report" and Appendix K in *North Site Decommissioning Plan*, Erwin, Tennessee, November, 1997 (Ref. 21).

Table 3.16 Proposed North Site decommissioning criteria for soil/sediment

Radionuclide/ Constituent	Concentration Guideline Level (pCi/g)[a]	Justification
Total Uranium (U-234+235+238)	250	BTP[b] Disposal Option 2 (Ref. 26)
Natural Thorium (Th-228+232)	10	BTP Disposal Option 1 (Ref. 26)
Pu-238	25	NRC Policy/Guidance Directive FC-83-23 (Ref. 27)
Pu-239+240	25	
Pu-242	25	
Am-241	30	
Th-230	5	Site modeling (resident farmer) with 15 mrem/year dose limit (Ref. 28)
Tc-99	100	
Pu-241	1,000	

a. Includes ingrowth of daughter radionuclides.
b. BTP = Branch Technical Position

Source: Nuclear Fuel Services, Inc., "North Site Characterization Report" in *North Site Decommissioning Plan*, Erwin, Tennessee, November 1997 (Ref. 21)

3.9.1.1 Radiological Contamination in Soil

Soil sampling identified uranium and thorium isotopes as the primary radiological contaminants (Ref. 21). Soil contamination above the release limits identified in Table 3.16 is primarily associated with Ponds 1, 2, 3, and 4; and along Banner Spring Branch. Most of the total uranium soil contamination is at the surface and from 0.3 to 1.2 meters (1 to 4 feet) below the surface (Ref. 19). At depths greater than 1.2 meters (4 feet), total uranium contamination is primarily associated with Banner Spring Branch and Pond 4. Thorium-232 (^{232}Th) contamination above the proposed release criteria (10 pCi/g) occurs at the surface down to a depth of about 1.2 meters (4 feet) at Ponds 1, 2, and 3; Pond 4; and the North Site Radiological Burial Ground. At depths greater than 1.2 meters (4 feet), ^{232}Th contamination is associated with Pond 4; isolated occurrences along the edges of Ponds 1, 2, and 3; and along Banner Spring Branch. At depths greater than 2.1 meters (7 feet), ^{232}Th contamination was detected in the Pond 4 area and at isolated occurrences along Banner Spring Branch. The distribution of thorium-230 (^{230}Th) soil contamination parallels that of ^{232}Th.

Total plutonium surface contamination is associated with Pond 1, a portion of Pond 2, Pond 4, an area within the North Site Radiological Burial Ground, the northwestern portion of the restricted area, and along Banner Spring Branch. At depths of 0.3 to 1.2 meters (1 to 4 feet), total plutonium contamination above the proposed release criteria is associated with Pond 4, the northwestern portion of the restricted area, and there are isolated occurrences along Banner Spring Branch. At depths between 1.2 and 2.1 meters (4 and 7 feet) and greater than 2.1 meters (7 feet), total plutonium contamination is associated with the Pond 4 area and an area parallel to Banner Spring Branch along the reach that intersects Martin Creek. Soil contamination by technetium-99 (^{99}Tc) above the proposed release criteria is primarily associated with the Pond 4 area between the depths of 0.3 to 1.2 meters (1 to 4 feet). From 1.2 to 2.1 meters (4 to 7 feet), there are isolated occurrences of ^{99}Tc above the proposed release criteria in the Pond 4 area.

3.9.1.2 Nonradiological Contamination in Soil

Nonradiological constituents, including antimony, arsenic, beryllium, lead, and mercury, were identified in soil at or above RCRA site-specific action levels in the North Site area (Ref. 30). Beryllium and lead have been detected in sediment samples from the North Site. The extent of this contamination is discussed below.

Arsenic soil contamination was detected in the vicinity of Pond 4, Building 110, in soil associated with Pond 4 waste materials, and along the inner northwest perimeter fence. Beryllium was detected in sediment samples from Banner Spring Branch between Ponds 2 and 3, and has been detected in soil samples from the surface to an approximate depth of 2.1 meters (7 feet) in the vicinity of Ponds 1, 2, 3, and Banner Spring Branch. In the vicinity of Pond 4, beryllium contamination extends from the surface to depths of 1.5 to 2.4 meters (5 to 8 feet) but was detected to a depth of 3.8 meters (12.7 feet) at one location (Ref. 21). Mercury soil contamination is primarily located in the vicinity of Ponds 1, 2, and 3 and along Banner Spring Branch and has been detected to depths of 2.1 meters (7 feet) adjacent to Banner Spring Branch in the vicinity of Pond 2 (Ref. 21). Antimony concentrations above the action level have been limited to the surface [i.e., to a depth of 15.24 centimeters (6 inches)] in the vicinity of Pond 3 and Banner Spring Branch. Lead has been detected at isolated occurrences above the action level to a depth of approximately 0.6 meters (2 feet) (Ref. 21). Polycyclic aromatic hydrocarbon contamination above the site-specific action levels has been primarily limited to surface soil inside the protected area and to sediment in Banner Spring Branch.

3.9.2 Surface Water Contamination

No radiological contaminants in surface water have been detected above the effluent concentration limits in 10 CFR Part 20 (Ref. 21). However, chemical constituents were detected in surface water samples above the Tennessee Water Quality Criteria, above site-specific action levels as defined by NFS, or EPA drinking water maximum contaminant levels. In downstream locations on Banner Spring Branch, total cyanide, nitrate/nitrite, copper, and zinc were detected at elevated concentrations. However, only one water sample contained nitrate/nitrite levels above site-specific criteria, and is considered by NFS to be an anomaly, possibly due to inappropriate preservation of the sample with nitric acid. In Martin Creek surface water, mercury was detected above the Tennessee Water Quality Criteria in upgradient rather than downgradient samples (Ref. 21).

3.9.3 Groundwater Contamination

As part of ongoing site characterization efforts, groundwater quality has been evaluated in the alluvial and bedrock aquifer, and the results are discussed in subsections 3.9.3.1 and 3.9.3.2, respectively. Table 3.16 summarizes the radiological and nonradiological parameters that are monitored in groundwater at different areas on the site. Groundwater monitoring for nonradiological constituents is conducted in accordance with EPA requirements.

The background radioactivity in wells that monitor the alluvial aquifer was determined by reviewing available data (1996-1997) for well 52 (see Figure 4.3 for well location). The gross alpha and gross beta activities at this location were about 2 pCi/l and 15 pCi/l, respectively.

The contamination criteria (i.e., preliminary guideline values) used for groundwater contamination in the North Site Decommissioning Plan are shown in Table 3.17, based on proposed revisions to EPA drinking water standards (40 CFR Part 141).

Table 3.17 Site area groundwater monitoring

Site Area Monitored/ Purpose[a]	Groundwater Monitoring Wells[a,b]	Radiological Constituents Monitored	Nonradiological Constituents Monitored
Main site area[c]			
Maintenance Shop Area/ Scale Pit	Zone 1: 93, 108A, 109A, 110A, 111A, 112A, 113A, 114A, 115A Zone 2: 114B	gross alpha, gross beta, U-233, U-234, U-235, U-238, Pu-238, Pu-239, Pu-242, Th-228, Th-230, Th-232, Tc-99	PCE, TCE, 1,2-DCE, vinyl chloride, 1,2-DCA, TBP, BEHP, Sb, Pb, Hg, F, nitrates, sulfates, PCBs
Leak detection for USTs (between Buildings 104 & 105)	Zone 1: LD-1A, LD-2A, 70A, 97A	gross alpha, gross beta, U-233, U-234, U-235, U-238, Pu-238, Pu-239, Pu-242, Th-228, Th-230, Th-232, Tc-99	Pb, F, nitrates
Building 234	Zone 1: 234-2, 234-3	gross alpha, gross beta, U-233, U-234, U-235, U-238, Pu-238, Pu-239, Pu-242, Th-228, Th-230, Th-232, Tc-99, Am-241	PCE, TCE, 1,2-DCE, vinyl chloride, TBP, Hg, F, nitrates, sulfates
North site decommissioning	Zone 1: 52	gross alpha, gross beta, U-233, U-234, U-235, U-238, Pu-238, Pu-239, Pu-242, Th-228, Th-230, Th-232, natural Th, Tc-99	PCE, TCE, 1,2-DCE, vinyl chloride, 1,2-DCA, TBP, BEHP, Sb, Pb, Hg, TPH, F, nitrates, sulfates, PCBs
	Zone 1: 63A Zone 2: 63B	Th-232, total Th, Tc-99	PCE, TCE, 1,2-DCE, vinyl chloride, 1,2-DCA, TBP, BEHP, Sb, Pb, Hg, TPH, F, nitrates, sulfates, PCBs
	Zone 1: 98A, 99A, 100A, 101A Zone 2: 100B	gross alpha, gross beta, U-233, U-234, U-235, U-238, Pu-238, Pu-239, Pu-242, Th-228, Th-230, Th-232	PCE, TCE, 1,2-DCE, vinyl chloride, 1,2-DCA, TBP, BEHP, Sb, Pb, Hg, TPH, F, nitrates, sulfates, PCBs
Burial ground	Zone 1: 64	gross alpha, gross beta, U-233, U-234, U-235, U-238, Pu-238, Pu-239, Pu-242, Th-228, Th-230, Th-232, natural Th, Tc-99 Th-232, total Th, Tc-99	PCE, TCE, 1,2-DCE, vinyl chloride, 1,2-DCA, TBP, BEHP, Sb, Pb, Hg, TPH, F, nitrates, sulfates, PCBs
	Zone 1: 55, 57, 60, 63, 95A Zone 2: 60B, 67B Zone 3: 67		PCE, TCE, 1,2-DCE, vinyl chloride, 1,2-DCA, TBP, BEHP, Sb, Pb, Hg, TPH, F, nitrates, sulfates, PCBs

Table 3.17 Site area groundwater monitoring (continued)

Site Area Monitored/ Purpose*	Groundwater Monitoring Wells[a,b]		Radiological Constituents Monitored	Nonradiological Constituents Monitored
Site boundary.			gross alpha, gross beta, U-233, U-234, U-235, U-238, Pu-238, Pu-239, Pu-242, Th-228, Th-230, Th-232	PCE, TCE, 1,2-DCE, vinyl chloride, 1,2-DCA, TBP, BEHP, Sb, Pb, Hg, TPH, F, nitrates, sulfates, PCBs
Near ponds	Zone 1:	102A, 103A		
Southwest burial trenches	Zone 1: Zone 2.	104A, 105A, 106A 107B		
Off site	Zone 1:	116A, 117A, 118A, 119A, 120A	U-233, U-234, U-235, U-238, Tc-99	Unknown
	Zone 2:	116B, 117B, 118B, 120B		

a. Refer to Figure 4 3 for locations of site areas and groundwater monitoring wells
b. Refer to Section 3 6 2 for a description of groundwater in zones 1, 2, and 3.

*BEHP = bis (2-ethyl hexyl) phthalate
DCA = dichloroethane
DCE = dichloroethylene
PCB = polychlorinated biphenyls
PCE = tetrachloroethylene
TBP = tributyl phosphate
TCE = trichloroethylene
TPH = total petroleum hydrocarbons

Source: Astwood, H., U.S. Nuclear Regulatory Commission, letter to P B. Swain, SAIC, June 30, 1998 (Ref. 29). Constituents monitored, compiled from information in the North Site Decommissioning Plan (Ref. 21).

Radiological contaminants of concern were identified by comparing average concentrations of radiological constituents in monitoring wells to the preliminary guideline values in Table 3.17. If the highest average contaminant concentration exceeded 10 percent of the preliminary guideline value, then the radiological constituent was classified as a radiological contaminant of concern (Ref. 21). The radiological constituent present at average concentrations greater than 10 percent of the preliminary guideline values is uranium (Ref. 21).

3.9.3.1 Contamination in the Alluvial Aquifer

As shown in Table 3.11, 56 groundwater wells monitor the alluvial aquifer (Zone 1). Four areas of uranium contamination in the alluvial aquifer have been identified: the northern part of the Burial Ground; underlying and downgradient of Ponds 1, 2, 3, and 4; near Building 234; and in the vicinity of Buildings 120, 130, and 131 (Ref. 21). Figure 3.7 shows uranium activity in the alluvial aquifer. Table 3.18 summarizes the uranium contamination in these areas.

Table 3.18 Contaminants of potential concern in groundwater and preliminary guideline values

Parent Radionuclides[a]	Preliminary Guideline Value (pCi/L)
Total U (U-234+235+238)	20 µg/L (~30 pCi/L, natural U)
U-234	see total U
U-235	see total U
U-238	see total U
Pu-238	7.15
Pu-239/240	64.9
Pu-241	62.6
Pu-242	68 3
Am-241	6 45
Tc-99	3790
Th-230	82.7
Th-232	91.8

a For alpha emitters (other than uranium which is based on chemical toxicity), the preliminary guideline value is the concentration that, if ingested at a rate of 2 liters/day for 70 years, results in a lifetime cancer mortality risk of 10^{-4}. For Beta emitters (other than Ra-228), the preliminary guideline value is the concentration which, if ingested at rate of 2 liters/day, results in an effective dose equivalent of 4 mrem/year (based on FR Vol 56, No. 138, p. 33120-21).

Source. Nuclear Fuel Services, Inc., "North Site Characterization Report" in *North Site Decommissioning Plan*, Erwin, Tennessee, November 1997 (Ref. 21).

Table 3.19 *Areas of radiological contamination in groundwater*

Aquifer	Area	Wells Contaminated[a]	Uranium Activity (pCi/L)
Alluvial			
	Burial Ground	96A, 60, 95A	73.4 - 596.3
	Ponds 1, 2, 3, and 4	31, 33, 26, 80, 28, 35, 27, 78, 33, 29, 39, 38	59.3 - 3556 6
	Building 130, 120, 131	109A, 108A, 72, 111A	56 3 - 1099.5
	Building 234	234-2, 234-3	117.2 - 890 4
Bedrock			
	Burial Ground	60B	403 5
	Ponds 1, 3, and 4	*30, 76, 79, 81*	*80 5 - 512.3*

a. Refer to Figure 4 3 for groundwater well locations.

Source: Nuclear Fuel Services, Inc., "North Site Characterization Report" in *North Site Decommissioning Plan*, Erwin, Tennessee, November 1997 (Ref. 21).

Nonradiological constituents have also been detected in groundwater at concentrations above EPA maximum contaminant levels. Concentrations of tetrachloroethylene, trichloroethylene, 1,2-dichloroethylene, vinyl chloride, tributyl phosphate, and bis (2-ethylhexyl) phthalate in groundwater exceed the EPA maximum contaminant levels for drinking water. Aroclor-1254 was the only PCB detected in groundwater above drinking water standards. Metals detected above the drinking water standard include antimony, lead, and mercury (Ref. 19). Total petroleum hydrocarbons, fluoride, nitrates, and sulfates were also above the EPA drinking-water standards.

3.9.3.2 Contamination in the Bedrock Aquifer

As shown in Table 3.11, 14 wells monitor groundwater quality in the bedrock aquifer (zone 2). Isolated occurrences of uranium contamination were detected in the Burial Ground (well 60B) and associated with Ponds 1, 3, and 4 (Table 3.17). Figure 3.8 shows the uranium activity in the bedrock wells. The bedrock aquifer is also contaminated by nonradiological constituents above EPA drinking-water standards, that include tetrachloroethylene, trichloroethylene, 1, 2-dichloroethylene, vinyl chloride, tributyl phosphate, mercury, fluoride, and nitrate (well 79) (Ref. 19).

Figure 3.7 Redacted

Figure 3.8 Redacted

3.10 References for Section 3

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19. Cline, W.E., U.S. Nuclear Regulatory Commission, letter to D. Ferguson, Nuclear Fuel Services, Inc., "NRC Inspection Report No. 70-143/94-02," March 18, 1994.

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4. EFFLUENT AND ENVIRONMENTAL MONITORING PROGRAM

The Nuclear Fuel Services (NFS) Erwin Plant conducts effluent and environmental monitoring programs to establish a basis for evaluating potential public health impacts and to comply with the U.S. Nuclear Regulatory Commission (NRC) effluent and environmental monitoring requirements. Gaseous, liquid, and solid waste streams that are produced during operations are monitored as part of the effluent monitoring program; air, surface water, sediment, soil, groundwater, and vegetation are monitored as part of the environmental monitoring program. This section describes NFS' commitments for effluent and environmental monitoring and briefly discusses historical monitoring data.

4.1 Effluent Monitoring

Gaseous, liquid, and solid effluent streams containing radioactive material are generated at the plant. The effluent monitoring program for radioactive material is summarized in Table 4.1, which presents the sampling frequency, the minimum detectable concentration, action levels, and the required actions if an action level is exceeded. Each of these effluent streams is monitored at or just before the point of release.

Gaseous and liquid effluents are also monitored for nonradiological constituents. Nonradiological constituents in gaseous effluents are monitored in accordance with State air-discharge permits. Liquid effluents discharged to surface waters are monitored for nonradiological constituents in accordance with an National Pollutant Discharge Elimination System (NPDES) permit. Liquid effluents discharged to the sanitary sewer are monitored for both radiological and nonradiological constituents in accordance with a pre-treatment permit from Erwin Utilities Publicly Owned Treatment Works (POTW).

4.1.1 Gaseous Effluent Monitoring

Gaseous effluents released from the NFS Erwin Plant contain both radiological and nonradiological constituents, as described in Section 2.1.4.1. Gaseous effluents from the Building [redacted] and [redacted] complexes are combined, treated using scrubbers and HEPA filtration, and discharged to the atmosphere through the main stack (stack no. 416). Several other stacks and building vents are used to discharge gaseous effluents from various buildings at the site (see Table 2.2). The stack locations are shown in Figure 2.3.

Each stack has a particulate filter and sample pump that continuously operates during facility operation. Particulate filters are collected daily from active processing areas and weekly from decommissioning and inactive processing areas. Samples are analyzed for both gross alpha and gross beta activity as indicated in Table 4.1. If action levels are exceeded, NFS has committed to notifying the environmental protection function manager and the responsible process engineering control personnel; investigating to identify the cause of the exceedance, and initiating the appropriate corrective action(s) to reduce release concentrations and to minimize likelihood of a recurrence. Corrective actions will also be documented (Ref. 1).

Table 4.1 Effluent monitoring programs at the NFS Erwin Plant

Effluent	Sample Type/ Collection Frequency	Radionuclide Minimum Detectable Concentration	Radionuclide Action Level	Required Action
Gaseous Effluent:				
Main Processing Stack	Continuous/ Daily[a]	gross alpha 8.0×10^{-14} µCi/mL	monthly average: $> 2.0 \times 10^{-11}$ µCi/mL	Notification of environmental protection function manager;
		gross beta 1.0×10^{-13} µCi/mL	monthly average: $> 4.7 \times 10^{-9}$ µCi/mL	Investigation, Initiation of corrective actions
Combined Releases from Other Uranium Stacks	Continuous/ Daily[a]	gross alpha 8.0×10^{-14} µCi/mL	monthly average: $> 2.0 \times 10^{-12}$ µCi/mL	Notification of environmental protection function manager;
		gross beta 1.0×10^{-13} µCi/mL	monthly average: $> 2.9 \times 10^{-10}$ µCi/mL	Investigation; Initiation of corrective actions
Combined Releases from Plutonium Stacks (Building 234)	Continuous/ Weekly	gross alpha 8.0×10^{-15} µCi/mL	monthly average: $> 7.0 \times 10^{-13}$ µCi/mL	Notification of environmental protection function manager;
		gross beta 1.0×10^{-14} µCi/mL	monthly average: $> 1.9 \times 10^{-12}$ µCi/mL	Investigation; Initiation of corrective actions
Liquid Effluent.				
Waste Water Treatment Facility Effluent	Grab/ Each Batch	gross alpha 1.5×10^{-7} µCi/mL	each batch $> 3.0 \times 10^{-7}$ µCi/mL	Notification of environmental protection function manager;
		gross beta 3.0×10^{-7} µCi/mL	each batch $> 6.0 \times 10^{-5}$ µCi/mL	Investigation; Initiation of corrective actions
	Composite/ Monthly	Isotopic uranium	sample SOF > 1.0[b]	
Non-Contact Cooling Water	Grab/ Weekly	gross alpha 1.5×10^{-8} µCi/mL	each batch $> 1.5 \times 10^{-7}$ µCi/mL	Notification of environmental protection function manager;
		gross beta 3.0×10^{-8} µCi/mL	each batch $> 6.0 \times 10^{-6}$ µCi/mL	Investigation; Initiation of corrective actions
Sanitary Sewer Discharges	Continuous/ Daily[a]	gross alpha 1.5×10^{-8} µCi/mL	each batch $> 3 \times 10^{-7}$ µCi/mL	Notification of environmental protection function manager;
		gross beta 3.0×10^{-8} µCi/mL	each batch $> 6.0 \times 10^{-6}$ µCi/mL	Investigation; Initiation of corrective actions
	Composite/ Monthly	Isotopic uranium	Sample SOF > 0.5[b]	

a. Daily means normal 5-operating-day work week. On holidays and weekends samplers will continue to accumulate samples; however, the sample will not be collected until the next normal operating day.

b. SOF = Sum of Fractions for the mixture of radionuclides. The SOF is determined by summing the ratios of each nuclide concentration to the applicable effluent concentration limit in Appendix B, Table 2, Column 2 of 10 CFR Part 20.

Source: Nuclear Fuel Services, Inc., "Revisions to Chapter 5 of License Renewal Application," Docket No. 70-143, August 28, 1998, (Ref. 1) and Nuclear Fuel Services, Inc., "Response to NRC Request for Additional Information to Complete Environmental Review for License SNM-124 (TAC No L30873), Dated 11/26/97," Docket No. 70-143, February 4, 1998 (Ref. 2).

Radionuclide concentrations in gaseous effluents have been decreasing since 1989, based on review of NRC inspection reports. Average concentrations of gross alpha from the main stack were lower during the first half of 1994 than in any previous reporting period during the previous

5 years (Ref. 3). The gross alpha concentration decreased from 1.67×10^{-12} µCi/mL in the second half of 1993 by an order of magnitude to 1.03×10^{-13} µCi/mL in the first half of 1994. This large decrease was due to the decrease in plant production activities (Refs. 3 and 4).

The process stacks are also monitored for nonradiological pollutants in accordance with several operating permits issued by the Tennessee Air Pollution Control Board, Department of Environment and Conservation (Ref. 5). NFS has historically maintained compliance with the emissions limits specified in these air permits (Ref. 6).

4.1.2 Liquid Effluent Monitoring

Three liquid effluent streams are monitored for both radiological and nonradiological constituents and discharged from the NFS Erwin Plant. These waste streams are liquid effluent from the Waste Water Treatment Facility, non-contact cooling water, and the sanitary sewage (see Table 4.1 and Section 2.1.4).

4.1.2.1 Waste Water Treatment Facility

Waste waters are generated by fuel manufacturing, fuel development, uranium recovery operations, laboratories, and the laundry facility (Ref. 1). The Waste Water Treatment Facility releases liquid effluent containing radioactive material in batches through outfall 001 to the Nolichucky River (refer to Figure 4.1 for location). Each liquid batch is sampled and analyzed for gross alpha and gross beta before discharge (Ref. 1) and the batch volume is reported in accordance with the State of Tennessee-issued NPDES permit. A monthly composite sample is analyzed for uranium isotopes (Ref. 1).

NFS has committed to using gross alpha and gross beta action levels as specified in Table 4.1. As with airborne effluents, if action levels are exceeded, NFS has committed to notifying the environmental protection function manager and the responsible process engineering control personnel, investigating to identify the cause of the exceedance, initiating the appropriate corrective action(s) to reduce release concentrations and to minimize likelihood of a recurrence, and documenting corrective actions (Ref. 1). Waste solutions in which the alpha or beta activity concentration exceeds one of the action levels will be discharged only after approval by the environmental protection function manager. NFS has indicated that no discharge will be authorized that will result in a 12-month average concentration exceeding the applicable levels specified in 10 CFR 20, Appendix B, Table 2, Column 2 (Ref. 1).

The gross alpha, gross beta, and isotope-specific concentrations (^{238}Pu, ^{239}Pu, ^{99}Tc, ^{228}Th, ^{230}Th, ^{232}Th, ^{234}Th, ^{234}U, ^{235}U, and ^{238}U) are averaged and reviewed quarterly to ensure that any 12-month average does not exceed the limits specified in 10 CFR Part 20, Appendix B, Table 2, Column 2 (Ref. 7). Activity-release data for uranium, thorium, and plutonium isotopes and technetium-99 from the Waste Water Treatment Facility are contained in semi-annual effluent monitoring reports submitted to NRC.

The gross beta activity in discharges from the Waste Water Treatment Facility has fluctuated over the reporting period. For example, from 1994 to 1996, average total uranium activity in effluent discharged (2.4×10^{-3} Ci) was about one order of magnitude lower than for the period

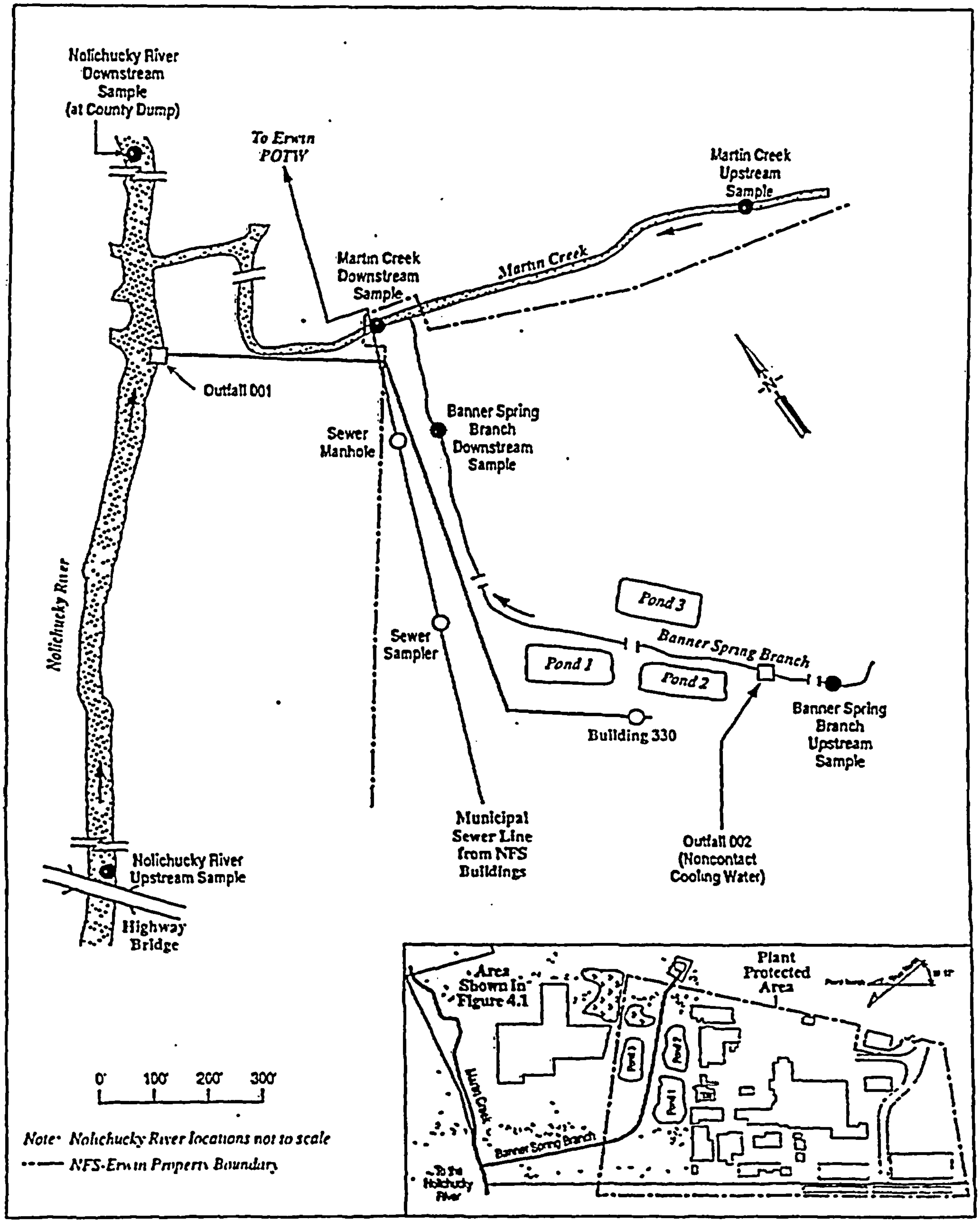

Figure 4.1 Liquid-effluent monitoring locations

from 1990 to 1993 (1.8×10^{-2} Ci) (Ref. 6). This decrease was most likely due to completion of decommissioning activities in Ponds 1, 2, and 3 in 1994 (Ref. 4).

Liquid effluent from the Waste Water Treatment Facility is also analyzed for nonradiological characteristics, in accordance with the NPDES permit. Table 4.2 summarizes the NPDES permit limits for waste water treatment effluents discharged through outfall 001. Among the constituents monitored are flow, pH, chlorine, fluoride, uranium, tetrachloroethylene, and several metals. *During the period from January 1990 to July 1996, a single chemical oxygen* demand (COD), cadmium, lead, and copper concentration measurement has exceeded the NPDES permit limits (Ref. 8).

Table 4.2 NPDES[a] permit limits for outfall 001 effluent

Parameter	NPDES Limit (Daily Maximum)
pH	6.0 - 9.0
Flow	report
Chemical Oxygen Demand	370 mg/L
Total Suspended Solids	40 mg/L
Settleable Solids	0.5 mg/L
Chlorine	2.0 mg/L
Fluoride	30 mg/L
Ammonia (as Nitrogen)	30 mg/L
Nitrates (as Nitrogen)	650 lb/day
Uranium	4.0 mg/L
Arsenic	report
Cadmium	0.01 mg/L
Chromium	report
Copper	1.0 mg/L
Lead	0.1 mg/L
Mercury	0.05 mg/L
Nickel	report
Silver	0.05 mg/L
Zinc	report
Tetrachloroethylene	report

a NPDES - National Pollutant Discharge Elimination System
Source: Nuclear Fuel Services, "KAST Fuel Manufacturing Process - Revised Response to NRC Questions," October 1, 1998 (Ref. 19).

4.1.2.2 Non-Contact Cooling Water

Non-contact cooling water is taken from and returned to Banner Spring Branch through outfall 002 (refer to Figure 4.1 for location). Grab samples of this process water, which serves the highly-enriched uranium recovery process, are taken weekly and analyzed for gross alpha and gross beta activity. NFS has indicated a typical lower limit of detection of 1.5×10^{-8} µCi/mL for the gross alpha analysis and 3.0×10^{-8} µCi/mL for the gross beta analysis. In addition, NFS has established actions levels of 1.5×10^{-7} µCi/mL and 6.0×10^{-6} µCi/mL for gross alpha activity and gross beta activity, respectively. If action levels are exceeded, the environmental protection function manager is notified, an investigation is undertaken, and appropriate corrective actions are initiated. Activity-release data for uranium, thorium, and plutonium isotopes are provided in semi-annual effluent monitoring reports to NRC.

In addition, this effluent is monitored for flow, temperature, chlorine, and pH, in accordance with the NPDES permit (Ref. 1). From January 1990 to July 1996, all of these constituents were within the NPDES permit limits (Ref. 8).

4.1.2.3 Sewer

Liquid effluents discharged to the sanitary sewer are sampled continuously and analyzed daily for both radiological (gross alpha and gross beta activity) and nonradiological constituents (Ref. 1). In addition, a monthly composite sample is analyzed for isotopic uranium. NFS has indicated a typical minimum detectable concentration of 1.5×10^{-8} µCi/mL and 3.0×10^{-8} µCi/mL for the gross alpha activity and gross beta activity analyses, respectively. In addition, NFS has established action levels of 3.0×10^{-7} µCi/mL for the gross alpha analysis and 6.0×10^{-6} µCi/mL for the gross beta analysis. If an action level is exceeded, the environmental protection function manager is notified, an investigation is conducted to determine the cause of the high activity, and corrective actions are implemented (Ref. 7). The total volume and concentration of isotopic uranium, thorium, and plutonium effluent is reported to the NRC in semi-annual effluent monitoring reports.

Radiological and nonradiological constituents from the sewer are also monitored monthly in accordance with Erwin Utilities POTW Permit No. 013 (Ref. 10). The POTW permit sets limits for average monthly gross alpha and gross beta concentrations, which must be less than 500 pCi/L and 300 pCi/L, respectively. Monthly average concentrations in 1996 and 1997 were below the permit limits; the maximum monthly gross alpha and gross beta concentrations were 214 pCi/L and 138 pCi/L, respectively (Ref. 2).

Gross alpha, gross beta, ^{234}U, ^{235}U, and ^{238}U are also analyzed quarterly under the POTW permit. The quarterly averages must be less than 500 pCi/L; 300 pCi/L; 500 pCi/L; 25 pCi/L; and 25 pCi/L, respectively. Table 4.3 presents radiological monitoring data from 1995 to 1997 for liquid effluents discharged to the sewer. All discharges to the POTW for 1996 and 1997 were within permit limits.

Liquid discharges to the sewer are also monitored for nonradiological constituents including pH, metals, and organics. The quarterly average discharge limits for nonradiological constituents are presented in Table 4.4. Review of quarterly monitoring data for effluents discharged to the sanitary sewer during 1996 and 1997 indicate that except for mercury, none of the parameters exceeded the discharge limits (Ref. 10).

In addition, grab samples of sewer sludge are collected at least quarterly at Erwin Utilities POTW and analyzed for isotopic uranium.

Table 4.3 Monitoring data for radiological constituents (pCi/L) in liquid effluent discharged to the sewer

Year-Quarter	Gross alpha	Gross beta	U-234	U-235	U-238
1995-1&2	—	—	58	2	8
1995-3&4	—	—	34	1	6
Average	—	—	46	1.5	7
1996-1	50	15	44	2	8
1996-2	76	9	53	3	10
1996-3	60	24	56	3	8
1996-4	15	38	14	0.5	2
Average	50	22	42	2	7
1997-1	62	38	77	3	11
1997-2	87	24	74	3	12
1997-3	148	26	123	4	13
1997-4	14	20	9	0.3	1
Average	78	27	71	2	9

Source: For 1995, only bi-annual monitoring data were available: "Bi-Annual Effluent Monitoring Report (January-June, 1995)," August 29, 1995, and "Bi-Annual Effluent Monitoring Report (July-December, 1995)," February 29, 1996, Docket 70-143/SNM-124 (Ref. 11). For 1996 and 1997, quarterly data submitted by Nuclear Fuel Services, Inc., in "Response to NRC Request for Additional Information to Complete Environmental Review for License SNM-124 (TAC No. L30873), Dated 11/26/97," February 4, 1998 (Ref. 2).

4.1.3 Solid Waste Monitoring

Solid wastes generated by production operations are packaged into drums or boxes, and each container is assayed for uranium content to ensure that storage, shipment, and disposal requirements are met.

4.2 Environmental Monitoring Program

NFS conducts a sampling program of ambient air, surface water, soil, sediment, vegetation, and groundwater to monitor impacts from the facility on the surrounding environment. The monitoring locations are shown in Figure 4.2, and the monitoring program is summarized in Table 4.5. The following subsections also describe the environmental monitoring data. The proposed environmental monitoring plan for North Site decommissioning is described in subsection 4.2.5.

4.2.1 Ambient Air Monitoring

Ambient air is sampled continuously for gross alpha and gross beta activity at a minimum of eight locations along the predominant wind directions (Figure 4.2). In addition, air samples are analyzed for isotopic uranium on a quarterly basis and isotopic plutonium and thorium on an annual basis for the sampling station nearest the predicted maximally exposed offsite individual (Refs. 1 and 12). NFS has established action levels, as shown in Table 4.6. If an action level is

Table 4.4 POTW[a] permit limits for nonradiological constituents (mg/L)[b] in liquid effluent discharged to the sewer.

Parameter	Discharge Limit
pH	Minimum: 5; Maximum 9
Phenols	0.5
Oil and grease	100
Cyanide	0.114
Cadmium	0.007
Chromium	0.702
Copper	0.202
Lead	0.667
Nickel	0 098
Silver	0.277
Zinc	0 387
Toluene	0 21
Benzene	0 012
1,1,1-trichloroethane	0.27
Ethylbenzene	0 02
Carbon tetrachloride	0.15
Chloroform	0 31
Tetrachlorothylene	0.139
Trichloroethylene	0.25
1,2 trans-dichloroethylene	0 05
Methylene chloride	0.17
Naphthalene	0.003
Total Phathalates	0 213
Mercury	0 0002
Vinyl chloride	0.10
Tributyl phosphate	0 088

a. POTW - Publicly Owned Treatment Works
b. All values have units of mg/L except for pH.

Source: Erwin Utilities, "Authorization to Discharge Under the Sewer Regulations and the Pretreatment Regulations of 1985 of the Town of Erwin, Tennessee," Permit No 013, (effective July 1,1994, and expires June 30, 1998) signed July 6, 1994. (Ref. 10)

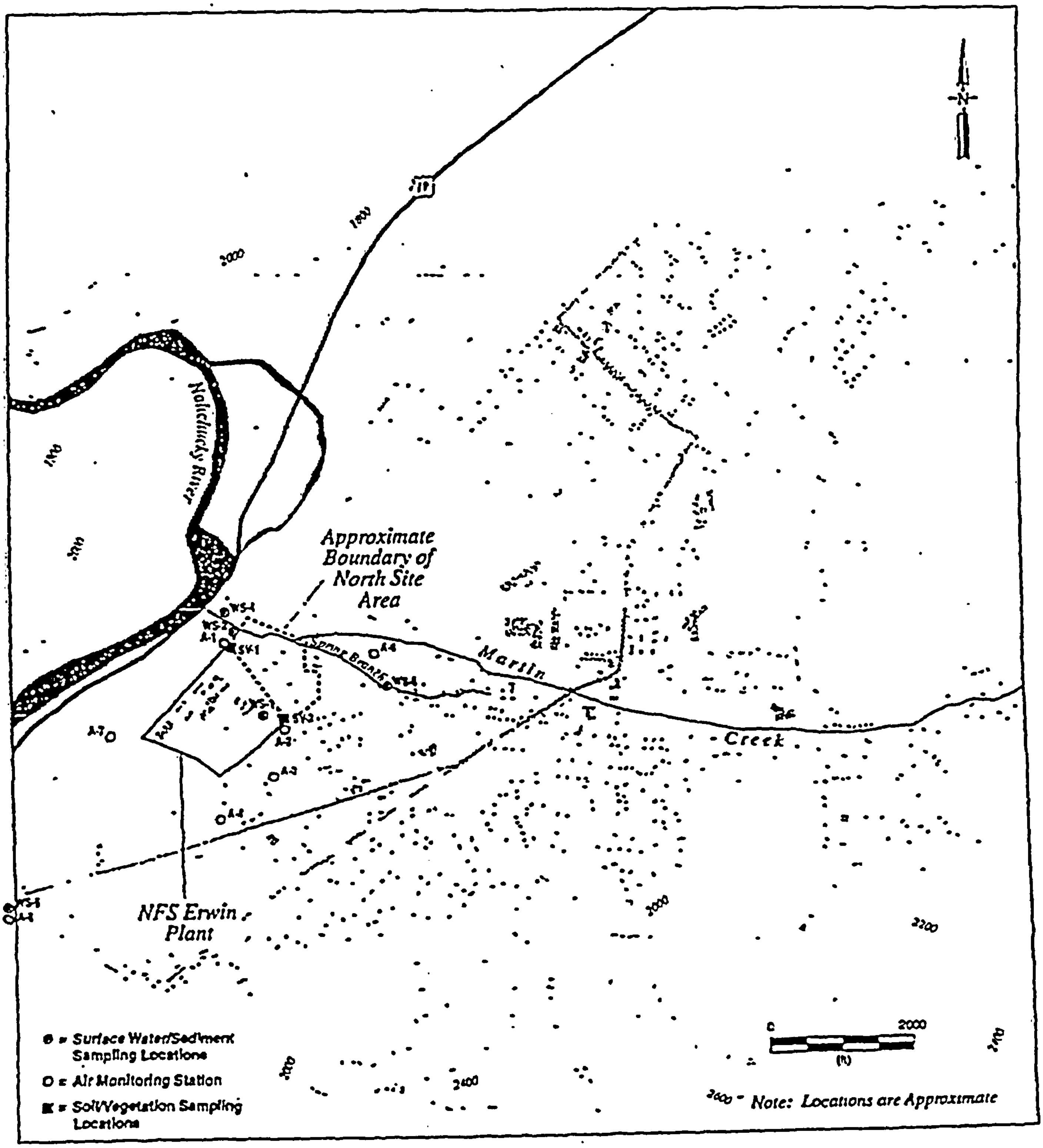

Figure 4.2 Environmental monitoring locations for ambient air, soil, vegetation, sediment, and surface water at the NFS Erwin Plant

Table 4.5 Summary of environmental monitoring program at the NFS Erwin Plant[a]

Sample Medium	No. of Stations	Sample Type/Collection Frequency	Parameters Analyzed	Action Level (μCi/mL unless otherwise stated)	Typical MDC (μCi/mL unless otherwise stated)
Ambient Air	8			Quarterly Ave	
		Continuous/Weekly	Gross Alpha	$> 5.0 \times 10^{15}$	$3\,0 \times 10^{-15}$
			Gross Beta	$> 9.0 \times 10^{-11}$	$1\,0 \times 10^{14}$
		Composite/Quarterly	Isotopic U	Total U $> 5\,0 \times 10^{15}$	$4\,0 \times 10^{-16}$
			Isotopic U	Total Th $> 4\,0 \times 10^{-16}$	$1\,0 \times 10^{-16}$
		Composite/Annually	Isotopic Pu	Total Pu $> 2\,0 \times 10^{15}$	$1\,0 \times 10^{-18}$
Surface Water:					
Banner Spring Branch, Upstream	(see note c)	Grab/Quarterly		Sample	
			Gross Alpha	$> 3.0 \times 10^{-8}$	$1\,0 \times 10^{-8}$
			Gross Beta	$> 3.0 \times 10^{-8}$	$2\,0 \times 10^{-8}$
Banner Spring Branch, Downstream	(see note c)	Continuous/Daily[a]		Sample	
			Gross Alpha	$> 3\,0 \times 10^{7}$	$1\,5 \times 10^{-8}$
			Gross Beta	$> 6.0 \times 10^{-8}$	$3\,0 \times 10^{-8}$
		Composite/Monthly	Isotopic U	Sample SOF > 1.0[b]	1.00×10^{-8}
Martin Creek, Upstream	(see note c)	Grab/Quarterly		Sample	
			Gross Alpha	$> 3\,0 \times 10^{-8}$	1.0×10^{-8}
			Gross Beta	$> 3.0 \times 10^{-8}$	2.0×10^{-8}
Martin Creek, Downstream	(see note c)	Grab/Weekly		Sample	
			Gross Alpha	$> 3\,0 \times 10^{7}$	1.5×10^{-8}
			Gross Beta	$> 6.0 \times 10^{-8}$	$3\,0 \times 10^{-8}$
Nolichucky River, Upstream	(see note c)	Grab Quarterly		Sample	
			Gross Alpha	$> 3.0 \times 10^{-8}$	1.0×10^{-8}
			Gross Beta	$> 3.0 \times 10^{-8}$	2.0×10^{-8}
Nolichucky River, Downstream	(see note c)	Grab/Quarterly		Sample	
			Gross Alpha	$> 3\,0 \times 10^{7}$	1.5×10^{-8}
			Gross Beta	$> 6\,0 \times 10^{-8}$	3.0×10^{-8}
Soil	4	Grab/Quarterly	Gross Alpha	Sample > 25 pCi/g	5 pCi/g
Silt/Sediment	(see note c)	Grab/Quarterly	Gross Alpha	Sample > 25 pCi/g	5 pCi/g
Vegetation	4	Grab/Quarterly	Gross Alpha	Sample > 25 pCi/g	5 pCi/g
Groundwater	16	Grab/Quarterly	Gross Alpha	Sample > 15 pCi/L	10 pCi/L
			Gross Beta	Sample > 50 pCi/L	15 pCi/L

a. Daily means normal 5-operating-day work week. On holidays and weekends samplers will continue to accumulate a samples; however, the sample will not be collected until the next normal operating day.
b. SOF = Sum of Fractions for the mixture of radionuclides. The SOF is determined by summing the ratios of each nuclide concentration to the applicable effluent concentration limit in Appendix B, Table 2, Column 2 of 10 CFR Part 20.
c. Sample locations are specified in onsite procedures and are subject to change.

Source. Nuclear Fuel Services, Inc., "Revisions to Chapter 5 of License Renewal Application," Docket No 70-143, August 28, 1998 (Ref. 1) exceeded, the environmental protection function manager will be notified and an investigation will be undertaken to determine the cause of the exceedance. Corrective actions will then be implemented (Ref. 1).

The radiological air-sampling data for six of the air-monitoring locations around the site for the period from 1990 to 1995 are summarized in Table 4.6. The gross alpha concentrations at all locations have been approximately $2x10^{-15}$ µCi/mL; no increasing or decreasing trends were noted. None of the annual average concentrations are above the $5x10^{-15}$ µCi/mL action level.

Table 4.6 Environmental monitoring for gross alpha radioactivity (µCi/mL) in air on or near the NFS Erwin Plant

	Onsite	Offsite				
Year	A-1 NFS mound at sewer (N)	A-2 Banner Hill Road (ESE)	A-3 Stalling Lane (SE)	A-4 Highland Avenue, 1st Street (S)	A-5 Spar Mill Road (ENE)	A-7 Industrial Park at Images, Inc. (W)
1990	$2.5x10^{-15}$	$2.2x10^{-15}$	$2.1x10^{-15}$	$2.3x10^{-15}$	$1.6x10^{-15}$	$1.9x10^{-15}$
1991	$1.7x10^{-15}$	$1.8x10^{-15}$	$1.6x10^{-15}$	$2.5x10^{-15}$	$1.7x10^{-15}$	$1.6x10^{-15}$
1992	$2.0x10^{-15}$	$2.4x10^{-15}$	$1.3x10^{-15}$	$1.4x10^{-15}$	$1.2x10^{-15}$	$1.3x10^{-15}$
1993	$1.7x10^{-15}$	$1.7x10^{-15}$	$1.8x10^{-15}$	$1.7x10^{-15}$	$1.6x10^{-15}$	$1.8x10^{-15}$
1994	$2.4x10^{-15}$	$2.0x10^{-15}$	$2.1x10^{-15}$	$2.0x10^{-15}$	$2.0x10^{-15}$	$2.1x10^{-15}$
1995	$2.4x10^{-15}$	$2.0x10^{-15}$	$1.9x10^{-15}$	$2.0x10^{-15}$	$1.9x10^{-15}$	$2.1x10^{-15}$

Source: Nuclear Fuel Services, "Applicant's Environmental Report for Renewal of Special Nuclear Material License No. SNM-124," December 1996 (Ref. 6).

4.2.2 Soil and Vegetation Sampling

Soil and vegetation samples are collected quarterly at a minimum of four locations to monitor for long-term buildup of radioactivity attributable to Plant operations. The samples are analyzed for gross alpha and gross beta radioactivity. NFS has established action levels for these media as shown in Table 4.5. If action levels are exceeded, isotopic analysis is performed on the sample (Ref. 1).

Soil and vegetation sampling results from 1990 to 1995 are shown in Table 4.7. In the December 1996 Environmental Report, NFS reported that the gross alpha activity in background vegetation samples is approximately 0.6 pCi/g and that the gross alpha activity in background soil is 3 pCi/g. The annual average concentrations of gross alpha activity in vegetation at the two sampling locations are not statistically different from background value and have been below the quarterly action level of 25 pCi/g at all sampling locations for each year in the reporting period. Gross alpha concentrations in offsite soil (SV-2) were also not statistically higher than background values. However, the annual average gross alpha concentrations in onsite soil (SV-1) were above the 25 pCi/g action level from 1990 to 1992. Soil from this area has since been removed for offsite disposal.

Table 4.7 Environmental monitoring for gross alpha emitters in soil and vegetation samples[a]

Year	SV-1 (Onsite) NFS mound at sewer (N) Soil (pCi/g)	SV-1 (Onsite) NFS mound at sewer (N) Vegetation (pCi/g)	SV-2 (Offsite) Banner Hill Road (ESE) Soil (pCi/g)	SV-2 (Offsite) Banner Hill Road (ESE) Vegetation (pCi/g)
1990	56.2	0 09	4.7	0 10
1991	79.3	0 46	6.1	0.50
1992	30.6	0.90	4.9	0.78
1993	6 9	0 75	4.4	1.10
1994	7 4	0 79	3.2	0.98
1995	20 7	0 91	3 2	1 0

a. The action level for soil and vegetation is 25 pCi/g.

Source: Nuclear Fuel Services, "Applicant's Environmental Report for Renewal of Special Nuclear Material License No. SNM-124," December 1996 (Ref. 6).

4.2.3 Surface Water and Sediment Sampling

Surface water and sediment samples are collected from upstream and downstream locations in Banner Spring Branch, Martin Creek, and the Nolichucky River and analyzed for gross alpha and gross beta radioactivity. Upstream surface water samples from Banner Spring Branch, Martin Creek, and the Nolichucky River are analyzed quarterly. Downstream samples are analyzed daily, weekly, and quarterly for each of the above surface water bodies, respectively. The surface water monitoring program is specified in Table 4.5.

The downstream surface water and sediment sample results from 1990 through 1995 are shown in Table 4.8. Review of the surface water data indicates that the gross alpha activity in downstream water samples from Banner Spring Branch and Martin Creek have increased over the past 6 years; no specific trend was observed in the Nolichucky River data. Gross alpha concentrations began to increase in 1992 and continued through 1995, which could result from earthmoving activities associated with the decommissioning activities. Decommissioning of the Banner Spring Branch streambed is included in the November 1997 North Site Decommissioning Plan.

Table 4.8 Environmental monitoring for gross alpha emitters in downstream surface water samples and stream-sediment samples

Year	Onsite: WS-2 Banner Spring Branch Surface Water (pCi/L)	Onsite: WS-2 Banner Spring Branch Sediment (pCi/g)	Offsite: WS-4 Martin Creek Surface Water (pCi/L)	Offsite: WS-4 Martin Creek Sediment (pCi/g)	Offsite: WS-6 Nolichucky River Surface Water (pCi/L)	Offsite: WS-6 Nolichucky River Sediment (pCi/g)
1990	8.7	11.4	5.1	0 87	2.1	0 20
1991	8 6	14.6	5 0	4 4	2.8	0.63
1992	11	47 2	5 4	8 0	2 4	0 94
1993	19	48 3	6 5	5 1	1 8	0.94
1994	14	50 8	6 3	12.3	2.7	1.37
1995	15	60 8	7 0	5 9	1 9	1 25

Source: Nuclear Fuel Services, "Applicant's Environmental Report for Renewal of Special Nuclear Material License No SNM-124," December 1996 (Ref 6).

4.2.4 Groundwater Monitoring

Groundwater quality at the NFS Erwin Plant is monitored for both radiological and nonradiological constituents throughout the site. The radiological monitoring program is summarized in Table 4.5 and current monitoring-well locations are shown on Figure 4.3 (Ref. 2). As discussed in Section 3.6.2, three groundwater zones are monitored-- the alluvial aquifer (zone 1), the bedrock aquifer (zone 2); and a deeper zone in the bedrock aquifer (zone 3) -- for site characterization efforts. Table 3.10 lists the wells used to monitor each zone. Under its special nuclear material license, NFS has committed to monitoring at a minimum 1 well upgradient of the site (52) and 10 wells downgradient of the site (98A, 99A, 100A, 100B, 101A, 102A, 103A, 104A, 105A, 106A). In addition, NFS has committed to monitoring 4 wells (LD-1A, LD-2A, 70A, and 91) in the vicinity of two 6,000-gallon underground storage tanks. Historic groundwater monitoring data at the site is summarized below.

4.2.4.1 Groundwater Monitoring in the Vicinity of the North Site (Main) Burial Ground

Quarterly groundwater monitoring for gross alpha and gross beta activity in the vicinity of the main burial ground has been conducted (Ref. 1). If gross alpha and gross beta action levels of 15 pCi/L and 50 pCi/L, respectively, have been exceeded, the groundwater samples have been analyzed for isotopic uranium, thorium, plutonium, and ^{99}Tc (Ref. 1).

Eight wells -- 96A, 95A, 62, 59, 98A, 99A, and 100A -- have historically monitored groundwater quality in the burial-ground vicinity. The alluvial aquifer (zone 1) is monitored by wells 96A, 95A, and 62, located on the downgradient burial-ground perimeter; well 59, located further downgradient, just west of Banner Spring Branch, near the site boundary; and wells 98A, 99A, and 100A, located at the site boundary (Figure 4.3). Well 63A is located upgradient of the burial ground.

Available gross alpha and gross beta monitoring data for 1991 to 1997 for boundary wells 98A, 99A, and 100A (downgradient of the burial ground) are presented in Table 4.9. Gross alpha and gross beta activities in wells 99A and 100A have fluctuated, with no discernible trend, and have been below the 15 pCi/L and 50 pCi/L action levels, respectively. In well 98A, gross alpha activity measurements have been above the 15 pCi/L action level in samples taken during 1996 and 1997. The gross beta activity was above the 50 pCi/L action level in 1997.

The available groundwater monitoring data for isotopic uranium, thorium, plutonium, and ^{99}Tc from the burial ground wells were reviewed for the period from 1991 to 1997. Total thorium concentrations in the upgradient well, perimeter wells, and boundary wells have remained about the same (ranging from about 0.1 to 3 pCi/L) and have not increased. Total plutonium in the boundary wells ranged from 0.2 to 2 pCi/L, and total uranium ranged from 5 to 40 pCi/L. Available monitoring data for ^{99}Tc indicate that the 1997 concentrations in well 98A are about twice as high (about 30 pCi/L) as in all previous years.

Well 100B monitors groundwater quality in the bedrock aquifer (zone 2) downgradient from the burial ground along the site boundary. Available gross alpha and gross beta monitoring data for this well (Ref. 2) during selected quarters in 1993, 1996, and 1997 show that gross alpha and gross beta activities have been lower than the 15 pCi/L and 50 pCi/L action levels, respectively.

Figure 4.3 Redacted.

Table 4.9 Groundwater monitoring for gross alpha and gross beta in the alluvial aquifer (zone 1) downgradient[a] from the burial ground

Year-Quarter	Gross alpha (pCi/L)			Gross beta (pCi/L)		
	98A	99A	100A	98A	99A	100A
1993-1						
1993-2						
1993-3						
1993-4	9 8	<5 0	37 9	22 3	38 5	21 3
1994-1						
1994-2						
1994-3						
1994-4						
1995-1			6.9			5.6
1995-2			5.5			7.8
1995-3			7.1			10.3
1995-4			8 9			10 9
1996-1			5.3			6.9
1996-2			2.6			8.0
1996-3	20.8		3.8	17.3		9.0
1996-4	16 0	3 3	7.3	38 0	9 1	17 2
1997-1	22 4	4.2	8.7	39.5	22 2	15.3
1997-2			8 4			18 1

a No monitoring data for gross alpha and gross beta are available for well 63A upgradient of the main burial ground.

Source: Nuclear Fuel Services, "Response to a request by NRC for additional information concerning NFS's 1996 license renewal request," License SNM-124, Docket No. 70-143, June 17, 1997 (Ref. 2).

4.2.4.2 Groundwater Monitoring in the Vicinity of the Surface Impoundments in the North Site Area

Historically, quarterly groundwater monitoring has been conducted for gross alpha and gross beta activity upgradient and downgradient of Ponds 1, 2, and 3 (Ref. 1). If the 15 pCi/L gross alpha and 50 pCi/L gross beta action levels were exceeded, NFS analyzed the samples for isotopic uranium, thorium, plutonium, and ^{99}Tc (Ref. 1).

Five wells have historically monitored groundwater quality in the alluvial aquifer in the vicinity of the surface impoundments. Well 52 is located upgradient of the surface impoundments; wells 26 and 28 are located downgradient; and wells 101A, 102A, and 103A are located along the site boundary (Figure 4.3).

Tables 4.10 and 4.11 present the available gross alpha and gross beta monitoring data, respectively, for 1991 to 1997 (i.e., data from 1994 to 1997) for these wells. Gross alpha activity in wells 26 and 28 have been above the 15 pCi/L action level for all but one quarter (well 28) during the past 4 years. Well 26, located downgradient of the impoundments closest to Pond 4, has had concentrations up to nearly 4000 pCi/L. Available groundwater monitoring data for the three downgradient boundary wells show that the activity in these boundary wells has been comparable to the upgradient well (well 52) and below the 15 pCi/L action level, indicating no migration offsite at these locations.

Table 4.11 shows that the gross beta activity in upgradient well 52 has ranged from about 5 to 16 pCi/L. Gross beta activities were the highest in well 26 (about 1500 pCi/L) and above the 50 pCi/L action level for each quarter of the reporting period. However, in well 28, the gross beta activity has been below the 50 pCi/L action level over the period from 1994-1997, except for one quarter. At the site boundary downgradient of the impoundments, the gross beta activity has been comparable to that seen in the upgradient well (well 52) and below the 50 pCi/L action level.

Table 4.10 Groundwater monitoring wells for gross alpha (pCi/L) in the alluvial aquifer (zone 1) in the vicinity of the surface impoundments

Year-Quarter	Upgradient	Downgradient		Downgradient boundary wells		
	52	26	28	101A	102A	103A
1994-3		2307	754			
1994-4		1943	140			
1995-1		3917	45 2			
1995-2		3023	102			
1995-3		3560	64 4			
1995-4		3572	62 0			
1996-1		2425	39.1			
1996-2		1596	11.7			
1996-3	2.1	1904	35 8	4 1	1.3	2 2
1996-4	0 94	2850	38 8	1 5	0 96	1 3
1997-1	2.1	2924	51.2	2 6	1.1	1.1
1997-2	1 2			2 2	1 6	2 4

Source: Nuclear Fuel Services, "Response to a request by NRC for additional information concerning NFS' 1996 license renewal request," License SNM-124, Docket No. 70-143, June 17, 1997 (Ref. 2).

Table 4.11 Groundwater monitoring wells for gross beta (pCi/L) in the alluvial aquifer (zone 1) in the vicinity of the surface impoundments

Year-Quarter	Upgradient	Downgradient		Downgradient boundary wells		
	52	26	28	101A	102A	103A
1994-1						
1994-2						
1994-3		1540	311			
1994-4		1083	36 3			
1995-1		1523	17.0			
1995-2		1460	23 3			
1995-3		1508	16.6			
1995-4		1783	18 7			
1996-1		1310	10.7			
1996-2		828	9 3			
1996-3	4.7	2806	46.7	14 2	10.8	11.5
1996-4	7 8	4713	55 5	8 2	11 2	14.9
1997-1	13.9	1818	45 0	15 9	16.6	12 7
1997-2	16 4			16 2	13 8	10 7

Source: Nuclear Fuel Services, "Response to a request by NRC for additional information concerning NFS' 1996 license renewal request," License SNM-124, Docket No. 70-143, June 17, 1997 (Ref. 2)

Isotopic data for thorium, uranium, plutonium, and ^{99}Tc were reviewed for the surface impoundment wells. Total plutonium and total thorium concentrations downgradient have been about the same as seen in upgradient well 52. The total uranium concentration downgradient (wells 26 and 28) has been measured up to 2500 pCi/L, and much higher than that in upgradient well 52 (1 to 5 pCi/L). However, at the boundary wells, the uranium concentration is about the same as in upgradient well 52.

Technetium-99 concentrations have increased by about two orders of magnitude in 1996 and 1997 in well 26 and have doubled in well 28. These data confirm groundwater contamination associated with the impoundments, but it does not appear the contamination has migrated offsite. The proposed North Site decommissioning actions will remove the source term from this area.

4.2.4.3 <u>Groundwater Monitoring for Leak Detection Near the Two 23000 Liter (6000-Gallon) Underground Storage Tanks in the Protected Area</u>

Monthly groundwater monitoring for gross alpha, gross beta, and pH in the vicinity of the two 23,000-liter (6000-gallon) underground storage tanks (USTs) has historically been conducted. NFS has also committed to analyzing a quarterly composite sample for isotopic uranium (Ref.1).

Four wells (70A, LD-1A, LD-2A, and 97A) have monitored groundwater quality near the two underground storage tanks (see Figure 4.3). Available gross alpha and gross beta groundwater monitoring data from the alluvial aquifer for the period from 1991 to 1997 are presented in
Table 4.12. The analytical results indicate that gross alpha and gross beta activities in well LD-1A have remained about the same as in well 70A (upgradient) and below the 15 pCi/L and 50 pCi/L action levels over the period of record. However, gross alpha and gross beta activities in well LD-2A have been higher and generally increased over the period of record. Table 4.12 shows that the gross alpha activity in wells LD-2A and 97A has been above the 15 pCi/L action level for nearly each reporting period. The gross beta activity in wells LD-2 and 97A has been above 50 pCi/L during several of the quarters.

NFS analyzes quarterly composite samples from the leak-detection wells for isotopic uranium (Ref. 1). Available monitoring data (i.e., from 1993 to 1997) for uranium-233/234, -235, and -238 were reviewed. Uranium concentrations in well LD-2A are about one order of magnitude higher than in well LD-1A. The isotopic uranium concentrations in wells LD-1A and LD-2A have remained the same over the reporting period, but the uranium-233/234 concentration in downgradient well 97A has generally increased, indicating possible contaminant migration.

4.2.4.4 <u>Groundwater Monitoring Near the Burial Trenches on CSX Railroad Property</u>

Quarterly groundwater monitoring for gross alpha and gross beta upgradient and downgradient of the burial trenches on CSX railroad property (i.e., the southwest burial trenches) historically has been conducted (Figure 4.3).

Four wells monitor groundwater quality in this area: three downgradient wells (wells 104A, 105A, and 106A) and one upgradient (well 107A) relative to the southwest burial trenches (Figure 4.3).

Table 4.12 Groundwater monitoring for gross alpha and gross beta in the alluvial aquifer (zone 1) leak-detection wells in the vicinity of the two 23000 liter (6000-gallon) underground storage tanks

Year-Quarter	Gross alpha (pCi/L)				Gross beta (pCi/L)			
	70A	LD-2A	LD-1A	97A	70A	LD-2A	LD-1A	97A
1993-4	<3 8				18.7			47 3
1994-1		59.8				<10.4		
1994-2		56.7				<5 6		
1994-3		39.6				<18.5		
1994-4		53 4	7.3			9 0	<5 8	
1995-1		67.5				13 2		
1995-2		70 5				<15 2		
1995-3		104 4				10.9		
1995-4		75.7				14.3		
1996-1		36 0		52 2		8 6		66 0
1996-2		41 0		17.0		10.7		64.4
1996-3		64.2	1.1			23 4	5.4	
1996-4	2 0	66 8	0.9	8 0	14.1	55 7	11 6	18.3
1997-1	6 0	93.3	2.2	33 7	17 7	65 5	11.0	41.7
1997-2		92 9	1 4			56.7	14.0	

Source: Nuclear Fuel Services, "Response to a request by NRC for additional information concerning NFS' 1996 license renewal request, License SNM-124, Docket No. 70-143, June 17, 1997 (Ref. 2)

Table 4.13 presents the available gross alpha and gross beta monitoring data for wells in the vicinity of the southwest burial trenches for the period from 1991 to 1997. The analytical results in Table 4.13 indicate that gross alpha and gross beta activities in both downgradient and upgradient wells have been about the same and below the 15 pCi/L and 50 pCi/L action levels, respectively, indicating no localized contamination in this area.

4.2.4.5 Groundwater Monitoring for Nonradiological Constituents

Chemical constituents are monitored under a Hazardous and Solid Waste Amendments permit issued by the U.S. EPA. The nonradiological constituents monitored in groundwater wells are identified in Table 3.16. Sections 3.9.3.1 and 3.9.3.2 discuss chemical contamination in the alluvial and bedrock aquifers, respectively.

Table 4.13 Groundwater monitoring for gross alpha and gross beta in the alluvial aquifer (zone 1) leak-detection wells in the vicinity of the burial trenches on CSX railroad property

Year-Quarter	Gross alpha (pCi/L)				Gross beta (pCi/L)			
	107A[a]	104A	105A	106	107A[a]	104A	105A	106A
1993-4	<2.8	<4.1	<3.2	<4.0	18.4	7.2	8.5	<6.9
1994								
1995								
1996-4		0.56	0.18			15.0	8.0	9.8
1997-1		1.0	0.82	2.1		14.9	15.3	13.1

a. Well 107A is not routinely monitored, but is used for available information.

Source: Nuclear Fuel Services, "Response to a request by NRC for additional information concerning NFS' 1996 license renewal request," License SNM-124, Docket No. 70-143, June 17, 1997 (Ref. 2).

4.2.5 Proposed Environmental Monitoring for the North Site Area Decommissioning

During final decommissioning of the North Site area, monitoring of radiological constituents in ambient air will continue as described in Section 4.2.1 (Ref. 13). In addition, NFS has proposed to increase the sediment sampling frequency from quarterly to monthly. Sediment samples would be collected downstream on Banner Spring Branch and at upstream and downstream locations on Martin Creek and the Nolichucky River. The monthly samples would be composited and analyzed for gross alpha, gross beta, and isotopic uranium, thorium, and plutonium semi-annually on Banner Spring Branch and Martin Creek samples, and annually on Nolichucky River samples (Ref. 13).

During decommissioning, surface water samples would be collected from Banner Spring Branch, Martin Creek, and the Nolichucky River at the frequencies identified in Table 4.5. The surface water samples collected upstream on Martin Creek would be analyzed for gross alpha, gross beta, and some nonradiological constituents. The other surface water locations would be sampled for gross alpha; gross beta; isotopic uranium, thorium, and plutonium; and nonradiological constituents. The sampling results will be summarized in semi-annual reports for the surface water monitoring program (Ref. 13).

The North Site Decommissioning Plan (Ref. 13) proposes at least quarterly monitoring (gross alpha, gross beta, and selected nonradiological constituents) of wells near the North Site during decommissioning. The wells will be monitored for at least 2 years following completion of decommissioning activities. Groundwater monitoring of both the alluvial aquifer and bedrock has been proposed. For the alluvial aquifer in the North Site area, NFS has proposed using wells 63A and 52, located upgradient of the burial ground and surface impoundments, respectively; well 59, located near the site boundary; boundary wells 98A, 99A, and 100A, located downgradient of the burial ground; and boundary well 101A, located downgradient of the surface impoundments. For the bedrock aquifer, NFS has proposed using wells 63B and 100B, located upgradient and downgradient, respectively, of the North Site area (Ref. 13).

4.3 References for Section 4

1. Nuclear Fuel Services, Inc., "Revisions to Chapter 5 of License Renewal Application," Docket No. 70-143, August 28, 1998.

2. Nuclear Fuel Services, Inc., "Response to NRC request for Additional Information to complete Environmental Review for License SNM-124 (TAC NO. L30873), February 4, 1998.

3. D. M. Collins, U.S. Nuclear Regulatory Commission, letter to D. Ferguson, Nuclear Fuel Services, Inc., "NRC Inspection Report No. 70-143/94-12," November 23, 1994.

4. D. M. Collins, U.S. Nuclear Regulatory Commission, letter to D. Ferguson, Nuclear Fuel Services, Inc., "Notice of Violation (NRC Inspection Report No. 70-143/95-02)," April 10, 1995.

5. Tennessee Air Pollution Control Board, Department of Environment and Conservation, "Operating Permit No. 037723F, issued to Nuclear Fuel Services, Inc., Erwin, Tennessee," March 15, 1994.

6. Nuclear Fuel Services, "Applicant's Environmental Report for Renewal of Special Nuclear Material License No. SNM-124," December 1996.

7. Nuclear Fuel Services, "Special Nuclear Material License SNM-124, Part II, Safety Demonstration, Renewal," June 1996.

8. U.S. Environmental Protection Agency, "Water Enforcement National Database (WENDB)," liquid effluent discharge monitoring data for Nuclear Fuel Services, Inc., NPDES Permit No. TN0002038, as of September 11, 1996.

9. State of Tennessee Department of Environment and Conservation Division of Water Pollution Control, "NPDES Permit No. TN0002038, Nuclear Fuel Services, Erwin, Unicoi County, Tennessee," April 3, 1996.

10. Erwin Utilities, "Authorization to Discharge under the Sewer Regulations and the Pretreatment Regulations of 1985 of the Town of Erwin, Tennessee, Permit #013," (effective July 1, 1994 and expired June 30, 1998), signed July 6, 1994.

11. Nuclear Fuel Services, Inc., "Bi-Annual Effluent Monitoring Reports, Docket No. 70-143/SNM-124," 1990 - 1996.

12. U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, "Environmental Assessment for Renewal of Special Nuclear Material License No. SNM-124, Nuclear Fuel Services, Inc., Erwin Plant, Erwin, Tennessee," Docket No. 70-143, August 1991.

13. Nuclear Fuel Services, "North Site Decommissioning Plan for Nuclear Fuel Services, Inc., Erwin, Tennessee," November 1997.

14. Nuclear Fuel Services, Inc., "Response to a request by NRC for additional information concerning NFS's 1996 license renewal request," Docket No. 70-143, June 17, 1997.

15. Nuclear Fuel Services, Inc., "North Site Characterization Report for Nuclear Fuel Services, Inc., Erwin, Tennessee," November 1997.

16. B.S. Mallett, U.S. Nuclear Regulatory Commission, letter to D. Ferguson, Nuclear Fuel Services, Inc., "NRC Inspection Report No. 70-143/96-14 and Notice of Violation," December 24, 1996.

17. W.E. Cline, U.S. Nuclear Regulatory Commission, letter to D. Ferguson, Nuclear Fuel Services, Inc., "NRC Inspection Report No. 70-143/93-22," October 27, 1993.

18. Nuclear Fuel Services, "KAST Fuel Manufacturing Process," June 8, 1998.

19. Nuclear Fuel Services, "KAST Fuel Manufacturing Process - Revised Response to NRC Questions," October 1, 1998.

5. ENVIRONMENTAL CONSEQUENCES

Implementing the proposed action will result in an impact on the environment. The environmental consequences of the proposed license renewal are described in Section 5.1. The environmental consequences of alternative 2, where decommissioning/ remediation actions, only, would be initiated, are described in Section 5.2, and the environmental consequences of the No-Action alternative are described in Section 5.3.

5.1 Environmental Consequences of the Proposed License Renewal

For the proposed license renewal, processing operations and decommissioning actions will result in the release of low levels of chemical and radioactive constituents to the environment. Under accident conditions, higher concentrations of materials could be released to the environment over a short period of time. Section 5.1.1 evaluates the impacts of normal operations, and Section 5.1.2 evaluates the impacts of postulated accidents at the Nuclear Fuel Services (NFS) Erwin Plant.

5.1.1 Normal Operations

Normal operations will involve discharges to the atmosphere and to surface water. The impacts of normal operations are discussed below. Nonradiological impacts are discussed in subsection 5.1.1.1 and radiological impacts are discussed in subsection 5.1.1.2.

5.1.1.1 Nonradiological

Air Quality

Air quality is protected by enforcing emission limits and requirements for the maintenance of pollution control equipment, as required under several operating permits issued by the Tennessee Air Pollution Control Board, Department of Environment and Conservation. Normal emissions of gaseous effluents through the process stacks are not expected to have a significant impact on offsite nonradiological air quality, because the estimated concentrations at the nearest site boundary are two to three orders of magnitude less than the most stringent State of Tennessee primary air-quality standards (see Table 3.4). The emission rate reported for hydrogen fluoride (HF) is estimated to result in a concentration that is at least 50 to 60 percent less than the most stringent State of Tennessee standard.

Surface Water

As discussed in Section 3.9.2, several chemical contaminants have been detected in Banner Spring Branch at levels which exceed health-based criteria. In the North Site Decommissioning Plan, NFS has proposed the removal of contaminated soils, sediments, and piping, which are believed to be the source of this contamination (Ref. 14). In addition, NFS will routinely monitor Banner Spring Branch for cyanide and zinc, as recommended in the RCRA Facility Investigation Report for areas of concern 2 (Building 111 boiler blowdown and backwash water) and 4 (storm sewer system). No contamination of other surface waters due to plant activities has been identified (Ref. 14).

Surface water quality is expected to be protected from future site activities by enforcing release limits and monitoring programs, as required under the National Pollutant Discharge Elimination

System (NPDES) permit. Furthermore, discharges are not expected to have significant impact on the surface water quality in the Nolichucky River because of the dilution volume in the river.

Groundwater

Previous operation of the plant has resulted in localized chemical and radiological contamination of groundwater as described in Section 3.9.3. Groundwater monitoring conducted by NFS indicates that plumes of uranium, tetrachloroethylene, trichloroethylene, 1,2-dichloroethylene, and vinyl chloride could migrate offsite in the direction of the Nolichucky River (Ref. 1). To address this contamination, NFS has removed much of the source of the contamination through extensive remediation projects including excavation of contaminated areas in the North Site. In addition, NFS is currently engaged in decommissioning of the Radiological Burial Ground and has proposed a final decommissioning plan for the entire North Site to remove more of the source of this contamination. NFS is also working with the Tennessee Department of Environment and Conservation and the Environmental Protection Agency to design remedial strategies and to investigate the offsite extent of these plumes.

Groundwater modeling conducted by NFS indicates that contamination from the NFS site should not have an impact on local drinking water because contaminant plumes are not expected to intersect the capture zone for this water. However, NFS will be required by the NRC to continue routine groundwater monitoring to assess the nature and extent of groundwater contamination and will be required to conduct remediation, if necessary, to prevent offsite impacts to human health and safety.

Land Use

As discussed in Section 3.9.1, extensive chemical contamination exists on the northern portion of the NFS facility. NFS has proposed remediation of these areas in the North Site Decommissioning Plan. Although the proposed decommissioning activities will result in the disturbance of about 10 hectares (24 acres) in the North Site area, this area has been previously disturbed by plant operations. The proposed activities would occur onsite and are consistent with its current land use.

Biotic Resources

The proposed decommissioning activities will result in earthmoving and localized impacts to plants and animals. As discussed above, since renewal activities would be occurring in areas previously disturbed by site operations, no critical habitat would be disrupted.

Cultural Resources

The proposed area to be disturbed under the license renewal has been previously disturbed by earthmoving activities such as grading at the site. Therefore, it is unlikely the proposed license renewal activities would disturb cultural resources. Regional historic properties would be undisturbed by the proposed activities because of their distance from the site.

Socioeconomics

The primary socioeconomic impact of continued operation of the NFS Erwin Plant will be the continued employment of about 350 workers. The facility is currently the major industrial employer in the area and granting the proposed license renewal would result in continued employment.

Transportation

*If the license is renewed to allow both production operations and decommissioning/site-*remediation activities, approximately 39,100 cubic meters (1,380,000 cubic feet) of waste would be shipped offsite to Envirocare in Utah. Assuming that each waste shipment contains 13.6 cubic meters (480 cubic feet) of waste (Appendix B of Ref. 2), 2874 shipments of soil would be transported to Envirocare. To estimate the number of fatalities from transporting waste, the fatal accident risk rate was multiplied by the distance traveled, where the distance traveled is the round trip between the facility and the disposal site. From reference 2, a fatal accident rate of 3.8×10^{-8} per kilometer (6.1×10^{-8} per mile) traveled was assumed. Multiplying this fatal accident rate by a round trip distance of 6560 kilometers (4100 miles) between the NFS plant in Erwin, Tennessee, and Envirocare in Clive, Utah, and the number of shipments yields a risk of less than one (0.72) fatality. The transportation impacts of operations at the facility will remain comparable to, and likely less than the transportation impacts produced when the site was in production operations in the past. This is due to the reduction in the size and number of UF_6 cylinders which will be received on-site and the reduced volume of processed material produced and shipped off-site.

5.1.1.2 <u>Radiological</u>

Potential radiological impacts of the proposed license renewal include release of small quantities of radioactive material to the atmosphere and surface water. Radionuclides that may be released include isotopes of the actinide elements uranium, thorium, plutonium, and americium and lesser amounts of fission products, including technicium. Sources of releases to the atmosphere are the main plant stack, secondary stacks in process buildings, and fugitive dust emissions from decommissioning/remediation activities. Sources of releases to surface water include the waste water treatment system, the secondary cooling system, surface run-off, and the sanitary sewer system. Because of their low vapor pressure, all radionuclide releases to the atmosphere are in the form of solid particulates, whereas releases to surface water are in the form of suspended and dissolved solids. The majority of the releases are expected to be in the insoluble oxide chemical form. A description of the nature and rates of these releases is presented in Chapter 2.

Potentially exposed individuals for the atmospheric releases are primarily residents along the southern and eastern boundaries of the site. Population density to the west of the plant is low and wind direction is primarily from the south and north. The impact analysis, however, considers individuals living near the plant and the surrounding population out to a distance of 80 kilometers (50 miles). Atmospheric dispersion analysis using the XOQDOQ computer code (Ref. 3) established that the maximally exposed individual is located south-southeast of the site, 200 meters (660 feet) from the main plant stack (stack no. 416).

Atmospheric dispersion for both individuals living near the plant and the population surrounding the plant was analyzed using the XOQDOQ computer code. To identify the maximally exposed individual, the residences nearest the plant must be located and the release magnitude and calculated χ/Qs to each of the residences for both ground-level and elevated releases must be considered. The maximally exposed individual is the individual for whom the product of release quantity and χ/Q is greatest for the sum of elevated and ground level releases. The magnitude of the χ/Q for a given location is influenced by distance from the source, frequency of occurrence of wind speed in a given direction, and the distribution of wind speeds for wind from a given direction. The magnitudes of χ/Q for residences near the plant are presented in Table 5.1. Because the magnitude of ground-level and elevated releases are approximately equal (see Table 2.3), Table 5.1 shows that the maximally exposed individual is located 200 meters (660 feet) south-southeast of the main plant stack (stack no. 416). Although wind blows most frequently into the north and north-northeast sectors, the distance from the stack is greater for these directions; therefore, the impacts are less relative to a residence in the south-southeast sector.

Liquid effluents are released directly or indirectly into the Nolichucky River. Small creeks receiving portions of the liquid discharge, Banner Spring Branch, and Martin Creek are not used as a drinking water supply for area residents. The analysis assumes that an individual along the Nolichucky River and the surrounding population out to a distance of 80 kilometers (50 miles) use this potentially contaminated water.

Table 5.1 Dispersion factors for NFS Erwin Plant nearest residents, normal operations

		χ/Q (s/m^3)[b]	
Direction	Distance (m)[a]	Ground level	Elevated
N	357	2 4x10^{5}	2.4x10^{5}
NE	381	2.5x10^{5}	1.4x10^{4}
E	262	1 3x10^{5}	6 5x10^{-7}
SE	226	2.4x10^{5}	1.3x10^{4}
SSE	202	6 1x10^{5}	3 5x10^{4}
S	214	4 5x10^{-5}	2 0x10^{4}

a. To convert meters to feet, multiply by 3.2808
b. To convert seconds per cubic meter to seconds per cubic foot, multiply by 0 02832.

Impacts for all radionuclides were estimated using the GENII computer code (Ref. 4). Atmospheric-release exposure pathways included inhalation, ingestion of contaminated crops and resuspended dirt, and external exposure to the airborne plume and contaminated ground. Liquid-release exposure pathways included ingestion of drinking water, fish, and irrigated crops and external exposure during recreational activities. Details on the radiological impact analysis methods are presented in Appendix A.

Atmospheric Pathway Impacts

Potential impacts of releases to the atmosphere from the NFS Erwin Plant are summarized in Tables 5.2 and 5.3 for the maximally exposed individual and the population, respectively. For these atmospheric releases, the largest tissue dose is to the lung from inhalation of ^{234}U, with minor contribution from the crop ingestion and external-exposure pathways. For the maximally exposed individual, the committed effective dose equivalent (CEDE) for combined releases from production operations and decommissioning/remediation activities was estimated as 2.6x10^{-5} Sv/yr (2.6 mrem/yr). Doses from remediation activities are about an order of magnitude less than doses from production activities. Although releases from the main plant stack and process building vents are comparable, the majority of the dose is from the release via the process building vents since atmospheric dispersion from these release points is less favorable. External doses are a factor of 1,000,000 less than internal doses.

Liquid Pathway Impacts

Potential impacts for the maximally exposed individual and the population from releases to surface water are presented in Tables 5.4 and 5.5, respectively. The largest tissue doses are to the bone surface from ingestion of thorium-232 and external doses are a factor of 2500 smaller than internal doses. Fish, crop, and drinking-water consumption account for 49, 37, and 14 percent of the dose, respectively. The CEDE for the maximally exposed individual was estimated as 9.7×10^{-7} Sv/yr (0.10 mrem/yr).

Transportation Impacts

As stated in Section 5.1.1.1, under the proposed action, about 2874 shipments of contaminated soil would be transported offsite to Envirocare. In Ref. 2, the reference value used for estimating radiological exposure to the public from transporting contaminated soil from a uranium fuel fabrication plant is 8.00×10^{-6} person-rem per shipment. Multiplying this dose rate by the number of waste shipments yields 23 person-mrem. Thus, a small fraction of one person-rem would be received by the public from transporting waste offsite.

Table 5.2 Radiological impacts to the maximally exposed individual from releases to the atmosphere (Sv/yr)[a]

Organ	During Production Operations	During Decommissioning/ Remediation Activities	Total[b]
Gonads	1.4×10^{-9}	5.7×10^{-9}	7.1×10^{-9}
Breast	5.6×10^{-10}	6.1×10^{-11}	6.2×10^{-10}
Red bone marrow	6.9×10^{-8}	7.1×10^{-8}	1.4×10^{-7}
Lungs	1.9×10^{-4}	2.0×10^{-5}	2.1×10^{-4}
Thyroid	5.6×10^{-10}	6.2×10^{-11}	6.2×10^{-10}
Bone surface	9.9×10^{-7}	9.1×10^{-7}	1.9×10^{-6}
Liver	1.1×10^{-8}	7.6×10^{-8}	8.7×10^{-8}
Kidneys	1.3×10^{-7}	1.2×10^{-8}	1.4×10^{-7}
Small intestine	1.6×10^{-8}	1.4×10^{-9}	1.7×10^{-8}
Upper large intestine	8.9×10^{-9}	9.0×10^{-10}	9.8×10^{-9}
Lower large intestine	2.6×10^{-7}	2.6×10^{-8}	2.9×10^{-7}
CEDE[c]	2.4×10^{-5}	2.4×10^{-6}	2.6×10^{-5}
External	9.8×10^{-13}	5.2×10^{-13}	1.5×10^{-12}
TEDE[d]	2.4×10^{-5}	2.4×10^{-6}	2.6×10^{-5}

a. To convert Sv/yr to mrem/yr, multiply by 100,000.
b. Total is the sum of releases from both production operations and decommissioning/remediation activities
c. CEDE = committed effective dose equivalent.
d. TEDE = total effective dose equivalent.

Table 5.3 Radiological impacts to the population from releases to the atmosphere (per-Sv/yr)[a]

Organ	During Production Operations	During Decommissioning/ Remediation Activities	Total[b]
Gonads	3.0×10^{-7}	1.9×10^{-4}	2.2×10^{-4}
Breast	1.2×10^{-7}	1.2×10^{-8}	1.3×10^{-7}
Red bone marrow	2.0×10^{-5}	2.2×10^{-5}	4.2×10^{-5}
Lungs	6.3×10^{-3}	6.4×10^{-3}	6.9×10^{-3}
Thyroid	1.2×10^{-7}	1.3×10^{-9}	1.3×10^{-7}
Bone surface	2.5×10^{-4}	2.8×10^{-4}	5.3×10^{-4}
Liver	3.0×10^{-6}	2.5×10^{-8}	2.8×10^{-6}
Kidneys	2.3×10^{-5}	2.1×10^{-6}	2.5×10^{-5}
Small intestine	2.1×10^{-6}	2.1×10^{-7}	2.3×10^{-6}
Upper large intestine	1.3×10^{-5}	1.2×10^{-6}	1.4×10^{-5}
Lower large intestine	3.6×10^{-5}	3.5×10^{-6}	3.9×10^{-5}
CEDE[c]	7.6×10^{-3}	7.7×10^{-4}	8.4×10^{-3}
External	4.6×10^{-3}	1.6×10^{-10}	4.6×10^{-10}
TEDE[d]	7.6×10^{-3}	7.7×10^{-4}	8.4×10^{-3}

a. To convert per-Sv/yr to per-mrem/yr, multiply by 100,000.
b. Total is the sum of releases from both production operations and decommissioning/remediation activities.
c. CEDE = committed effective dose equivalent.
d. TEDE = total effective dose equivalent.

Table 5.4 Radiological impacts to the maximally exposed individual from liquid releases (Sv/yr)[a]

Organ	During Production Operations	During Decommissioning/ Remediation Activities	Total[b]
Gonads	1.9×10^{-9}	1.6×10^{-9}	3.5×10^{-9}
Breast	1.8×10^{-9}	1.4×10^{-9}	3.2×10^{-9}
Red bone marrow	8.4×10^{-7}	8.6×10^{-7}	1.7×10^{-6}
Lungs	1.8×10^{-9}	1.4×10^{-9}	3.2×10^{-9}
Thyroid	8.9×10^{-9}	2.1×10^{-9}	1.1×10^{-8}
Bone surface	1.1×10^{-5}	1.1×10^{-5}	2.2×10^{-5}
Liver	1.8×10^{-8}	1.8×10^{-8}	3.6×10^{-8}
Kidneys	1.6×10^{-7}	1.3×10^{-7}	2.9×10^{-7}
Small intestine	2.9×10^{-8}	2.6×10^{-8}	5.5×10^{-8}
Upper large intestine	1.8×10^{-7}	1.5×10^{-7}	3.3×10^{-7}
Lower large intestine	5.3×10^{-7}	4.7×10^{-7}	1.0×10^{-6}
CEDE[c]	5.0×10^{-7}	4.7×10^{-7}	9.7×10^{-7}
External	2.2×10^{-10}	2.2×10^{-10}	4.4×10^{-10}
TEDE[d]	5.0×10^{-7}	4.7×10^{-7}	9.7×10^{-7}

a To convert Sv/yr to mrem/yr, multiply by 100,000.
b Total is the sum of releases from both production operations and decommissioning/remediation activities.
c *CEDE = committed effective dose equivalent*
d. TEDE = total effective dose equivalent.

Table 5.5 Radiological impacts to the population from liquid releases (per-Sv/yr)[a]

Organ	During Production Operations	During Decommissioning/ Remediation Activities	Total[b]
Gonads	7.1×10^{-4}	5.9×10^{-4}	0.0013
Breast	6.6×10^{-4}	5.4×10^{-4}	0.0012
Red bone marrow	0.35	0.34	0.69
Lungs	6.6×10^{-4}	5.4×10^{-4}	0.0012
Thyroid	0.0031	7.9×10^{-4}	0.0039
Bone surface	4.4	4.3	8.7
Liver	0.0073	0.0067	0.014
Kidneys	0.053	0.047	0.10
Small intestine	0.011	0.0091	0.02
Upper large intestine	0.065	0.055	0.12
Lower large intestine	0.19	0.17	0.36
CEDE[c]	0.19	0.19	0.38
External	7.8×10^{-6}	7.2×10^{-6}	1.5×10^{-5}
TEDE[d]	0.19	0.19	0.38

a. To convert per-Sv/yr to per-mrem/yr, multiply by 100,000.
b. Total is the sum of releases from both production operations and decommissioning/ remediation activities.
c. CEDE = committed effective dose equivalent.
d. TEDE = total effective dose equivalent

Total Radiological Impact of the Proposed Action

NRC regulations in 10 CFR 20.1301(a)(1) require that the total effective dose equivalent (TEDE) for members of the public not exceed 1.0×10^{-3} Sv (100 mrem) per year. In addition, 10 CFR 20.1101(d) requires licensees to implement a constraint on atmospheric releases other than radon such that an individual member of the public will not be expected to receive a dose in excess of 1×10^{-4} Sv (10 mrem)/yr from these releases. Although not applicable to the NFS Erwin Plant because it does not process uranium for the production of electric power, U.S. Environmental Protection Agency (EPA) regulations (Ref. 6) require that for routine releases, the annual dose equivalent for all pathways not exceed 2.5×10^{-4} Sv (25 mrem) to the whole body; 7.5×10^{-4} Sv (75 mrem) to the thyroid; and 2.5×10^{-4} Sv (25 mrem) to any other organ. Doses related to NFS Erwin Plant operations are dominated by releases to the atmosphere. For the maximally exposed individual, the annual TEDE was estimated as 2.6×10^{-5} Sv (2.6 mrem), well within the limits established by NRC and EPA. The largest annual tissue dose was estimated as 2.1×10^{-4} Sv (21 mrem) to the lung. Although this tissue dose approaches the 40 CFR 190 limit, it is based on conservative estimates of atmospheric dispersion and of releases from process vents to bound all possible activities. The actual impacts are expected to be less than these estimates. The estimated dose from all other releases are small fractions of applicable limits.

The total population dose (about 0.4 per-Sv/yr) is a small addition to a background dose for the affected population of 950,000, which is approximately 1000 per-Sv/yr.

5.1.2 Evaluation of Potential Accidents

The handling, processing, and storage of material containing radioactive constituents at the NFS Erwin Plant could result in uncontrolled release of radioactive material to the environment from accidents. Facility operations also use hazardous chemicals whose uncontrolled release could pose a worker risk and a risk to public health and safety. The nature of and relatively small quantities of hazardous chemicals are both factors that constrain the potential impact from accidents. This section describes accident analysis methods and presents the impact from a representative set of potential accidents.

5.1.2.1 Accident Analysis Methods

The accident analysis included the identification of potential hazards, review of potential accident initiators and release mechanisms, development of accident scenarios, and estimation of consequences for a set of potential accident scenarios. The analysis is based on the inventory, equipment, and process descriptions presented in the emergency plan (Ref. 7). The hazard review identified as primary hazards the radionuclides in the feed material and process equipment; and hazardous chemicals that include relatively non-volatile fuels and mineral acids. For radioactive material in solid form, the primary release mechanisms would be drop and resuspension during transfer and failure of filtration systems during processing. For radioactive material in liquid solution, the primary release mechanism would be equipment failure during processing and transfer. Because all process areas and buildings have floor drains connected to process or storage tanks, small-scale spills would likely be completely contained. A fuel storage fire or explosion would be the hazardous chemical scenario with the largest potential impact.

The concentration of materials released to the atmosphere is decreased by mixing during transport. NRC has guidance to estimate concentrations per unit source (χ/Q) for accident conditions in Regulatory Guide 1.145 (Ref. 8). Airborne contaminant concentrations were estimated in accordance with procedures in this guidance. The predicted concentrations were those expected to occur less than 5.0 percent of the time. The accident condition χ/Qs were estimated as 1.4×10^{-2} s/m^3 for ground-level releases at a distance of 50 meters (160 feet) and 1.2×10^{-4} s/m^3 for elevated releases, at a distance of 200 meters (660 feet). Dose factors were estimated using the GENII computer code (Ref. 4) described in Appendix A.

5.1.2.2 Accident Evaluations

Based on the above considerations, drop of contaminated dirt during remediation activities, failure of a HEPA filter as a consequence of fire, and a generic criticality event were selected as representative accidents. Consequences for these events are summarized below.

Drop of Contaminated Soil

Contaminated soil will be excavated and packaged for storage or disposal during remediation activities in the North Site area. Equipment failure or improper operation could result in inadvertent dumping of a load. The typical capacity for a front-end loader was estimated as 1.0 cubic meter (35.3 cubic feet) or 2000 kilograms (4400 pounds). Previous NRC analysis (Ref. 9) established that the fraction of spilled material that becomes airborne after a drop event correlates with gravitational energy. For a drop of 1 meter (3.3 feet), the amount of airborne material was estimated to be 240 grams. Using the maximum estimated uranium and thorium content in sludge measured at Pond 3, 936 pCi/g of uranium and 436 pCi/g of thorium (Ref. 7), the release would be 1.87×10^{-3} Ci of uranium-234 (U-234) and 8.72×10^{-4} Ci of thorium-232 (Th-232). From the dispersion analysis, for the distance of 50 meters (164 feet) from Pond 3 to the fenceline, the χ/Q occurring less than 5 percent of the time would be 1.4×10^{-2} s/m^3. The CEDE estimated for this release would be 7.3×10^{-6} Sv (0.73 mrem), about 1 percent of annual background exposure.

Filter Degradation Due to Facility Fire

Process off-gases are vented through ducts, scrubbers, and filters before release to the environment through the main plant stack (stack No. 416). The primary control for particulate releases is HEPA filtration of the particulates entrained in the gas. Tests have demonstrated that at the maximum pressure differentials recommended for operation (Ref. 10), filter loadings can be as high as 1000 grams (2.2 pounds) (Ref. 11). Fire in process equipment or entrainment of a hot particle could initiate a fire in dust and debris that has collected in the ventilation ducts. The hot air generated by the fire could degrade the integrity of the HEPA filters, leading to a release. Airborne-release fractions recommended for this scenario are approximately 1×10^{-4} (dimensionless) (Ref. 9). It was conservatively assumed that 6.3×10^{-4} Ci of U-234, the radionuclide of highest activity, was released. For an elevated release and the maximum exposed individual (200 meters), the χ/Q occurring less than 5 percent of the time would be 1.2×10^{-4} seconds per cubic meter (3.4×10^{-6} seconds per cubic foot). The dose for this accident was estimated as 3.4×10^{-5} Sv (3.4 mrem), a small fraction of annual background exposure.

Inadvertent Nuclear Criticality

Enriched uranium is in storage facilities and process equipment at the NFS Erwin Plant. To evaluate NFS activities in relation to public health and safety, a generic nuclear criticality was postulated. The event was assumed to involve enriched uranium in solution in the uranium processing building (Building 302) and it was assumed there was no damage to ventilation systems. In accordance with NRC guidance (Ref. 9), the total number of fissions was assumed to be 1×10^{19} with the source term dominated by prompt radiation and release of iodine and noble gas isotopes. A receptor located at the closest fenceline, a distance of approximately 100 meters (330 feet), would receive the largest prompt dose (from instantaneous emission of gamma and neutron radiation) of 0.031 Sv (3.1 rem) and minimal external and internal dose from noble gases and iodine isotopes. The prompt, external, and internal doses for the resident at a distance of 200 meters (656 feet) from the stack would be 5.0×10^{-3}, 1.5×10^{-2}, and 2.6×10^{-1} Sv (0.5, 1.5, and 0.026 rem), respectively. These exposures are below levels which would result in acute health effects.

Because two independent, concurrent failures must occur before initiation of a nuclear criticality, the possibility of such an event occurring is considered by the NRC staff to be extremely low. Therefore, the overall risk from such an accident is acceptable.

5.1.3 Cumulative Impacts

In addition to the production operations and activities associated with final decommissioning of the North Site area, decommissioning activities in the Radiological Burial Ground and the Southwest Burial Trenches will be on-going during the renewal period. Impacts from decommissioning of the Radiological Burial Ground and the Southwest Burial Trenches were estimated in NRC's March 27, 1997 Safety Evaluation Report supporting amendment of the license to authorize these activities. This analysis reported an incremental increase in radioactivity at the closest offsite sampling station of 5×10^{-11} $\mu Ci/m^3$, a 2 percent increase in concentration for the closest offsite station. No increased radionuclide concentrations in offsite surface water were projected from exhuming the Burial Ground (Ref. 12).

No dose estimate was made for the maximally exposed individual. Applying the 2 percent increase in airborne radionuclide concentration presented above to the dose presented in Section 5.1.1.2, the actions authorized under the March 1997 license amendment would result in an additional exposure of 5×10^{-7} Sv/yr (0.05 mrem/yr). The incremental dose from liquid releases is projected to be essentially zero.

Specific impacts from specific activities are identified in Table 5.6. Table 5.6 shows that radiological air impacts are dominated by the proposed production operations. Radiological impacts from liquid releases are similar for both production and decommissioning operations. Transportation impacts are dominated by decommissioning actions.

There is essentially no incremental impact for the excavation of the Radiological Burial Ground and the Southwest Burial Trenches; therefore, the cumulative impact to the maximally exposed individual and to the population is the same as the impact from the proposed license renewal.

5.2 Impacts of Authorizing Only Decommissioning Activities

The analysis of the proposed action shows that individual and population doses are dominated by atmospheric releases associated with production operations (See Table 5.6). Therefore, if the license is not renewed and only current D&D activities associated with the Radiological Burial Ground and the Southwest Trenches are authorized, the impact to offsite individuals and populations are expected to be less than those expected under the proposed action.

However, if authorization for HEU fuel production and scrap recovery is denied, NFS would be required to initiate final decommissioning of the entire site. Decommissioning operations would be conducted in accordance with an approved decommissioning plan prepared by NFS after a thorough site survey. The NRC would assess the environmental impacts of site-wide decommissioning activities during review of this plan.

Ceasing operations at the NFS Erwin Plant would imply either loss of HEU processing services for the government or an increase in the same type of operations at another facility where there would be similar environmental impacts.

Table 5.6 Comparison of environmental impacts

Impact Category	Production Operations	Final D&D of the North Site	D&D of the Radiological Burial Ground and the Southwestern Trenches
Air Quality	Concentrations of SO_2, CO, and NO_x << applicable standards, concentration of HF at ½ applicable standard	Insignificant levels of emissions	Insignificant levels of emissions
Surface Water	Discharge of 83,000 L/day (22,000 gallons/day), concentrations below NPDES limits	discharge of 61,000 L/day (16,000 gallons/day), concentrations below NPDES limits	
Ground water	Localized contamination, monitoring program in place	Localized contamination, monitoring program in place	Localized contamination, monitoring program in place
Land Use	26 hectares (65 acres) occupied for 10-year license period plus subsequent D&D period	26 hectares (65 acres) occupied for D&D period	
Biotic Resources	All activities in previously disturbed areas, no critical habitat disrupted	All activities in previously disrupted areas, no critical habitat disrupted	All activities in previously disrupted areas, no critical habitat disrupted
Socioeconomics	Employs 350 people, 17 percent of local industry	Loss of production-related employment	
Cultural Resources	No known impact	No known impact	No known impact
Radiological, Normal Operations			
Maximally exposed individual, air releases	2.4×10^{-5} Sv/yr (2.4 mrem/yr)	2.4×10^{-6} Sv/yr (0.24 mrem/yr)	5×10^{-7} Sv/yr[a] (0.05 mrem/yr)
Maximally exposed individual, liquid releases	5.0×10^{-7} Sv/yr (0.05 mrem/yr)	4.7×10^{-7} Sv/yr (0.047 mrem/yr)	0[a]
Population, air releases	7.6×10^{-3} per-Sv (0.76 per-rem)	7.7×10^{-4} per-Sv, (0.077 per-rem)	1.5×10^{-4} Sv/yr[a] (0.002 mrem/yr)
Population, liquid releases	0.19 per-Sv (19 per-rem)	0.19 per-Sv (19 per-rem)	
Population, transportation	2.0×10^{-6} per-Sv (2.0×10^{-4} per-rem)	2.3×10^{-4} per-Sv (0.023 per-rem)	
Accidents			
• Radiological	0.73 mrem to 1.5 rem	0.73 mrem	
• Transportation, vehicular	0.007 fatality	0.71 fatality	

a Estimates developed by applying scaling factors identified in the March 27, 1997 Safety Evaluation Report to the dose estimates presented in this EA for the proposed actions.

5.3 Impacts of the No-Action Alternative

If the license is not renewed to authorize operations or decommissioning, no additional natural resources would be consumed (such as municipal water and electricity) and planned releases to the atmosphere and surface water would not occur. However, current chemical and radiological contaminants in soil would continue to erode groundwater and surface water quality.

NFS would be required to initiate final decommissioning of the entire site at a later time. As stated in Section 5.2, decommissioning operations would be conducted in accordance with an approved decommissioning plan and the NRC would assess the environmental impacts of site-wide decommissioning activities during review of this plan.

As in alternative 2, ceasing operations at the NFS Erwin Plant would imply either loss of HEU processing services for the government or an increase in the same type of operations at another facility where there would be similar environmental impacts.

5.4 References for Section 5

1. Geraghty & Miller, Inc., "Final Project Report Groundwater Flow and Constituent Transport Modeling at the Nuclear Fuel Services Facility, Erwin, Tennessee," Oak Ridge, Tennessee, April 1996.

2. U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for Decommissioning of NRC-Licensed Nuclear Facilities, NUREG-1496, Vol.2*, Appendix B, "Impact and Cost Analysis," July 1997.

3. Sagendorf, J.F., J.T. Goll, and W.F. Sandusky, "XOQDOQ, Computer Program for the Meteorological Evaluation of Routine Releases at Nuclear Power Stations," NUREG/CR-4013, Pacific Northwest Laboratory, Richland, Washington, September 1982.

4. Napier, B.A., R.A. Peloquin, D.L. Strenge, and J.V. Ramsdell, "GENII - The Hanford Environmental Radiation Dosimetry Software System," PNL-6584, Pacific Northwest Laboratory, Richland, Washington, December 1988.

5. U.S. Code of Federal Regulations, "Standards for Protection Against Radiation," Part 20, Chapter I, Title 10, *Energy*.

6. U.S. Code of Federal Regulations, "Environmental Radiation Protection Standards for Nuclear Power Operations," Part 190, Subchapter F, Chapter I, Title 40, *Protection of Environment*.

7. Nuclear Fuel Services, Inc., "Emergency Plan," Revision 1, Erwin, Tennessee, May 23, 1997.

8. U.S. Nuclear Regulatory Commission, Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants, Regulatory Guide 1.145, Rev. 1, Washington, DC, February 1983.

9. U.S. Nuclear Regulatory Commission, "Nuclear Fuel Cycle Facility Accident Analysis Handbook," NUREG-6410, Washington D.C., March 1998.

10. Burchsted, C.A., A.B. Fuller, and J.E. Kahn, Nuclear Air Cleaning Handbook, ERDA 76-21, Oak Ridge National Laboratory, Oak Ridge, Tennessee, March 31, 1976.

11. Fenton, D.L., M.V. Gunaji, P.K. Tang, and R.A. Martin, "HEPA Filter Loading by Combustion Products," in *Proceedings of the CSNI Specialist Meeting on Interaction of Fire and Explosion with Ventilation Systems in Nuclear Facilities*, LA-9911-C, Vol II, Los Alamos National Laboratory, Los Alamos, New Mexico, October, 1983

12. Attachment 3 to letter, A.H. Maxin, Nuclear Fuel Services, Inc., to R.C. Pierson, U.S. Nuclear Regulatory Commission, "Demonstration of Categorical Exclusion for Exhumation of the NFS Burial Ground," Revision 1, December 12, 1996.

13. M.F. Weber, U.S. Nuclear Regulatory Commission, to A.H. Maxin, Nuclear Fuel Services, Inc., "Amendment of License SNM-124 Concerning the North Site Burial Ground Remediation (TAC No. L30886), and the SWMU 11 Remediation (TAC No. L30808), and Acknowledgment of Changes to Revision 2 of Pond 4 Workplan (TAC No. 30897)," March 27, 1997.

14. Nuclear Fuel Services, Inc., "North Site Decommissioning Plan," Erwin, Tennessee, November 1997.

6. REGULATORY CONSULTATION

During the preparation of the Environmental Assessment, various State and Federal agencies were contacted for gathering information. The nature of these contacts is summarized in Table 6.1.

Table 6.1 Information consultations

Agency	Point of Contact	Date	Purpose
Chamber of Commerce, Unicoi County, Tennessee	--[a]	September 10, 1996	Obtain population statistics and major employers.
Tennessee Historical Commission	Rebecca Parker	November 1, 1996	Obtain a current list of historic places in Unicoi County
Tennessee Wildlife Resources Agency	--[a]	September 10, 1996	Request wetlands map for Erwin, Tennessee.
Natural Resources Conservation, Erwin, Tennessee	Russell Kinser	October 31, 1996	Obtain statistics on land use in Unicoi County.
Freedom of Information Agency, Water Pollution Control	--[a]	September 11, 1996	Request copies of the NPDES discharge monitoring reports.
State of Tennessee, Department of Environment and Conservation	William Christie	November 25, 1996	Obtain list of threatened and endangered species.
Federal Emergency Management Agency	--[a]	September 10, 1996	Obtain floodplain maps for the area.
Tennessee Department of Environmental Conservatism, Air Pollution Control	--[a]	November 1, 1996	Request clarification if State of Tennessee ambient air quality standards are the same or more stringent than NAAQ standards.
State of Tennessee, Department of Environment and Conservation	Charles Arnott (615) 532-0378	December 7, 1998	Discuss renewal of the NFS license and determine if the Department had any concerns about potential environmental impacts. No concerns were identified

a. -- Name of contact not recorded
NPDES - National Pollution Discharge Elimination System
NAAQ - National Ambient Air Quality

APPENDIX A

METHODS TO ASSESS RADIOLOGICAL IMPACTS

This appendix describes the radiological impact and environmental pathway models used for this environmental assessment. Radionuclides released from the Nuclear Fuel Services (NFS) Erwin Plant could travel through the environment and potentially cause adverse impacts on members of the population around the plant. These impacts were assessed by estimating the amount of material leaving the facility, the rate of travel and change in concentration as the material moved through the environment, and by developing an estimate of the potential harm, given contact with individuals. The estimate of material released from the facility was described in Section 2. The rate and dispersion of material moving through the environment were estimated using mass balance models similar to those recommended by the U.S. Nuclear Regulatory Commission (NRC) in Regulatory Guide 1.109 (Ref. 1). The potential for harm was assessed using methods developed by the International Commission on Radiological Protection (ICRP) (Refs. 2 and 3).

A.1 Radiological Impact Models

Radionuclides can cause harm by depositing energy generated during decay in the various body tissues. External radiation is energy deposited in the body by radionuclides outside the body, whereas internal radiation is energy deposited in the body by radionuclides within the body. External radiation only causes harm during the period of immediate exposure, whereas inhaled or ingested radionuclides continue to deposit energy over later periods of time. The ICRP models used for this assessment (Refs. 2 and 3) represent bodily tissues as compartments capable of retaining and exchanging material. The time-dependent rate of energy deposition in tissues was estimated by simultaneous solution of a set of differential mass and energy balances formulated for each body tissue and each radionuclide. The amount of energy deposited in a unit mass of tissue, corrected for effectiveness of the energy, is termed equivalent dose. The risk-weighted sum of tissue equivalent doses is termed effective dose equivalent (EDE) and the summation of EDE over time is referred to as committed effective dose equivalent (CEDE). The sum of internal CEDE and external dose is termed total effective dose equivalent (TEDE). Dose factors for external and internal doses for all radionuclides except radon were calculated using the GENII computer code (Ref. 4). Radionuclides considered in the analysis included technetium-99 (Tc-99), uranium-234 (U-234), thorium-228 (Th-228), thorium-230 (Th-230), thorium-232 (Th-232), plutonium-239 (Pu-239), plutonium-241 (Pu-241), and americium-241 (Am-241). The factors used to estimate internal and external doses are summarized in Table A.1.

A.2 Environmental Pathway Models

A schematic representation of the potential paths radionuclides may follow through the environment is shown in Figure A.1. As indicated in Figure A.1, transport through the atmosphere and through surface water occur by different mechanisms; therefore, different exposure modes may be involved. The models used to estimate impacts for each release mode are described below.

Table A.1 Committed effective dose equivalents over 50 years per unit intake of activity

Radionuclide	Dose Conversion Factor (Sv/Bq)[a] Inhalation	Ingestion
Tc-99	2.3×10^{9}	3.5×10^{-13}
U-234	3.6×10^{5}	6.3×10^{8}
Th-228	9.3×10^{5}	1.1×10^{-7}
Th-230	7.0×10^{5}	1.4×10^{7}
Th-232	3.1×10^{-4}	7.4×10^{-7}
Pu-2390	8.1×10^{5}	1.3×10^{8}
Pu-241	1.3×10^{-6}	2.0×10^{-10}
Am-241	1.2×10^{-4}	9.4×10^{-7}

a. To convert Sv/Bq to mrem/Ci, multiply by 3.7×10^{15}.

A.2.1 Atmospheric Pathways

Radionuclides released to the atmosphere are dispersed by wind and transported to potential receptors. Radionuclide concentrations are reduced during transport by mixing and decay, and deposited on plant and ground surfaces. The atmospheric dispersion model in the XOQDOQ computer code (Ref. 5) was used to estimate radionuclide concentrations in the atmosphere. The XOQDOQ model implements NRC guidance (Ref. 6) by using a Gaussian plume dispersion model and the joint frequency of occurrence of wind velocity, stability class, and direction, to estimate annual average concentrations per unit quantity of material released (χ/Q). Meteorological data collected onsite were used in the analysis (Ref. 7). Because the current set of data does not include the distribution of occurrence of stability classes, the atmospheric dispersion analyses were based on Class A stability for elevated releases and Class F stability for ground-level releases. The estimated annual average χ/Qs are presented in Tables A.2, for elevated releases, and in Table A.3, for ground-level releases, for 10 radial distances and 16 compass directions centered on the main plant stack. Releases from the main plant stack were modeled as elevated releases, whereas releases from the other stacks and fugitive dust emissions were modeled as ground-level releases.

Air is exhausted from a number of other stacks and vents at buildings that house the laboratories, laundry dryers, furnace, boilers, diesel generator, the Waste Water Treatment Facility, and the Groundwater Treatment Facility. Because of its height, air exhausted from the main stack is considered for assessment purposes to be released in a vertical direction. The average height of the remaining stacks and points of release is 10 meters. Because this is generally less than the building heights, these releases are considered to be ground-level releases. This is consistent with the recommendations in Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors" (Ref. 9), which states that releases at elevations less than the height of the building should be treated as ground-level releases.

Because χ/Qs decrease uniformly with distance from the source for ground-level releases, but increase to a maximum and then decrease with distance for an elevated source, identification of the maximally exposed individual for atmospheric releases involves consideration of the relative magnitudes of ground level and elevated releases and the distances to actual receptors. As indicated in Table 2.3, elevated and ground-level releases of uranium are of equal magnitude,

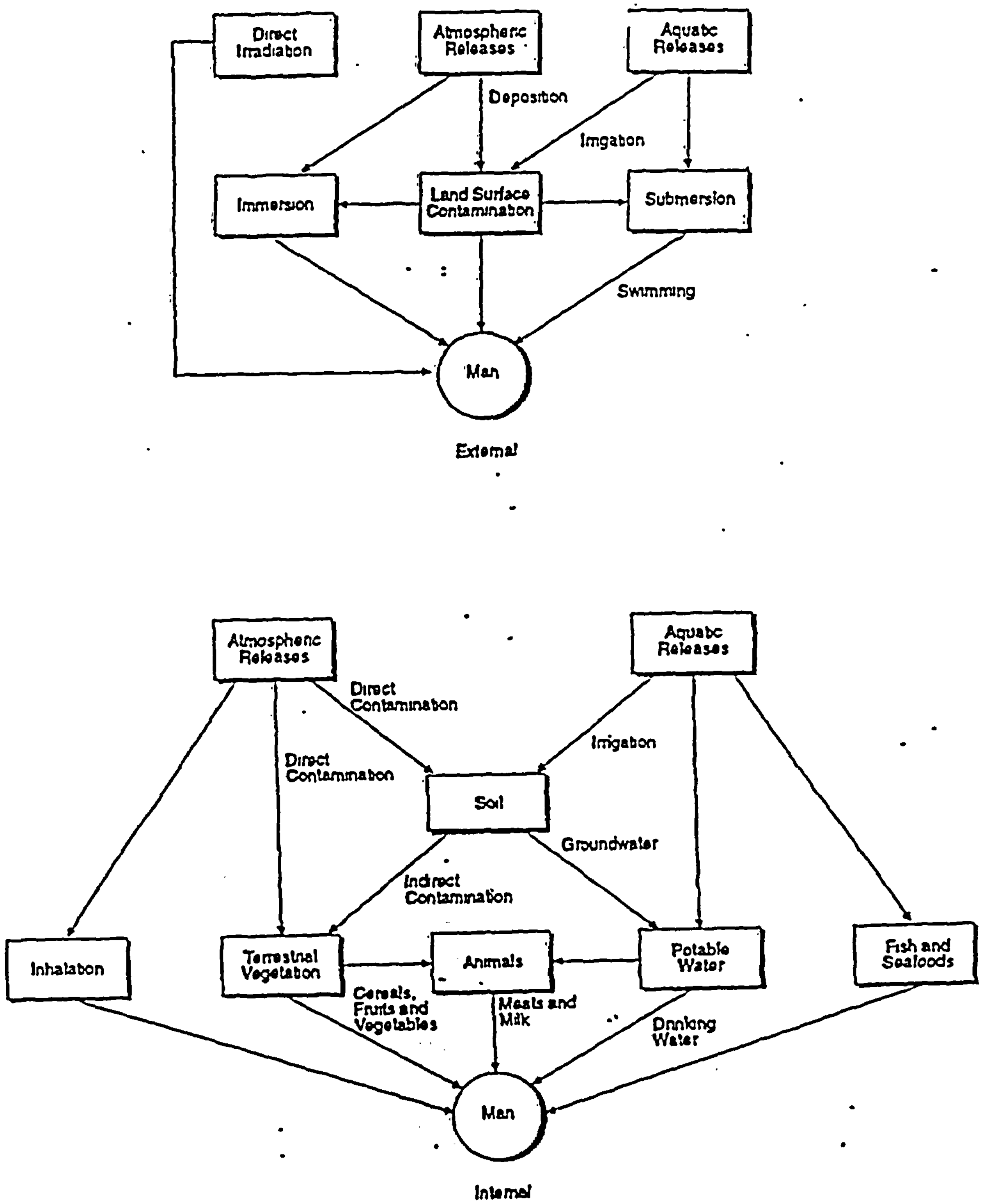

Figure A.1 Pathways for exposure to man from external sources (upper diagram) and from intake of radionuclides released to the environment (lower diagram)

Table A.2 Annual average concentrations per unit source term (χ/Q) for elevated releases (s/m^3)[a]

	Distance (km)[b]									
Direction	0 - 1.6	1.6 - 3.2	3.2 - 4.8	4.8 - 6.4	6.4 - 8.0	8.0 - 16.0	16.0 - 32.0	32.0 - 48.0	48.0 - 64.0	64.0 - 80.0
N	2.1×10^{-7}	2.1×10^{-8}	1.3×10^{-8}	8.9×10^{-9}	6.9×10^{-9}	4.2×10^{-9}	2.1×10^{-9}	1.3×10^{-9}	8.9×10^{-10}	6.9×10^{-10}
NNE	3.4×10^{-7}	3.4×10^{-8}	2.1×10^{-8}	1.5×10^{-8}	1.1×10^{-8}	6.8×10^{-9}	3.4×10^{-9}	2.1×10^{-9}	1.5×10^{-9}	1.1×10^{-9}
NE	2.4×10^{-7}	2.4×10^{-8}	1.4×10^{-8}	1.0×10^{-8}	7.9×10^{-9}	4.8×10^{-9}	2.4×10^{-9}	1.4×10^{-9}	1.0×10^{-9}	7.9×10^{-10}
ENE	1.1×10^{-7}	1.1×10^{-8}	6.8×10^{-9}	4.9×10^{-9}	3.8×10^{-9}	2.3×10^{-9}	1.1×10^{-9}	6.8×10^{-10}	4.9×10^{-10}	3.8×10^{-10}
E	6.8×10^{-8}	6.8×10^{-9}	4.1×10^{-9}	2.9×10^{-9}	2.3×10^{-9}	1.4×10^{-9}	6.8×10^{-10}	4.1×10^{-10}	2.9×10^{-10}	2.3×10^{-10}
ESE	6.8×10^{-8}	6.9×10^{-9}	4.1×10^{-9}	2.9×10^{-9}	2.3×10^{-9}	1.4×10^{-9}	6.8×10^{-10}	4.1×10^{-10}	2.9×10^{-10}	2.3×10^{-10}
SE	1.0×10^{-7}	1.0×10^{-8}	6.2×10^{-9}	4.4×10^{-9}	3.4×10^{-9}	2.1×10^{-9}	1.0×10^{-9}	6.2×10^{-10}	4.4×10^{-10}	3.4×10^{-10}
SSE	2.3×10^{-7}	2.2×10^{-8}	1.3×10^{-8}	9.6×10^{-9}	7.5×10^{-9}	4.5×10^{-9}	2.2×10^{-9}	1.3×10^{-9}	9.6×10^{-10}	7.5×10^{-10}
S	1.8×10^{-7}	1.8×10^{-8}	1.1×10^{-8}	7.6×10^{-9}	5.9×10^{-9}	3.6×10^{-9}	1.8×10^{-9}	1.1×10^{-9}	7.6×10^{-10}	5.9×10^{-10}
SSW	1.2×10^{-7}	1.2×10^{-8}	7.0×10^{-9}	5.0×10^{-9}	3.9×10^{-9}	2.3×10^{-9}	1.2×10^{-9}	7.0×10^{-10}	5.0×10^{-10}	3.9×10^{-10}
SW	1.0×10^{-7}	1.0×10^{-8}	6.2×10^{-9}	4.4×10^{-9}	3.4×10^{-9}	2.1×10^{-9}	1.0×10^{-9}	6.2×10^{-10}	4.4×10^{-10}	3.4×10^{-10}
WSW	8.2×10^{-8}	8.3×10^{-9}	5.0×10^{-9}	3.6×10^{-9}	2.8×10^{-9}	1.7×10^{-9}	8.3×10^{-10}	5.0×10^{-10}	3.6×10^{-10}	2.8×10^{-10}
W	6.6×10^{-8}	6.6×10^{-9}	4.0×10^{-9}	2.8×10^{-9}	2.2×10^{-9}	1.3×10^{-9}	6.6×10^{-10}	4.0×10^{-10}	2.8×10^{-10}	2.2×10^{-10}
WNW	5.9×10^{-8}	6.0×10^{-9}	3.6×10^{-9}	2.6×10^{-9}	2.0×10^{-9}	1.2×10^{-9}	6.0×10^{-10}	3.6×10^{-10}	2.6×10^{-10}	2.0×10^{-10}
NW	7.9×10^{-8}	7.9×10^{-9}	4.8×10^{-9}	3.4×10^{-9}	2.6×10^{-9}	1.6×10^{-9}	7.9×10^{-10}	4.8×10^{-10}	3.4×10^{-10}	2.6×10^{-10}
NNW	1.3×10^{-7}	1.3×10^{-8}	7.8×10^{-9}	5.6×10^{-9}	4.3×10^{-9}	2.6×10^{-9}	1.3×10^{-9}	7.8×10^{-10}	5.6×10^{-10}	4.3×10^{-10}

a. To convert second per cubic meter to second per cubic foot, multiply by 0.02832.
b. To convert kilometers to miles, multiply by 0.6214.

Table A.3 Annual average concentrations per unit source term (χ/Q) for ground level releases (s/m³)[a]

	Distance (km)[b]									
Direction	0 - 1.6	1.6 - 3.2	3.2 - 4.8	4.8 - 6.4	6.4 - 8.0	8.0 - 16.0	16.0 - 32.0	32.0 - 48.0	48.0 - 64.0	64.0 - 80.0
N	6.4×10^{-6}	1.1×10^{-6}	5.0×10^{-7}	3.1×10^{-7}	2.2×10^{-7}	1.1×10^{-7}	4.3×10^{-8}	2.2×10^{-8}	1.4×10^{-8}	1.0×10^{-8}
NNE	1.1×10^{-5}	1.8×10^{-6}	8.3×10^{-7}	5.1×10^{-7}	3.6×10^{-7}	1.8×10^{-7}	7.1×10^{-8}	3.6×10^{-8}	2.3×10^{-8}	1.7×10^{-8}
NE	7.3×10^{-6}	1.3×10^{-6}	5.8×10^{-7}	3.5×10^{-7}	2.5×10^{-7}	1.3×10^{-7}	5.0×10^{-8}	2.5×10^{-8}	1.6×10^{-8}	1.2×10^{-8}
ENE	3.5×10^{-6}	6.1×10^{-7}	2.8×10^{-7}	1.7×10^{-7}	1.2×10^{-7}	6.0×10^{-8}	2.4×10^{-8}	1.2×10^{-8}	7.8×10^{-9}	5.6×10^{-9}
E	2.2×10^{-6}	3.7×10^{-7}	1.7×10^{-7}	1.0×10^{-7}	7.3×10^{-8}	3.7×10^{-8}	1.5×10^{-8}	7.4×10^{-9}	4.8×10^{-9}	3.4×10^{-9}
ESE	2.2×10^{-6}	3.7×10^{-7}	1.7×10^{-7}	1.0×10^{-7}	7.3×10^{-8}	3.7×10^{-8}	1.5×10^{-8}	7.4×10^{-9}	5.0×10^{-9}	3.5×10^{-9}
SE	3.2×10^{-6}	5.5×10^{-7}	2.5×10^{-7}	1.6×10^{-7}	1.1×10^{-7}	5.5×10^{-8}	2.2×10^{-8}	1.1×10^{-8}	7.1×10^{-9}	5.1×10^{-9}
SSE	6.9×10^{-6}	1.2×10^{-6}	5.4×10^{-7}	3.3×10^{-7}	2.3×10^{-7}	1.2×10^{-7}	4.7×10^{-8}	2.4×10^{-8}	1.5×10^{-8}	1.1×10^{-8}
S	5.6×10^{-6}	9.6×10^{-7}	4.4×10^{-7}	2.7×10^{-7}	1.9×10^{-7}	9.6×10^{-8}	3.8×10^{-8}	1.9×10^{-8}	1.2×10^{-8}	8.9×10^{-9}
SSW	3.7×10^{-6}	6.4×10^{-7}	2.9×10^{-7}	1.8×10^{-7}	1.3×10^{-7}	6.3×10^{-8}	2.5×10^{-8}	1.3×10^{-8}	8.2×10^{-9}	5.9×10^{-9}
SW	3.3×10^{-6}	5.7×10^{-7}	2.6×10^{-7}	1.6×10^{-7}	1.1×10^{-7}	5.7×10^{-8}	2.2×10^{-8}	1.1×10^{-8}	7.3×10^{-9}	5.3×10^{-9}
WSW	2.7×10^{-6}	4.6×10^{-7}	2.1×10^{-7}	1.3×10^{-7}	9.1×10^{-8}	4.6×10^{-8}	1.8×10^{-8}	9.2×10^{-9}	6.0×10^{-9}	4.3×10^{-9}
W	2.2×10^{-6}	3.7×10^{-7}	1.7×10^{-7}	1.0×10^{-7}	7.3×10^{-8}	3.7×10^{-8}	1.5×10^{-7}	7.4×10^{-9}	4.8×10^{-9}	3.4×10^{-9}
WNW	1.9×10^{-6}	3.3×10^{-7}	1.5×10^{-7}	9.2×10^{-8}	6.5×10^{-8}	3.3×10^{-8}	1.3×10^{-8}	6.5×10^{-9}	4.2×10^{-9}	3.1×10^{-9}
NW	2.5×10^{-6}	4.3×10^{-7}	1.9×10^{-7}	1.2×10^{-7}	8.4×10^{-8}	4.2×10^{-8}	1.7×10^{-8}	8.5×10^{-9}	5.5×10^{-9}	4.0×10^{-9}
NNW	4.0×10^{-6}	6.9×10^{-7}	3.2×10^{-7}	1.9×10^{-7}	1.4×10^{-7}	6.9×10^{-8}	2.7×10^{-8}	1.4×10^{-8}	8.8×10^{-9}	6.4×10^{-9}

a. To convert second per cubic meter to second per cubic foot, multiply by 0.02832.
b. To convert kilometers to miles, multiply by 0.6214.

whereas elevated releases of thorium are an order of magnitude greater than ground-level releases of thorium. Because the population density west of the site is low, the actual residents who may be maximally exposed are located north, east, and south of the site. The results of dispersion analysis identify the maximally exposed individual and are presented in Table A.4. The results indicate that for both ground-level and elevated releases, the maximally exposed individual is located 200 meters (655 feet) south-southwest of the main plant stack.

Table A.4 Normal operations dispersion factors for NFS facility nearest residents

		χ/Q (s/m^3)[a]	
Direction	Distance (m)[b]	Ground level	Elevated
N	357	2.4×10^{-5}	1.4×10^{-6}
NE	381	2.5×10^{-5}	1.4×10^{-6}
E	262	1.3×10^{-5}	6.5×10^{-7}
SE	226	2.4×10^{-5}	1.3×10^{-6}
SSE	202	6.1×10^{-5}	3.5×10^{-6}
S	214	4.5×10^{-5}	2.0×10^{-6}

a. To convert seconds per cubic meter to seconds per cubic foot, multiply by 0 02832.

b. To convert meters to feet, multiply by 3 2808.

Although no individuals are located at the boundary of the restricted area, estimates of atmospheric concentrations for these locations can be compared with the concentration limit of Table 2 of 10 CFR Part 20, to provide perspective on potential impacts. Distances, χ/Qs, and concentrations of uranium estimated for receptors at the boundary of the restricted area are presented in Table A.5. Each reported total concentration in Table A.5 is less than the most restrictive, potentially applicable limit of Table 2 of Part 20 (i.e., 5×10^{-14} µCi/mL of uranium). Even though the analysis is based on conservative assumptions, the results indicate compliance with NRC regulations.

The exposure pathways analyzed included inhalation of potentially contaminated air, ingestion of crops potentially contaminated by deposition from air, ingestion of animal products fed with potentially contaminated crops, ingestion of resuspended soil contaminated by deposition, and direct exposure from the airborne plume and from ground potentially contaminated by deposition from the air. The exposure rates for these pathways were estimated using the GENII computer code (Ref. 4), which implements pathway distribution models similar to those recommended by NRC (Ref. 1). The major parameters analyzed were derived from NRC guidance and are summarized in Table A.6. In addition to the maximally exposed individual, impacts were estimated for the population surrounding the NFS Erwin Plant out to a distance of 80 kilometers (50 miles).

Table A.5 Restricted area boundary concentrations of uranium for atmospheric releases

Direction	Distance (m)[b]	χ/Q (s/m^3)[a]		Concentration (µCi/mL)		
		Ground level	Elevated	Ground level	Elevated	Total
S	73	2.5×10^{-4}	6.3×10^{-8}	8.7×10^{-15}	2.2×10^{-18}	8.9×10^{-15}
SSW	120	6.8×10^{-5}	1.5×10^{-6}	2.4×10^{-15}	5.2×10^{-17}	2.5×10^{-15}
SW	134	5.0×10^{-5}	4.2×10^{-7}	1.7×10^{-15}	1.5×10^{-17}	1.7×10^{-15}
WSW	149	3.6×10^{-5}	8.7×10^{-8}	1.3×10^{-15}	3.1×10^{-18}	1.3×10^{-15}
W	193	2.0×10^{-5}	2.5×10^{-7}	7.0×10^{-16}	8.7×10^{-18}	7.1×10^{-16}
WNW	156	2.4×10^{-5}	3.4×10^{-7}	8.4×10^{-16}	1.2×10^{-17}	8.5×10^{-16}
NW	154	3.1×10^{-5}	1.2×10^{-6}	1.1×10^{-15}	4.2×10^{-17}	1.1×10^{-15}
NNW	178	4.2×10^{-5}	2.1×10^{-6}	1.5×10^{-15}	7.3×10^{-17}	1.6×10^{-15}
N	268	3.7×10^{-5}	2.4×10^{-6}	1.3×10^{-15}	8.4×10^{-17}	1.4×10^{-15}
NNE	300	5.2×10^{-5}	3.2×10^{-6}	1.8×10^{-15}	1.1×10^{-16}	1.9×10^{-15}
NE	271	4.2×10^{-5}	2.7×10^{-6}	1.5×10^{-15}	9.4×10^{-17}	1.6×10^{-15}
ENE	232	2.5×10^{-5}	1.5×10^{-6}	8.7×10^{-16}	5.2×10^{-17}	8.8×10^{-16}
E	88	7.0×10^{-5}	1.5×10^{-6}	2.4×10^{-15}	5.2×10^{-17}	2.5×10^{-15}
ESE	63	1.3×10^{-4}	2.6×10^{-6}	4.5×10^{-15}	9.1×10^{-17}	4.6×10^{-15}
SE	56	2.4×10^{-4}	7.8×10^{-6}	8.4×10^{-15}	2.7×10^{-16}	8.7×10^{-15}
SSE	54	5.4×10^{-4}	2.2×10^{-5}	1.9×10^{-14}	7.7×10^{-16}	2.0×10^{-14}

a. To convert seconds per cubic meter to seconds per cubic foot, multiply by 0.02832.
b. To convert meters to feet, multiply by 3.2808

Greater than 90 percent of the estimated dose from the atmospheric pathway for each individual occurred through inhalation of potentially contaminated air. For this exposure mode, air radionuclide concentrations were estimated as the product of χ/Q and the radionuclide release rate. The inhaled amount was estimated as the product of radionuclide concentration and breathing rate, while the dose was estimated as the product of dose conversion factor and amount inhaled. This radionuclide dose estimate was expressed as:

$$D_{i,j} = (\chi/Q) \times Q_{i,a} \times BR \times DCF_i \ ,$$

where:

$D_{i,j}$ = inhalation dose from radionuclide i, Sv/Bq

χ/Q = atmospheric concentration per unit source term, s/m^3

$Q_{i,a}$ = annual release rate of radionuclide i to the atmosphere (Table A.4), Bq/yr

BR = breathing rate (Table A.1), m^3/s

DCF_i = inhalation dose conversion factor for radionuclide i (Table A.1), Sv/Bq

Table A.6 Exposure pathway intake parameters

Parameter	Maximally Exposed Individual	Average Member of Population
Fruits, vegetables, & grain (kg/yr)[a]	520	190
Leafy vegetables (kg/yr)[a]	64	24
Milk (L/yr)[b]	310	110
Meat & poultry (kg/yr)[a]	110	95
Fish (kg/yr)[a]	21	6.9
Drinking water (L/yr)[b]	730	370
Inhalation (m^3/yr)[c]	8000	8000

a. To convert kilograms to pounds, multiply by 2.205.
b. To convert liters to gallons, multiply by 0.2642.
c. To convert cubic meters per year to cubic feet per year, multiply by 35.315

Total individual dose was estimated as the sum of the doses of all radionuclides. The χ/Q values for the maximally exposed individual for elevated and ground level releases were 3.5×10^{-6} and 6.1×10^{-5} s/m^3 (9.9×10^{-8} and 1.7×10^{-6} s/ft^3), respectively. Population dose was estimated as the sum of the doses for individuals located in 160 sectors surrounding the facility. The number of individuals in each sector was presented in Table 3.3, whereas the χ/Q value for each sector was presented in Tables A.2 and A.3. Dose-estimation methods for the food ingestion and external exposure modes are more complex, but since these pathways contribute a small portion of the total dose, the methods are not presented here.

The results for the maximally exposed individual and the population are summarized in Tables A.7 and A.8 respectively. As shown in the tables, external doses are small fractions of internal doses, and the TEDEs are numerically equal to the CEDEs. In general, the radiological impacts from only decommissioning/remediation activities are about 2 to 10 times less than the impacts from both production operations and decommissioning activities.

A.2.2 Surface-Water Pathways

Radionuclides released to surface water are diluted by stream flow and may impact individuals through various pathways. Liquid-release pathways analyzed included ingestion of potentially contaminated drinking water, ingestion of crops irrigated with potentially contaminated water, ingestion of animal products grown with potentially contaminated crops, ingestion of fish harvested from the potentially contaminated stream, and direct exposure during recreational activity in or near the potentially contaminated stream. The exposure rates for these pathways were estimated using the GENII computer code (Ref. 4). The major parameters used for analysis of the surface-water pathways are summarized in Table A.6. The stream dilution model used for the analysis is the same as that recommended in NRC guidance (Ref. 8).

Table A.7 Radiological impacts to the maximally exposed individual from releases to the atmosphere (Sv/yr)[a]

Organ	During Production Operations	During Decommissioning/ Remediation Activities	Total[b]
Gonads	1.4×10^{-9}	5.7×10^{-9}	7.1×10^{-9}
Breast	5.6×10^{-12}	6.1×10^{-11}	6.2×10^{-10}
Red bone marrow	6.9×10^{-8}	7.1×10^{-8}	1.4×10^{-7}
Lungs	1.9×10^{-4}	2.0×10^{-5}	2.1×10^{-4}
Thyroid	5.6×10^{-12}	6.2×10^{-11}	6.2×10^{-10}
Bone surface	9.9×10^{-7}	9.1×10^{-7}	1.9×10^{-6}
Liver	1.1×10^{-8}	7.6×10^{-8}	8.7×10^{-8}
Kidneys	1.3×10^{-7}	1.2×10^{-8}	1.4×10^{-7}
Small intestine	1.6×10^{-8}	1.4×10^{-9}	1.7×10^{-8}
Upper large intestine	8.9×10^{-9}	9.0×10^{-9}	9.8×10^{-9}
Lower large intestine	2.6×10^{-7}	2.6×10^{-8}	2.9×10^{-7}
CEDE[c]	2.4×10^{-5}	2.4×10^{-6}	2.6×10^{-5}
External	9.8×10^{-13}	5.2×10^{-13}	1.5×10^{-12}
TEDE[d]	2.4×10^{-5}	2.4×10^{-6}	2.6×10^{-5}

a. To convert Sv/yr to mrem/yr, multiply by 100,000.
b. Total is the sum of releases from both production operations and decommissioning/ remediation activities.
c. CEDE = committed effective dose equivalent.
d. TEDE = total effective dose equivalent.

Because flows in Banner Spring Branch, Martin Creek, and North Indian Creek are low and irregular, they are not sources of drinking water. Therefore, the maximally exposed individual was located along the Nolichucky River downstream of the confluence with North Indian Creek. The population out to a distance of 80 kilometers (50 miles) was also assumed to use this potentially contaminated water.

For surface-water pathways, fish-ingestion doses dominated the drinking water, irrigated food ingestion, and direct-exposure doses. Concentrations of each radionuclide in the water were estimated as the quotient of release rate and river-flow rate. Radionuclide intake in drinking water was estimated as the product of radionuclide concentration and water-usage rate, and dose was estimated as the product of intake rate and dose-conversion factor.

For each exposed individual and each radionuclide, dose was expressed as:

$$D_{dw,i} = (Q_{l,i}/Q_r) \times IR_{dw} \times DCF_i$$

where:

$D_{dw,i}$ = drinking water dose for radionuclide i, Sv/Bq

$Q_{l,i}$ = liquid effluent release rate of radionuclide i (Table A.1), Bq/s

Q_r = river flow rate, m^3/s

IR_{dw} = drinking water ingestion rate (Table A.6), m^3/yr

DCF_i = ingestion dose conversion factor (Table A.1), Sv/Bq

Table A.8 Radiological impacts to the population from releases to the atmosphere (per-Sv/yr)[a]

Organ	During Production Operations	During Decommissioning/ Remediation Activities	Total[b]
Gonads	3.0×10^{-7}	1.9×10^{-6}	2.2×10^{-6}
Breast	1.2×10^{-7}	1.2×10^{-8}	1.3×10^{-7}
Red bone marrow	2.0×10^{-5}	2.2×10^{-5}	4.2×10^{-5}
Lungs	6.3×10^{-2}	6.4×10^{-3}	6.9×10^{-2}
Thyroid	1.2×10^{-7}	1.3×10^{-8}	1.3×10^{-7}
Bone surface	2.5×10^{-4}	2.8×10^{-4}	5.3×10^{-4}
Liver	3.0×10^{-6}	2.5×10^{-5}	2.8×10^{-5}
Kidneys	2.3×10^{-5}	2.1×10^{-6}	2.5×10^{-5}
Small intestine	2.1×10^{-6}	2.1×10^{-7}	2.3×10^{-6}
Upper large intestine	1.3×10^{-5}	1.2×10^{-6}	1.4×10^{-5}
Lower large intestine	3.6×10^{-5}	3.5×10^{-6}	3.9×10^{-5}
CEDE[c]	7.6×10^{-3}	7.7×10^{-4}	8.4×10^{-3}
External	*4.6×10^{-3}*	*1.6×10^{-10}*	*4.6×10^{-3}*
TEDE[d]	7.6×10^{-3}	7.7×10^{-4}	8.4×10^{-3}

a. To convert per-Sv/yr to per-mrem/yr, multiply by 100.
b. Total is the sum of releases from both production operations and decommissioning/ remediation activities.
c. CEDE = committed effective dose equivalent
d. TEDE = total effective dose equivalent.

Total dose was estimated as the sum of the doses for all radionuclides and the river flow rate was 38.1 m^3/s (1,347 ft^3/s). The concentration of each radionuclide in fish was determined using the estimated river-water concentration and the bioaccumulation factors presented in Table A.9. The dose from ingestion of fish was estimated as:

$$D_{f,i} = (Q_{r,i}/Q_r) \times B_{f,i} \times IR_f \times DCF_i$$

where:

$D_{f,i}$ = fish-ingestion dose for radionuclide i, Sv/Bq

$B_{i,f}$ = bioaccumulation factor for radionuclide i in fish (Table A.9), (Bq/kg)/(Bq/m³)

Ir_f = fish ingestion rate (Table A.6), kg/yr

Table A.9 Fresh-water fish bioaccumulation factors

Element	Bioaccumulation Factor (Bq/kg per Bq/L)
K	0
U	50
Th	100
Pa	30
Ac	330
Ra	50
Rn	0
Pb	2,000
Bi	15
Po	50

Source: B.S. Napier, R.A. Peloquin, D.L. Strenge, and J.V. Ramsdell, "GENII - The Hanford Environmental Radiation Dosimetry Software System," PNL-6584, Pacific Northwest Laboratory, Richland, Washington, December 1988 (Ref. 4).

and all other variables defined as above. Total dose was estimated as the sum of the dose of all radionuclides. For the liquid pathway, all individuals were equally exposed, and the collective dose was estimated as the product of the number of people and the average individual dose estimated as described above. Dose-estimation methods for food ingestion and external exposure were more complex, but account for a small portion of the total dose. Therefore, the methods are not presented here.

Tables A.10 and A.11 summarize the analysis for the maximally exposed individual and the population, respectively. As with atmospheric releases, external doses are small fractions of the internal doses, and the TEDEs are numerically equal to the CEDEs. Also, the radiological impacts from only decommissioning/remediation activities are about 2 to 10 times less than the impacts from both production and decommissioning activities.

Table A.10 Radiological impacts to the maximally exposed individual from liquid releases (Sv/yr)[a]

Organ	During Production Operations	During Decommissioning/ Remediation Activities	Total[b]
Gonads	1.9×10^{-9}	1.6×10^{-9}	3.5×10^{-9}
Breast	1.8×10^{-8}	1.4×10^{-8}	3.2×10^{-8}
Red bone marrow	8.4×10^{-7}	8.6×10^{-7}	1.7×10^{-6}
Lungs	1.8×10^{-8}	1.4×10^{-8}	3.2×10^{-8}
Thyroid	8.9×10^{-9}	2.1×10^{-9}	1.1×10^{-8}
Bone surface	1.1×10^{-5}	1.1×10^{-5}	2.2×10^{-5}
Liver	1.8×10^{-8}	1.8×10^{-8}	3.6×10^{-8}
Kidneys	1.6×10^{-7}	1.3×10^{-7}	2.9×10^{-7}
Small intestine	2.9×10^{-8}	2.6×10^{-8}	5.5×10^{-8}
Upper large intestine	1.8×10^{-7}	1.5×10^{-7}	3.3×10^{-7}
Lower large intestine	5.3×10^{-7}	4.7×10^{-7}	1.0×10^{-6}
CEDE[c]	5.0×10^{-7}	4.7×10^{-7}	9.7×10^{-7}
External	2.2×10^{-10}	2.2×10^{-10}	4.4×10^{-10}
TEDE[d]	5.0×10^{-7}	4.7×10^{-7}	9.7×10^{-7}

a. To convert Sv/yr to mrem/yr, multiply by 100,000.
b. Total is the sum of releases from both production operations and decommissioning/ remediation activities.
c. CEDE = committed effective dose equivalent.
d. TEDE = total effective dose equivalent.

Table A.11 Radiological impacts to the population from liquid releases (per-Sv/yr)[a]

Organ	During Production Operations	During Decommissioning/ Remediation Activities	Total[b]
Gonads	7.1×10^{-4}	5.9×10^{-4}	0.0013
Breast	$6\ 6\times10^{-4}$	5.4×10^{-4}	0 0012
Red bone marrow	0.35	0.34	0 69
Lungs	6.6×10^{-4}	5.4×10^{-4}	0 0012
Thyroid	0 0031	7.9×10^{-4}	0.0039
Bone surface	4 4	4 3	8.7
Liver	0.0073	0 0067	0 014
Kidneys	0.053	0 047	0.10
Small intestine	0 011	0.0091	0.02
Upper large intestine	0.065	0.055	0 12
Lower large intestine	0.19	0.17	0.36
CEDE[c]	0.19	0 19	0 38
External	7.8×10^{-4}	7.2×10^{-4}	1.5×10^{-3}
TEDE[d]	0.19	0 19	0 38

a. *To convert per Sv/yr to mrem/yr, multiply by 100,000.*
b. Total is the sum of releases from both production operations and decommissioning/ *remediation activities*
c. CEDE = committed effective dose equivalent.
d. TEDE = total effective dose equivalent

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